TO: Mayor and Council

FROM: Larry Collins, Interim Community Services Administrator
Craig Hupy, Public Services Area Administrator
Matt Horning, Treasurer/Interim CFO
Nick Hutchinson, City Engineer
Cresson Slotten, Systems Planning Manager

CC: Tom Crawford, Interim City Administrator

SUBJECT: Council Agenda Responses – Excluding B-2 & DB-1

DATE: 1/19/16

CA -3 - Resolution to Approve an Agreement with the Ann Arbor Area Transportation Authority for Modifications to the South Maple Road & Scio Church Intersection

Question: Does the City have drawings of the planned work? Residents are curious about how the work can be done with the physical characteristics of the intersection. (Councilmember Eaton)

Response: As the work is being performed internally by the City's Field Operations Unit, formal plans for the work were not created. The work consists primarily of moving back the stop bar on eastbound Scio Church Road and moving the traffic signal mast arm accordingly. Attached are the hand sketches developed by staff outlining the work to be done.

<u>CA – 4</u> – Resolution to Authorize Professional Services Agreements with Rowe Professional Services Company for $100,000.00; Fishbeck, Thompson, Carr & Huber, Inc. for $150,000.00; and Hubbell, Roth & Clark, Inc. for $150,000.00 for General Civil Engineering and Surveying Services

<u>Question</u>: What were the amounts of the two bids received fort the Sanitary Sewer RFP? (Councilmember Eaton)

<u>Response</u>: The RFP process for professional services is not a bidding process. Proposals received are evaluated based on qualifications, past experience, and their proposed work plans. Fee proposals are then only opened for the top qualified firms based on this evaluation. The fee proposals are then figured into the scoring system to determine which firm to recommend for a contract.

In the case of this RFP, the second consultant, Jones & Henry, submitted a proposal that was deficient on multiple counts. Therefore, staff determined they were not qualified for the proposed work, and did not open their fee proposal.

<u>Question</u>: Can the difference in the details provided in each bids be attributable to the prior work by OHM on city sewer work? Should a contract bidder be disadvantaged by not having involvement in prior work with the City? On the other hand, shouldn't the RFP provide enough detail to put all bidders on equal footing for submitting a complete bit? (Councilmember Eaton)

<u>Response</u>: The RFP provided a sufficient level of detail as to what was required in a responding proposal. It also provided access for all potential proposers to all of the information and reports that were produced from the previous study (Sanitary Sewer Wet Weather Evaluation Project), including access to the sanitary sewer model. In the evaluation of the proposals, the review committee takes into account the proposer's experience with related projects, but they are not scored lower if they have not previously done work with the City of Ann Arbor.

<u>CA – 6</u> – Resolution to Award a Contract with CB&I Environmental & Infrastructure, Inc. for Material Recycling Facility Contract Development ($121,780.00) and Contingency ($12,178.00) (RFP No. 931)

<u>Question</u>: The cover memo indicates the complexity of the contract has become an impediment and that the marketplace for recyclables has evolved, but does not provide any specific information on either. Can you please explain why the contract itself is an impediment/problem and what specifically has changed in the marketplace for recyclables and what the implications are for the MRF. (Councilmember Lumm)

<u>Response</u>: The contract is a 217-page document and complex in nature with multiple amendments. It is a burdensome document to interpret; with an origination date of 1993 many aspects of the contract are obsolete or no longer used in the industry. The commodities market has taken a marked decrease in the last few years and revenues on recyclables are very low, affecting the revenue generated by the MRF.

<u>Question</u>: The cover memo also suggests that changes in the business model may be appropriate. Can you please elaborate on that as well including what specific changes might be contemplated in the business model, partnership or operations? (Councilmember Lumm)

<u>Response</u>: The City is interested in understanding the current market norm for municipal contracts and CB & I will investigate this as part of their work. The City will take this information and apply it to future scenarios with any future MRF contracts or amendments.

<u>Question</u>: According to the cover memo, there are six years remaining on the existing contract with the operator. Are there provisions in the existing contract that allow for revising the contract structure or business model? What is ReCommunity's role and view on this – do they support revisiting the contract structure and business model? Will they be participating in the study or sharing any of the cost? (Councilmember Lumm)

<u>Response</u>: The current provision for revising the structure of the contract or business model is amending the current contract. ReCommunity is interested in having a more streamlined contract, but the City's main goal with this work is researching current market norms for municipal contracts. ReCommunity will not be participating or sharing in the cost of the study.

<u>CA – 8</u> – Resolution to Approve a Contract with Fishbeck, Thompson, Carr & Huber, Inc. to Develop a Biodigester Feasibility Study ($65,990.00)

<u>Question</u>: The cover memo states that the June 2014 feasibility report indicated that "a basic cost model was developed based on the waste stream estimates that showed a positive return on investment if a biodigester was built." Can you please provide the key data and assumptions of that study – up-front investment, operating costs, volumes, revenue sources and amounts? (Councilmember Lumm)

<u>Response</u>: The June 2014 study is attached. The assumptions and a summary of the model conclusions are in Section 7, which are found on pages 30-45.

<u>Question</u>: The cover memo also indicates that "many cities have explored the economic feasibility of biodigesters to manage community organic materials and to generate renewable energy to offset the system costs." Can you please provide additional information on the other municipalities that are doing this and what their experience has been in terms of the participation, costs and return? Finally, can you also please elaborate on what is contemplated by the sentence "explore the potential benefits of accepting material from a broader region surrounding the city" – how that might work, whether other municipalities that are in this business are operating that way and how, e.g., they ensure local residents/taxpayers do not bear an inordinate share of the cost? (Councilmember Lumm)

Response: : Over time, staff has spoken with colleagues in Portland, OR, San Jose, CA and Orlando, FL who have operating facilities, but staff has inquired about their cost and return experience. Staff is not be able to gather the specific cost data prior to tonight's City Council meeting. However, the following web pages are available regarding operating facilities in Portland, OR and Columbus, OH.

Columbus, OH - http://www.quasarenergygroup.com/pages/profile_columbus.pdf
Portland, OR - http://columbiabiogas.com/ourFacility/index.html

Locally, Grandville Michigan has a biodigester, which was designed by a subconsultant on the Fishbeck, Thompson, Carr & Huber, Inc. team proposed for this contract.

With regards to the potential of accepting material from outside the City, the main focus of the project is to explore the potential of designing a project that works for City residents and businesses. This project will explore whether there are specific sources of organic material from nearby, non-City sources (e.g., EMU) that would lower the cost for Ann Arbor residents.

CA – 9 – Resolution to Approve an Agreement with the Downtown Development Authority for the Design of North Fifth Avenue between Catherine and Kingsley and Detroit Street between Catherine and Kingsley ($342,310.00)

Question: Does the presence of brick pavers change the design costs for the road portions of this project? If so, how does this compare to the proposed cost sharing agreement? (Councilmember Warpehoski)

Response: The difference in design cost between a brick pavement and traditional pavement is minimal. The project scope currently includes the design of a brick pavement, and this is reflected in the cost sharing agreement.

