Metro Nashville Public Works

Commercial Food Waste Anaerobic Digestion Study Summary

Introduction

The 2019 Solid Waste Master Plan revealed that food waste is one of the largest components of the Davidson County waste stream being landfilled. In an effort to reduce the volume of landfilled food waste, CDM Smith conducted an evaluation of two food waste treatment options: *a standalone food waste processing facility* and *processing at the Dry Creek Wastewater Treatment Plant*. Both options use anaerobic digestion for treatment of food waste.

Anaerobic Digestion Overview

Anaerobic digestion (AD) is a stabilization process to reduce the volume of residual wastewater solids. The process is utilized at numerous wastewater facilities throughout the country, including the Central and Dry Creek facilities in Nashville. The AD process can be modified to operate as a co-digestion process, which involves digestion of mixed materials (e.g., wastewater residuals + food waste). Byproducts of digestion are biogas and biosolids. Biogas can be utilized as a renewable fuel. Biosolids can be further processed to a fertilizer or soil amendment, as is currently occurring at the Central plant.

Standalone Food Waste Processing Facility

A standalone food waste processing facility could be located in the greater Nashville area for treatment of commercial food waste. This option would be a public-private partnership with the new facility owned and operated by private entities.

- Facility includes a food waste receiving station, AD processing tanks and equipment, biosolids processing equipment, and a biogas-fueled engine.
- Biosolids produced in AD can be processed off-site at a composting facility.
- Biogas produced in AD can provide power and heating for the facility.

Co-Digestion of Food Waste at Dry Creek Wastewater Treatment Plant

Alternatively, food waste could be co-digested with wastewater residuals at the Dry Creek plant.

- Modifications to Dry Creek include installation of a food waste receiving facility, a new digestion tank, and expanded biosolids processing facilities.
- Biosolids produced in AD can be further processed in a drying system on site to produce a high-quality pelletized product that is in high demand from the local agricultural community
- Biogas produced in AD can provide a heat source for a biosolids dryer.

Recommendations & Next Steps

The evaluation ranked the food waste processing alternatives with the Dry Creek co-digestion facility coupled with a biosolids dryer highest because of the unique benefit of not only diverting food waste from the landfill, but also diverting wastewater biosolids from the Dry Creek facility that are also currently landfilled. In this alternative **40,800 tons per year** of food waste and biosolids are estimated to be diverted from the landfill with an approximate total project cost of $58 million. Installing a dryer at Dry Creek will utilize existing wastewater infrastructure and allow for production of a high-quality biosolids product while utilizing renewable energy from the plant in the form of biogas. Use of a dryer was determined to be favorable over composting as it can be performed at the plant, is void of odor problems, and is more marketable.

CDM Smith

Memorandum

To: *Sharon Smith – Metro Nashville Public Works*

From: *Dustin Craig, Chris Gabel, Martin Sanford, Laurel Schaich – CDM Smith*

Date: *January 6, 2020*

Subject: *Metro Public Works – Commercial Food Waste Anaerobic Digestion Study – FINAL*

Project Overview

The Metro Public Works Department (Metro PW) recently completed a Solid Waste Master Plan to facilitate a long-term move towards zero waste. The results of a waste audit, conducted in support of the master plan, indicated that organics, and specifically, food waste, is one of the largest components of the Davidson County waste stream currently being landfilled. Anaerobic digestion (AD) is one of the options identified in the master plan for increasing food waste diversion from landfills. This technical memorandum evaluates AD options for food waste generated within the commercial sector of Davidson County.

For the study, two alternatives were selected for evaluation:

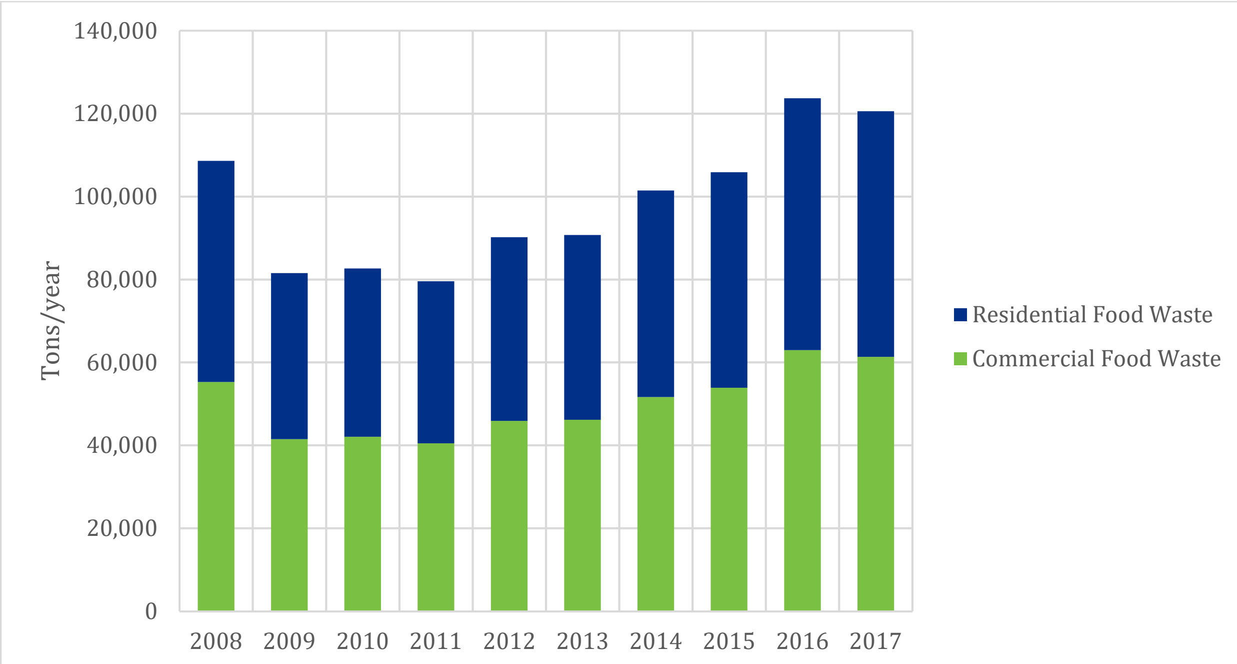
- **A standalone AD facility** – this would be a new facility designed solely for processing and digesting food waste. It could be a custom design or a packaged design from an AD facility provider, such as Quasar or Bioferm. This facility could be owned by Metro PW and operated through a private contract operations agreement or entirely privatized.

- **Codigestion of food waste with wastewater sludge at the Dry Creek Wastewater Treatment Plant (Dry Creek)** – this option includes making modifications to the existing plant facilities and operations to allow food waste to be mixed with wastewater sludge and codigested in common tanks.

Current Management of Food Waste

Food waste in Davidson County accounts for approximately 13 percent of commercial landfilled waste and 21 percent of residential landfilled waste. The focus of this study is commercial food waste; however, future expansion of AD facilities could allow for receiving of both commercial and residential food wastes**.** Figure 1 shows the historical trend for food waste within Davidson County.

Figure 1: Historical Food Waste Generation in Davidson County



Metro Water Services (MWS) owns and operates the Dry Creek WWTP located at 61 Edenwold Road in northeast Davidson County. For biosolids treatment, Dry Creek operates two anaerobic digesters and four belt filter presses for dewatered Class B biosolids production. All biosolids produced at Dry Creek are currently landfilled at the Middle Point Landfill located in Rutherford County. Average biosolids production is six to eight dry tons per day (30 to 40 wet tons per day). The average annual cake production is 39 wet tons per day at 17 to 21 percent total solids. Hauling of biosolids to Middle Point Landfill is reported to cost $528,000 annually, inclusive of landfill tipping fees and hauling costs. With Middle Point Landfill anticipated to reach capacity within the next 5 to 10 years, MWS will need to secure an alternate disposal facility in the near future. Given that the Middle Point Landfill is the closest disposal facility to Dry Creek that is permitted to receive biosolids, it is assumed that hauling costs will increase due to a longer hauling distance after the Middle Point Landfill closes.

Design Criteria

The design criteria for the proposed AD evaluation are based on data generated during the preparation of the Solid Waste Master Plan along with values recorded at similar AD facilities. An estimated 61,000 tons of commercial food waste was generated in 2017. Experience from existing food waste collection programs shows that focusing on large scale generators (i.e. commercial units that generate 1 ton or more of food waste per week) will reduce collection costs and contamination levels. Based on previous experience, CDM Smith estimates large scale generators account for approximately 50 percent of the total commercial food waste. Therefore, based on the 2017 food waste of 61,000 tons, the assumed design capacity for the proposed facility is 31,000 tons per year.

Solids analysis performed on the commercial food waste received at the Greater Lawrence Sanitary District (GLSD) WWTP in North Andover, MA for codigestion shows the composition is, on average, 14 percent total solids, of which 93 percent are volatile solids (refer to Figure 2). This solids analysis is consistent with conservative literature values for food waste, including data reported at the full scale food waste facilities at East Bay Municipal District (EBMUD), and is assumed to be a reasonable design criteria value for the food waste digestion facility. Table 1 summarizes the AD design criteria established for this evaluation.

Figure 2: Commercial Food Waste Solids Analysis Results at GLSD WWTP

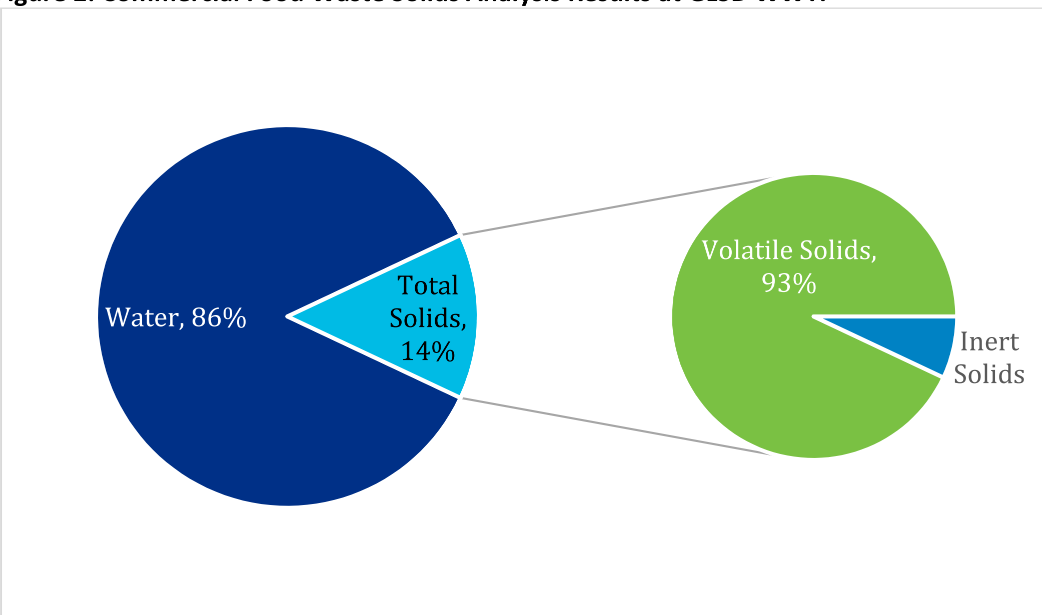


Table 1: Anaerobic Digester Design Criteria

Description	Value
Food Waste Loading	31,000 tons/year 168,000 lbs/day 20,000 gals/day
Total Solids Loading	4,300 dry tons/year 24,000 lbs/day
Volatile Solids Loading	4,000 dry tons/year 22,000 lbs/day
Total Required Digester Volume[1]	99,000 ft^3 0.74 MGal
Volatile Solids Reduced[2]	16,000 lbs/day
Biogas Production[3]	240,000 ft^3/day 168 scfm

1. Assuming loading of 0.22 lbs/ft^3-day, based on *Anaerobic Digestion of Food Waste*, EPA-R9-WST-06-005.
2. Assuming 73.8% volatile solids destruction, based on *Anaerobic Digestion of Food Waste*, EPA-R9-WST-06-005.
3. Assuming 15 cf/lb VSD, based on recorded data from GLSD WWTP.

Process Components

Food Waste Preprocessing Facility

Food waste collected from commercial sources, such as grocery stores, restaurants, and institutional cafeterias, comes in the form of expired food (in packages or bulk), kitchen scraps, and post-consumer leftovers. Despite being source separated, food waste requires preprocessing to remove packaging and other trash that errantly gets thrown into the organics bin. Preprocessing is also required to blend the waste into a pumpable slurry.

For this evaluation, it was assumed that a centralized preprocessing facility will be employed (as opposed to each food waste generator performing this function). The centralized facility will be an enclosed building equipped with negative pressure ventilation and a biofiltration system to manage odors. Food waste will be offloaded inside the building onto a tipping floor where it will be stored until it is processed.

