CO-DIGESTION FEASIBILITY STUDY

FOR THE DISTRICT OF COLUMBIA

PREPARED BY:

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COMMISSIONED BY:

DISTRICT OF COLUMBIA DEPARTMENT OF PUBLIC WORKS "The Preferred Choice"

Department of Public Works

EXECUTIVE SUMMARY

The District of Columbia has a goal of reaching an 80% solid waste diversion rate. Organic waste diversion is an important part of that goal. In May 2017, the District issued a Compost Feasibility Study that assessed the implementation of a curbside organics collection program and the siting of an in-district composting facility. Additionally, the District is considering the use of co-digestion at DC Water's Blue Plains Wastewater Treatment Facility (Blue Plains) to process food waste from Industrial, Commercial, and Institutional (ICI) sources. This study evaluated the operational and financial feasibility for managing a portion of the organic waste generated in the District, including determining costs of developing a pre-processing facility to prepare and deliver ICI food waste for co-digestion at Blue Plains.

An evaluation of waste generated by the ICI sector during this study determined that 85,195 tons of ICI food waste are generated per year in the District. An estimated 42,000 tons of this food waste are generated by the largest generators and are highly available for collection. The majority of food waste is generated by the Commercial and Institutional sectors, while the Industrial sector generates negligible volumes of this material. The generation rates presented are estimates and the actual amount may vary. The capture rates will depend strongly on supportive policy levels and outreach and education efforts.

Operationally, co-digestion of 78,000 tons per year (tons/year) of C&I waste is possible using current excess capacity at Blue Plains. As described in the ICI section of this report, 78,000 tons is slightly below the level of organic waste generated by the C&I sector in the District (approximately 5,600 entities). Achieving a 100% capture rate is most likely not realistic, however for financial comparison purposes, this report assumes eight-five thousand tons of annual throughput which equates to a daily rate of 200 additional tons per day of slurry ("wet tons") at the WWTP. A pre-processing facility would need to be constructed to convert as-collected C&I food waste into that slurry at 14% total solids for the co-digestion process.

Financial analysis is based on a throughput of 78,000 tons of food waste per year. At that rate, the tipping fee required by DC Water would be $16/wet ton. Once the program surpasses 42,000 tons, which is the estimated quantity generated by the largest commercial generators in the District, the additional tonnage comes from a much larger number of smaller generators. Increasing the number of commercial generators equates to more difficult collection and higher administrative and program execution costs. Therefore, this report places additional focus on the publicly financed option with lower annual tonnages and tipping fees that were required to support the project.

The selection of a pre-processing site within hauling distance of the Blue Plains plant is crucial to the financial viability of this project. The Project Team focused on the Benning Road Transfer Station site as it is in close proximity to Blue Plains and is co-located with existing District-operated waste processing infrastructure. Financial analysis shows that capital costs are significantly lower for constructing a pre-processing facility at the Benning Road Transfer Station as opposed to developing a greenfield site, which would require considerable time and additional costs for new facilities and site infrastructure ($7.5M versus $16.4M, respectively).

The pre-processing facility entails development, capital, and operational costs that range based on the site selected and the financing method chosen. Several scenarios were evaluated:

- Building the facility at the Benning Road Transfer Station versus at a greenfield site;
- Using public-private financing versus public-only financing; and

- Running the co-digestion system at 42,000 tons/year on the low end; 55,000 tons/year as mid-range; and 78,000 tons/year on the high end.

The highest-cost scenario is associated with the development of a pre-processing facility on a greenfield site using private funding and results in a tipping fee of $114/dry ton. The lowest-cost scenario is associated with the development of a pre-processing facility at the Benning Road Transfer Station using public financing for a total tipping fee of $60/dry ton.

Two key benefits to this project emerged. Based on DC Water's modeling, the addition of food waste to the digesters would generate approximately one additional megawatt (MW) of electricity. The digesters also produce Class A biosolids for beneficial reuse in land application and as soil amendment.

This report further recommends that the District develop a comprehensive Organics Site Management Plan that addresses the following facility-related topics:

- Determining the co-location and symbiotic relationship between an in-District compost site, a pre-processing site for co-digestion, and co-digestion at Blue Plains WWTP;
- Permitting and zoning requirements for pre-processing facility;
- Environmental emissions impacts including storm water runoff, air pollution and greenhouse gas (GHG) reductions from organics diversion;
- Health and safety regulations; and
- Organics Processing Facility reporting requirements.

Providing one comprehensive plan provides clarity for differently classified generators, illuminates areas for mutual efficiencies, alerts to areas of potential competing priorities and adverse impacts, and allows for whole cloth consideration of planning and impacts as the District works toward its waste diversion goals. It is also recommended that the District consider the role of supportive policy in implementing a co-digestion program to both ensure proper feedstock and address community and environmental justice concerns.

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BACKGROUND AND PURPOSE

INTRODUCTION

The District of Columbia was directed to develop a plan for reaching an 80% diversion rate from landfills and waste-to-energy.[1][2] As part of the efforts to achieve this zero-waste future, the District turned its attention toward organic waste diversion solutions. In May 2017, the District issued a Compost Feasibility Study that assessed the implementation of an organics curbside collection program and the siting of an in-district composting facility. In addition to composting, the District considers the use of co-digestion at DC Water's Blue Plains Wastewater Treatment Facility (DC Water) for Industrial, Commercial, and Institutional (ICI) food waste. To evaluate the feasibility of co-digestion, the District's Department of Public Works (DC DPW) commissioned RRS to conduct this study to assess the potential opportunity for managing a portion of the organic waste generated in the District through co-digestion at DC Water.

OBJECTIVE AND METHODOLOGY

This report presents the results of the economic and logistical feasibility of diverting commercial food waste generated by the IC sector in DC via anaerobic digestion at DC Water.

The study builds on learnings from the Compost Feasibility Study conducted a year prior by RRS, including furthering the analysis of the ICI waste stream and evaluating the use of co-digestion as a complementary approach to composting for managing organic waste generated in the District. This study identifies and evaluates the fundamental aspects required for a successful co-digestion program at DC Water. These fundamental aspects included:

- **ICI Waste Stream Evaluation.** Detailed assessment of the quantity and composition of the District's ICI waste stream.
- **Operational Feasibility.** Technical feasibility of co-digestion within existing site constraints and infrastructure at DC Water; plus, considerations for additional equipment, processes, and adjustments at the DC Water facility; and additional modelling.
- **Financial Feasibility.** Financial evaluation of full-system costs (defined as pre-processing activities and co-digestion) to determine an all-inclusive per-ton tipping fee, which was compared against current District refuse tipping fees to determine "financial feasibility".
- **Pre-Processing Needs.** Identification of the need for design, build, and operation of a separate pre-processing facility to turn food waste into a slurry that is compatible for entry into the co-digestion system at DC Water.
- **Technology Recommendations.** Technology evaluation to identify best-suited equipment for the pre-processing site and DC Water facility.
- **Site Criteria.** Minimum site requirements for a pre-processing facility.
- **Supportive Policy.** Policy recommendations to ensure a suitable quantity and quality of feedstock for the co-digestion process, and to remove barriers to implementing an ICI source-separated collection and processing program.

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[1] Read more about Zero Waste in the District at https://zerowaste.dc.gov/

[2] Additionally, the Budget Support Act of 2016 requires the District to complete a study to assess the feasibility of sending organic waste to DC Water for processing. This study is designed to fulfill this requirement.

- **Implementation Recommendations.** Recommendations for financing and operating a stand-alone pre-processing facility and co-digestion at DC Water.

CO-DIGESTION

Wastewater from residential, industrial and commercial sources requires treatment prior to being released into the environment. As part of the treatment process, solids are separated from the treated effluent, and are referred to as sewage sludge. Removed sludge can be further treated through anaerobic digestion in which microorganisms break down organic material in absence of oxygen and pathogen reduction is achieved through high temperatures. This process creates biogas which can be used to generate heat and electricity, and a biosolids product which can be beneficially reused as a soil amendment or fertilizer.

Co-digestion refers to the process in which organic waste materials are added to wastewater digesters that have excess capacity. Organic food waste has higher methane production potential than sewage sludge, resulting in higher biogas yield when added to existing wastewater digesters. The addition of organic food waste to existing wastewater digesters results in the production of additional biogas, reduced greenhouse gas production, and the diversion of organic waste from landfills.

Other material, including yard waste, is not a viable feedstock for co-digestion due to difficulties with conveyance and handling, as well as low biogas yield potential. There are limitations to the co-digestion material's consistency and characteristics based on DC Water's existing solids handling system and equipment that restrict the acceptable material to food waste.

DC WATER BLUE PLAINS WASTEWATER TREATMENT FACILITY

DC Water maintains and operates the Blue Plains Advanced Wastewater Treatment Facility located in Washington, DC, designed to treat 370 million gallons of wastewater per day. Blue Plains is one of the largest and most advanced wastewater treatment plants in the world. The plant was first operated as a primary treatment facility in 1937, and has since expanded to include secondary treatment, nitrification and denitrification, multimedia filtration, and chlorination.

In 2015, DC Water expanded the facility's solids processing system to include dewatering, thermal hydrolysis (THP), and anaerobic digestion (MAD) of organic matter to produce both methane for electricity and Class A biosolids product[3]. The electricity helps power the facility's operations and the resulting biosolids are sold as a valuable soil amendment and fertilizer. There is a potential to convert this operation to co-digestion with the introduction of food waste to DC Water's anaerobic digesters to produce additional gas, thereby reducing grid dependence.

The Blue Plains solids processing system is shown in the figure below, followed by a detailed description of the process.

[3] Class A biosolids, as defined in the US EPA, Part 503 Rule, must achieve high pathogen reduction levels and must also comply with strict standards regarding metals, odors and vector attraction reduction. Class A biosolids meet the US EPA guidelines for land application and can be legally used as fertilizer or compost.