Question: It is my understanding that the City and DDA will share the costs of this project with the City's share of the Project to be $342,310 and the DDA's share to be $318,138.15. How was the division of costs determined? (Councilmember Eaton)

Response: City and DDA staff went through the scope of work for the project and divided the work into Road/Utility work (City share) and Streetscape work (DDA share) to develop the values in the cost sharing agreement.

Question: Is this project included in the DDA's Development Plan? (Councilmember Eaton)

Response: Yes.

Question: Why is the City contributing any portion of the cost for this project within the DDA area? (Councilmember Eaton)

Response: The City is responsible for maintaining the streets and utilities throughout the City, including the downtown. The cost sharing agreement, and adopted City CIP, reflects these responsibilities. The DDA is contributing to the City road reconstruction project by funding some of the elements that are beyond the typical scope of work, including new light poles and restoration of historic brick.

CA-11 – Resolution to Approve Contract with Unum Life Insurance Company of America, Inc. to Provide Group Term Life, Accidental Death and Dismemberment, Short-Term Disability, and Long-Term Disability Insurance Coverage to City Employees and their Dependents ($630,000)

CA-12 – Resolution to Approve the Renewal Contract with Medicare Part D Advisors, Inc. to Fulfill Administrative and Actuarial Services to the City ($165,000)

CA-13 – Resolution to Approve Contract with Delta Dental of Michigan, Inc. to Provide Dental Insurance Coverage to City Employees and their Dependents ($2,125,000)

CA-14 – Resolution to Approve a Contract with Flores and Associates to Provide Flexible Benefit Plan and Health Reimbursement Account Administration to City Employees and their Dependents ($142,500)

Question: Can you please indicate when each of these four employee-benefit-related contracts was last put out to bid? (Councilmember Lumm)

Response: All Health and Welfare plans were out to bid in September 2013, prior to that it was August 2010. Under Public Act 106, we are required to bid the Health and Welfare plans every 3 years. Our next scheduled bid process will begin in summer 2016 for our January 2017 renewals. The RFP process is handled by our Benefits Consultants, MMA of Michigan.

DS-1 - Resolution to Affirm and Approve CORE as the Selected Developer of 319 South Fifth and Authorize the City Administrator and City Attorney to Begin the Negotiation Process for the Sale of the Property

Question: Assuming the ultimate sales price is $10 million, how much money would go into the Affordable Housing Trust Fund after fees and other related closing costs? (Councilmember Grand)

Response: Closing costs are typically a negotiable item; however, the Seller could be responsible for the base title insurance premium in the amount of the Purchase Price, a portion of the title company closing fee, transfer taxes and City closing costs. The property under the City's ownership has not been subject to taxation so no allocation of tax costs will be necessary. It is estimated that net revenue from the sale would be approximately $9.8 million. Therefore, under these assumptions, the Affordable Housing Trust Fund would receive approximately $4.9 million.

Question: It would be helpful if the Attorney's Office (or Treasurer's Office) could provide advice/guidance regarding the long-standing question whether selling (or entering a long-term lease for) 200 parking spaces to a private entity violates any of the City's bond covenants/documents related to the parking garage's financing, or is in conflict with any disclosures made by the City related to the financing, or violates any statutory or SEC provisions defining prohibited uses of Build America Bond proceeds (e.g., not more than 10% for private purposes)? (Councilmember Lumm)

Response: Library Lane Parking Structure has two physical components: 35 surface spaces and 709 below ground spaces. The Parking Structure was constructed with a combination of (1) a portion of the proceeds of tax-advantaged Build America Bonds and (2) other sources. The total cost of the Parking Structure was originally allocated 27.957% to non-bond proceeds and the 10% portion of the bonds that may be used for non-public purposes (authorized under IRC §141(b)(1)) and 72.043% to the bond proceeds. Based on this allocation 208 of the total spaces was determined to be the max allowable number of private use spaces for federal tax purposes. As part of the surface/air space development of the site, 35 surface parking spaces will be eliminated. Currently there are 709 below ground spaces. Reallocation of costs would reduce available parking spaces for private use from 208 to 196. The original allocation and the necessary reallocation are in conformance with statutory and SEC regulations.

Question: If it's decided to proceed with this sale to Core, who is responsible (City Council, DDA) for making the decision with regard to selling (or leasing) the parking spaces? At what point in the process would that decision be made? (Councilmember Lumm)

Response: City Council would be responsible for making the decision as part of the terms of sale. If City Council authorizes staff to pursue negotiations with Core, a recommendation regarding the parking would be presented to City Council as part of a larger recommended sales agreement.

Question: Also related to parking, please provide the parking demand data/analysis and assumptions that were developed for this proposal. It would seem that 360 apartment units, 130 hotel rooms plus what's necessary for the office space would generate parking demand well beyond 200 spaces (probably 500+ spaces). Also, what is the current capacity utilization in the underground garage, and how would accommodating this significant new demand impact existing users and businesses? (Councilmember Lumm)

Response: The parking structure contains approximately 709 underground parking spaces in addition to parking atop Library Lane. The structure has the greatest demand during the work week in the middle of the work day, but has many spaces available for use in the evenings and weekends, which is when many hotel guests would need parking. Further, it has been the DDA's experience that many downtown apartment residents appear to be living car-free. Despite the large number of new apartments that have come on line in the past few years we have not seen a dramatic increase in the demand for off-peak/over-night monthly parking permits (they provide parking in the structures from 3pm to 9am for only $30/month). And the majority of our standard monthly permit holders appear to be downtown employees, with relatively few downtown residents. Further, one of the assets for this development is that the site is located directly across the street from the Blake Transit Center, which is the hub for transit in our community, including staging for AirRide which provides 13/day service to/from the Detroit Metropolitan Airport. Transit-oriented developments have been very successful across the county. It anticipated that many of Core's residents, hotel guests and hotel employees, and office employees would likely utilize transit service due to its convenience and reduced cost.

Question: My understanding (may be wrong) is that the 520% FAR calculation and setbacks are not based on just the lot itself, but include Library Lane. Is that correct, and if so, why, and what would the FAR and set-back's be based on just the lot itself? Also, how does the lot size (excluding Library Lane), building size and set-backs of this proposal compare with 413 E. Huron? (Councilmember Lumm)

Response: The calculations of the FAR include the entire site which includes "Library Lane". "Library Lane" is not within the public right-of-way; it is located on the Library Lot parcel. Therefore it can be included toward the FAR calculation. The size of the 413 E. Huron site is 39,957 square feet. The building size is 265,815 square feet; the front setbacks are 0-feet for N. Division and 0-feet for E. Huron. The east side setback is 26 feet. The Rear setback is 30 feet.