During preprocessing inert contaminants such as plastics, metals, and glass are removed to provide a clean feedstock for digestion. Removal of contaminants is commonly achieved by manual separation of bulky materials, such as boxes, and through use of depackaging technology. Following depackaging, a variety of technologies can be used to shred, grind, macerate, screen, and extrude food waste into a homogeneous slurry that can be pumped into tanker trucks for delivery to an AD facility. Some equipment, such as the DODA Bio Separator and the Scott Turbo Separator, perform both depackaging and slurry processing.

Many food waste AD programs use proprietary preprocessing systems to prepare the slurry. Two turn-key providers include Waste Management, Inc. (WMI) and Anaergia Inc.

Waste Management's CORe technology, refer to Figure 3, is a patented system that is currently being used to preprocess food waste for codigestion projects in Boston, New York City, northern New Jersey, and Los Angeles. Food waste from the tipping floor is offloaded into a hopper using front-end loaders where it is fed into a bioseparator to remove contaminants and pulverize the waste into a slurry using a hammer mill. The separated organics are then transferred to product tanks for high COD (chemical oxygen demand) organics and make-up product tanks for low COD organics. Blending of the high and low COD organics is tailored to match the specific characteristics of the food waste being collected in order to produce an optimal slurry for digestion. Water is added as needed to meet the desired water content for the pumping systems. The resulting slurry produced by the CORe system is trademarked by WMI as EBS (engineered bioslurry).

Figure 3: Waste Management's CORe Technology

Anaergia's trademarked OREX (Organics Extrusion Press) technology, refer to Figure 4, uses an extrusion process to separate and breakdown organics. It can be used for source separated organics and unsorted municipal solid waste (MSW). The wet fraction (organics) are pressed through a perforated wall of a rotating drum and sent to a polishing system for maceration and water addition. The dry fraction contaminants are contained within the extrusion drum and discharged out the end onto a conveyor belt. Anaergia processes the dry fraction residuals into a refuse derived fuel for use in cement kilns. Anaergia's Rialto Bioenergy Facility, scheduled for completion in 2020, will process 700 tons per day of food waste from the Los Angeles metropolitan area.

Figure 4: Anaergia's OREX Technology

Waste Receiving Station

From the preprocessing facility, the food waste slurry is transported in tanker trucks to the AD facility. Tanker trucks unload the food waste slurry at a waste receiving station consisting of a tanker connection, offloading pumps, settling tank(s), and an equalization tank. The equalization tank allows food waste to be added to the digesters in a controlled manner to avoid potential upset of the AD process.

Truck scales can be installed before and after unloading to verify the weight of food waste offloaded for tracking and billing purposes. The slurry is offloaded into a settling tank with removable bar screens. From the settling tank, the waste flows by gravity or is pumped to an equalization tank. The tanks are equipped with odor control equipment and are enclosed to prevent access to insects and rodents.

Figure 5 shows the receiving station installed at the Des Moines Wastewater Reclamation Facility (WRF)in Des Moines, Iowa. Appendix A provides a conceptual design for a food waste receiving station that could be employed at the Dry Creek WWTP.

Figure 5: Organic Waste Receiving Station at Des Moines WRF

Anaerobic Digestion System

Anaerobic digestion (AD) is a stabilization process to reduce pathogen levels and overall volume of wastewater residuals. AD is used successfully at numerous wastewater treatment facilities throughout the country, including the Central and Dry Creek WWTPs in Nashville. AD can be modified to operate as a codigestion process which involves digestion of mixed materials; for example, wastewater residuals and food waste. Byproducts of digestion are biogas and biosolids. Biogas produced contains approximately 60 to 65 percent methane and can be used as a fuel or converted to electrical energy and heat through cogeneration. The biosolids produced by AD are typically categorized as Class B under 40 CFR Part 503, Standards for the Use of Disposal of Sewage Sludge. Class B biosolids are defined as solids that are processed to significantly reduce pathogens, whereas Class A biosolids are defined as solids that are processed to further reduce pathogens. Class A solids require additional processing and have a lower pathogen level than Class B, however, they are much less limited in their disposal, including much broader options for beneficial reuse.

Biogas Equipment

Biogas produced from AD can be used to produce electricity and heat in a combined heat and power (CHP) system. A CHP system includes an engine that cogenerates power and heat from its fuel source (i.e., biogas). CHP systems typically have an electrical conversion efficiency of 38 to 42 percent and a heat recovery efficiency of 40 percent. Power produced by CHP systems can be utilized on-site by other wastewater treatment processes, and the heat recovered can be utilized to for digester process heating. Excess biogas that cannot be used in the CHP system must be flared in a waste gas burner to combust the remaining methane.

Dewatering Equipment

The product of AD, digestate, typically contains three to six percent total solids content. Dewatering equipment is used to decrease the water content and increase the solids to 16 to 24 percent. Numerous technologies exist for dewatering, ranging from mechanical rotating equipment to belt presses for water removal. Typically, a coagulant, such as a polymer solution, is mixed with the digestate prior to dewatering to promote flocculation and further increase solids content of the dewatered product (i.e., cake). This cake, which is Class B after AD, can be land applied as a fertilizer additive or substitute.

Biosolids Processing Equipment

Additional biosolids processing equipment can be located downstream of dewatering for further processing to produce a Class A biosolids product. One such process is biosolids drying, which heats the biosolids to produce a pelletized product with a solids content greater than 90 percent. The dryer can be fueled by biogas produced from AD, by natural gas, or more commonly a combination of both.

Another biosolids process is lime stabilization, which increases the temperature and pH for pathogen reduction. Lime and acid are added to the biosolids, and the solids content of the product is increased to approximately 29 percent.

There are numerous other technologies that can be introduced or implemented within the biosolids process train to achieve Class A biosolids; however, these are the two auxiliary processes that were the focus of the evaluation. Other systems could be evaluated for comparative purposes should the project move into more detailed preliminary design.

Alternatives Analysis

Food Waste Preprocessing Facility

Planning level cost estimates for a turnkey preprocessing facility were obtained from WMI and Anaergia. WMI recommended a 10,000 square foot facility consisting of a 6,000 square foot tipping floor and a 4,000 square foot area for processing equipment. WMI noted that siting the facility at the Antioch Transfer Station or another local WMI property would be preferable from permitting and cost savings perspectives. Both companies stated that there would be no wastewater discharges from their facility, as all liquid is retained for creating the slurry mix. The combined capital costs and O&M costs ranged from $45 to $65 per wet ton.

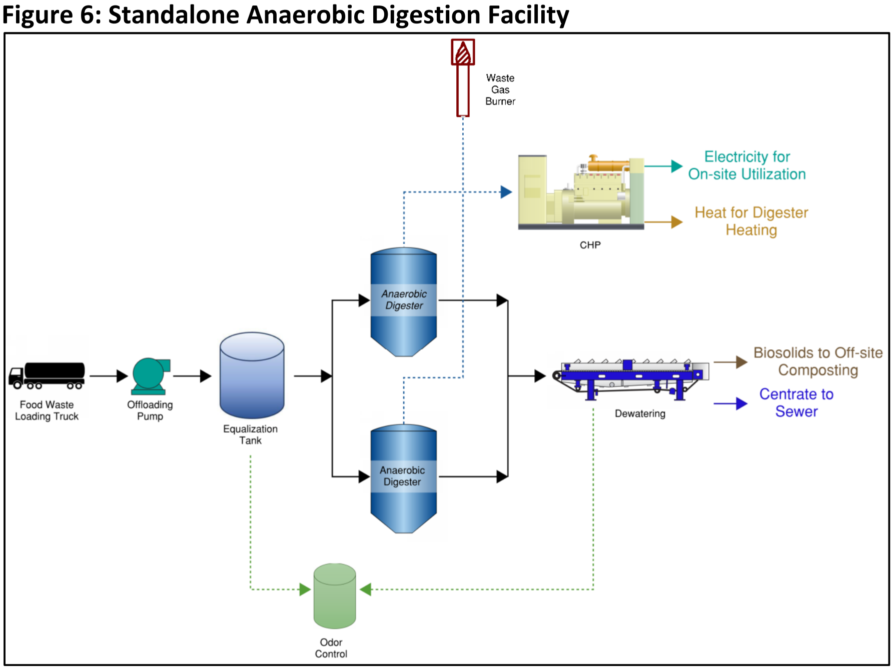
Standalone Anaerobic Digestion Facility

A standalone anaerobic digestion facility would be constructed to process food waste from the Nashville metropolitan area. The food waste would be transported by truck to the processing facility, where it would be pumped into an equalization tank. Two anaerobic digesters would be provided for food waste stabilization and solids reduction. Food waste, when compared to municipal waste, can have deficient levels of COD and trace minerals, including cobalt, nickel, molybdenum, and selenium. The standalone facility will likely require feeding supplemental COD and trace minerals to alleviate ammonium toxicity and prevent digester instability[1]. It is assumed a chemical addition system will be required for the standalone AD system with capability of feeding these nutrients and minerals to ensure stable digestion.

The digestate (output of anaerobic digesters) would be dewatered, with the biosolids sent to an off-site composting facility and the centrate (liquid removed from digestate during dewatering) discharged to the public sewer system (to MWS treatment facility). Biogas produced in the digesters would be processed in a CHP system for electricity and heat generation. The energy from biogas produced at the standalone facility is expected to far exceed the facility demand (670 kilowatts [kw] vs. 150 kw). It is assumed that the CHP system is sized only for the onsite facility demand since the TVA purchase price is too low to warrant the additional cost of switchgear and other interconnection infrastructure. Because the biogas cannot be used elsewhere on-site, it is assumed the excess biogas generated will be flared in a waste gas burner.

A process flow diagram of the facility is presented below in Figure 6.

Figure 6: Standalone Anaerobic Digestion Facility



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[1] Evans, P. J., Patel, U., & Stensel, H. D. (2015). Anaerobic Digestion at the US Air Force Academy Results in Solids Reduction and Renewable Fuel. WEFTEC, 1637-1646.

Components of the standalone facility are listed below.

- Waste receiving station; including tanker truck connections, offloading pumps, settling tank, and truck scales.
- Equalization tank; including odor control, mixing, and transfer pumps.
- Anaerobic digesters and digester processing equipment; including heat exchangers, pumps, mixing system, chemical addition system, and piping.
- Dewatering equipment; including feed pumps, cake conveyance system, centrate pumps, polymer system, and containment for the equipment.
- Digester gas processing equipment; including engine, gas booster, gas conditioning equipment, gas safety equipment, and waste gas burner.

The total land required for the standalone AD facility is estimated to be three to five acres. Utilities required for the facility include electricity (480 volt), natural gas, water, and sewer.

Quasar Energy Group of Cleveland, Ohio provided a budgetary quote for a standalone anaerobic digestion system. Quasar's quote includes a 230,000 gallon mixed equalization tank, two 550,000 gallon steel digester tanks, a digestion mixing system, pumps for feeding and discharge, a shed structure for weather protection on valves, and miscellaneous process piping, instrumentation, valves, and electrical equipment. Note that Quasar requires dilution water for the standalone facility due to the high solids content of the food waste; therefore, the digesters are larger than those estimated in Table 1. Quasar has experience in digestion of biosolids, food waste, FOG (fats, oils, and grease) and septage at greenfield codigestion facilities, rehabilitation of existing wastewater treatment facilities, and installations at wastewater facilities for Class A biosolids production. However, their experience with food waste-only digestion is limited. One key consideration moving forward will be balance of micronutrients in the digestion process, as discussed previously. Piloting is recommended if a standalone facility is to be constructed to verify digester stability of commercial food waste. In some cases, codigestion of food waste with small amounts of septage, municipal residuals, or FOG (fats, oils, and grease) may provide some of these necessary nutrients. Quasar's budgetary price was $5,100,000 and is included as an appendix to this TM.

CDM Smith also received price quotes the CHP system. The quote for the CHP system and the Quasar quote included only equipment costs. Quasar's proposal did not include feedstock receiving, an operations building, laboratory analysis equipment, dewatering, biogas utilization equipment, or general sitework. CDM Smith developed equipment costs for these exclusions based on previous project experience, inflated to current pricing.

Design allowances were added as a percentage of the equipment cost for site civil, geotechnical, piping, HVAC, plumbing, electrical, instrumentation, and system installation. A separate land development contingency is included due to the unknown location for the standalone facility and high variability of land prices in Davidson County. Construction allowances were also included, inclusive of a 30 percent overall project contingency. Table 2 summarizes the allowances assumed for the project; these allowances are used for capital cost development of both the standalone and codigestion facilities.

Overall, costs were developed for the receiving station, anaerobic digesters, digester gas equipment, and dewatering equipment, inclusive of project allowances and contingencies, as summarized in Table 3. The entirety of Quasar's proposal is included in the anaerobic digesters line item of Table 3, although some of their scope could be divided between the anaerobic digesters and receiving station line items.