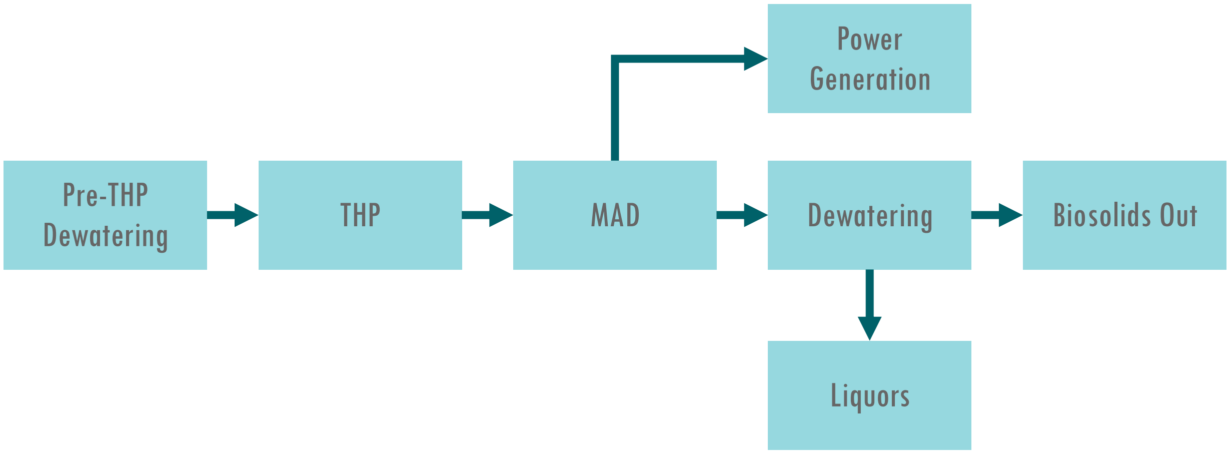

Figure 1: Blue Plains Solids Processing Facility Block Diagram

Solids from primary and secondary treatment are dewatered and sent through a thermal hydrolysis process (THP). This process subjects the solids to high temperature and pressure, instigating cell lysis and destruction of pathogens. This results in increased gas production, increased digester capacity and reduction in biosolids mass. Following THP, solids enter the mesophilic anaerobic digesters (MAD). The digesters generate biogas which is captured and combusted in 3-5 MW turbines, producing a net 10 MW of electricity through the combined heat and power system. Based on DC Water's modeling, the addition of food waste to the digesters would generate approximately one additional MW of electricity. The digesters also produce Class A biosolids for beneficial reuse in land application and as soil amendment.

Based on modeling and analysis, DC Water has indicated there is available capacity within the existing equipment and treatment process to introduce organic waste feedstock to the solids handling systems and accommodate co-digestion. This would result in additional renewable energy production at the facility, further reduce greenhouse gas production and provide tipping fee revenue for DC Water.

GEOGRAPHY COVERED

The District of Columbia spans nearly 70 square miles and is bordered by Montgomery County, Maryland to the northwest, Prince George's County, Maryland to the east, and Arlington and Alexandria, Virginia to the south. The District is divided into eight planning sections, or Wards, which are home to approximately 5,600 commercial and institutional generators. The Blue Plains WWTP is located in the southern end of the District in Ward 8, bordering the Potomac River. The two transfer stations owned and operated by District government are the Benning Road Transfer Station, located in eastern Washington DC along the Anacostia River, and Fort Totten located in northern Washington DC. As reported in the Compost Feasibility Study, there are only six sizeable composting facilities within 40 miles of the District, and only two are accepting food waste and yard waste.

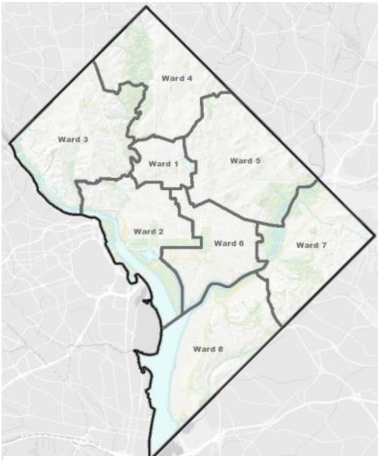

Figure 2 DC Region

FEASIBILITY ANALYSIS RESULTS

Part 1: ICI Waste Stream Evaluation

Industrial, Commercial, and Institutional (ICI) food waste is pre- and post-consumer food waste that originates from non-residential sources, such as:

- Restaurants
- Hotels
- Industrial facilities
- Cafes
- Office buildings
- Colleges/universities
- Supermarkets
- Schools
- Government buildings
- Nursing homes
- Hospitals
- Shopping malls
- Food manufacturers
- Airports
- Conference centers and sports facilities

This sector provides an excellent opportunity for low contamination collection in what is often referred to as "back door collection" or "back of house collection", referring to collection that occurs in the kitchens of restaurants, schools, colleges, universities, and other institutions. George Washington University is currently managing back door collection at two Starbucks locations on campus and diverts 150 pounds per day in coffee grounds from the landfill. These organics are being composted at the Prince George's County facility. Examples of other entities in the District that already are composting food waste include the Smithsonian, Whole Foods, and Mom's Organics.

When developing estimates for proposed processing facilities, an analysis of potentially available tons is required. This approach involves the identification of specific locations by business type as identified by the North American Industrial Standard Classification (NAISC) and the associated number of employees. There are several databases that provide commercial business data, including the number of employees at each location.

This analysis includes a calculation of the potentially available waste by quantifying the various waste streams based on the employment numbers from site specific commercial locations in the District of Columbia. The research team compiled NAISC data for target commercial operations and applied pounds per employee per day waste generation standards. This information was aggregated to the DC metropolitan level for the following sectors:

- Grocery stores
- Restaurants
- Nursing homes
- Hospitals
- Public Schools
- Colleges/Universities

The quantities of waste estimated in this evaluation represent the amount of material that is generated based on location specific data. The analysis does not calculate the net quantity of material that may be available after consideration of current uses of specific waste streams. The quantification of any specific waste stream within the numerous types of generators cannot be determined without assessments of individual waste streams from a specific generator because each generator exhibits a wide variety of inputs with different qualities of material.

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The estimate for total food waste generation from the Commercial and Institutional sector illustrates that 85,194 tons of food waste are potentially available from approximately 5,600 C&I generators[4]. Usually, materials from these sources will only be available by contracting with large waste haulers that have contracts to collect this type of material or with large institutions that have large amounts of waste. This material is not currently collected; collection guidelines and requirements will need to be developed to ensure that the source separated organics (SSO) material to be collected has low contamination that is within the specifications of feedstock required by a co-digester and preprocessing facility.

The quantity of food waste generated by the largest commercial generators in the District of Columbia, and therefore the most highly and easily available, represents 42,000 tons of material and is therefore an attractive source of material.

A small portion of organics, under 1,500 tons per year, is generated in the industrial sector and not included in the estimated tonnage capture. Organics generated by the industrial sector are generally different in nature from the commercial sector, tending to include much higher moisture content. As a result, organics from the industrial sector can be more difficult to manage and thus are often not included in SSO diversion programs unless they can be "dewatered".

Table 1: Potentially Available Food Waste Generation by Sector (Tons per Year, rounded)

NUMBER OF EMPLOYEES	GROCERY STORES	RESTAURANT	COLLEGES/ UNIVERSITIES	SCHOOLS	HOTELS	NURSING HOMES	HOSPITALS	TOTAL	RUNNING TOTAL
5,000 - 10,000	-	-	19,742	-	-	-	2,187	21,929	21,929
1,000 - 4,999	-	-	5,040	-	767	-	2,005	7,812	29,741
500-999	-	-	741	-	450	-	328	1,520	31,261
200-499	-	1,235	226	238	3,470	881	273	6,324	37,585
100-199	-	2,955	-	431	605	344	174	4,509	**42,094**
75-99	112	2,807	62	264	1,050	82	-	4,377	46,471
50-74	75	7,623	316	369	691	152	62	9,288	55,759
25-49	351	10,958	88	192	537	134	30	12,290	68,049
15-24	195	5,278	41	120	152	48	15	5,849	73,898
10-14	187	3,095	28	43	88	15	11	3,467	77,365
Less than 10	1,812	5,663	66	70	111	87	20	7,830	85,195
TOTAL	2,733	39,614	26,350	1,728	7,922	1,743	5,106	85,194	**85,195**

[4] A study released in 2017 estimated 114,365 tons per year are generated by the ICI sector. This estimate was done using ReFED supported generation rates applied to the generalized Business Census data. The total number of employees by each commercial category can vary significantly from US Business Census data due to the aggregation of data within the census into ranges.

Approximately 50% of the material is generated by the largest 100 establishments or 2% of the total establishments; colleges and universities generate approximately 30% of that material. Although nearly 46% of the food waste is generated in the restaurant sector nearly half of this quantity is generated by smaller restaurants that present a challenge when developing programs to collect that material.

Table 2: Percent of Total Food Waste Generation by Sector

NO. OF EMPLOYEES	GROCERY STORES	RESTAURANT	COLLEGES/ UNIVERSITIES	SCHOOLS	HOTELS	NURSING HOMES	HOSPITALS	TOTAL	PERCENT OF TOTAL
Greater than 10,000	0%	0%	0%	0%	0%	0%	0%	0%	0%
5,000-10,000	0%	0%	23%	0%	0%	0%	3%	26%	26%
1,000- 4,999	0%	0%	6%	0%	1%	0%	2%	9%	35%
500-999	0%	0%	1%	0%	1%	0%	0%	2%	37%
200-499	0%	1%	0%	0%	4%	1%	0%	7%	44%
100-199	0%	3%	0%	1%	1%	0%	0%	5%	49%
75-99	0%	3%	0%	0%	1%	0%	0%	5%	55%
50-74	0%	9%	0%	0%	1%	0%	0%	11%	65%
25-49	0%	13%	0%	0%	1%	0%	0%	14%	80%
15-24	0%	6%	0%	0%	0%	0%	0%	7%	87%
10- 14	0%	4%	0%	0%	0%	0%	0%	4%	91%
Less than 10	2%	7%	0%	0%	0%	0%	0%	9%	100%
PERCENT OF TOTAL	3%	46%	31%	2%	9%	2%	6%	100%	

In summary, analysis of the sector reveals that an estimated 85,000 tons of food waste are potentially available for source separated collection within the Commercial and Institutional sectors annually, and 42,000 tons are highly available. This material is generated both from food preparation areas and front of house consumers and collection guidelines and requirements will need to be developed to ensure that SSO material has low contamination. The Industrial sector produces negligible amounts of food waste and is therefore an unlikely candidate to pursue for co-digestion. The generation rates presented are estimates and the actual amount may vary. Capture rates will depend strongly on supportive policy levels and outreach and education efforts.

Part 2: Technology Recommendations

PRE-PROCESSING FACILITY

The pre-processing of C&I food waste involves turning the food waste that is segregated and collected into a suitable, refined feedstock, ready for introduction to the digestion process at DC Water. Pre-processing operations can include, but may not require all the following activities:

- Debagging and/or shredding of the materials;
- Manual inspection for physical contaminants;
- Manual and/or mechanical removal of recyclables and/or wastes;
- Particle size reduction;
- Addition of amendments (e.g. water or low solids organic wastewaters) for slurrying; and
- Degritting to remove physical contaminants that made it through other activities in the process.

The extent of pre-processing is a function of the feedstock, the processing technology used, and the ultimate disposal/outlet for the materials.