Question: The cover memo speaks to the potential property tax revenue from the proposal indicating the City's portion could be up to $1M annually "depending on whether the DDA's cap has been met." Can you please provide the latest projections (50/50 forecasts, not conservative budgets) on the DDA TIF revenues vis-à-vis the cap for the next 3-5 years. (I may be wrong, but recall the TIF forecast for FY16 was about $5.3M and the FY17 cap was $6M). (Councilmember Lumm)

Response: The DDA will capture approximately $5.35 million in FY16. The DDA plan uses a 3% growth rate in it's realistic scenario, which would result in the following future revenues:

FY17	5.51
FY18	5.67
FY19	5.84
FY20	6.02
FY21	6.20

However, it is likely that new construction will outpace the 3% estimate, and the DDA capture will exceed this forecast. A detailed FY17 forecast is in development, and will be available by early February. The FY17 capture will be capped at 224,000,000 in taxable value, which translates to approximately $6.26 million in TIF revenue.

Question: The last resolved clause states that "the selection of CORE does not alter the process required or approvals needed for the sale, lease, and development of the property." What specifically is that referencing/what does it mean? (Councilmember Lumm)

Response: This is just to clarify that the passage of this resolution will in no way affect the normal requirements that need to be satisfied in the development process, e.g. site plan approval.

Question: As we know, a citizens group is working to obtain the necessary signatures to place a referendum on the ballot related to the Library Lot property. Other than the obvious issue of timing, would approving this resolution/beginning negotiations of a sales agreement have any other impacts or in any way inhibit/preclude that process (e.g., what is the level of commitment we'd be making/liability if the sale is not consummated)? (Councilmember Lumm)

Response: Passage of this resolution will not directly inhibit that process. The City has the option to discontinue activity with CORE at any time.

Question: If we were to conduct a public hearing on the Library Lot and the development proposals, does staff have a preference on a specific date for the hearing? Is there a date when the offer from CORE would expire? (Councilmember Lumm)

Response: The proposal does not have an explicit expiration date. The City has an opportunity to obtain a legally binding agreement for development reflecting the city's desires as expressed in the RFP. The developer has the ability to discontinue discussions at any time prior to entering into the agreement. Below is the timeline proposed in the developer's best and final offer:

> As outlined in the initial response and offering, Core Spaces will require the time indicated below from the date of commencement of the Purse Sale Agreement to complete the following:

Due Diligence: 60 Days
Entitlements: 180 Days or as needed to complete entitlements with the City of Ann Arbor
Closing: 60 Days After Completion of Entitlements

To get to this point the developer has already expended significant resources without a guarantee of any return. Scheduling a public hearing prior to the developer obtaining control of the site would have to be discussed with the developer.

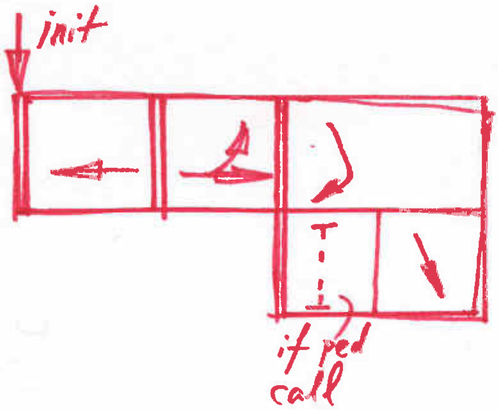
Maple & Scio Church #121

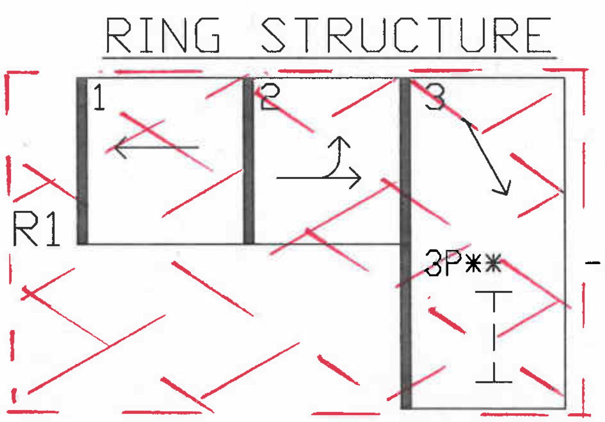
traffic signal

NOTES:

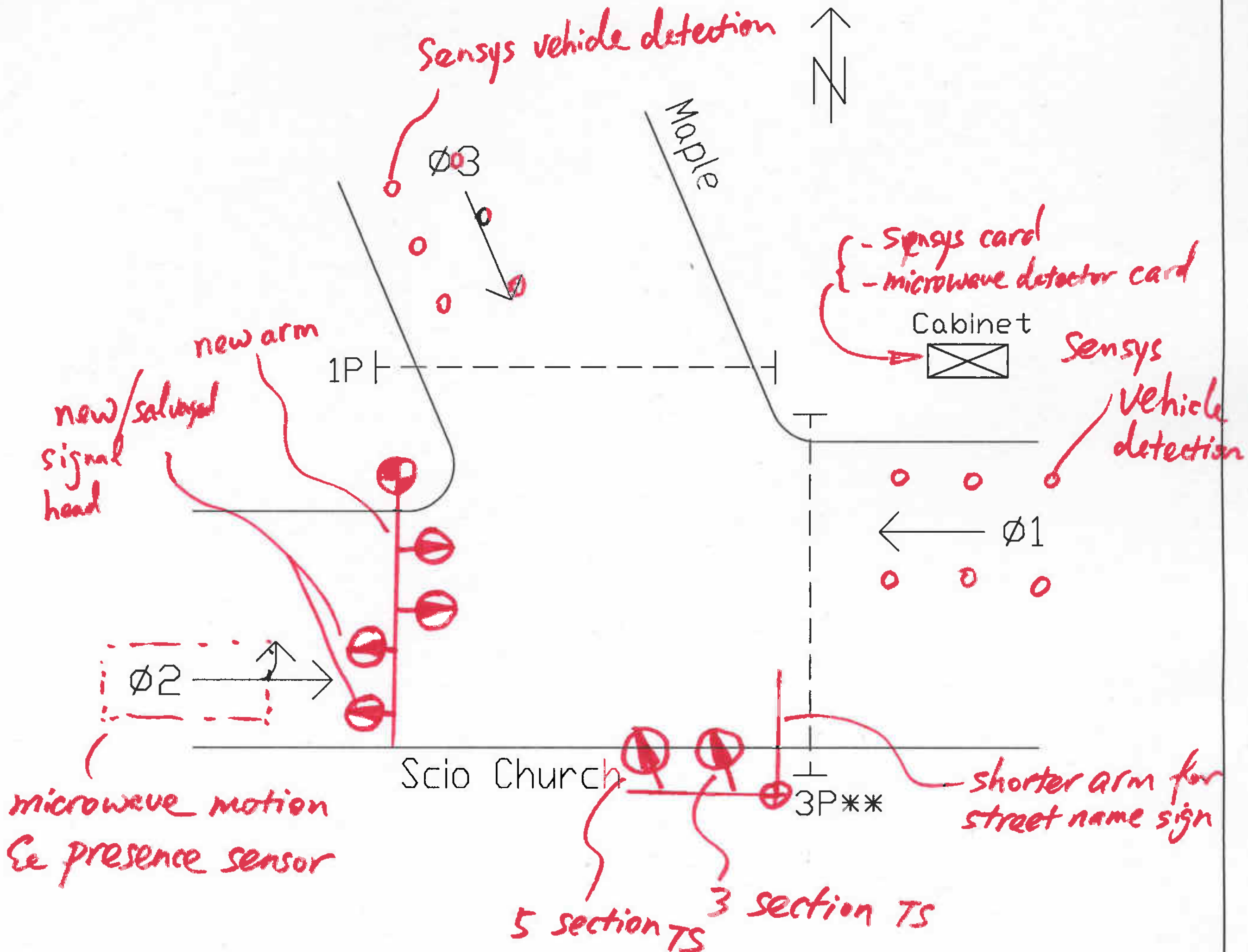
**3P is 5 second leading walk, but is seen in conflict monitor as 4W.