Table 2: Project Allowances

Description	Allowance, %
Design Allowances	
Site Civil / Geotechnical	10%
Piping	5%
HVAC	5%
Plumbing	3%
Electrical	15%
Instrumentation	8%
Installation	15%
Subtotal Design Allowances	***61%***
Land Development Contingency	**40%**
Construction Costs	
GC General Conditions	15%
GC Overhead & Profit	12%
Construction Contingency	30%
Escalation to Mid-Point of Construction	9%
Subtotal Construction Costs	***66%***
Project Costs	
Engineering Design, Bidding, & CPS	10%
Legal & Administration	3%
Subtotal Project Costs	***13%***

Table 3: Standalone Facility Capital Costs

Description	Capital Cost
Land Development	$6,000,000
Receiving Station	$1,300,000
Anaerobic Digesters	$17,000,000
Digester Gas Equipment	$1,600,000
Dewatering Equipment	$5,100,000
Total Estimated Project Cost	**$31,000,000**

O&M Cost Estimate

Annual operations and maintenance (O&M) costs and annual revenue/savings (i.e., "values") were developed for the standalone facility and are presented in Table 4. Below is a summary of the items included in the tables:

- Receiving station annual costs, inclusive of electricity for pumps and odor control.
- Anaerobic digesters annual costs, inclusive of chemical addition, electricity for pumps, and digester cleaning. It is assumed digester cleaning is required every five years. Costs are not included for digester heating; it is assumed heat from the CHP system can be utilized for all required digester heating.
- Digester gas equipment annual costs, inclusive of CHP system O&M, engine major overhaul maintenance (assumed to occur every 10 years), the parasitic load of the CHP system and associated equipment, gas conditioning system media, gas blower maintenance, and the gas conditioning system parasitic load.
- Dewatering equipment annual costs, inclusive of electricity for the pumps and equipment and polymer.
- Sidestream treatment annual costs for the centrate, inclusive of sewer discharge fees for ammonia, total suspended solids, and biochemical oxygen demand (BOD).
- Annual costs for solids end use, assumed for hauling to compost site and a tipping fee for composting of the food waste digestate.
- Annual payment on capital, assuming a 20-year loan term at 4-percent interest.
- CHP system annual value, inclusive of a power credit equal to the electricity cost of the receiving station, anaerobic digesters, digester gas equipment, and dewatering equipment. Because heating costs are not included in the annual digester cost above, a heating credit is not included.

Table 4: Standalone AD Facility Annual Costs and Values

Description	Annual Costs
Receiving Station	$10,000
Anaerobic Digesters	$200,000
Digester Gas Equipment	$110,000
Dewatering Equipment	$57,000
Sidestream Discharge to Sewer	$41,000
Solids End Use	$170,000
Annual Payment on Capital	$600,000
Total Annual Cost	**$1,200,000**
CHP – Power Purchase Savings	$75,000
Net Annual Cost	**$1,150,000**

Table 5 includes details of the cost and process assumptions made for both the standalone facility and codigestion facility.

Table 5: Project Assumptions

Description	Assumption
Electricity	$0.08/kwh
Natural Gas	$6/MMBtu
Digester Cleaning Cost	$115/CY
Polymer Cost	$1.60/lb
Dewatering Polymer Dosage	20 lb/DT
Centrate Ammonia	1,200 mg/L
Centrate TSS	2,000 mg/L
Centrate BOD	200 mg/L
Ammonia Treatment	$0.4406/lb
TSS Treatment	$0.1657/lb
BOD Treatment	$0.3264/lb
Lime	$160/ton
Acid	$1,400/ton
Food Waste Composting Fee	$30/WT
Class A Dried Biosolids Fee	$15/WT
Class A Lime Stabilized Biosolids Fee	$30/WT
Landfilling Fee	$22.32/ton
Biosolids Transportation Fee	$0.37/ton/mile
Loan Term	20 Years
Interest Rate	4%

Codigestion of Food Waste at Dry Creek WWTP

Scope of Work

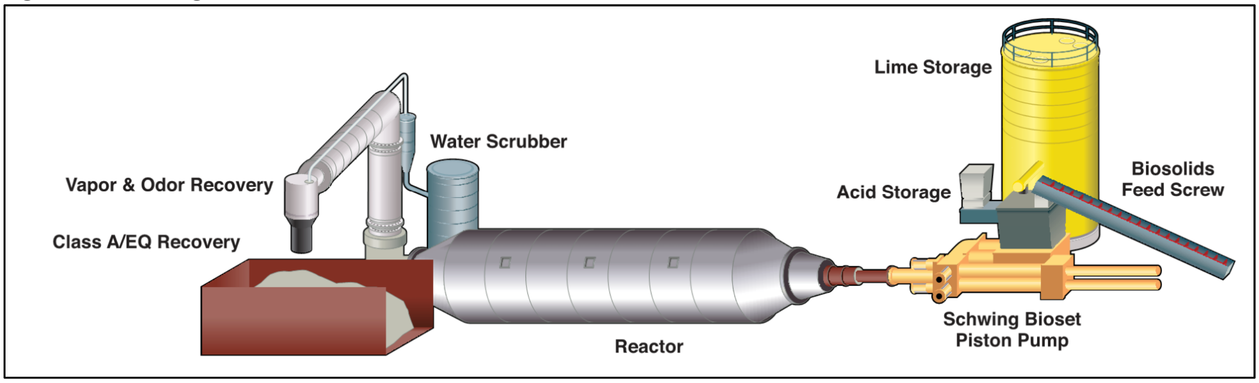
In this scenario, food waste would be codigested with waste activated sludge (WAS) and primary sludge (PS) in the existing digesters and one new anaerobic digester. The codigested sludge would be dewatered and further processed to Class A biosolids. The centrate would be pumped to an equalization tank and ultimately to the head of the facility. The Class A biosolids process could be either a dryer or an enclosed lime stabilization process (such as the Bioset process by Schwing). Both processes are included in this analysis and are detailed herein. Biogas produced by the three anaerobic digesters could be used to fuel the biosolids dryer or in a CHP system to produce heat and power.

The existing digestion and dewatering facilities are not sufficiently sized for the additional flows and loads from food waste. The food waste will require a minimum of 744,000 gallons of additional digester capacity. One new 860,000-gallon digester would be added to match the size of the existing digesters. The existing digester building would be expanded to house the additional digestion equipment. The food waste digestion will produce an additional 18,000 gallons per day of digestate for dewatering. At Dry Creek's current dewatering schedule of five days per week for seven hours per day, this will require an additional 60 to 70 gallons per minute (gpm) of dewatering capacity. One new belt press would be installed in the existing Filter Building to meet this requirement. Pilot testing is recommended to confirm the dewatering system sizing and feasibility of utilizing belt presses. In some cases, the high fiber content of food waste can be problematic for belt cleaning and may blind the belts early and lead to reduced dewatering performance.

If a dryer is used for biosolids processing, biogas would be used to fuel the dryer. Based on preliminary sizing calculations, the biogas can fully fuel the dryer and no supplemental heat will be required. Additional biogas produced in the digester can be used for digester heating in the existing boiler system. The pelletized biosolids product would be managed by a third party for transportation, marketing, and distribution.

The lime stabilization process is assumed to be an enclosed system, such as the Bioset system (shown in Figure 7). This system includes a completely enclosed hopper and reactor to contain toxic gases, odors and dust. Lime stabilization of anaerobically-digested biosolids liberates ammonia from the solids and produces toxic ammonia gas. Although the Bioset system is entirely enclosed, air handling is recommended to alleviate the ammonia toxicity concerns.

Figure 7: Schwing Bioset Lime Stabilization Process



If lime stabilization is used for biosolids processing, 100 percent of the biogas would be used to produce power and heat in a CHP system. This CHP system is sized for Dry Creek wastewater solids and food waste. Dry Creek averages 110 standard cubic feet per minute (scfm) in biogas production. When combined with the projected food waste biogas, the total biogas produced is anticipated to be 278 scfm. All of this biogas would be fed to a cogeneration system, sized at 1,160 kw. This engine is sized to provide power for most of the Dry Creek facility, which has an average electricity consumption of 1,300 kw. The lime stabilized biosolids product would be managed by a third party for transportation, storage, marketing, and distribution.

Figure 8 shows the process flow diagram of the codigestion facility with a biosolids dryer, and Figure 9 shows the flow diagram for lime stabilization and CHP.

Figure 8: Codigestion with Biosolids Dryer at Dry Creek WWTP

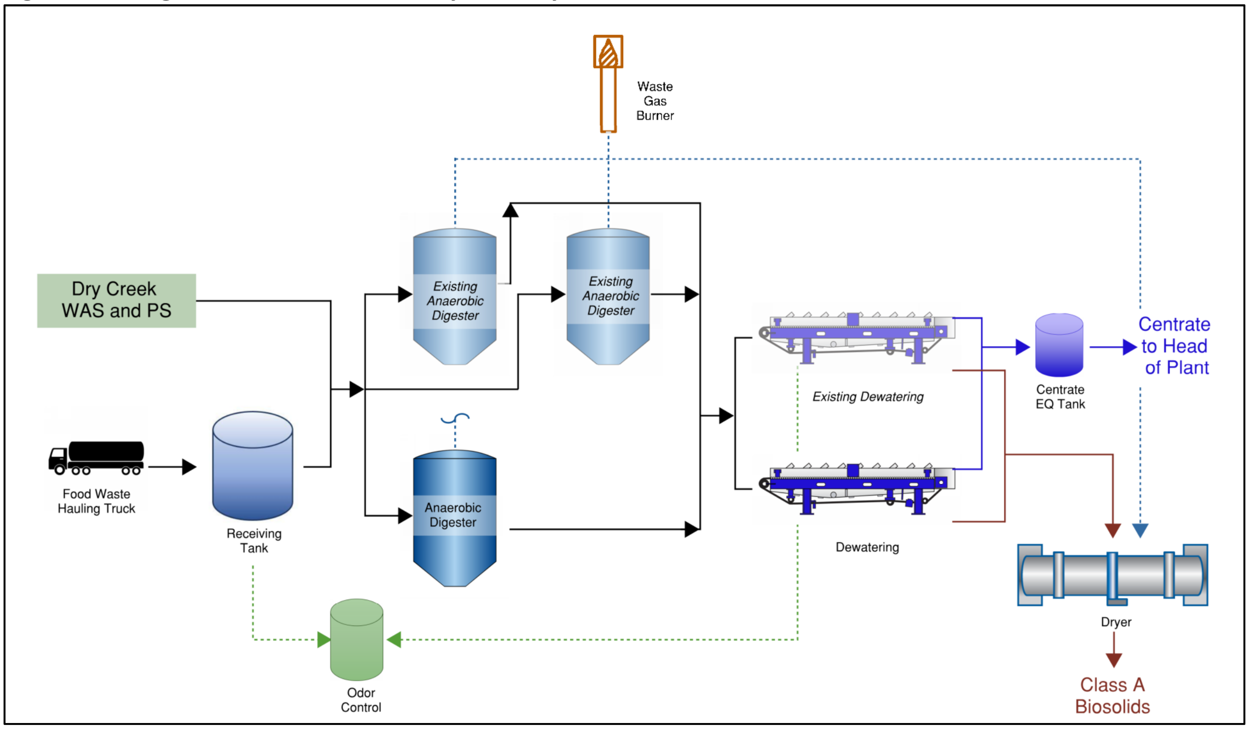
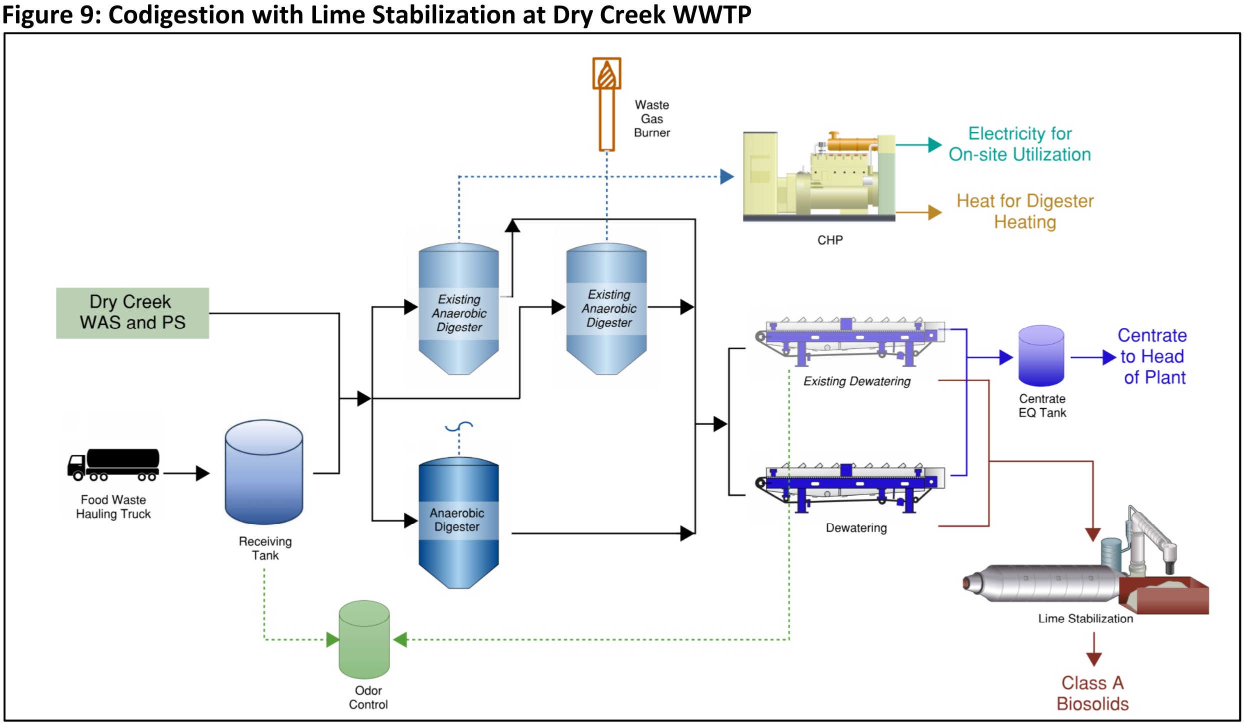


Figure 9: Codigestion with Lime Stabilization at Dry Creek WWTP



Components of the codigestion facility are listed below.