Pre-processing involves several sequential steps to convert as-delivered food waste into a slurry at 14% TS. The process flow diagram below outlines the steps and equipment needed. Inputs include the incoming material (the source separated food waste) and supplemental water. The incoming material is unloaded onto a tipping floor, fed into a hopper, shredded (optional), fed through a turbo separator for particle size reduction and contamination removal, and stored in onsite storage tanks before being hauled in a tanker truck to DC Water's Blue Plains WWTP.

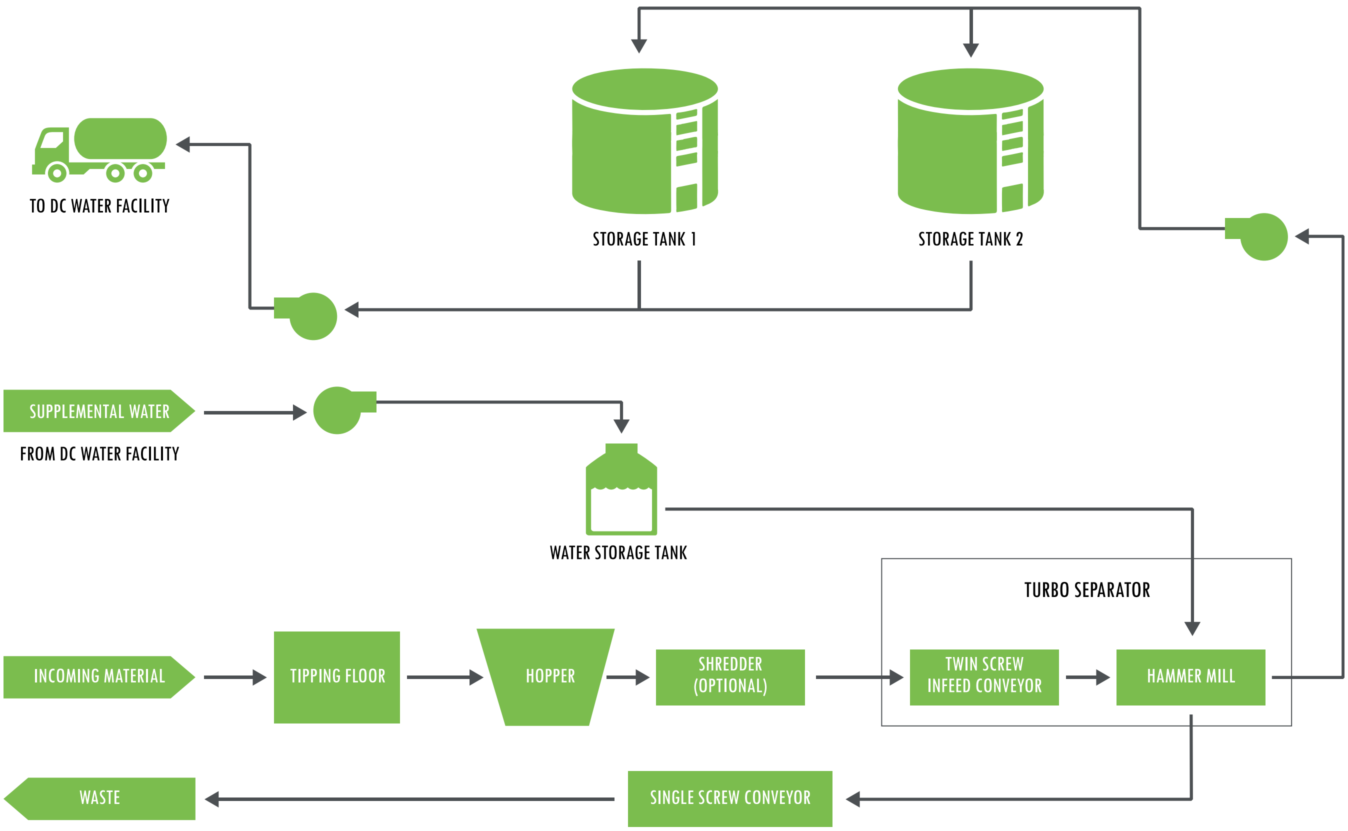

Figure 3: Process Flow Diagram for Pre-Processing Site

In the case of the pre-processing technologies, the equipment categories can be broken down into hammer mills, pulverizes, pulpers, and extruders. These technologies have their various pros/cons associated with capital costs, operational costs, removal efficiency, throughput, uptime/availability, space requirements, etc. Based on the feedstocks that are projected from the sources outlined earlier, the expected tonnages from the DC area and the level of contamination expected, an integrated hammer mill operation would be highly appropriate. Appendix A contains a detailed description of equipment options and their function in pre-processing, and Appendix B delivers technology recommendations for Blue Plains WWTP.

Part 3: Pre-Processing Site Criteria

The selection of a pre-processing site within hauling distance of the Blue Plains WWTP is crucial to the financial viability of this project. Ideally, the pre-processing site would be located within the District, in close proximity to the Blue Plains WWTP, and adjacent to or co-located with existing District-operated waste processing infrastructure, such as the Benning Road Transfer Station. This allows for the utilization of existing infrastructure and offsets the need to develop a new facility from scratch. As shown in the financial analysis above, costs are significantly (200%) lower to construct a pre-processing facility at the Benning Road Transfer Station as opposed to developing a greenfield site.

Nevertheless, there are factors that need to be considered when selecting a site, such as setback, ingress and egress, internal traffic flow, size, zoning, consistency, proximity to transfer stations, proximity to sensitive receptors, storm water management, composting operations, site layout, etc.

The space required for the site is a direct function of tonnage throughput. At an estimated 78,000 tons/year, approximately 15,000 square feet of enclosed building space would be required. To facilitate truck access, odor control, office space, and more, the open area required would be one-half to two acres depending on the shape of the site. The site would be required to be zoned heavy industrial to facilitate the type of operation proposed. It should be noted that if the tonnage to be processed was lowered to 42,000 to 55,000 tons/year, it would not have any impact on the space requirements as the equipment would be the same, but the operational hours would likely be reduced.

Organics pre-processing requires electricity to allow for the operation of the processing equipment, as well as a water source to facilitate wash-down of the facility; however, gray water that is stored for moisture adjustment can be used for this purpose. All wash-down water could also be collected and subsequently used for moisture adjustment thus negating the need for any wastewater treatment system.

Depending on the receiving hours and loadout timing, the facility could initially be staffed as a one-shift operation, but as the tonnage increases, the facility may require two shifts. Staffing consists of a receiver/load operator and a supervisor to ensure that the materials are received and processed. The transportation and delivery of the organic slurry from the pre-processing site to Blue Plains WWTP could occur through third party permitted contractors.

If the pre-processing facility is co-located with a composting operation, then the combined facility would need the following:

- Heaviest Industrial Zoning (PDR – Production, Distribution, and Repair)
- 5-10+ acres
- Water & Sanitary Sewer
- Utilities (electricity, and natural gas a nice to have)
- Truck traffic – current and expandable
- Local Engagement

Regardless of the type of facility, it is important to ensure that land is acquired and environmental assessment work is finalized prior to engaging with design-build partners, as the uncertainty of the land and permitting status will add risk to the project.

Part 4: Financial and Operational Feasibility

Financial and operational feasibility are two critical factors used to determine the viability of co-digestion as an organic waste diversion strategy for the District. Financial feasibility is assessed by determining the tip fee that would be required to make co-digestion cost-effective for DC Water, and combining it with related system costs, such as pre-processing costs and slurry transport (also calculated as a tipping fee per ton). Distilling the analysis down to a dollar-per-ton figure enables the District to understand the cost of delivering material at the WWTP on a unit-basis and compare it to current solid waste disposal tip fees at transfer stations within the District, once the costs of other related project factors (such as pre-processing) are included.

Operational feasibility considers operations at both DC Water and at a pre-processing facility. An analysis at DC Water determines whether or not the co-digestion system at the WWTP can handle food waste being introduced to it, quantities it can tolerate, and under what circumstances. All else equal, Blue Plains has the operational capability of processing food waste, as long as the food waste is delivered as a slurry at 14% total solids (TS), according to model analysis. The next set of questions to be answered concern the limitations, parameters, and criteria of the co-digestion facility, equipment, site footprint, and infeed material. These factors are evaluated in this study as a function of financial feasibility and are described below.

FINANCIAL AND OPERATIONAL ANALYSIS OF CO-DIGESTION AT BLUE PLAINS

Part of this evaluation relies on a model developed by DC Water. DC Water's model, which was thoroughly reviewed for relevance and application to the subject matter at hand, incorporates a range of technical and financial characteristics and allows users to test scenarios by adjusting inputs and assumptions. Based on these variables, the Blue Plains model reveals the limitations, advantages, and impacts of introducing food waste into the solids processing system for different scenarios. Therefore, the model can be used to determine which components of the system act as limiting factors, which can in turn be used to define critical knowledge such as the specifications that are needed for infeed material, maximum quantities and throughput, and where opportunities exist or do not exist for system modifications. The model ultimately calculates the tipping fee that would need to be charged at the door to customers delivering pre-processed slurry, which lends insight into the overall financial feasibility of co-digestion.

BLUE PLAINS MODEL ASSUMPTIONS AND INPUTS

Many of the technical inputs in the Blue Plains model are based on experiments performed at Bucknell University. The team at Bucknell conducted research for DC Water using a bench scale model of the thermal hydrolysis process and anaerobic digesters. The team used samples of DC Water's biosolids in combination with different feedstocks to determine many of the parameters included in the electronic model that was developed to aid in DC Water's internal decision-making process. This research also aided in understanding the feasibility of accepting food waste by providing an indication on the available capacity of the existing equipment and systems, as well as, how the facility's treatment process and sludge production would be affected. This research indicated that excess capacity does exist to allow for the acceptance of food waste.

MODEL ASSUMPTIONS

- Infeed of 200 tpd at 14% TS
- 7 days/week operation
- Food waste arrives in slurry form
- Slurry is delivered directly to Blue Plains

Figure 4: Model Assumptions

The model currently assumes DC Water would receive an organics feed of 200 tons per day (tpd) – 73,000 tons per year – at 14% total solids (TS), seven days per week. The model also assumes that the food waste will arrive pre-processed, in slurry form, to the receiving station at Blue Plains. Preliminary cost estimates and conceptual drawings indicate that the slurry would pass through a screening process and pulper before being fed to the existing Cambi[5] process.

DC Water has estimated that the receiving station will cost approximately $4,000,000 to construct and includes a pre-engineered building, multiple screen presses for screening, two storage tanks, progressive cavity pumps for transport of material, pulpers and an electrical building. In addition to this capital investment, the system would impart additional operational and maintenance costs, and the added operational risk of accepting food waste. In return, DC Water would require a tipping fee per gallon of food waste accepted that would result in net positive cash flow in order to be considered financially feasible. In addition, the cost of the receiving facility must result in a payback of less than 10 years in order to be considered a viable project.