Monitor jumper 3-4 for leading ped.





-shows up in conflict monitor as 4W



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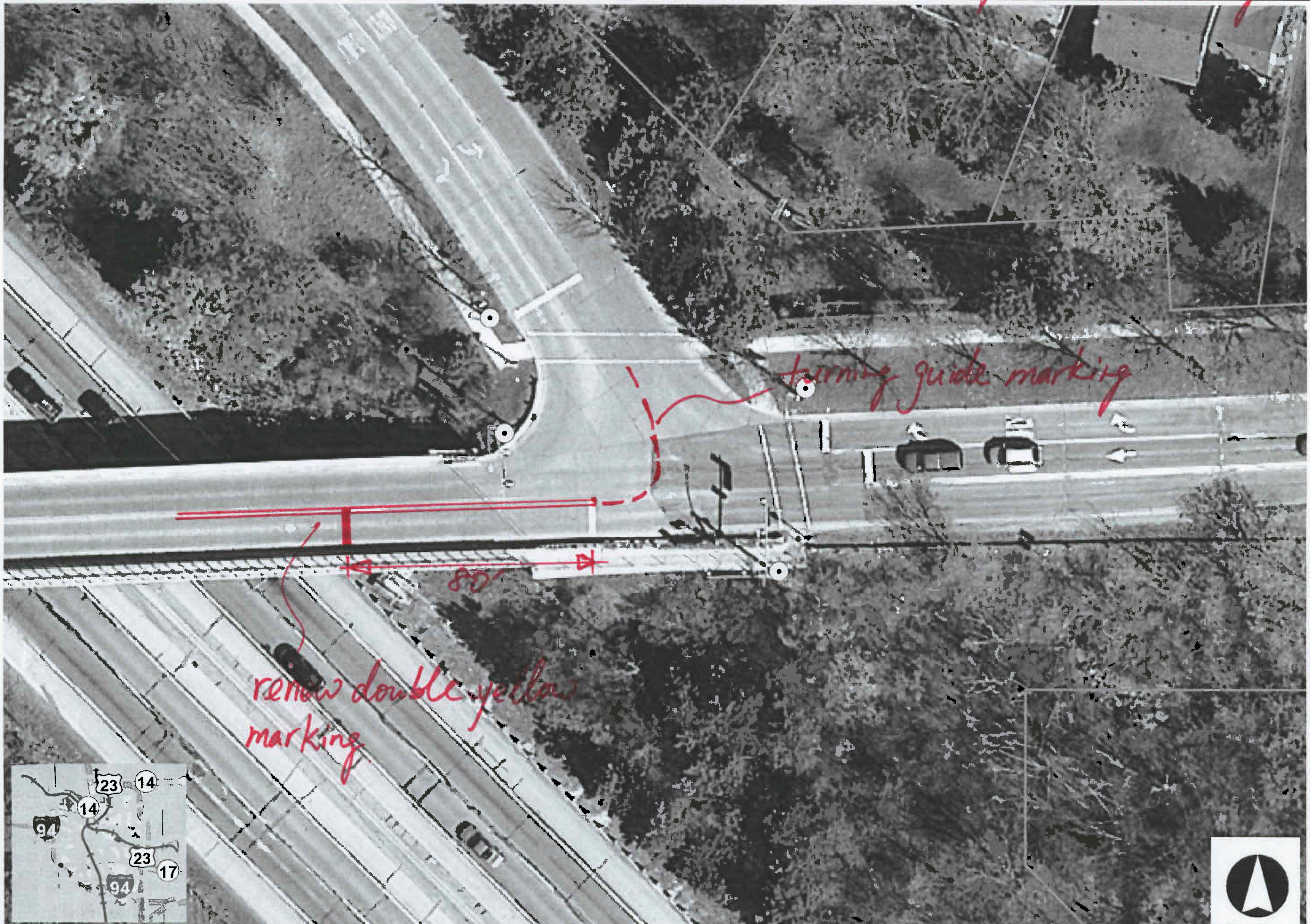
Pavement marking



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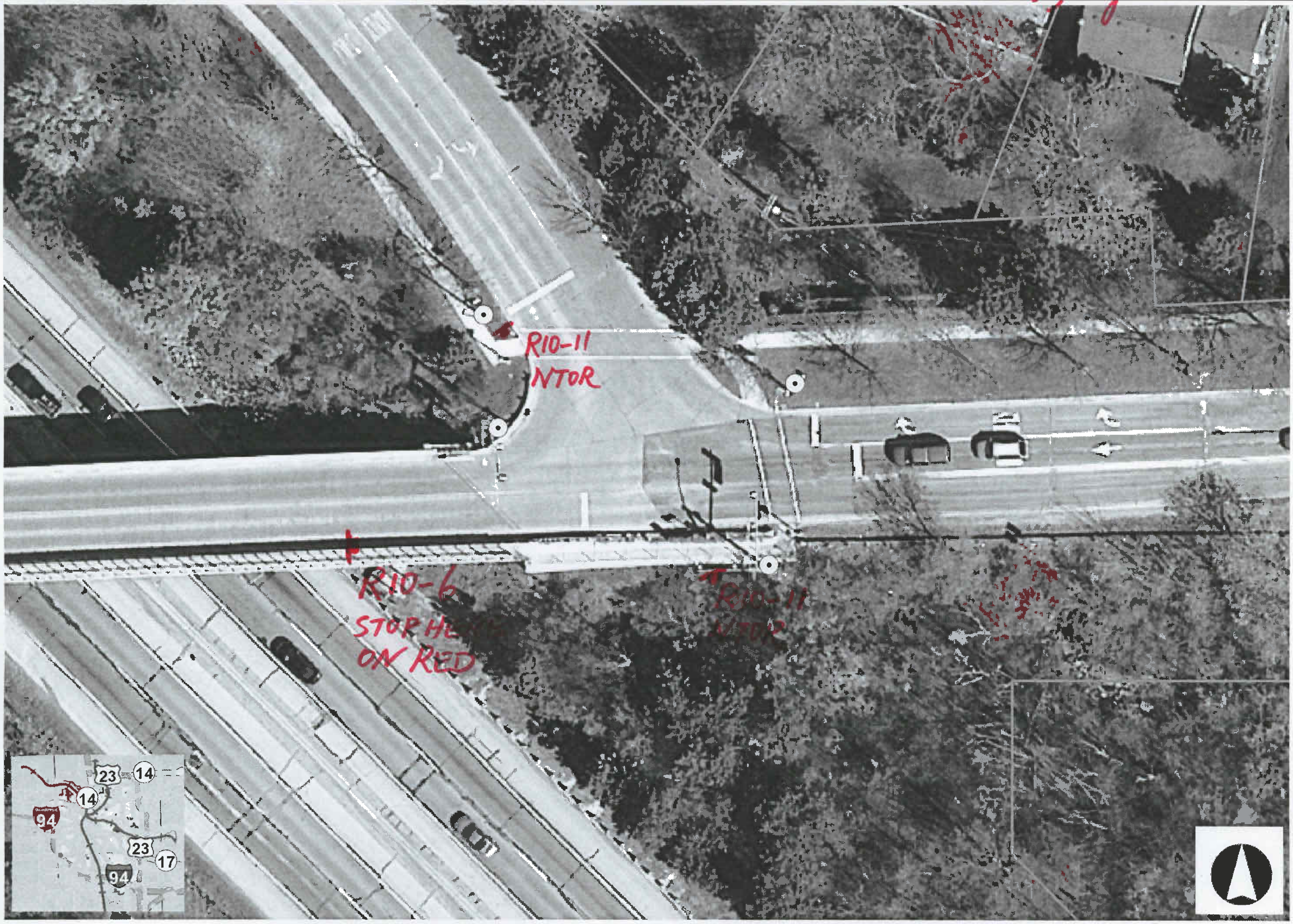
signing