- Waste receiving station; including tanker truck connections, offloading pumps, settling box, and truck scales.
- Equalization tank; including odor control, mixing, and transfer pumps.
- Anaerobic digesters (two existing and one new); including expansion of the existing digester facility.
- Digester processing equipment; including heat exchangers, pumps, mixing system, and piping.
- Dewatering equipment; including feed pumps, cake conveyance system, centrate pumps, polymer system, and a centrate equalization tank.
- Biosolids processing equipment; including a lime stabilization system or dryer.
- Digester gas processing equipment; including gas conditioning equipment, gas safety equipment, and waste gas burner. The CHP system is only included with the lime stabilization option.

Capital Cost Estimate

Capital cost estimates were developed for the dryer and lime stabilization options using quotes received from manufacturers, CDM Smith project experience, and industry standard values. The receiving station is expected to have a similar cost to the receiving station for the standalone facility. Note that there are some differences between the codigestion and standalone facilities in receiving station cost due to items included in Quasar's proposal that were all included in the anaerobic digester line item in Table 3.

The anaerobic digester tanks are more expensive than the standalone facility tanks. Quasar's proposal includes steel tanks, whereas the cost estimate for Dry Creek includes digester construction to match the existing concrete tanks. Additionally, the anaerobic digesters line item includes costs for the digester building expansion.

The digester gas equipment line item includes gas conditioning equipment, gas safety equipment, and a waste gas burner for both codigestion options. The lime stabilization option also includes a CHP system and significant electrical upgrades to Dry Creek to allow for use of the electricity generated onsite.

The dewatering quote is the same for both codigestion options and includes additional dewatering and polymer equipment, pumping, conveyance, and the centrate equalization tank and pump. The biosolids equipment includes the dryer or lime stabilization equipment, plus an allowance for a new building at Dry Creek.

Table 6: Codigestion Facility Capital Costs

Description	Capital, Dryer	Capital, Lime + CHP
Receiving Station	$1,600,000	$1,600,000
Anaerobic Digesters & Building Expansion	$27,000,000	$27,000,000
Digester Gas Equipment	$2,100,000	$12,400,000
Dewatering Equipment & Filtrate EQ	$3,800,000	$3,800,000
Biosolids Equipment	$23,800,000	$10,600,000
Total Estimated Project Cost	**$58,000,000**	**$56,000,000**

O&M Cost Estimate

Annual O&M costs and annual revenue/savings (i.e., "values") were developed for the codigestion facility alternatives and are presented in Table 7 and Table 8. Below is a summary of the items included in the tables:

- Receiving station annual costs, inclusive of electricity for pumps and odor control.
- Anaerobic digesters annual costs, inclusive of electricity for pumps and digester cleaning. It is assumed digester cleaning is required every five years; costs have been annualized to include an average yearly cost. Costs are not included for digester heating; it is assumed heat from the CHP system or excess heat from the dryer scenario can be utilized for digester heating.
- Digester gas equipment annual costs, inclusive of gas conditioning system media, gas blower maintenance, and the gas conditioning system parasitic load for both codigestion alternatives.
- For the lime stabilization option, costs are included for CHP system O&M, annualized engine major overhaul maintenance (assumed to occur every 10 years), the parasitic load of the CHP system, and associated equipment.
- Dewatering equipment annual costs, inclusive of electricity for the pumps and equipment and polymer.
- Biosolids processing and end use annual costs.
    - For the dryer alternative, this includes heating for the dryer, electricity for the blower, general O&M for the dryer, and biosolids end use.
    - For the lime stabilization alternative, this includes lime and acid for processing, electricity, general O&M for the lime stabilization process, and biosolids end use.
- Annual payment on capital, assuming a 20-year loan term at 4-percent interest.

- Biosolids utilization credit, which is the "savings" by diverting Class B biosolids produced at Dry Creek from the landfill. The credit is inclusive of landfill fees and hauling costs. It is assumed the Middle Point landfill would reach capacity after five years into the project; and therefore, the biosolids would be hauled to the WMI West Camden Landfill for the remaining years in the evaluation. The table below includes the costs for both disposal at Middle Point and West Camden.

- CHP system annual value, inclusive of a power credit equal to the engine capacity (1,160 kw). Because heating costs are not included in the annual digester cost above, a heating credit is not included. This annual value is only included for the lime stabilization option.

- Biosolids processing annual value, inclusive of a natural gas credit for the dryer process. This annual value is only included for the dryer option.

Table 7: Codigestion Facility Annual Costs

Description	Dryer	Lime + CHP
Receiving Station	$10,000	$10,000
Anaerobic Digesters	$130,000	$130,000
Digester Gas Equipment	$34,000	$220,000
Dewatering Equipment	$57,000	$57,000
Biosolids Processing & End Use	$390,000	$860,000
Annual Payment on Capital	$1,200,000	$1,100,000
Total Annual Cost	$1,800,000	$2,400,000
Net Annual Cost	***$800,000 - $1,100,000***	***$800,000 -$1,100,000***

Table 8: Codigestion Facility Annual Values

Description	Dryer	Lime + CHP
Biosolids Utilization Credit	$530,000 - $820,000	$530,000 - $820,000
CHP System	$0	$810,000
Biosolids Processing	$220,000	$0
Total Annual Value	$750,000 - $1,000,000	$1,300,000 - $1,600,000

Summary of Alternatives for Food Waste Management

This study evaluated three food waste management alternatives:

- A Standalone Food Waste Processing Facility with Food Waste Composting

- A Codigestion Facility at Dry Creek WWTP with Biosolids Dryer

- A Codigestion Facility at Dry Creek WWTP with Lime Stabilized Biosolids and CHP

An alternatives analysis was conducted to compare the three alternatives. Each alternative is ranked on a scale from one (worst) to three (best) for various criteria. The criteria are assigned different weighting factors, and the criteria points assigned to each alternative is the product of the ranking and the weighting factor. A total score for each alternative is given by the sum of the criteria points, and the alternative with the highest score is considered the preferred alternative. To compare the three alternatives, the following criteria were developed for evaluation:

- Present worth analysis: cost evaluation including capital and O&M costs/values over a 20-year period. inflation factor is equal to the discount factor.
- Ease of construction; inclusive of construction time, permitting requirements, and coordination needs between Metro Water, Metro Public Works, engineering, and the construction team.
- Ease of operation; inclusive of operations and maintenance requirements, impact to current processes, amount of equipment to maintain, and facility safety.
- Maintenance of operation during construction, focused on continued operation of Dry Creek WWTP throughout implementation of the project.
- End product quality and quantity, accounting for classification under 503 regulations, water content, and wet mass produced.
- Landfill diversion; inclusive of both food waste and Dry Creek biosolids diversion.
- Energy production and utilization, including evaluation of biogas beneficial use from digestion.
- Equipment life, accounting for expected longevity of processing equipment.
- Digester stability, accounting for the long-term operation of the anaerobic digestion process, including the likelihood of digester upsets and nutrient deficiencies.

These criteria are weighted for the evaluation per the factors as presented in Table 9.

Table 9: Alternatives Analysis, Criteria Weighting Factors

Description	Weighting Factor
Present Worth Costs	20%
Ease of Construction	5%
Ease of Operations	5%
Maintenance of Dry Creek WWTP Operation During Construction	5%
End Product Quality and Quantity	15%
Landfill Diversion	15%
Energy Production and Utilization	15%
Equipment Life	10%
Digester Stability	10%

Figure 10 shows the lifecycle cost comparison of the three alternatives, accounting for capital costs, annual O&M costs, and annual values over a 20-year period. Table 10 provides a summary comparison of the alternatives. The standalone facility has the lowest capital cost; and therefore, the lowest 20-year lifecycle cost.

Figure 10: Present Worth Cost Comparison

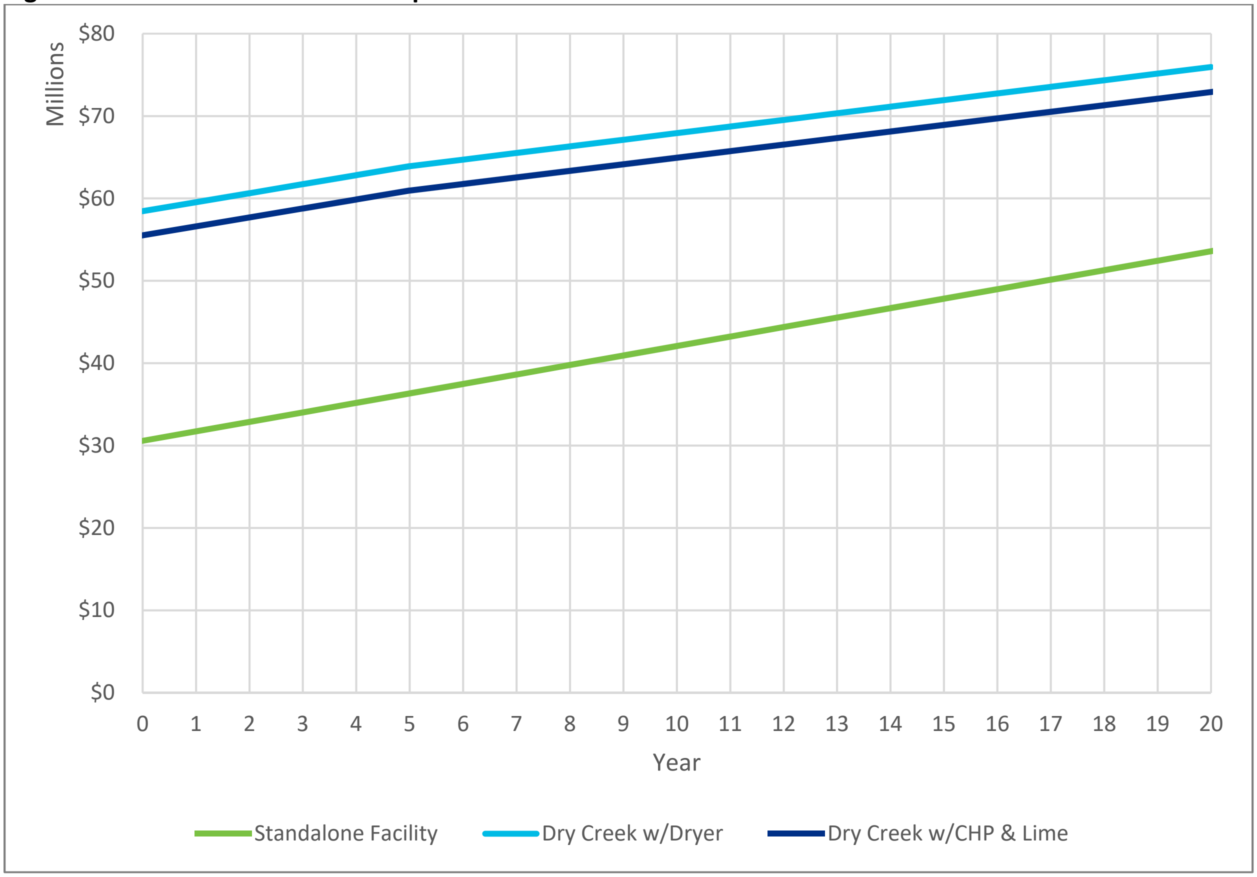


Table 10: Cost Comparison

Description	Standalone	Dry Creek, Dryer	Dry Creek, Lime + CHP
Capital	$31,000,000	$58,000,000	$56,000,000
Total Annual Cost	$1,200,000	$1,800,000	$2,400,000
Total Annual Value	$75,000	$750,000 - $1,000,000	$1,300,000 - $1,600,000
Net Annual Cost	$1,150,000	$800,000 - $1,100,000	$800,000 - $1,100,000
20-Year Cost	$54,000,000	$73,000,000	$76,000,000

Because the standalone has the least equipment, it is ranked easiest to construct and easiest to operate. In addition, the standalone facility construction will not have an impact on Dry Creek WWTP operations; and is therefore the easiest for maintenance of operation during construction. Conversely, the codigestion alternative with lime and CHP has the most equipment of the three alternatives and will be the most difficult to construct and operate, and will have the highest impact on Dry Creek WWTP operations during construction. Furthermore, due to the ammonia gas generation during the lime stabilization process, this alternative also has the highest concern from a safety perspective in operation.