The parameters defined here are the basis of the Blue Plains model and are therefore integral to determining a dollar-per-ton tipping fee.

TIPPING FEE DETERMINATION

Under the model scenario described above, the key assumptions outlined result in a tipping fee of $0.067 per gallon of slurry at 14% TS, or $16 per wet ton.

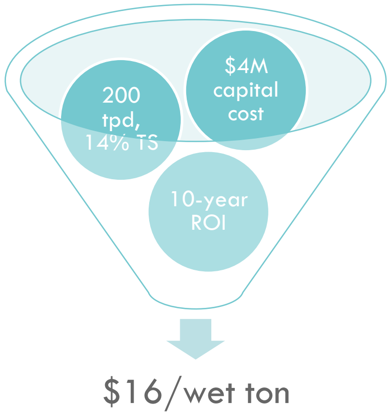

Figure 5: Tipping Fee Inputs

SENSITIVITY PARAMETERS AND ADDITIONAL CONSIDERATIONS

A sensitivity analysis was performed on many of the technical and financial inputs of the Blue Plains model to identify the parameters that would have the most significant impact on the required tipping fee, and therefore the feasibility of the project. The sensitivity analysis used a base case of a $16/wet ton tipping fee at 14% solids.

The analysis revealed that sludge yield is the most sensitive parameter, followed by the price of power, co-digestate feed rate, and percent total solids. Detailed results of the sensitivity analysis are provided in Appendix C.

FINANCIAL AND OPERATIONAL ANALYSIS OF SLURRY DEVELOPMENT AT A PRE-PROCESSING FACILITY

The second part of the financial and operational feasibility analysis evaluates the capital and operating costs of building and operating a pre-processing facility that accepts food waste as-delivered, converts it into a slurry at 14% TS, and transports the slurry to DC Water for co-digestion.

Costs vary significantly based on the site selected for pre-processing. This study evaluates two scenarios:

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[5] The Cambi process is a sludge stabilization system that utilizes thermal hydrolysis to instigate cell lysis and disinfection. This process makes the sludge more biodegradable which improves digestion performance.

(1) Building the pre-processing facility at the Benning Road Transfer Station, which has useful built infrastructure in place[6]; and
(2) Developing a new site and building a pre-processing facility and all related infrastructure as a stand-alone pre-processing facility would require considerable time and additional costs for new facilities and infrastructure.

The first set of financial indicators considered are the costs of operating the pre-processing facility. These costs include the $16/wet ton tipping fee for slurry delivered to the Blue Plains WWTP, among the other operating costs shown below in 7. Operating costs are intentionally the same across the two scenarios evaluated here (Benning Road and a greenfield site), given that a greenfield site assumes generic hauling costs since site location is not known.

Table 3: Pre-Processing Facility Operational Costs

OPEX	COST
Plant Manager	$117,000
Plant Staff (4 staff)[7]	$208,000
Pre-Processing Installation Maintenance	$188,500
Insurance	$20,000
Administration	$20,000
Lease Payment	- -
Testing	$25,000
Emissions + Regulatory Testing	$40,000
Electricity[8]	$168,192
Rolling Stock Lease Payment[9]	$82,000
Rolling Stock Fuel[10]	$90,000
Property Taxes	-
Slurry Disposal Cost	$16/Wet Ton
Slurry Hauling Cost	As per Proforma
Residuals Disposal Costs	As per Proforma
Diverted Loads	As per Proforma
TOTAL OPEX	$958,692
OPEX Contingency	10%

[6] The Benning Road site was used as a proxy site to demonstrate benefits of co-locating a pre-processing facility with an existing waste transfer station where infrastructure is already present (scales, electricity, water, etc.), for which the land is appropriately zoned, and on which space theoretically exists to house both traditional waste transfer and pre-processing operations for co-digestion. While it is useful for the purposes of modelling the feasibility of co-digestion, additional analysis would be needed to determine the specific costs to upgrading the Benning Road site for this purpose as the study does not consider the existing layout or the existing condition of the Benning Road Transfer Station as part of the analysis.

[7] Includes 30% for overhead
[8] Accounts for 120kw at 16 cents per KWH
[9] Includes lease of a loader to feed the hammermill
[10] Assumes diesel; co-usage of simultaneous water and gas injection (SWAG) may lower costs

BENNING ROAD PREPROCESSING FACILITY ANALYSIS

The cost of preprocessing commercial food waste within the District suggests serious consideration should be made for developing a composting or anaerobic digestion (AD) facility as close to the generators as possible. If this facility were located within the District, commercial collection vehicles could direct haul to the facility and residents could drop-off at the same location.

The operating proforma used in this analysis includes development, capital, and operating expense estimates, including site development costs. The proforma also includes a two-year development process including engineering and permitting, an eight-month construction period, and ramping up the operations of the facility once it is constructed over another two-year period.

In addition to the operating costs shown in Table 3, analysis included the development and capital costs assumed in Tables 4 and 5.

Table 4: Benning Road Development Costs

ITEM	COST
Legal and Admin	
Land Acquisition	-
Feedstock	$40,000
Engineering Contracting	$100,000
Other	$50,000
TOTAL LEGAL AND ADMIN	$190,000
Engineering	
Air & Noise	$50,000
Civil	$25,000
Process	$150,000
TOTAL ENGINEERING	$225,000
Other	
Environmental Permitting	$75,000
Feedstock Testing	$10,000
Additional Consulting / Third-Party Reports	$100,000
TOTAL OTHER	$185,000
TOTAL	**$600,000**

Table 5: Benning Capital Cost Assessment

ITEM	COST
Land Costs	-
Detail Engineering	-
Site Works	$500,000
Pre-Processing	$3,000,000
Reception Building	$500,000
Slurry Tank	$250,000
Piping & Equipment	$300,000
Electrical Controls	$500,000
Construction Insurance	$100,000
Construction Management/Wrap Costs	$500,000
Working Capital	$150,000
Contingency (30% of costs)	$1,740,000
Financing Costs	-
TOTAL	**$7,540,000**

Table 6 details the results of the financial analysis. A minimum tip fee of $80/ton is required to support a private sector investment in a facility to preprocess commercial and institutional food waste infrastructure at a 23.3% rate of return. The model accounts for a ramp-up of SSO collection between 2020 and 2022. Although the C&I waste stream analysis shows that 85,000 tons of food waste are realistically available for collection, the model uses a maximum of 78,000 tons, due to the 200 TPD capacity limit of DC Water's co-digestion process.

In all likelihood, a tip fee at $80/ton guaranteed over a contract period of 10 to 20 years with the inputs of 78,000 tons per year of raw material, would support a capital investment of approximately $7.54 million. The rate of return on a private sector equity investment would need to be in the 20-25% range, at a minimum, depending on the structure of the financing and tax expense. The rate of return will be risk adjusted depending on the term of the feedstock supply agreement and the "put or pay" provisions that are ultimately agreed upon.

Table 6: Benning Road Pre-Processing Facility Cost Analysis Using Private Financing

ITEM	COST		
Capital Expense	$7,540,000		
Development Expense	$600,000		
SSO Processing Tip Fee ($/Ton)	$80.00		
	2020	2021	2022-2040
DC DPW Food Waste Processed (Tons)	9,425	43,875	78,000
Annual Revenue (Tip Fee)	$754,000	$3,510,000	$6,240,000
Annual Operating Expense	$1,090,988	$2,627,533	$3,850,955
NET (EBITDA*)	-$336,988	$882,467	$2,389,045
Cash Flow IRR	23.3%		

*Earnings Before Income Tax, Depreciation, and Amortization

Overall, this type of facility investment could be undertaken as part of a public-private partnership often employed to create investment opportunities in recycling facilities. A publicly owned facility that is financed through municipal bonds or other municipal finance instruments could lower the annual cost by eliminating the higher return on investment factors that are needed if the project is privately financed. In a publicly financed project at the Benning Road Transfer Station, with an IRR of 5.7%, the tipping fee could be reduced to $60/ton assuming 78,000 tons/year of food waste, as shown in the table below.

Table 7: Benning Road Pre-Processing Facility Cost Analysis Using Public Financing

ITEM	COST		
Capital Expense	$7,540,000		
Development Expense	$600,000		
SSO Processing Tip Fee ($/Ton)	$60.00		
	2020	2021	2022-2040
DC DPW Food Waste Processed (Tons)	9,425	43,875	78,000
Annual Revenue (Tip Fee)	$565,500	$2,632,500	$4,680,000
Annual Operating Expense	$1,090,988	$2,627,533	$3,850,955
NET (EBITDA*)	-$525,488	$4,967	$829,045
Cash Flow IRR	5.7%		

For greater clarity, if the 42,000 tons of food waste is utilized as the base level of material to be processed under the publicly financed pre-processing facility, the tipping fee would increase to $80/ton to allow for the facility to cover itself or the facility could offer a tipping fee of $70/ton if it could attract 55,000 tons of food waste per year.

In an effort to show the sensitivity of the project, the project was modelled at 55,000 tons/year of food waste and a tipping fee of $70/ton. Based on these assumptions the project achieved a pre-tax unlevered return of 6% which would allow it to cover itself and be able to handle some volatility on the key parameters including disposal costs, capital costs, tipping fees to attract material, and annual throughput:

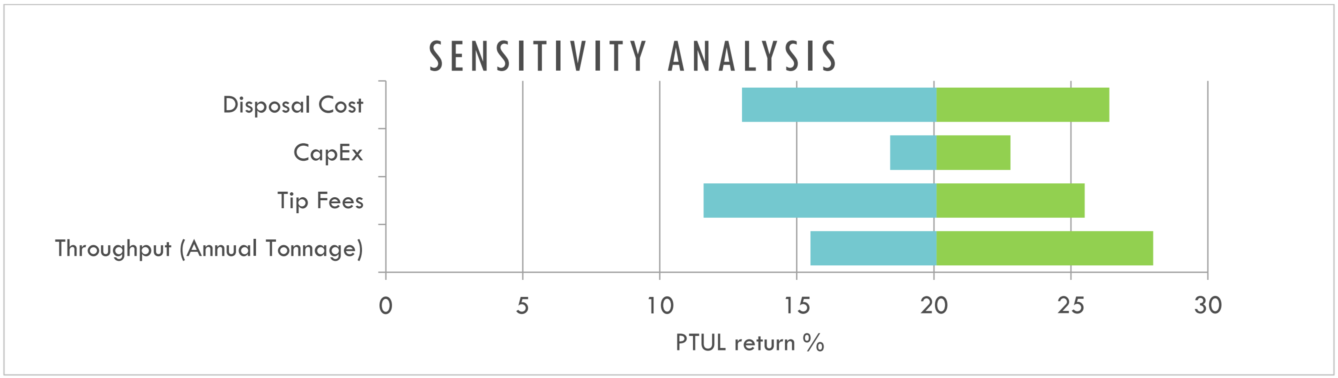

Figure 6: Sensitivity Analysis

GREENFIELD PRE-PROCESSING FACILITY ANALYSIS

The development of a new greenfield facility at a publicly owned location would experience a different cost profile than a development at the Benning Road Transfer Station due to increased site infrastructure and building development requirements, which results in a capital cost more than 200% higher than at Benning Road. The breakdown of Development and Capital Costs are included Tables 8 and 9, respectively. If this facility were located within the District, commercial collection vehicles could direct-haul to the facility.