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10/13/2015

Ann Arbor Biodigester

A Feasibility Study

30 June 2014

Submitted to the City of Ann Arbor
City of Ann Arbor
301 E. Huron
Ann Arbor, Michigan 48107

In fulfillment of the Scope of Work offered in RFP 889
By Quantalux LLC

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Acknowledgements

The Team of Quantalux/Swedish Biogas would like to acknowledge the assistance from the following people during the preparation of this Study:

Mr. Tom McMurtrie and *Mr. Matt Naud* from the City of Ann Arbor: Both Mr. McMurtrie and Mr. Naud met with Quantalux multiple times during the course of this Study in order to provide technical inputs, and recommend mid-course corrections (where needed). These meetings were very collaborative, and provided valuable opportunities for the Team to focus the tasks in the Feasibility Study to the specific needs of the City of Ann Arbor.

Mr. Keith Sanders and *Mr. Earl Kenzie* from the Ann Arbor Wastewater Treatment Plant (WWTP): Mr. Sanders and Mr. Kenzie provided the Team with technical data and detailed specifications on current WWTP plant operation. Mr. Sanders and Mr. Kenzie were very open to discussions on alternative processing techniques, and were quick to respond to the Team's request for detailed technical information.

Ms. Tracy Artley, Manager, Waste Reduction & Recycling Office, University of Michigan: Ms. Artley has worked for several years to determine the available food waste at the University of Michigan, and as the Study shows, the pre-consumer food waste from the University can be a valuable addition to the proposed Ann Arbor biodigester. Ms. Artley generously provided details on the University's food sort data, and shared technical information on the challenges facing a large institution with food waste collection.

Ms. Jean Henry, Sustainability Coordinator, Zingermans, Ann Arbor: Ms. Henry is responsible for managing the sustainable disposal of large amounts of food waste from Zingermans' restaurants and food production units. She shared data on the food waste generated by Zingermans, and identified the company's current methods for food waste composting. She was also particularly helpful in helping us understand the challenge of separating pre- and post-consumer food waste in the restaurant disposal stream.

Many other managers and owners of restaurants and breweries were interviewed to determine how food waste is disposed of in their establishments, including *Mr. Kevin Gudejko* (Main Street Ventures), *Mr. Dan Peron* (Corner Brewery) and *Mr. Tony Grant* (Northern United Breweries). We are grateful for the opportunity to see their businesses in person, and to discuss the various day-to-day issues they face with food waste disposal.

Ann Arbor Biodigester
A Feasibility Study

Introduction

A Request for Proposal (RFP) 889 was issued in March of 2014 to conduct a Feasibility Study on the use of biodigesters to process food waste from the City. This RFP was motivated by a Call to Action in the 2013 Ann Arbor Solid Waste Resource Plan, which calls for the City to research options to collect and process all food waste produced within the city. While the City already composts small amounts of food waste mixed with yard waste via weekly pickup from City residences, as much as 40% of the current trash load may consist of food waste, which – with good planning – can be diverted to a beneficial use.

Biodigesters are a good option for processing food waste, and are used routinely in Europe where the landfilling of food waste is prohibited. European systems typically find a good revenue stream from generating electricity from the biogas produced by the biodigester, and this is their primary revenue source. However, since electrical production is far less valuable in the US market, the successful adaptation of biodigester technology here requires that a biodigester find diverse revenue streams in order to maintain financial viability. Other revenue sources can include the sale of digested solids (a soil amendment), biogas (for heat or electricity) and the receipt of tipping fees when accepting materials to put into the digester. Another important revenue stream is the avoided cost of disposing of materials such as food waste or biosolids in the local landfill.

This Feasibility Study is an initial look at the resources needed for a successful biodigester near Ann Arbor. Our goals in the Study were to:

- Identify available food waste from commercial and industrial sources in the Ann Arbor region (excluding residential)
- Develop a high-level Biodigester cost description that is scaled to the available feedstocks
- Estimate the financial viability of the Biodigester (both short term and long term) based on revenues and expenses.

Using the results from this Feasibility Study, the City of Ann Arbor can assess options for enhanced solid waste disposal in the future.

1. Executive Summary

This Feasibility Study evaluates the potential for a biodigester for the City of Ann Arbor. Biodigestion is a method for processing organic waste materials (termed "feedstocks") such as food waste, grease, oils and sludges/manures. A biodigester earns revenue from the production of renewable electricity, from the sale of soil amendments, tipping fees for accepting feedstocks and via the avoided cost of landfilling the raw waste.

The Study focused on three main goals:

1. Identify available food waste and other organic waste from commercial and industrial sources in the Ann Arbor region.
2. Create an accurate system description for a biodigester that is scaled to the available feedstocks.
3. Develop software based cost-models to calculate financial viability of the Biodigester based on available feedstocks, including a 20 year pro forma model that includes all anticipated revenues and expenses.

The inclusion of sewage sludge in the list of available feedstocks is an important factor to economic success. Processing sewage sludge in a biodigester offers significant cost savings over the disposal of sludge in landfills or by land application (the current disposal method.)

The Study included the digestion of food waste from restaurants and food processors in the Ann Arbor area, and from the University of Michigan cafeterias. Food waste is a highly desirable feedstock, generating high quality biogas. The renewable electricity created from the biodigestion of food waste will earn significant annual revenue for the proposed biodigester.