The codigestion facility with the dryer will produce a highest quality end product because it is a dried biosolids product with significant water reduction (i.e., volume reduction) and is a Class A biosolids product. The total biosolids production from the dryer is expected to be approximately nine wet tons per day. The codigestion facility with lime stabilization will also produce a Class A product; however, the moisture content will be much higher, with an expected biosolids production of 44 wet tons per day. The standalone facility, because it only processes food waste (whereas the codigestion process includes wastewater residuals) will produce 16 wet tons per day of compost. The composted product is not subject to 503 regulations because it is 100 percent food waste and will not contain fecal content. The compost, similar to the Class A product, can be used as a fertilizer substitute or amendment. Since the dryer codigestion facility produces the least volume of biosolids, it is ranked first for the end product quality assessment. The lime stabilization codigestion facility produces the most volume of biosolids and is therefore ranked third for this assessment.

Both Dry Creek codigestion alternatives will divert 40,800 tons per year from the landfill. This is inclusive of both food waste and wastewater biosolids. The standalone food waste facility will only divert the food waste from the landfill, a total of 30,700 tons per year.

The codigestion facility with lime stabilization has the highest renewable energy production and utilization, because electricity can be produced from the CHP system and beneficially used on-site. Additionally, the heat produced from CHP can be recovered and utilized for digester heating. The codigestion facility with the dryer ranks second for energy utilization, because biogas produced from AD is used for the drying process and digester heating. The standalone facility does not have a high energy utilization due to the limitations on energy demand from the facility, and therefore, much of the energy produced as biogas must be flared.

The standalone facility ranks last in equipment life, due to the quality and materials of construction of the digesters. The steel digesters (quoted by Quasar) are expected to have a much shorter lifespan than concrete digesters that would be constructed at Dry Creek WWTP for either codigestion alternative.

The Dry Creek codigestion facility options are ranked equally for highest digestion stability. The standalone facility ranks lowest due to the nutrient deficiency and potential need for supplemental chemicals, such as COD, cobalt, nickel, molybdenum, and selenium. Codigestion of food waste with municipal residuals will allow the digesters to have ample micronutrient levels and will not require chemical addition.

Table 11 summarizes the alternatives analysis for the three options, based on the discussion above. Table 12 correlates the comparison to the relative scoring (three is highest, one is lowest). In some cases, two alternatives tied in ranking. Finally, Table 13 summarizes the total weighted score for each alternative based on the rankings.

Table 11: Alternatives Analysis Comparison

Description	Standalone	Dry Creek, Dryer	Dry Creek, Lime + CHP
Present Worth Costs	$52,000,000	$74,000,000	$71,000,000
Ease of Construction	Easiest	Medium	Hardest
Ease of Operations	Easiest	Medium	Hardest
Maintenance of Operation During Construction	Easiest	Medium	Hardest
End Product Quality and Quantity	Compost, 16 WT/day	Class A, 9 WT/day	Class A, 44 WT/day
Landfill Diversion	Lowest	Highest	Highest
Energy Production and Utilization	Lowest	Medium	Highest
Equipment Life	Lowest	Highest	Highest
Digestion Stability	Lowest	Highest	Highest

Table 12: Alternatives Analysis Scoring

Description	Standalone	Dry Creek, Dryer	Dry Creek, Lime + CHP
Present Worth Costs	3	1	2
Ease of Construction	3	2	1
Ease of Operations	3	2	1
Maintenance of Operation During Construction	3	2	1
End Product Quality	2	3	1
Landfill Diversion	1	3	3
Energy Production and Utilization	1	2	3
Equipment Life	1	3	3
Digestion Stability	1	3	3

Table 13: Alternatives Analysis Weighted Scoring

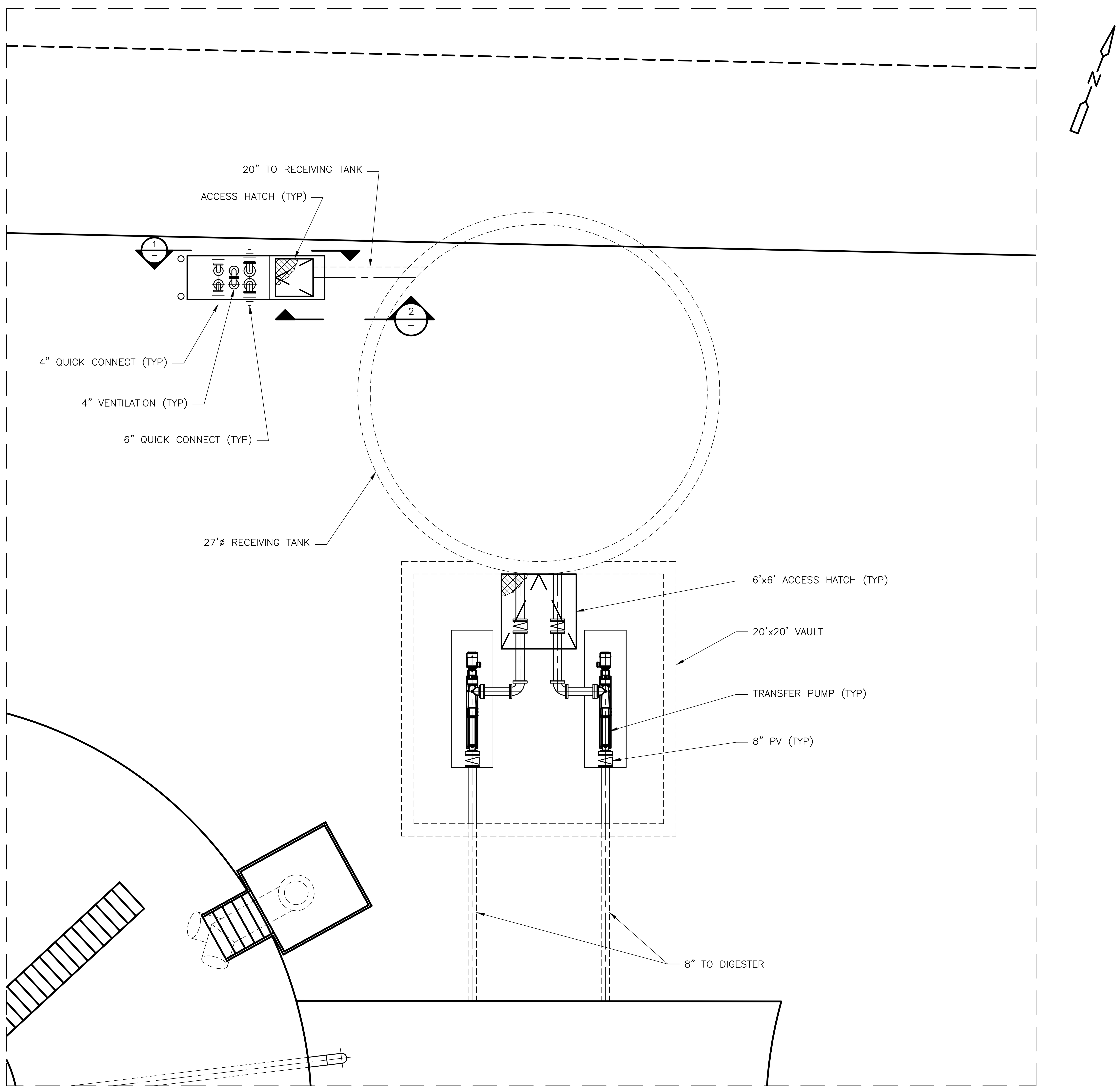
Description	Weight	Standalone	Dry Creek, Dryer	Dry Creek, Lime + CHP
Present Worth Costs	20%	60	20	40
Ease of Construction	5%	15	10	5
Ease of Operations	5%	15	10	5
Maintenance of Operation During Construction	5%	15	10	5
End Product Quality	15%	30	45	15
Landfill Diversion	15%	15	45	45
Energy Production and Utilization	15%	15	30	45
Equipment Life	10%	10	30	30
Digester Stability	10%	10	30	30
Total		**185**	**230**	**220**

Overall, the Dry Creek codigestion facility with the dryer ranked the highest in the evaluation. This is primarily due to the high end product quality from the drying process. Ultimately, all three alternatives ranked very closely in our evaluations and the final selection will vary depending on the balance of the evaluation of criteria balance between the overall capital and operating costs and the potential for increased diversion and beneficial use of the biogas produced. Pilot testing of food waste codigestion or standalone food waste digestion would be beneficial and may aid in decision-making.