Table 8: New Greenfield Site Development Costs

ITEM	COST
Legal and Admin	
Land Acquisition	$0
Feedstock	$40,000
Engineering Contracting	$100,000
Other	$50,000
TOTAL LEGAL AND ADMIN	$190,000
Engineering	
Air & Noise	$50,000
Civil	$125,000
Process	$250,000
TOTAL ENGINEERING	$425,000
Other	
Environmental Permitting	$150,000
Feedstock Testing	$10,000
Additional Consulting / Third-Party Reports	$200,000
TOTAL OTHER	**$360,000**

Table 9: New Greenfield Site Capital Cost Assessment

ITEM		COST
Land Costs		$0
Site Works		$500,000
Pre-Processing		$7,000,000
Weigh Bridge		$200,000
Reception Building		$2,000,000
Slurry Tank		$250,000
Piping & Equipment		$300,000
Electrical Controls		$500,000
Construction Insurance		$200,000
Construction Management/Wrap Costs		$1,500,000
Working Capital		$150,000
Contingency	30%	$3,780,000
Financing Costs		$0
TOTAL		**$16,380,000**

The proforma analysis includes the same ramp up schedule as the two-year development process scenario including engineering and permitting, an eight-month construction period, and ramping up the operations of the facility once it is constructed over another two-year period.

shows the financial analysis for a public-private financing scenario at a 23.1% IRR, whereas Table 11 presents a financing scenario using only public funding.

Table 10: Greenfield Facility Pre-Processing Facility Cost Analysis – Public-Private Financing

ITEM	COST		
Capital Expense	$16,380,000		
Development Expense	$975,000		
SSO Processing Tip Fee ($/Ton)	$114.00		
	2020	2021	2022-2040
DC DPW Food Waste Processed (Tons)	9,425	43,875	78,000
Annual Revenue (Tip Fee)	$1,074,450	$5,001,750	$8,892,000
Annual Expense	$1,253,055	$2,870,633	$4,094,055
NET (EBITDA)	-$178,605	$2,131,117	$4,797,945
Cash Flow IRR	23.1%		

*Earnings Before Income Tax, Depreciation, and Amortization

Table 11: Greenfield Facility Pre-Processing Facility Cost Analysis – Public-Only Financing

ITEM	COST		
Capital Expense	$ 16,380,000		
Development Expense	$975,000		
SSO Processing Tip Fee ($/Ton)	$80.00		
	2020	2021	2022-2040
DC DPW Food Waste Processed (Tons)	9,425	43,875	78,000
Annual Revenue (Tip Fee)	$754,000	$3,510,000	$6,240,000
Annual Expense	$1,253,055	$2,870,633	$4,094,055
NET (EBITDA)	-$499,055	$639,367	2,145,945
Cash Flow IRR	8.8%		

A minimum tip fee of $114/ton would be required to support a private sector investment in a facility to preprocess C&I food waste infrastructure. In all likelihood a tip fee at this level, guaranteed over a contract period of 10 to 20 years with the inputs of 78,000 tons per year of raw material, would support a capital investment of approximately $16.4 million. The rate of return on a private section equity investment would need to be in the 20-25% range, at a minimum, depending on the structure of the financing and tax expense. Given a public-only financing scenario with a much lower IRR, a reasonable tip fee could fall in the range of $80/ton.

CHALLENGES

The financial analysis above is based on a throughput of 78,000 tons of food waste per year. As described in the ICI section of this report, 78,000 tons is just below the C&I sector organics generation in the District (from approximately 5,600 entities). Achieving a capture rate of this level requires aggressive program implementation, strong supportive policies, extensive education, and enforcement. Once the program surpasses 40,000 tons, which is the estimated quantity generated by the largest commercial generators in the District, the additional tonnage comes from a much larger number of generators. More generators equate to more difficult collection and higher administrative and program execution costs. Therefore, additional focus was placed on the publicly financed option with lower annual tonnages and tipping fees required to support the project.

SUMMARY

In the first scenario, a tipping fee of $80/ton would be required for financial project independence using private financing and $60/ton using public-only financing and assuming 78,000 tons/year of food waste. In the second scenario, $114/ton is required for private financing and $80/ton for full public financing assuming 78,000 tons/year of food waste. These tipping fees are reflective of rates for comparative co-digestion projects across the industry but are higher than current refuse disposal tipping fees at District-operated transfer stations. The higher rates ($114 and $80) may hinder public support for the program. However, certain financing strategies and supportive policies may create a more favorable economic environment for co-digestion. For example, analysis shows that a 10% change in the slurry disposal costs (raising or lowering the $16/wet ton slurry tipping fee by $1.6/ton) results in a 1% change in return, which makes the project increasingly more attractive to prospective financers. If a private developer is willing to accept lower returns, the tipping fees can be respectively lowered. Additionally, if the costs of development and construction can be reduced or shared with an in-District composting facility the economics may tip in favor of the project. Finally, the District has the option of setting tipping fees based on levels that would encourage participation, not based on actual cost. The other area to focus on would be the minimum tonnages that would be committed to the project such as assuming that the 42,000 tons of food waste was used as the base level of material to be processed under the publicly financed pre-processing facility. This would lead to a tipping fee of $80/ton to allow for the facility to cover itself, or the facility could offer a tipping fee of $70/ton if it could attract 55,000 tons of food waste per year. These ideas are explored more fully in the Supportive Policy and Financing and Implementation sections.

Part 5: Supportive Policy Recommendations

A C&I organics collection and co-digestion program would be most successful with the support of policy. If leveraged, supportive policies around feedstock regulation, facility siting, community and environmental justice, and financing can contribute to creating a more cost-effective and optimally designed co-digestion program.

FEEDSTOCK REGULATION

The co-digestion program requires a reliable and consistent volume of organic material to maintain efficiencies of scale, warrant investment, and contribute toward the District's zero waste goals. Several policies can accomplish this goal.

C&I Food Waste Landfill Ban. It is recommended that the District enact a landfill ban for food waste generated by the C&I sector in the District. Such a policy will help to ensure the success and development of new organics recycling infrastructure. As of early 2017, similar legislation has been passed in six states. Furthermore, the Sustainable Solid Waste Management Amendment Act of 2014 provides the Mayor with the ability to promulgate regulations to require C&I organic materials to be diverted towards appropriate organics processing facilities.

Hauler Licensing and Reporting. There should be a provision for hauler licensing that requires haulers to offer mandatory SSO collection services and report annually to the District. A licensing structure like this ensures that all generators in the District have access to SSO collection services.

Flow Control. Flow control regulates the movement of solid waste within and between jurisdictions. It is recommended that the District investigate options for flow control of organic waste generated in the District to ensure adequate quantities of feedstock are directed to the District's co-digestion program. If not utilized, generators and haulers can transport SSO to processors outside of the district instead of using preferred in-district sites.

Generator Guidelines. Since implementation of a C&I co-digestion program is likely to be paired with the implementation of a residential composting program, the District should develop generator guidelines that distinguish between SSO for composting and SSO for co-digestion and define program differences. The guidelines should define contaminants based on the material mixes the different systems can handle. A guide will provide clarity for differently classified generators and reduce contamination.

Contamination Limits. The co-digestion process is sensitive to contamination. It is therefore recommended that haulers be permitted to refuse collection of containers with contamination levels greater than 2% by volume. Haulers should be required to report contamination rates. It should be noted that most ICI food waste generators will use plastic liners/paper bags to ensure cleanliness of the collection bins, which will require appropriate processing equipment at the pre-processing facility. If contamination is not clearly defined and regulated, the pre-processing facility may receive un-processable material, which can add significant costs to manage.

Additional supportive policies suggested for consideration related to feedstock management are described in Appendix E.

FACILITY OPERATIONS

The District should develop a comprehensive Organics Site Management Plan that addresses the following facility-related topics:

- Determining the co-location and symbiotic relationship between an in-District compost site, a pre-processing site for co-digestion, and co-digestion at Blue Plains WWTP.
- Permitting and Zoning Requirements for Pre-Processing Facility
- Air Pollution
- GHG reductions from organics diversion
- Stormwater Runoff
- Stormwater Environmental Emissions
- Health and Safety Regulations
- Organics Processing Facility Reporting Requirements

Providing one comprehensive plan provides clarity for differently classified generators, illuminates areas for mutual efficiencies, alerts to areas of potential competing priorities and adverse impacts, and allows for whole cloth consideration of planning and impacts.

Detailed descriptions of the above supportive policies are included in Appendix E.

FINANCIAL POLICIES

The financial analysis above reveals that tipping fees must be set between $80/ton and $114/ton for the project to be financially viable. However, certain policies can shift the economics of the system in favor of a co-digestion program.

Tipping Fees. The District should set a tipping fee at a lower rate than refuse disposal to incentivize organics diversion. If fees are not set to incentivize diversion, the cost of disposal will be the major determining factor in costing other recovery services.

CONTRACT TERM LIMIT EXTENSIONS.

Currently, District contracts may not exceed a term of ten years. It is recommended that contract term limits be extended to over 10 years with allowable extensions or a total period of 20 years. Longer contracts enable private sector investment by allowing for capital recovery over the life of the asset, not over a shortened life of a contract. Without longer term limits, public-private investment will be difficult to acquire, except at very high tip fees.

COMMODITY USE

Finally, the District needs to consider policies for the end use of final products from the co-digestion process.

Renewable Natural Gas. The District should work with DC Water to develop a plan for best and highest use of renewable natural gas generated by the co-digestion process. Recommend uses include using renewable natural gas (RNG) to fuel District waste and recycling collection fleet. This presents an opportunity to achieve near net zero fuels for the fleet.

A full list of supportive policy recommendations is located in Appendix E.

Part 6: Financing and Implementation Recommendations

The selection of a financing and implementation approach needs to be carefully weighed by assessing the pros and cons of each option.