Financial modeling of a biodigester showed the following results:

Case #	Type of financing	Fraction of sludge	Cost of Electricity ₵/kWh	Discount Rate, %	Cost of Money %	Term, years	Return on Investment, %	Internal Rate of Return, %	NPV
3	Public	100%	9 ₵/kWh	2.1%	3.5%	10	13.5%	6.06%	$2,705,235
4			5.5 ₵/kWh				15.6%	4.58%	$1,658,744

Key requirements for financial viability (i.e. profitabiliy) include the use of public financing using tax-exempt bonds, and the diversion of the sludge from the Ann Arbor Wastewaster Treatment Plant. Revenue from electrical generation can be earned via sale to the local utility (at 5.5 ₵/kWh) or by self-consumption for the plant and other City facilities (at 9 ₵/kWh).

Assuming these requirements are met, the models developed in this Feasibility Study show that an investment in the development of a biodigester system can be profitable to the City. The Study's financial modeling was fairly conservative, assuming very low inflation over the 20 year lifetime of the project. Should costs for current solid waste disposal increase significantly, then the biodigester's project profitability will improve further.

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2. Background

Organic waste makes up a large component of the total municipal solid waste (MSW) landfilled in the US. It is estimated that over 34 million tons of food waste is generated each year, which is approximately 15% of the total landfill volume.[1] Landfilling of food waste results in increased methane emissions through the natural decomposition of organic matter. While many landfills seek to capture and destroy methane using flaring and/or gas-to-energy systems, significant leakage means that approximately half of the landfill methane is emitted into the atmosphere

Conversely, biodigesters[i] use sealed vessels to process food waste, which captures nearly 100% of the methane produced from decomposing food waste. The methane can be used for a variety of power generation activities including electricity, natural gas replacement, and or vehicle fuel. Using the residual materials from the biodigester (digestate) as a soil amendment such as compost offers the opportunity to recycle valuable nutrients back into the ecosystem.

Biodigestion of food waste is a natural solution for a number of reasons:

- Food waste is high in nutrients, and can readily be broken-down by anaerobic digestion. Furthermore, food waste is inherently diverse, providing the required trace elements and nutrients for optimal digestion.
- Food waste has a very low potential for unwanted chemicals. In many cases, food waste is produced in USDA and FDA-compliant food processing facilities, assuring quality.
- Biodigesters can sustainably process many types of food waste that are not appropriate for composting. For example, sugary or soupy waste is a challenge to compost, but ideal for biodigestion.
- Businesses typically have loading docks and good site access for trucks to pick up food waste before it is transported to the biodigestion facility.

From an economic development-viewpoint, a biodigester can offer the following advantages:

- Businesses that desire a green solution to waste management can use this fact to offer legitimate green branding to attract and retain customers. Diverting food waste from landfills to a community digester makes business sense.
- A biodigester offers a responsible disposal option to a food production company contemplating a move in the Ann Arbor area. This is an economic development incentive.
- "Clean industries" such as food processing (as opposed to heavy industry) benefit from responsible and cost-effective waste disposal options, and are therefore more likely to expand in the Ann Arbor region.

[i] Biodigesters are also referred to as methane digesters or anaerobic digesters). For simplicity, this Study will use the term "biodigester".

Recent Food Waste Studies and State-of-the-Industry Investigation

The following is a set of summaries from recent food waste studies.

- A study by BSR, conducted on behalf of the Food Waste Reduction Alliance[2], investigated the quantities and disposal methods of food manufacturing and retail grocery sectors. The study surveyed 13 food manufactures (equating to 17% of U.S. industry represented by revenue) and 13 retail stores (30% of U.S. industry represented by revenue). The results showed that a majority of the food waste, 93% from manufacturing was diverted either to animal feed, land application, or compost. Retail grocery stores diverted a much smaller percentage of total waste generated, 37% was recycled, and 17% was donated. Composting was observed to be the primary recycling option accounting for 43% of all diverted waste.

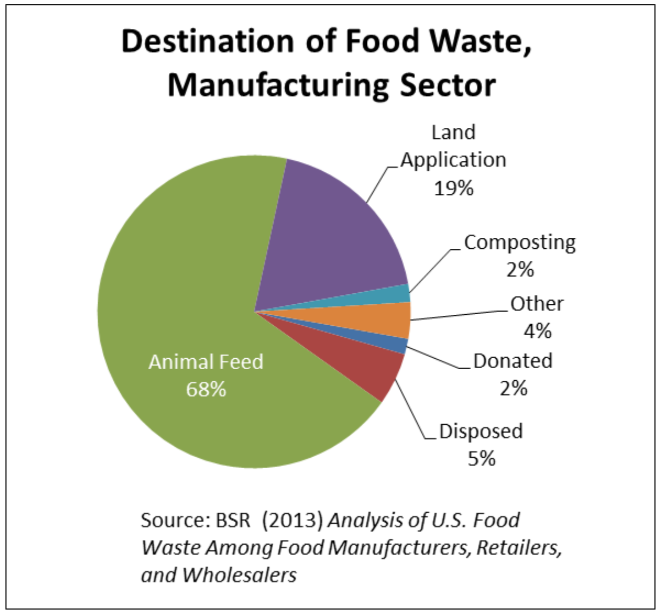

Figure 1: BSR manufacturing food waste study

- A study from 2008 for the City of New York estimated 1,640 tons/day of commercial food waste were produced in New York City alone.[3] A second study by the Coalition for Resource Recovery (CoRR) used this data to calculate the primary sources of this waste and the economic feasibility of diverting it from landfills.[4, 5] The breakdown of the sources showed restaurants and hotels being the largest producer (53%) followed by other food establishments and retail stores (20% and 14%). The report also showed that capacity for diverting food waste to compost or to anaerobic digestion facilities was limited. One of the potential diversion options proposed was transporting food waste to the City's wastewater treatment plant (WWTP), similar to the operation currently in practice at East Bay Municipal Utility District (EBMUD).