Appendix A
Food Waste Receiving Station Drawings

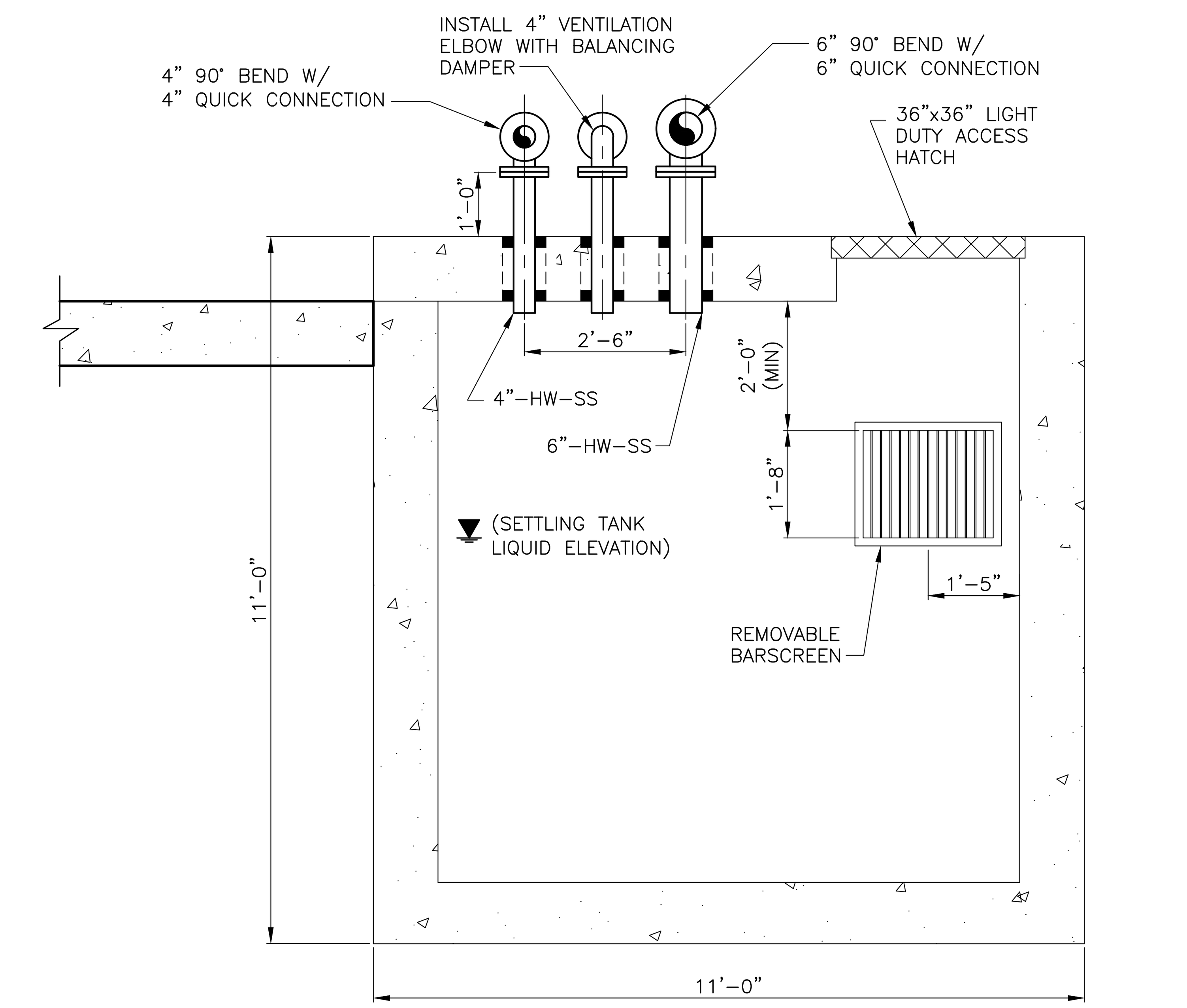
CDM Smith

Figure A-1
Food Waste Receiving Station
September 2019

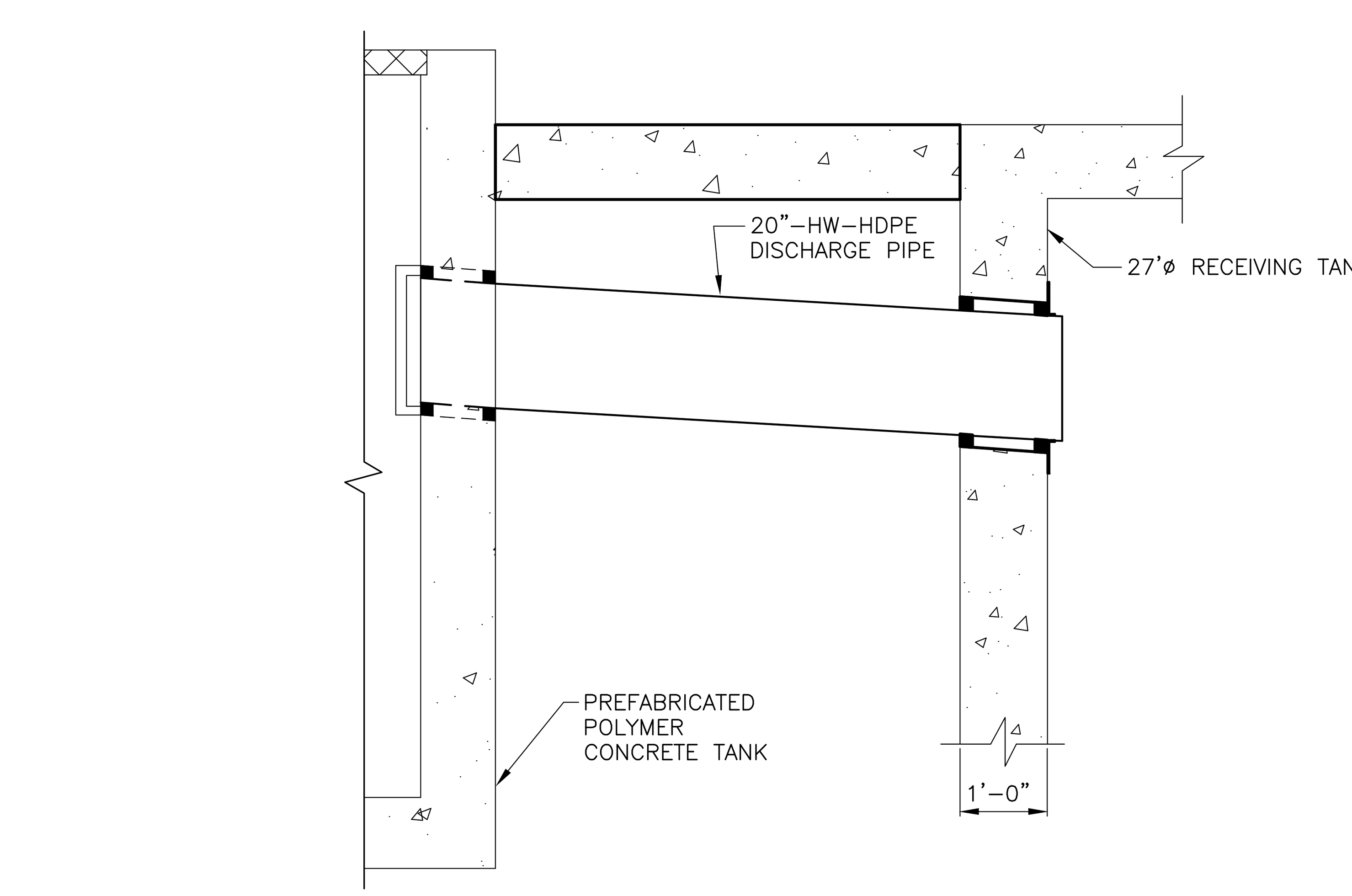


ENLARGED PLAN

PLAN
NTS



SECTION 1
1/2" = 1'-0"



SECTION 2
1/2" = 1'-0"

CDM Smith

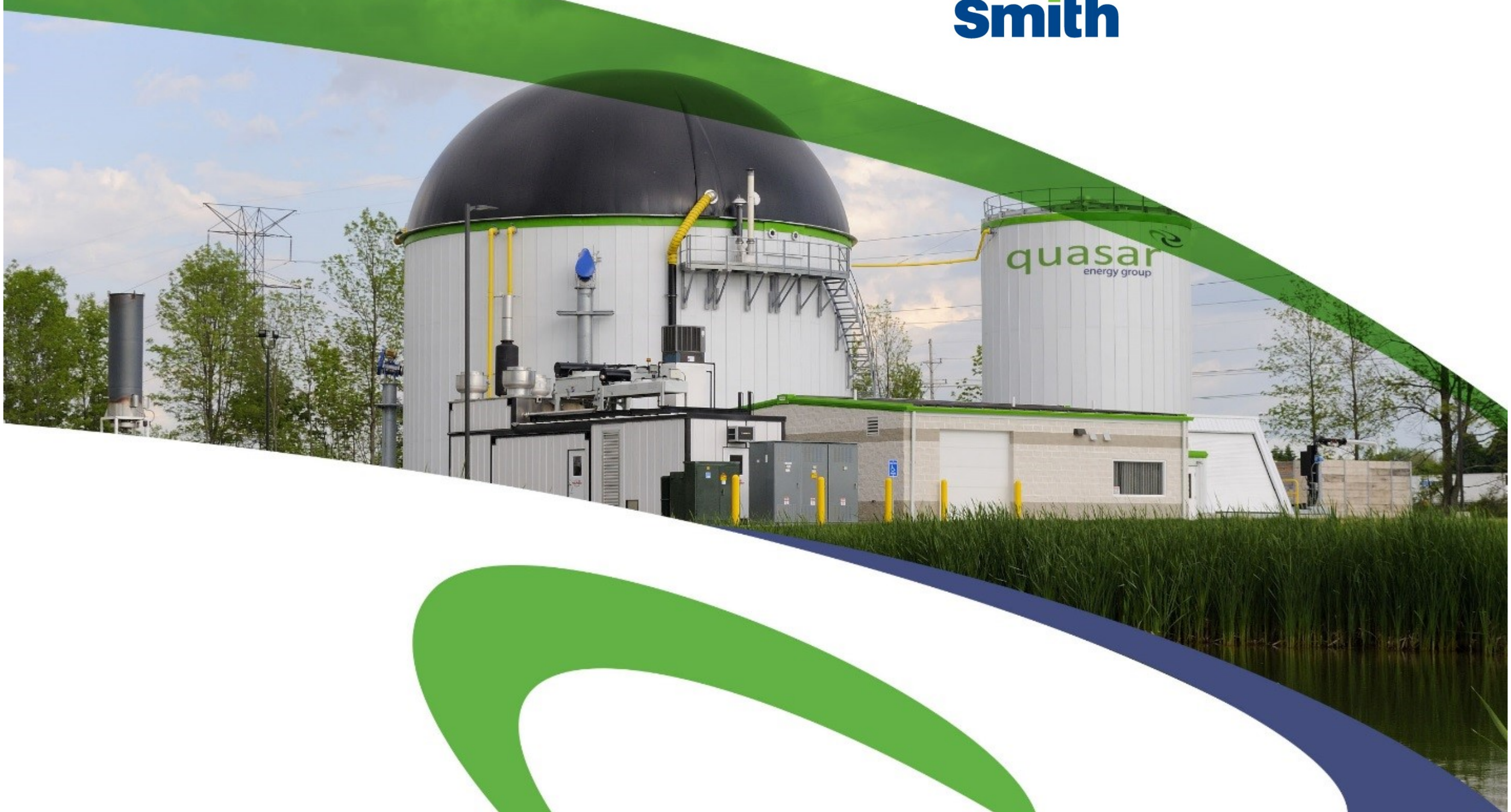
Appendix B
Quasar Energy Group Budgetary Proposal

quasar
energy group

Nashville, TN Food Waste Digester Budgetary Quote

Prepared for:

CDM Smith



March 27th, 2019

For Information Only

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Business Sensitive Proprietary Commercial Information

quasar considers the information included in this study as proprietary commercial information and not for distribution. All intentions to share any material included in this proposal with other parties requires written consent of quasar energy group and the opportunity to retract business sensitive information.

SECTION II: **Project Background & Design Basis**

quasar was approached by CDM Smith in support of a study evaluating the feasibility of a food waste digestion facility for the Nashville regional area. quasar has collaborated with CDM Smith on past studies and informs its estimates based on its firsthand experience in designing, building and operating various aspects of its 20 US based anaerobic digestion projects. quasar has prepared an initial high level quote for design, equipment and construction installation services for two 550,000 gallon anaerobic digesters. The project quotes are based on the following design parameters:

Incoming Feedstock Quality & Energy Potential

INCOMING BIOMASS	Per Day Basis (based on 7 days per week digester feeding)											
Feedstock	Wet Tons	%TS	%VS	Dry Tons	Gal	Tons VS	BMP CH4	BMP Biogas	CH4 %	Ft3 CH4	Ft3 Biogas	MMBTU
1) Food Waste	85	14%	93%	12	20,392	11	7.2	12.0	60.0%	159,236	265,394	161
2) Dilution	14	0%	0%	0	3,361	0	0.0	0.0	0.0%	0	0	0
Total Blended Biomass with Dilution	**99**	**12.0%**	**93.0%**	**12**	**23,753**	**11**	7.2	12.0	60.0%	159,236	265,394	**161**

SECTION II: **Proposed Scope of Work**

The quote is based on the design, equipment procurement, construction and commissioning of the following scope of work:

Anaerobic Digester System:

- 1x 0.23M gallon steel bolted insulated feedstock equalization tank
    - Carbon steel epoxy coated rolled tapered panel bolted design tank
    - Top ring 304 stainless steel
    - Steel cone external rafter roof
    - Vertical standing seem insulation (2” polyiso with stucco aluminum painted sheathing)
    - Instrumentation to include tank level sensor and temperature sensor
    - 1x side entry mechanical propeller mixer
    - Tank foundation
    - Mixing concrete pad
    - Tank erection
    - Process piping material supply and installation
    - Electrical material supply and installation
    - Shed structure for weather protection on valves
    - Gravel finish in area around tank

- 2x 550,000 gallon steel bolted insulated anaerobic digester tanks
    - Carbon steel epoxy coated rolled tapered panel bolted design tank
    - Top ring 304 stainless steel
    - Steel cone external rafter roof
    - Hydraulic mixing system with foam buster
    - Vertical standing seem insulation (2” polyiso with stucco aluminum painted sheathing)

- Progressive cavity pump for feeding and discharge
- Instrumentation to include tank level sensor and temperature sensor
- 2x Gas flow meter and 2x gas quality analyzer
- Pneumatic valves
- Tank foundation
- Mixing concrete pad
- Tank erection
- Shed structure for weather protection on valves
- Gravel finish in area around tank
- Process piping material supply and installation
- Electrical material supply and installation

Excluded/Assumed by Others:

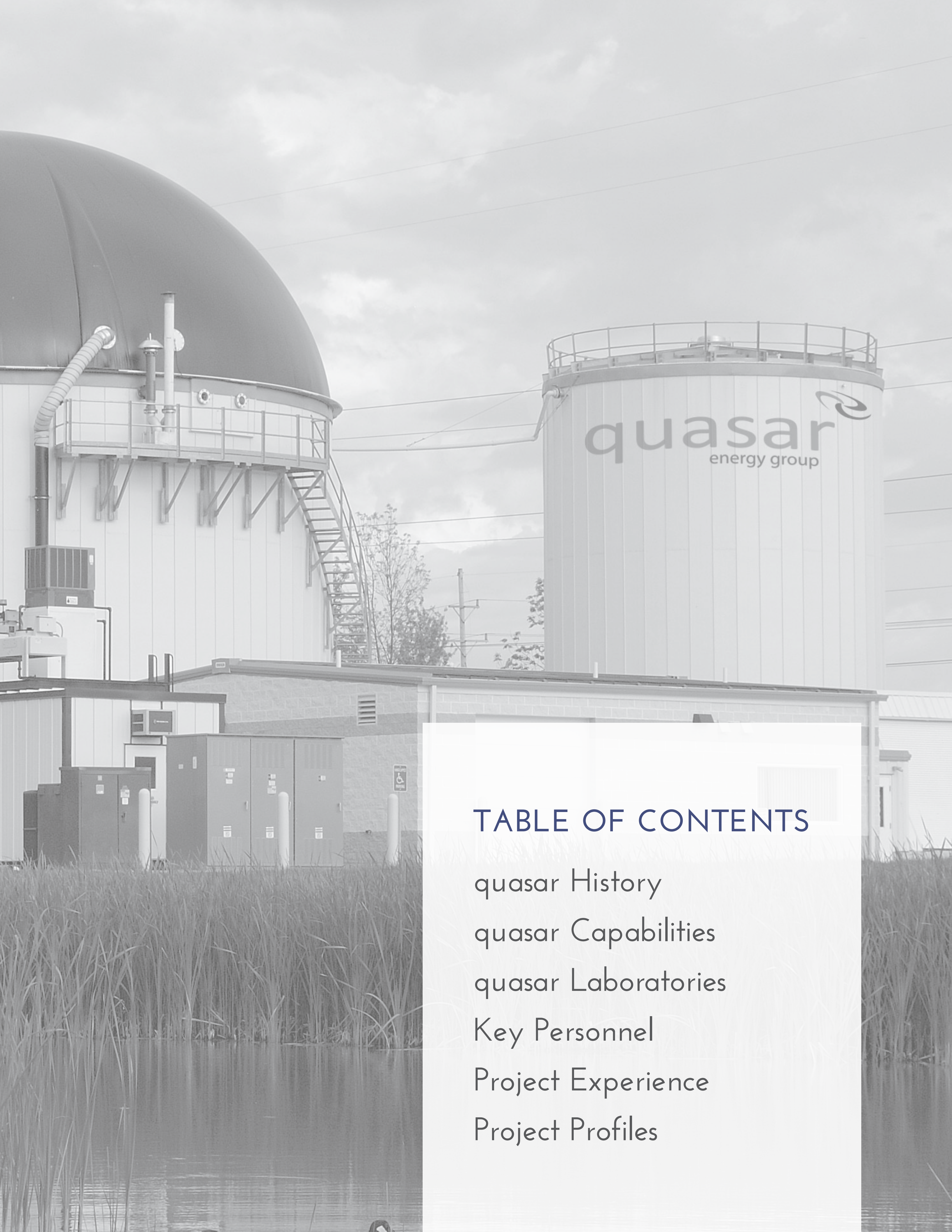
- Feedstock receiving
- Operations building / lab equipment
- Dewatering
- Biogas cleanup or electrical generation equipment
- General sitework

SECTION III: Budgetary CAPEX Estimate

Budgetary Pricing: $5.1M
Preliminary Timeline for Engineering/Permitting/Procurement/Construction: 18 Months

SECTION IV: Qualifications

STATEMENT OF QUALIFICATIONS



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QUASAR HISTORY

quasar is one of several privately held, family owned companies born out of a multi-generational business, Kurtz Brothers, which has specialized in material reuse and resource recovery for decades. In 1991, quasar's President and Founder, Melvin Kurtz, in collaboration with Kurtz Brothers, privatized the City of Akron, OH municipal wastewater treatment biosolids handling facility, a $90M facility. The City of Akron retained ownership of the facility, and KB Compost Services, Inc. began operating the largest in-vessel compost facility in the US for biosolids. After identifying the process as extremely costly, KB Compost Services sought a sustainable, economical, long-term solution for biosolids management.

It was on a trip to Germany in 2001, the Kurtz Family was introduced to the anaerobic digestion process. Using a high-solids anaerobic digestion process by the German firm of Schmack Biogas, the plant was transformed to integrate anaerobic digestion with composting. The project generated renewable energy and resulted in cost savings. Phase I was completed in 2007; after the success of the 2007 project, the composting portion of the project was shut down in 2012 and completely converted to an anaerobic digestion process. In 2006, Mel Kurtz went on to develop quasar energy group.

quasar is a Cleveland, OH based renewable energy and organics management firm wholly focused in deploying anaerobic digestion technology for sustainable waste management solutions in municipal, industrial, and agricultural applications. To date, quasar has completed fifteen projects in four states with a combined capacity to process over 800,000 wet tons of organic material and generate 72,000 MWh of electricity annually.

Since its founding in 2006, quasar has provided clients with turnkey solutions to waste management challenges, cost saving initiatives, and environmental stewardship goals. quasar's complete mix anaerobic digestion system processes organic waste to produce clean, renewable energy. Our collaboration with numerous entities – both federal and higher education – has given us invaluable insight to maximizing biogas productivity at anaerobic digestion facilities.

One of quasar's unique strengths is our exclusive US supply chain. quasar has developed the capacity to design system components in-house when a technology solution was not readily available in the marketplace. As a result of 100% US sourced components, quasar's lead times are significantly reduced, and maintenance and replacement efficiencies are improved.

Mission | Vision | Values

Each quasar project is firmly rooted in our company mission: to create resources by repurposing waste. We aim to provide our clients with advanced technology that produces affordable renewable energy from municipal and commercial organic biomass, while improving the environment. We bolster our mission by consistently acting on our company values:

Trust. Earning the trust of our coworkers, customers, and community partners through competence, reliability and good faith.

Accountability. Doing what we say we will do ethically and honestly.

Collaboration. Recognizing that by working together we are stronger than working on our own.

Balance. Fostering a work environment that contributes to both professional achievement and personal fulfillment.

Stewardship. Committing to health, safety, and environmental responsibility.

QUASAR'S CAPABILITIES

Project Development

quasar's in-house project development team is wholly committed to ensuring the viability of projects before the start of complete design and construction. The project development team is responsible for completing due-diligence activities, including market research, competitive research, financial modeling, and high-level technical viability.

Engineering & Design

quasar has an in-house engineering team, responsible for designing each of quasar's operational facilities.

Regulatory Compliance

quasar has in-house regulatory staff on-hand to ensure that each project meets regulatory compliance. quasar seeks to understand the regulatory landscape in each state early in project development to ensure long-term success.

Construction

Our construction team has built 15 operational anaerobic digesters in the United States. The construction team closely collaborates with the engineering & design team to ensure constructability and practical design.

Operations & Maintenance

Unique to the industry, quasar has hands on operations experience at anaerobic digestion facilities. Each quasar project is designed with functional operational experience taken into consideration. quasar offers a wide range of operational involvement to our customers, including full operations and maintenance responsibility, 24-hour remote operations oversight and consulting, and as-need operational advising.

Biomass Sourcing

quasar's biomass team is skilled at surveying the marketplace to ensure sufficient feedstock to maintain the biological health of all our anaerobic digestion projects. The biomass team has a proven track record of building successful relationships with both local and national businesses.

Beneficial Reuse

A comprehensive effluent management plan is essential to the success of anaerobic digestion projects; our effluent management team works with our clients to ensure the project has a sound plan for effluent management.

Laboratory Services

quasar operates two full-service laboratories: one at corporate headquarters in Independence, Ohio and one in partnership with The Ohio State University's campus in Wooster, Ohio. quasar's laboratory allows us to make informed and optimized operational decisions. The lab is equipped with pilot scale digesters. Designed by quasar engineers, the pilot scale digesters allow us to replicate the complete mix process of full-size facilities to minimize operational challenges and optimize performance.

QUASAR LABORATORIES

Capabilities

quasar's analaytical laboratories perform testing services for biomass generators and municipal clients across the county under the supervision of Dr. Yebo Li and Dr. Xumeng Ge. Services include evaluation of biomass substrates and gases using a variety of instruments on site.

25 Gallon Pilot Scale Digesters

Our laboratories house ten 25 gallon pilot scale digesters which simulate the performance of the full scale facilities. The compact digesters are also used to stress test the contained system to identify potential issues with biomass such as composition and gas-production performance.

Biomethane Potential (BMP)

quasar performs full characterization of biomass feedstocks including biomethane potential (BMP), which is used to evaluate the feasibility of feedstocks for codigestion based on the energy potentials, potential inhibitors/toxic components, and heavy metals and NPK values. The full characterization of feedstocks includes: Total Solids (TS) and Volatile Solids (VS); Carbon, Nitrogen, Sulfur (C/N/S); pH; Chemical Oxygen Demand (COD), Minerals and heavy metals (ICP-MS). The BMP tests are 4-weeks flask tests with frequent monitoring of biomethane production.

Refining Treatment Plant Operations

Codigestion presents a significant opportunity for wastewater treatment plants to achieve energy neutrality while bringing in additional revenue from tipping fees. quasar's laboratories specialize in testing and analyzing anaerobic digestion feedstocks to predict performance and diagnose the origin of common challenges such as foaming, low gas yields and excess hydrogen sulfide production. The laboratory assists customers across the county in successfully developing and managing their codigestion projects.

Testing Capabilities

Total solids (TS)	TKN
Volatile solids (VS)	Ammonia
pH	Heavy metals (ICP-MS)
Chemical Oxygen Demand (COD)	Minerals (ICP-MS)
Carbon, Nitrogen (CN)	VFA profile (GC)
Sulfur (S)	Biogas Volume
Heavy metals + Minerals (ICP-MS)	Biogas composition (CO_2, O_2, N_2, CH_4)
VFA/TIC	Hydrogen sulfide (H_2S)

KEY PERSONNEL

Mel Kurtz

For forty four years, Kurtz has founded, directed, and operated several businesses from start up to millions in annual sales through effective business planning, creative sales techniques, and innovative marketing. His accomplishments include initiating well-planned and executed acquisitions and mergers. Prior to founding quasar, Mel spent fifteen years managing a compost operation. While managing the Kurtz Brothers Compost Services, Inc., Mel managed the largest in-vessel compost facility for biosolids in the U.S.; this facility sold 90,000 cubic yards of compost annually. Kurtz is currently the Chief Executive Officer at quasar energy group. Kurtz has been at quasar since its' founding in 2006.

Steve Smith

Steve is responsible for finding and assessing financing options for all fifteen of quasar's anaerobic digestion systems. Smith consistently finds financing options to meet diverse client needs, including grant funding, public/private partnerships, and low-interest loans. Since starting at quasar, Smith is responsible for securing over $6.5 million of USDA Rural Energy for America Program funds and $1 million in USDA NRCS Conservation & Innovation Grant funding. He has over twenty-five years of experience in the financial industry. Smith manages financial due diligence with regards to energy value, tip fee, and operations and maintenance costs.

Alan Johnson

Johnson has more than 30 years of experience in business startup and manufacturing having held positions in industrial engineering, quality control, and marketing, among others. Johnson has been with quasar for seven years, where he manages high-profile clients and oversees due diligence efforts on all development based projects. Alan has led engineers in a number of innovative changes in design to optimize plant performance based feedstock specific concerns. Alan works closely with quasar's internal construction team to ensure the on-time and within budget projects on all of quasar's facilities. Johnson is a professional engineer in 13 states including California.

Monte King

Monte has constructed eleven of quasar's anaerobic digestion facilities during his five years with the company. King has proven expertise in the construction of all quasar facilities. He closely collaborates with plant operators to ensure that digester construction and design are practical when compared operational knowledge. Monte consistently delivers turnkey systems to clients under budget and on schedule. Throughout the development process, King works with Civil, Mechanical, and Industrial engineers to produce engineering drawings and cost effective solutions for each unique customer. King has optimized quasar's technology for processing wastewater treatment biosolids.

KEY PERSONNEL

Mark Suchan	Over Suchan's tenure with quasar, he has been involved in all aspects of project development from conducting due diligence to managing digester health. Suchan has experience working both in quasar's in-house laboratory and sourcing feedstock from municipal clients to fill anaerobic digestion systems. Suchan's knowledge of anaerobic digestion system feedstock results in optimal performance of quasar's systems. During his time as lab manager at quasar (2010-2011), Mark worked closely with Ohio State University personnel to develop advanced anaerobic digestion technology for optimized energy production from biomass. Suchan's current responsibilities include sourcing feedstock for all of quasar's digesters and managing residual effluent for beneficial use. Suchan has over ten years of experience with biosolids, food waste, and fats, oils, and grease (FOG) feedstock and the associated energy value, nutrient makeup, and effluent concerns.
Yebo Li	Dr. Yebo Li is the Vice President of Technology at quasar energy group. His current research and development focuses on the conversion of waste streams to fuels and chemicals via anaerobic digestion. His research and development efforts focus on enhanced biogas production, biogas upgrading to transportation fuels and chemicals, effluent utilization and odor control. He is devoting most his time on the commercial production of bioenergy. During his career at The Ohio State University, Dr. Li received more than $12 million in research and training grants from the U.S. Department of Agriculture, U.S. Department of Energy, and industry. Dr. Li has published more than 130 peer reviewed journal articles with more than 4700 citations. Dr. Li has authored two books on bioenergy and bio-based polymers. Among other awards, Dr. Li received the 2012 Rain Bird Engineering Concept of the Year Award from the American Society for Agricultural and Biological Engineers.
Dave Baran	Dave Baran is a core member of quasar's project development team and is responsible for business development, due diligence on new projects, and preconstruction project management. Since joining the firm in 2014 Dave has played an active role in developing numerous facilities in new geographies. Baran comes from a background in management consulting where he managed projects and advised clients in renewable energy, environmental services and industrial manufacturing clientele. He also has international experience, having worked in Nairobi, Kenya with a sanitation, composting and waste to energy social enterprise.