PRE-PROCESSING FACILITY

In the case of the pre-processing facility, the inbound food waste (i.e. feedstock) is the ultimate driver in the development of the facility and commercial contracting that DC DPW would undertake. The land-use permits and siting need to be addressed by DC DPW regardless of whether public or private financing is used. These types of projects generally take a considerable period of time to develop and construct, therefore, clarity on feedstock volumes and contractual obligations need to be determined early. This includes, but is not limited to:

- Quality of feedstock at delivery;
- Ramp up schedule for reaching optimal throughput;
- Contract type – put or pay, exclusivity, etc.;
- Slurry specifications;
- Maximum and minimum volumes;
- Delivery method (type of truck, frequency, load out method, etc.); and
- Other organics that can be addressed.

Therefore, DC DPW should clearly identify:

1. Feedstocks that are under its control and/or planned to be regulated;
2. Quantities of food waste planned to be collected; and
3. Current costs for management to address type of project delivery.

If a public financing scenario is pursued, it is recommended that the following approaches are explored:

- Grants (federal);
- Low interest loans;
- Sales tax exemptions;

- Bonds;
- Investment tax credits/production tax credits; and
- New market tax credits.

Private financing approaches include:

- Equity from focused funds and stakeholders; and
- Traditional debt.

Error! Reference source not found. below provides the various public-private partnership models that can be u ndertaken in relation to the pre-processing facility. The project execution for the pre-processing facility will differ depending on whether the equipment is housed at the Benning Road transfer station, constructed on the Benning Road site independent of the existing transfer station or sited on a new facility separately or in conjunction with a composting facility.

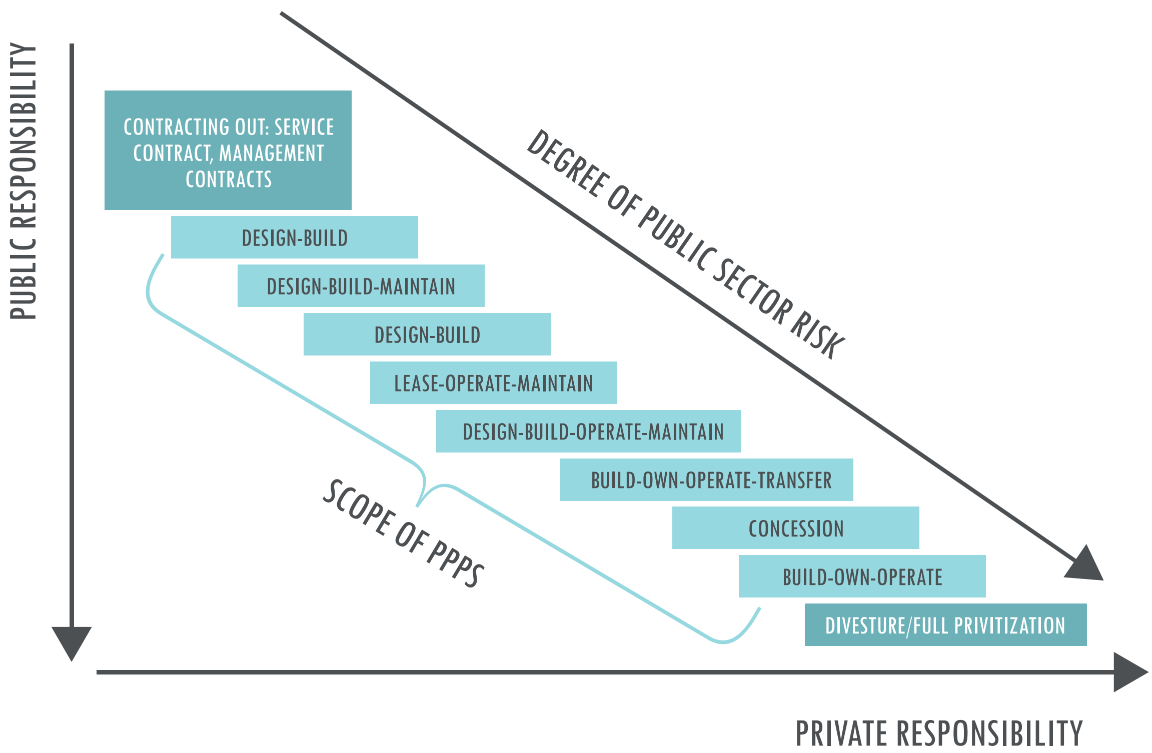

Figure 7: Public-Private Financing Models

The two areas that cause challenges for complex facilities like these are the development capital and land option agreements.

If DC DPW chooses to do a private partnership, it is recommended that appropriate security measures are requested, including Liquidated Damages/Performance Guarantees as well as Holdbacks/Bonding/Letters of Credit.

In summary, the following financing and implementation strategies are recommended:

- **Siting at Benning Road**. It is recommended that DC DPW request a design-build contract with a private entity so that it can ensure that the pre-processing facility is implemented appropriately. It should explore an operations contract; however, the status of union support at the transfer station needs to be addressed. An alternative would be to have a consulting/support contract by the design-build firm that could allow for commissioning and proper training of relevant staff.
- **Co-location with a composting site**. It is recommended that DC DPW request a design-build-finance-operate-maintain contract from the private sector for the composting facility; the pre-processing facility could be integrated into this facility.

DC WATER RECEIVING STATION

DC Water is planning to design-build for its receiving station and should continue to follow this model for the project that is being considered.

CONCLUSION

Operationally, co-digestion of C&I waste is possible using current excess capacity at DC Water's Blue Plains WWTP. At a capacity of 200 tons per day, Blue Plains can accommodate slightly more than the food waste now generated by businesses and institutions in the District at $16/ton. A pre-processing facility would need to be constructed to convert as-collected C&I food waste into slurry at 14% total solids for the co-digestion process. The pre-processing facility entails development, capital, and operational costs that range based on the site selected and the financing method chosen. The highest-cost scenario is associated with the development of a pre-processing facility on a greenfield site using private funding and results in a dry-ton tipping fee of $114/ton. The lowest-cost scenario is associated with the development of a pre-processing facility at the Benning Road Transfer Station using public financing for a total tipping fee of $60/dry ton. It is recommended that the District consider the role of supportive policy in implementing a co-digestion program to both ensure proper feedstock and address community and environmental justice concerns.

APPENDIX A

Pre-Processing Technology Recommendations

HAMMER MILL

A photograph of an example hammer mill that is used in the organics pre-processing industry today is shown on the right. The hammer mill acts as a depackager, shredder, and grinder. Several other manufacturers can provide similar equipment and systems to the unit found in the photograph. However, the hammer mill is the primary component of the organics pre-processing facility and covers a number of the pre-processing steps. Based on the feedback from DC DPW and DC Water, the hammer mill would need to be integrated into a custom system to ensure that it could handle the inbound material and meet the technical specifications from DC Water. The rationale for the integrated hammer mill is that it is a relatively turn-key operation that can be integrated into the existing transfer station or developed at a new facility and provides ease of use and is known for success in organics pre-processing at similar facilities in North America.

The example integrated hammer mill system has a number of components to achieve the desired feedstock consistency. These components include a loading hopper, several conveyors for material movement, the main hammer mill unit, a liquid manifold to allow for total solids (TS) adjustment, and organics pump and conveyor for removal of reject fraction and the organic slurry from the system. The integrated hammer mill system can be batch mode or fed continuously, depending on incoming tonnage and frequency of deliveries which would work well for the proposed DC facility, as it is expected to ramp up volumes over time.

SYSTEM FEED

At the existing transfer station or new facility, the material would be unloaded onto a tipping floor where the C&I food waste would be loaded into the hopper with a skid steer or bucket loader. As an alternative, the collection trucks could also tip directly into a below grade pit which feeds the system in place of the hopper to avoid double handling of material. The loading of organics into the processing equipment will allow for quality control between the delivery and processing of waste. The operators would be able to identify materials that may damage equipment and thus could remove them prior to processing. As outlined in the earlier steps, prior to be processed in the hammer mill, the material could be shredded to liberate the material from the bags/liners that were in the collection bins as outlined earlier. This would allow for increased throughput (~20 tons per hour) and alleviate clogging concerns in the conveyance and downstream processing equipment.

PROCESS

The food waste loaded into the system would feed into a twin-screw infeed conveyor to reduce particle size and direct the food waste into the main barrel of the hammer mill. The main barrel provides the primary function which is particle size reduction, emulsification and the removal of the packaging and/or contamination from the organics stream.

Based on the feedback from DC Water on the total solids percentage that they can receive to facilitate pumping is <15%TS. It is expected that to prepare the C&I food waste as a digester feedstock would require the addition of moisture as eluded to earlier with the liquid manifold on the main hammer mill unit. C&I food waste is typically between 20-30% TS and the addition of the liquids would facilitate the emulsification and pumpability of the resultant organic slurry. The system can include controls on the processing equipment that will assess the composition of the material output in order to adjust the moisture content, as necessary.

The processed material would become an organic slurry that would be further mixed in the storage tank to maintain consistency. Graywater from DC Water may be used for the moisture addition; however other sources of industrial liquid organics in the region can be explored to provide the moisture adjustment for the material. It should be noted that the actual moisture addition will depend on actual waste quantities received and the consistency of the incoming material.

The organic slurry would be piped directly out the bottom of the system to a pump for conveyance to a storage tank prior to pumping into a tanker for transport to DC Water. The slurried organics would be stored in storage tanks that would be located above grade and inside the building. It is expected that two 25,000-gallon tanks would be required for storing the organic slurry as well as for redundancy for tank maintenance and cleaning. In order to maintain the pumpable consistency of the processed SSO for anaerobic digestion, the tanks will need to be equipped with mixing capabilities. The tanks will also be equipped with a loadout system for transportation by truck in case of pump downtime or in the event that DC Water cannot accept the processed SSO material, so that it can be transferred to other anaerobic digester facilities. The storage tanks would also require proper odor control to manage the emissions from the headspace in the tank and the rationale for indoor storage relates to temperature control in the tank as the material is active and could begin to ferment if not managed appropriately.

Packaging and contamination that is removed from the integrated hammer mill system apart from the organic material would be conveyed via single screw conveyor out of the system for disposal. The conveyor would typically terminate over a dumpster or other means of waste collection. However, if sited at the existing transfer station, due to the proximity of the pre-processing facility to the tip floor, the reject material could be pushed over into the existing tip floor to allow for management of this fraction. This would eliminate the need to transfer the reject material through a roll off bin or compactor and thus mitigate additional costs for this fraction.

APPENDIX B

Co-Digestion Technology Recommendations

BLUE PLAINS WWTP

Organic slurry requires degritting because the integrated pre-processing system is effective at removing large but not small physical contamination and film plastics; small, hard plastics/glass and other forms of grit can pass through

the equipment and would end up in the organic slurry. Therefore, prior to the anaerobic digestion of these materials at DC Water, they will require degritting. In similar facilities, this is achieved through the use of hydro cyclones; however, they typically operate at higher removal efficiencies when the TS is <10% which would not be the case at the organics pre-processing system at the transfer station. Therefore, the degritting step should occur at the DC Water facility.