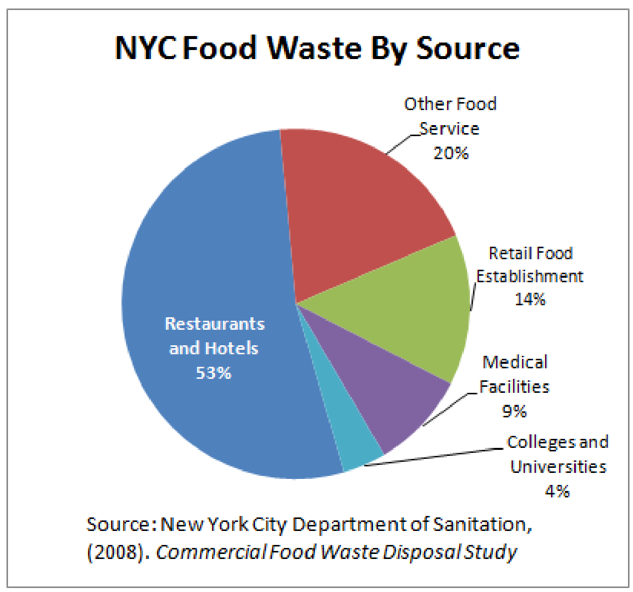

Figure 2: New York City commercial food waste by source

- East Bay Municipal Utility District WWTP in Oakland, California currently accepts 40 tons/day of food waste from restaurants and hotels. The WWTP also processes food processing waste and municipal sludge. The result is that the WWTP is able to produce 90% of its onsite power requirements from its anaerobic digesters to produce biogas. Future design of the system and expansion of organic waste acceptance is expected to turn the WWTP into an energy exporter.[6] In the Bay Area, there is approximately 2,100 tons/day of commercial food waste. *Recology*, the waste management company operating in the area, is building a preprocessing plant next to EBMUD's anaerobic digesters to remove non-digestible items from the organic waste stream that it collects.[7] The facility will be able to process up to 600 tons of material per day and feed directly into EMBUD front-end processing facility.[8]

Both EBMUD and the City of New York operate in a vastly different scale to Ann Arbor in terms of population and infrastructure. However, some of the information and lessons learned from these examples can serve as guidance for evaluating the feasibility of a community digester for the City of Ann Arbor. Food waste generation in the retail and food service establishments are expected to be fairly universal in terms of generation on a revenue or per customer basis. What is highly variable is the quantity of production across different types of food service establishments and retail stores. Also, the availability of alternative disposal options varies greatly as well. The comparison to a similar feasibility study effort by AECOM for Dane County, Wisconsin adds valuable insight into a city of comparable size to Ann Arbor.

- The Dane County Phase I feasibility study[9] showed that the diversion of organics from landfill are primarily driven by cost. The food processor waste survey estimated that on average 86% of waste was diverted from landfill. The primary diversion pathways included animal feed, compost, or rendering with only 14% of organics going to landfill. These findings reflect a similar breakdown to the BSR study mentioned previously. Diverting processor waste streams to animal feed and rendering are cost saving, or even revenue generating, opportunities for the food processors in the Dane County area. Another point of interest outlined in the Dane County survey is that waste quantity and disposal data was difficult to generate. This proved to be a similar challenge in Ann Arbor, Michigan.

All of these studies and active projects provide insight into an investigation into the Ann Arbor area. The technology and logistics for operating a community style digester has been proven both on a national and regional level.

Biodigester Overview

A flowchart for a typical biodigester is shown in Figure 3. The materials on the left (referred to as "feedstocks") are fed into the anaerobic digester at a pre-determined rate. Feedstocks include manure, wastewater treatment plant sludge, food waste, grease and fats from the surrounding community. Unlike a composting operation, biodigesters are anaerobic, which means that the system is sealed in order to eliminate oxygen, which is toxic to the culture of organisms inside the digester that consume the feedstocks to produce biogas and digested solids. As a result, the systems have very little odor, and are highly efficient at extracting biogas.

Feedstocks are held in the digesters for set period of time (typically 20 to 40 days) in order to allow the methanogenic organisms to break down the organic material. The output is then expelled for post-processing (moisture removal). Figure 1 also shows that the digestion process can earn revenues in several ways: direct payment of tipping fees, avoidance of landfill costs, and by the sale of byproducts (compost and bioenergy)

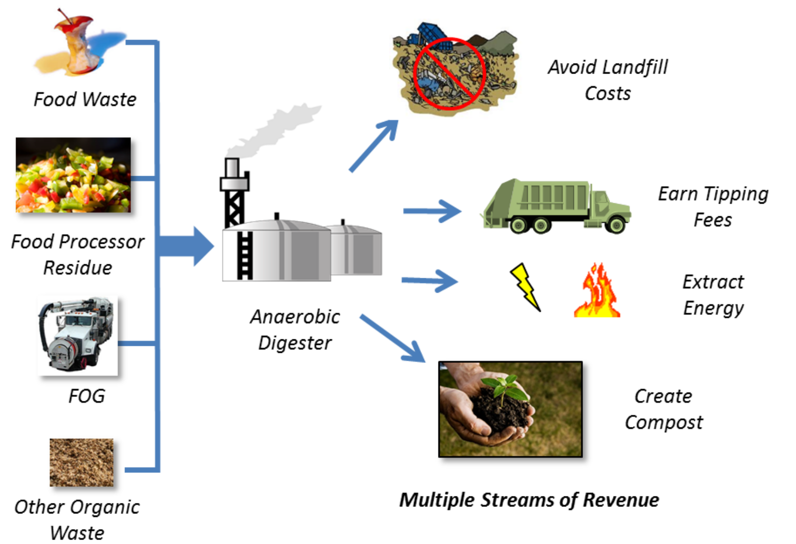

Figure 3: Multiple Feedstocks can be processed in a biodigester, yielding revenue from multiple sources.

Examples of Food Waste Biodigesters

While food-waste biodigesters are common in Germany and Sweden, the specific use of food waste as a feedstock is an emerging technique in the US, motivated by both environmental and fiscal considerations. Several examples of successfully operating food waste digesters are in operation today (see Figure 4.) These include:

Central Florida Energy Garden: The Energy Garden near Orlando is designed to process organic waste from the Central Florida region. The largest supplier of food waste will be Walt Disney World Resort. Other suppliers include restaurants, hotels and food processors in Central Florida. Energy production is 5.4 MW of renewable electrical generation

ecoCitysystem Columbus, OH: The ecoCitysystem processes biosolids from the City of Columbus, regional food waste and FOG (fats, oil and grease) to generate 1 MW of renewable energy.

South Campus Digester at Michigan State University: This facility processes dairy manure, food wastes and food scraps from the MSU dorms and other eating facilities on campus. The system is also designed as a research asset for MSU, allowing researchers to explore optimum feedstock combinations. Energy production is 400 kW of renewable electricity for the MSU campus.

Forest County Potawatomi Community, Milwaukee, WI: A biodigester at the Potawatomi Bingo Casino accepts food waste from casino food services in addition to soy, whey, and bakery byproducts from local industry. The plant is designed to process 132,000 gallons of material per day and will generate 2 MW of renewable power.

Central Florida Energy Garden
Orlando, FL

South Campus Digester, Michigan State University

ecoCitysystem, Columbus, OH

Potawatomi Casino, Milwaukee WI

Figure 4: Examples of biodigesters that process food waste and food residues

Note that all of the digesters shown in Figure 4 are large-scale, centralized facilities. Experience in Europe and the US has shown that large scale facilities are required to achieve the required economies of scale for financial viability.

Biodigester Feedstocks

While biodigestion is a mature and reliable technology, the key design and operational challenge is to identify a <u>locally available, continuous supply</u> of feedstocks to feed the digester during operation. In addition, the correct mixture of feedstocks must be fed to the biodigester. (This is essentially the "diet" for the biodigester). The following is a list of potential feedstock materials:

- Vegetative: Fruit and vegetable trimmings, spoiled produce
- Non-Vegetative: Meats, dairy, fish
- Industrial/Food Processing: Vegetative or Non-Vegetative (often referred to as food residue).