PROJECT EXPERIENCE

Facility	Project Description	Date Operational	Feedstock	Energy Use	quasar Project Role
Buckeye Biogas	Greenfield codigestion facility	2010	Biosolids, Food waste/FOG	CHP/CNG	Feasibility, Design/Build, Commission, Biomass Sourcing, O&M
Zanesville Energy	Greenfield codigestion facility	2010	Biosolids, Food waste/FOG	CHP/CNG	Feasibility, Design/Build, Commission, Biomass Sourcing, O&M
Agreen Energy	Greenfield agricultural digester	2011	Manure, Food waste/FOG	CHP	Design/Build, Commission, Staff Training
Collinwood BioEnergy	Greenfield ADS and thermal treatment	2012	Biosolids, Food waste/FOG	CHP	Feasibility, Design/Build, Commission, Biomass Sourcing, O&M
Central Ohio BioEnergy	ADS and thermal treatment	2012	Biosolids, Food waste/FOG	CHP/CNG	Feasibility, Design/Build, Commission, Biomass Sourcing, O&M
Haviland Energy	Greenfield codigestion facility	2012	Biosolids, Food waste/FOG	CHP	Design/Build, Commission, Biomass Sourcing, Staff Training
Three Creek BioEnergy	Codigestion at WWTP	2012	Biosolids, Food waste/FOG	CHP/CNG	Feasibility, Design/Build, Commission, Biomass Sourcing, O&M
Buffalo BioEnergy	Greenfield food waste ADS	2013	Food waste/ FOG	CHP	Feasibility, Design/Build, Commission, Biomass Sourcing, O&M
Wooster Renewable Energy	Digester retrofit at WWTP	2013	Biosolids, Food waste/FOG	CHP	Design/Build, Commission, Biomass Sourcing, O&M
Village Green Brunswick Landing	Economic development project at old airport, including digestion, Class A, dewatering	2015	Biosolids, Food waste/FOG, septage	CHP	Feasibility, Design/Build, Commission, Staff Training
Dovetail	Greenfield agricultural digester at hog farm	2015	Biosolids, Food waste/FOG	CHP	Design/Build, Commission, Biomass Sourcing, Staff Training
Ringler	Greenfield agricultural digester at hog farm	2013	Biosolids, Food waste/FOG	CHP	Design/Build, Commission, Biomass Sourcing, Staff Training

PROJECT EXPERIENCE

Facility	Project Description	Date Operational	Feedstock	Energy Use	quasar Project Role
Niagara BioEnergy	Greenfield digester for economic development project	2013	Biosolids, Food waste/FOG (currently only food waste/ FOG)	CHP	Feasibility, Design/Build, Commission, Biomass Sourcing, O&M
Lime Lakes Energy	Digester at lime-contaminated site for land reclamation project	2013	Biosolids, Food waste/FOG (currently only food waste/ FOG)	CHP	Feasibility, Design/Build, Commission, Biomass Sourcing, O&M
Campbell's Soup Company	Digester repair and retrofit	2017	Food waste	CHP	Design/Build, Commission, Staff Training
Lucas County (Construction Phase)	Digester retrofit at WWTP	2018 (anticipated)	Biosolids, Food waste/FOG	CHP	Feasibility, Design/Build, Commission, Biomass Sourcing, Staff Training
EORWA (Construction Phase)	Digester retrofit at WWTP	2018 (anticipated)	Biosolids, Food waste/FOG	CHP	Feasibility, Design/Build, Commission, Biomass Sourcing, Staff Training
Alliance (Construction Phase)	Class A Implementation at WWTP	2018 (anticipated)	Biosolids	Boiler	Feasibility, Design/Build, Commission, Staff Training
Dairy Digester (Private Developer; Construction Phase)	Agricultural greenfield digester	2018 (anticipated)	Manure, Food waste/FOG	RNG Pipeline Injection	Feasibility, Design/Build, Commission

PROJECT PROFILES

Wooster Renewable Energy - Wooster, OH
The City of Wooster Wastewater Treatment Plant

Wooster Renewable Energy (WRE) is a custom designed quasar facility integrated with a wastewater treatment plant. The City of Wooster was facing hundreds of violations regarding solids handling, partially associated with antiquated, non functioning anaerobic digesters. The City's engineer recommended upgrades to the plant's biotower, influent pumping, FOG tank, primary settling tanks, and gravity thickener, estimated at $7.4 million; however, the engineering team was unable to determine if these upgrades would allow the plant to operate in full NPDES compliance and recommended further studies after upgrades were complete. The City of Wooster turned to quasar to provide a functional, economical solution to return the plant to EPA compliance. quasar's upgrades fulfilled the plant's NPDES permit requirements in under $7 million in cost to the City of Wooster. quasar entered a 20-year public/private partnership with the City, contributing capital funds to the project and completing construction in 14 weeks. WRE processes 100% of the City's wastewater sludge and creates over 100% of the electrical energy required by the plant. Power generation at quasar's facility has been so reliable and successful, the City of Wooster invested in additional infrastructure to wheel power to other city owned buildings in the summer of 2015. Starting in summer 2015, energy generated at Wooster Renewable Energy supports 100% of the wastewater plant needs and the needs of the water plant, located across the street.

Feedstock Accepted: Wastewater sludge, food waste, FOG

Ownership Structure: WRE was a public/private partnership between the Wooster and quasar energy group. quasar owned and operated the facility until the City of Wooster purchased the plant in 2016.

Awards Received/Public Recognition: WRE was awarded the municipal Biogas Project of the Year by the American Biogas Council for the facilities ability to digest biosolids, food waste, and FOG at a rate that is five times the City's original throughput capacity – in addition to generating electric in excess of the plant's needs. Wooster Renewable Energy was awarded a $500k USDA REAP grant and a $750k USDA REAP loan in 2011. Projects are awarded REAP funding on the basis of technical merit, financial feasibility, and environmental benefit.

PROJECT PROFILES

Central Ohio BioEnergy - Columbus, OH
In Collaboration with SWACO & Kurtz Bros., Inc.

quasar, the Solid Waste Authority of Central Ohio (SWACO), and Kurtz Bros., Inc. collaborated for the construction and operation of the Central Ohio BioEnergy (COBE) ADS. The system processes food waste, FOG, and municipal solid waste to produce 1MW of electric energy an hour or 3,600 gallons of gasoline equivalent daily. Phase I of COBE was completed in 2011. As a result of the project's success, Phase II was expanded in 2013, which more than doubled the size of the facility. The expansion was fully integrated into Phase I for a total of 2,100,000 gallons of digester capacity. quasar's system design is modular and scalable, which allows for full integration and expansion as needed.

Feedstock Accepted: Foodwaste, FOG, municipal biosolids

Collinwood BioEnergy - Cleveland, OH
Owned by quasar energy group

First commissioned as a greenfield in 2012, with an expansion in 2013, Collinwood BioEnergy accepts regional biosolids, food waste, and FOG. This facility has the capacity to process over 250 wet tons per day of material, and generate 1MW of electricity. The site also has a CNG fueling station that quasar utilizes for it's natural gas fleet. The project transformed a vacant urban brownfield site into a sustainable waste management facility.

Feedstock Accepted: Regional biosolids, industrial food waste, and fats, oils, and grease

PROJECT PROFILES

Freestate Farms LLC- Manassas, VA

quasar has designed, developed, and performed extensive labwork on a 750k-gallon food waste-only digester to be constructed in Manassas, Virgina. Freestate Farms will be integrating the digester with composting and greenhouse operations. Because of the high strength nature of the food waste only feedstock, quasar's laboratory performed several pilot digesters to help the client to fully understand the operational parameters needed to maintain the facility. quasar also has performed in depth financial analyses to understand the best use of the digester biogas and the characteristics of the effluent following digestion. quasar anticipates construction of this facility in 2018. When operational, the plant will produce nearly 1MW of electricity, used to power and heat the digester, compost, and greenhouse operations.

Feedstock Accepted: Food waste and FOG

Buffalo BioEnergy - Buffalo, NY
Owned by Generate

Project Description: quasar's New York facility processes 40,000 tons per year of regional food waste and FOG to produce electricity that is sold to New York State Electric and Gas (NYSEG). We feel that this facility can help to serve as a model for Organic Energy Solutions, as it is currently operating as a food waste only digester. quasar's laboratory has used this facility to optimize the dosing rates of micronutrients and alkaline stabilizers for successful food waste digester operation.

Feedstock Accepted: Food waste and FOG

PROJECT PROFILES

GreenA Energy - Rutland, MA

Project Description: AGreen Energy selected quasar energy group to design and construct an anaerobic digestion system on site at Jordan Dairy Farm in Rutland, MA. The digester processes manure from the host farm and source separated organics provided from Casella Waste Systems. The digester was completed in 2011 and is the first commercial digester in the State of Massachusetts. The digester supplies 100% of the farm's electric needs and exports excess power via virtual net metering to nearby universities and food manufacturers. This facility has 550k gallons of digester capacity and produces 500kW. The Rutland ADS combined heat and power (CHP) unit boasts a 98% uptime and consistently produces energy at 90% of CHP capacity.

Feedstock Accepted: Dairy manure, foodwaste, FOG

Ownership Structure: AGreen Energy is 100% owned by Vanguard Renewables. quasar energy group provides remote O&M via SCADA technology from its' corporate offices.

Zainsville Energy - Zainsville, OH

Project Description: Zanesville Energy uses innovative technology to combine quasar's liquid digestion process with solid state anaerobic digestion to accept feedstocks ranging from 0.5% to 85% solids content. This project was completed through a partnership of quasar and Ohio State University and was made possible, in part, by an Ohio Third Frontier Advanced Energy grant. Zanesville Energy has the ability to toggle between electric generation via CHP and CNG on an as-needed basis at the on-site fueling station.

Feedstock Accepted: Biosolids, food waste, FOG, other organic wastes

Ownership Structure: quasar energy group

PROJECT PROFILES

Buckeye BioGas - Wooster, OH

Buckeye Biogas is quasar's flagship digester in the BioHio Research Park. The digester was built in collaboration with OARDC, Ohio BioProducts Innovation Center, USDA, and the Ohio Department of Development, among others. The system accepts 20,000 wet tons of pumpable and high solids organic biomass annually and has 550,000 gallons of digester capacity. The system produces 5,525MW of electricity annually.

Feedstock Accepted: Municipal solid waste, food waste, FOG

Ownership Structure: quasar energy group

Haviland Energy - Haviland, OH

Haviland Energy is the result of a partnership between Haviland PlasticnProducts and quasar. The system has the capacity to process 42,600 wet tons of material annually and has 750,000 gallons of digester capacity. Electric energy generated in a 1MW CHP is sold to the neighboring Haviland Plastic.

Feedstock Accepted: Biosolids, regional food waste, FOG, animal manure

PROJECT PROFILES

Three Creek BioGas - Sheffield Lake, OH

The Three Creek BioEnergy facility manages all of the sludge currently produced at the French Creek Wastewater Treatment Plant and offers local businesses a sustainable way to dispose of organic waste. This facility has a design capacity for managing 42,000 wet tons of organic waste annually and has 980,000 gallons of tank capacity. Electric energy is generated in a 1MW CHP. The plant also produces compressed natural gas (CNG) for fueling vehicles and pipeline quality natural gas.

Feedstock Accepted: Municipal solid waste, food waste, FOG

Ownership Structure: City of North Ridgeville & quasar energy group

Lucas County Resource Recovery Facility - Waterville, OH

Lucas County has contracted with quasar energy group to upgrade its existing anaerobic digestion operations. This project includes the addition of solids and liquids receiving equipment to accommodate outside material brought to the plant, an additional feedstock tank, new hydraulic mixing systems, a Class A thermal treatment system, gas storage, and increased energy generation capacity through two new CHP units. quasar has completed the project design and construction has recently commenced. The project is scheduled to be completed in late 2018, at which time it will have the capacity to process over 400 tons per day of material and produce over 2MW of electricity, making the water treatment facility energy neutral.

Feedstock Accepted: Biosolids, regional food waste, FOG, animal manure

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