It is recommended that DC Water does not inject the organic slurry into the Cambi system but implements a series of batch pasteurization tanks that would heat the material up to 158 degrees Fahrenheit for 1 hour. During this step, the viscosity of the material will drop and thus allow for easier removal of the grit fraction via a conical bottom on the tank as well as a hydro cyclone in series with the pasteurization tank. The hydro cyclone system is available from a number of vendors; however, the Project Team has proposed Hydro Cyclone as they have been used in North America and have a history of handling food waste materials.

APPENDIX C

Sensitivity Parameters and Additional Considerations for the Blue Plains Model

A sensitivity analysis was performed on many of the technical and financial inputs of the Blue Plains model to identify the parameters that would have the most significant impact on the required tipping fee, and therefore on the feasibility of the project. The sensitivity analysis involved defining a base case, consisting of the existing parameters in DC Water's model and resulting tipping fee of $0.067 per gallon at 14% solids. Individual parameter inputs were then increased or decreased and the resulting tipping fee was quantified for various scenarios. To determine the sensitivity of each parameter, the percent change in tipping fee was divided by the percent change in the parameter value. This data is summarized in the table below. The parameters shown below are not necessarily recommended and may not be viable but were adjusted to show how significantly they impacted the model's resulting tipping fee. Definitions of the parameters are outlined in Appendix D.

Table 12: Sensitivity Analysis Data

PARAMETER	UNITS	BASE VALUE	NEW VALUE	PARAMETER CHANGE (%)	TIPPING FEE	TIP FEE CHANGE (%)	SENSITIVITY INDEX (%)
Sludge yield	%	0%	-10%	-10%	$0.059	-12%	119%
Price of Power	$/kWh	$0.08	$0.12	48%	$0.053	-21%	44%
Co-digestate Feed	wet tons/day	200	600	200%	$0.025	-63%	31%
% DS	%	14%	10%	-29%	$0.062	-7%	26%
COD	mg/l	180000	165000	-8%	$0.068	1%	18%
% CODR	%	78%	70%	-10%	$0.068	1%	15%
% Volatile Solids	%	80%	70%	-13%	$0.066	-1%	12%
Polymer Cost	$/lb.	$1.35	$2.00	48%	$0.070	4%	9%
Biosolids Disposal Cost	$/wet ton	$45.00	$60.00	33%	$0.068	1%	4%
Full Time Employee	NA	0	1	100%	$0.070	4%	4%
Methanol Cost	$/gallon	$1.37	$2.50	82%	$0.069	3%	4%
Simple Payback	years	10	5	-50%	$0.066	-1%	3%
REC Price	$/MW	$4.00	$0.00	-100%	$0.069	3%	3%
N% of VS	%	3.86%	4.50%	17%	$0.067	0%	0%
Biogas CH4 Organics	%	62%	100%	61%	$0.067	0%	0%

The results of this analysis are also summarized in the figure below.

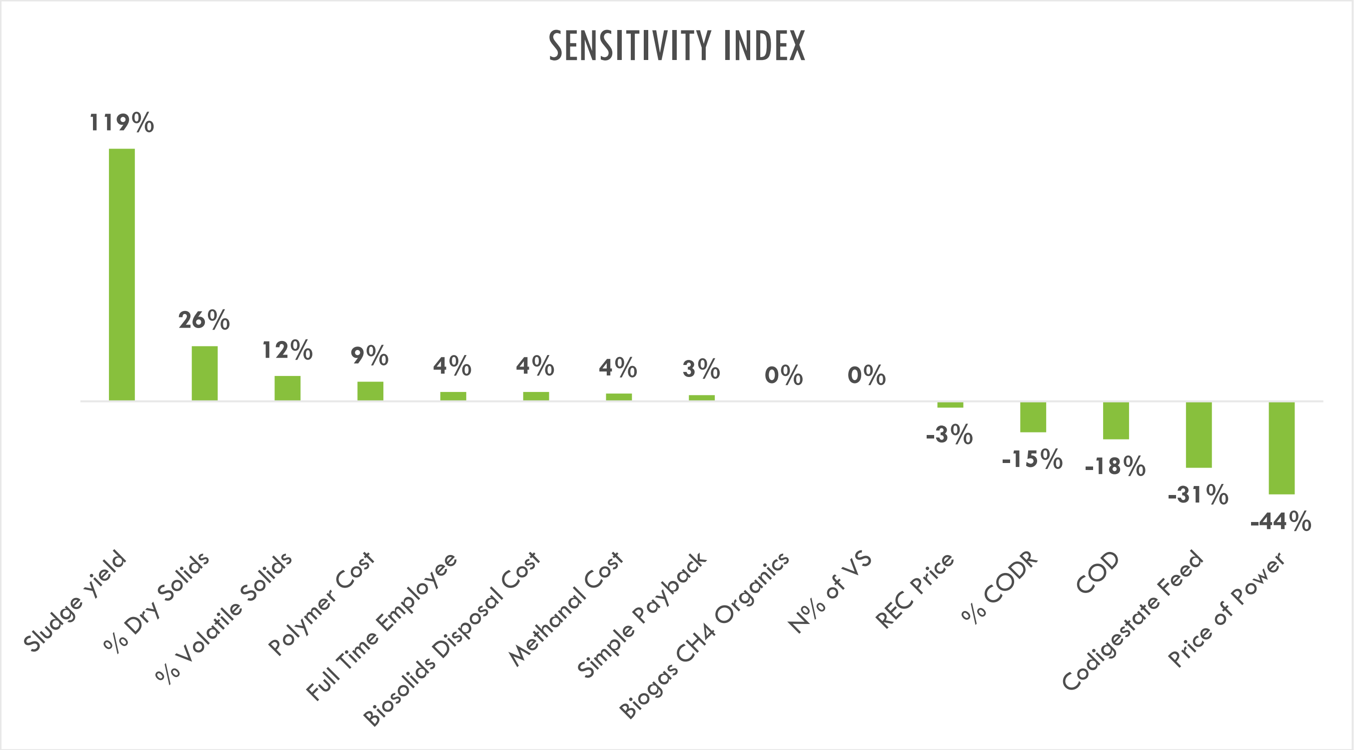

Figure 8: Sensitivity Analysis Results

Results. The analysis revealed that sludge yield is the most sensitive parameter, followed by the price of power, co-digestate feed rate, and percent total solids.

Sludge Yield. In the model, sludge yield is defined as the expected sludge production from the added co-digestate. The model currently assumes zero percent sludge yield. It is possible that the addition of feedstock materials will enhance the volatile solids destruction of the sludge solids, however there will be sludge production resulting from the added co-digestate. It is unclear how the model is accounting for enhanced volatile destruction of biosolids and sludge production resulting from additional organics feed. Due to the highly sensitive nature of this parameter, it is recommended that additional research be done to determine the most realistic assumption for this value.

Price of Power. The price of power also had a significant effect on the tipping fee in the model. This parameter represents the cost of purchased electricity in units of $/kWh. When increasing the price of power in the model, the resulting tipping fee is reduced due to the financial benefit of on-site power production at the existing co-generation facility. The current model does not include an escalation factor to project future increases of this value or others. The price of power, and many of the other financial inputs in the model (polymer cost, methanol cost, price of RECs, and biosolids disposal cost) can be expected to vary over time. It may be beneficial to escalate prices that are expected to change over the lifecycle of the project and have a significant impact on the tipping fee.

System Limitations. The daily co-digestate feed, currently modeled at 200 wet tons per day, also has a significant effect on tipping fee. This value is based on research at Bucknell University and represents the amount of feed the facility is likely to accept at this time, given capacity constraints of existing equipment. The model assumes that operations are not constrained until a piece of equipment is above 85% capacity. At 200 wet tons per day, the dewatering equipment that precedes the Cambi process is at 50% capacity, the Cambi process is at 64% capacity, the digesters are at 70% capacity, the turbines are at 82% capacity and the dewatering equipment following digestion is at 43% capacity. To eliminate any capacity constraints on the Cambi process, the model could be modified to reflect bypassing the Cambi process, as discussed later in the recommendations section. The available food waste in the marketplace is another constraint that will impact this parameter.

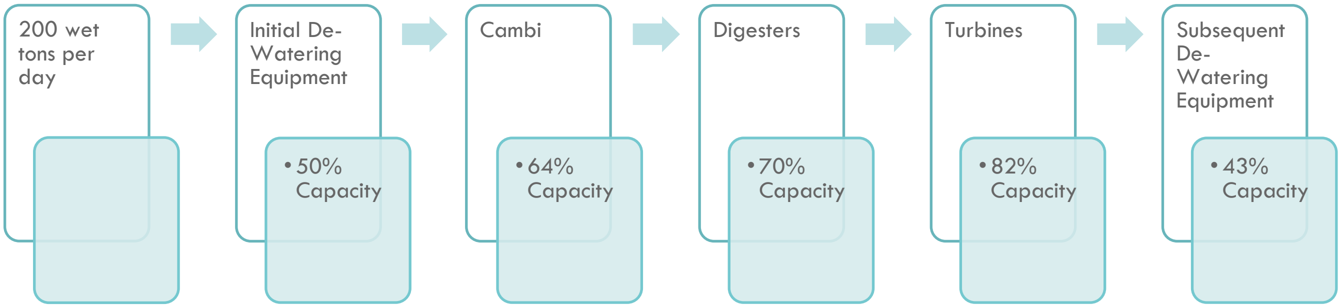

Figure 9: System Limitations

Based on current model assumptions, DC Water has the capacity to accept up to 300 tons per day without surpassing the 85%. The capacity of the turbines is the limiting factor to accepting additional food waste. At 300 tons per day feed, the turbine capacity is approximately 85%. Based on discussions with DC Water, there is space available for a fourth turbine to be installed in the future, as well as the potential to divert some digester gas from the turbines and prepare it for pipeline injection if necessary and deemed financially feasible. This alternative could be a potential in the future, however the feasibility of this project becomes more viable when the financial modeling remains within the bounds of the existing equipment and capacity of the DC Water facility. In addition, the current assumption of 200 tons per day is a more realistic volume to expect for this facility, especially in the first few years of operation. The facility may need to accept less organic material at the beginning of the operation and slowly ramp up to the expected 200 wet tons per day. The financial model included in this report assumes it will take two years to increase the co-digestate feed to 200 tons per day. This will impact the return on investment for DC Water and may affect tipping fee.

Slurry versus Cake. The percent total solids of the co-digestate is also a significant parameter in the model. The model assumes the co-digestate will be fed into the Cambi process as a pumpable slurry at 14% solids. An alternative to accepting a slurry at 14% solids would be to accept the food waste as a cake, at 18 to 23% solids. In addition to the change in this parameter, the capital cost of the receiving facility would also change, reflecting the appropriate technology needed to receive, slurry, convey, degrit and screen the co-digestate feed if received as cake. It is recommended to use the current assumptions as the basis of analysis. As part of the development of scenarios for optimizing the project benefits and costs, the option to accept a thicker feed may be viable. The equipment requirements at the receiving station would change under this scenario and the receiving facility costs would need to be modified to reflect this type of facility.

DC WATER FACILITY OPERATIONS

Based on feedback from DC Water, the primary driver for project feasibility lies in the financial hurdles, with operational risk also being a concern. DC Water does not anticipate the need to hire additional staff for the successful co-digestion operation. Based on discussions with DC Water staff, meeting the discharge permit and handling the additional side streams from the co-digestion process are not expected to create capacity constraints that would limit food waste acceptance. The model accounted for the increase in blower usage associated with secondary treatment to meet the discharge permit. The permit does not include restrictions on electrical conductivity or salinity, therefore, this is not a concern.

If additional capacity in the existing headworks grit washers exists, it is recommended that DC Water consider disposing of grit from the organics feed with this system to minimize costs. Based on typical removal percentages at other co-digestion facilities, it is estimated that approximately 0.9 tons per day would be removed with the hydro cyclone dedicated degritting system at the receiving facility.

Based on DC Water's communications with Cambi, there are limited concerns with accepting food waste in the Cambi process, as this has been done successfully at other installation sites. However, potential bottlenecks at this stage could be minimized by sending the organics to pasteurization tanks at 70 C for one hour to obtain pathogen kill. This would be done in parallel with the Cambi process, potentially creating a more efficient process. This scenario would bypass the Cambi process, while still obtaining the gas production through anaerobic digestion.

APPENDIX D

Co-digestion Model Input Definitions

Sludge Yield	Expected sludge production from co-digestate added
Price of Power	Cost of purchased electricity in $/kWh
Co-digestate Feed	Volume of co-digestate added per day in wet tons
% DS	Percentage of dry solids content of co-digestate
COD	Concentration of co-digestate
% CODR	Percent COD destruction of co-digestate fraction
% Volatile Solids	Percentage volatile solids content of co-digestate
Polymer Cost	Price of polymer for dewatering
Biosolids Disposal Cost	Cost of biosolids recycling
Full Time Employee	Number of additional full-time employees needed for co-digestion operation
Methanol Cost	Price of methanol for denitrification
Simple Payback	Number of years over which the additional capital costs are repaid
REC Price	Value of renewable energy credits in $/MW energy
N% of VS	Nitrogen content of volatile solids
Biogas CH4 Organics	Expected methane composition of biogas produced from co-digestate digestion

APPENDIX E

Supportive Policy Descriptions

FEEDSTOCK REGULATION

TOPIC AREA	RECOMMENDED ACTION	OPPORTUNITY	THREAT
Commercial Food Waste Disposal Ban	Enact a landfill ban for food waste generated by the C&I sector in the District. More than half of the organics generated in the District is from the commercial sector. To achieve the 80 percent zero waste goal, organic collection requirements are needed. These regulations also support the greenhouse gas reduction emissions goals and can spur the development of needed composting infrastructure in the region. These types of policies will help to ensure the success and development of new organics recycling infrastructure including DC Water's accepting of food waste or the District or private entity developing an in-district composting facility. As of early 2017 similar legislation has been passed in six states, four of which are located in the Northeast. The Sustainable Solid Waste Management Amendment Act of 2014 provides the Mayor with the ability to promulgate regulations to require Institutional, Commercial, and Industrial (ICI) organic materials to be diverted towards appropriate organics processing facilities.	Drives needed SSO feedstocks to newly developed processing infrastructure.	If not implemented, may not generate enough SSO to operate facilities cost-effectively.

Allow for SSO Collection and Storage	Update clause 704.2 by eliminating reference to grinding and requiring food waste to be drained, wrapped, and stored for collection with rubbish to enable source separated collection and storage of food waste for collection.	Defines collection and delivery standards.	If not addressed, generators are technically prohibited from source separating organics.
Distinguish between SSO for composting and SSO for Co-Digestion	Develop generator guidelines based on ultimate disposition of material (compost or co-digestion), and define contaminants based on the material mixes the different systems can handle.	Provides clarity for differently classified generators.	If not done correctly, prohibitives and contamination may negatively impact or shut down processing.
Yard Waste Composting Requirement	Consider a commercial yard waste composting requirement so that it does not contaminate the co-digestion stream.	Return organic resources to local soils and limit methane emissions, while keeping co-digestion stream clean.	
Flow Control	Investigate options for flow control of organic waste generated in the District to ensure adequate minimum and optimal levels of feedstock for the Co-Digestion facility (and compost site).	Allows the District to manage the flow of SSO from generators to pre-determined processors in the district.	If not used, generators and haulers can transport SSO to processors outside of the district instead of using preferred in-district sites.
Hauler Licensing and Reporting	Require through licensing that haulers offer mandatory SSO collection services and impose annual reporting requirements. Haulers should be required to obtain local license, permit and approval.	Ensures that everyone in the District has access to SSO collection services.	If not addressed, access to SSO collection may be limited in the District.
Self-Haul Allowances	Consider allowing self-haul direct to the pre-processing and/or compost facility.	Enables residents to manage their own material at their discretion.	
Compostable Foodservice Products Policy	Regulate the use of compostable foodservice packaging according to the requirements of the processing facility. Note: Compostable foodservice products are not suitable for co-digestion, but may	Allows for clarity on whether compostable products can be used and if so, which ones.	If not addressed, could cause confusion and contamination.

	be suitable for industrial composting.		
Contamination Limits	Recommend that hauler may refuse to collect container if it finds contamination >2% by volume (definition of contamination may differ between end processors). Also require hauler to inform jurisdiction of contamination. It should be noted that most C&I food waste generators will use plastic liners/paper bags to ensure cleanliness of the collection bins which will require appropriate processing equipment at the pre-processing facility.	Limits contaminants and prohibitives.	If not addressed, may receive un-processable material, which can add significant costs.
SSO Education and Enforcement	Develop an action plan for compliance and participation for generators and haulers, and establish penalties for noncompliance.	Educates participants on proper participation and provides disincentives for participating improperly.	If not addressed, could see higher rates of contamination and improper participation.

FACILITY OPERATIONS

TOPIC AREA	RECOMMENDED ACTION	OPPORTUNITY	THREAT
Identify synergies between compost site, pre-processing site, and co-digestion facility	Develop a comprehensive Organics Management Plan to determine the co-location and symbiotic relationship between an in-District compost site, a pre-processing site for co-digestion, and a co-digestion facility. Include definitions of feedstock requirements for each and determine how generators in the district, both residential and C&I will contribute to each and be regulated.	Provides clarity for differently classified generators and illuminates areas for mutual efficiencies.	Lack of a plan may result in competing priorities, inefficient operations, and adverse impacts.
Permitting and Zoning Requirements for Pre-Processing Facility	Streamline process for business interested in design/build/operate in the District by updating permitting and zoning requirements. Identify and address permitting and zoning requirements for composting	Attracts public private partnerships.	Lack of attention to permitting and zoning may impede site selection.

	and anaerobic digestion facilities in the District. Address any zoning changes that may be needed to develop a facility on preferred sites.		
Air Pollution	Address air pollution controls in the Organics Site Management Plan, to create one concise document that identifies specific site design, construction, and operational means of limiting impacts.	A single master plan allows for comprehensive consideration of planning and impacts.	Lack of a plan may result in competing priorities, inefficient operations, and adverse impacts.
GHG reductions from organics diversion	Address GHG impacts of organics management in the Organics Site Management Plan, to create one concise document that identifies specific site design, construction, and operational means of limiting impacts.	A single master plan allows for comprehensive consideration of planning and impacts.	Lack of a plan may result in competing priorities, inefficient operations, and adverse impacts.
Stormwater Runoff	Address stormwater runoff in the Organics Site Management Plan, to create one concise document that identifies specific site design, construction, and operational means of limiting impacts.	A single master plan allows for comprehensive consideration of planning and impacts.	Lack of a plan may result in competing priorities, inefficient operations, and adverse impacts.
Stormwater Environmental Emissions	Address stormwater environmental emissions in the Organics Site Management Plan, to create one concise document that identifies specific site design, construction, and operational means of limiting impacts.	A single master plan allows for comprehensive consideration of planning and impacts.	Lack of a plan may result in competing priorities, inefficient operations, and adverse impacts.
Health and Safety Regulations	Address health and safety issues in the Organics Site Management Plan, to create one concise document that identifies specific site design, construction, and operational means of limiting impacts.	A single master plan allows for comprehensive consideration of planning and impacts.	Lack of a plan may result in competing priorities, inefficient operations, and adverse impacts.

Organics Processing Facility Reporting Requirements	Require processors to report quantities of organics processed and contamination (daily/monthly). Include in Organics Site Management Plan.	A single master plan allows for comprehensive consideration of planning and impacts.	Lack of a plan may result in competing priorities, inefficient operations, and adverse impacts.
Transfer Facility Reporting Requirements	Require processors to report quantities of organics by volume being sent for disposal. District should define measurement protocol; require reporting for amount of contamination in each organics material type and list of main contaminants.	Allows the District to gain full picture understanding of organics handling and allows for identification of possible interventions.	Lack of reporting means lack of sightlines into program functionality.

FINANCIAL POLICIES

TOPIC AREA	RECOMMENDED ACTION	OPPORTUNITY	THREAT
Tip Fees/Rate Setting	Impose appropriate tip fees for SSO to incentivize recovery-oriented efforts.	Incentivize diversion.	If fees are not set to incentivize diversion, cost of disposal will be the major determining factor in costing other recovery services.
Contract Term Limit Extensions	Currently, District contracts and agreements may not exceed 10 years. It is recommended that contract term limits are extend to >10 years with allowable extensions or a total period of 20 years. Recommended contract durations are as follows: o Collection 7-10 years o New compost facility 10-20 years o New Digester Facility 15+ Years	Enables private sector investment by allowing for capital recovery over the life of the asset, not over a shortened life of a contract.	Without longer term limits, PPP investment will be difficult to acquire, except at very high tip fees.

COMMODITY USE

TOPIC AREA	RECOMMENDED ACTION	OPPORTUNITY	THREAT
Renewable Natural Gas	Develop a plan for best and highest use of renewable natural gas generated by the co-digestion process. Recommend using RNG to fuel District fleet.	Opportunity to achieve near net zero fuels for DC fleet.	If not addressed, is a lost opportunity for emissions reductions.