- Food that has been served but not consumed, e.g., plate scrapings, salad bar contents
- Fats, oils and grease (FOG) from restaurant grease traps and other sources
- Biodiesel by-products (glycerin and oilseed meal)

In addition, biodigesters can readily process animal and human wastes:

- Manure from feedlots, dairies or concentrated animal feeding operations (CAFOs)
- Waste activated sewage sludge from municipal wastewater treatment plants (WWTP).

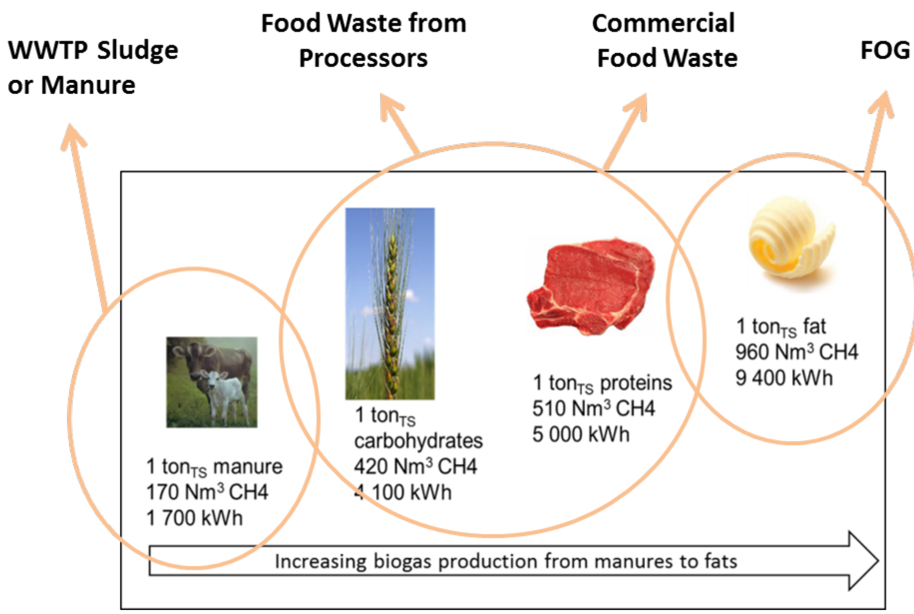

Figure 5: Energy content in different feedstocks, ranging from manure to fats and greases

Figure 5 shows the energy content for different types of food wastes. Sludges or manures have the lowest energy content because they are already partially digested. Carbohydrates and proteins (typically found in food waste) have the next highest energy content, and Fats, Oils and Greases (FOG) from cooking oils and greases has the highest energy density.

Optimizing Digester Performance

In order to generate the maximum amount of biogas and maintain system stability, this Feasibly Study focused on mixing five available feedstocks from the Ann Arbor area (see Figure 6). While the percentage of each feedstock can vary, this blend of feedstocks has been shown in other biodigesters to yield optimum performance and stability. Major feedstocks include:

Manure, or Sludge: The largest fraction of feedstock material in a digester is often manure or sludge because it readily available, and also provides an excellent buffering material for the higher energy organic materials such as food waste and FOG. Use of a manure/sludge buffer results in very stable digester performance, resulting in consistent and uniform biogas production. This material is sourced from either a local farm, or a wastewater treatment plant (WWTP).

Pre-Consumer Food Waste: Food waste gathered from community sources such as hospitals, universities, restaurants and even consumers provides a higher energy density feedstock. A major advantage is that food waste has a rich, diverse range of nutrients for the organisms inside the digester vessel that produce biogas.

Food waste from Processors: Feedstocks from out-of-spec food, past-date materials and other inedible food materials are excellent digester feedstocks, although they often need to be depackaged to separate the non-digestable wrappers or enclosures from the organic food. A key advantage with a food processor as a feedstock source is that the companies typically have good information on the material characteristics and daily quantity available.

Milk Waste: Dairies routinely need to dispose of spoiled milk, cheese whey, and other non-edible dairy products that are generated during the milk-production process. Because this material is mostly liquid, disposal in a landfill is a particularly poor option. Conversely, disposal in a biodigester is the ideal option. Several dairies near Ann Arbor are candidates to supply milk waste.

Fats, Oils and Greases (FOG): A very desirable feedstock for any biodigester is the grease or oils that comes from cooking food in restaurants, termed FOG. The majority of this material is grease trap waste (GTW), which is accumulated in grease traps and interceptors where nonresidential food preparation activities take place. Due to its high energy content (and low economic value elsewhere), FOG is an excellent material to add to a biodigester in modest quantities.

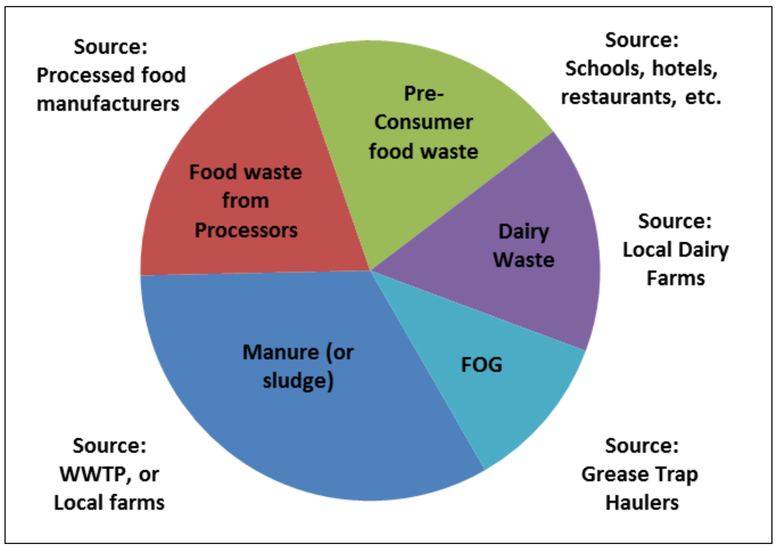

Figure 6: A biodigester performs best with a diverse range of feedstocks Typical Feedstocks and Sources

3. Food Waste Sources in the Ann Arbor Area

This feasibility study focused on the opportunities to divert food waste generated in the processor, retail and food service sector in Ann Arbor, Michigan. The major focus was on non-residential food waste sources within a distance of 25 miles from Ann Arbor. (This distance was chosen because it is the typical range for a logistics pickup system.) A systematic approach was used to identify the types and quantities of food waste, including: on-site interviews, phone interviews and data gathered from previous food sorts. A full rollup of the available food waste was compiled using the data gathered.

The primary objectives for reaching out to Ann Arbor food processors, retail stores, and food service establishments were to:

1) Determine if Ann Arbor food waste generation follows similar trends to the national and regional studies.

2) Estimate the quantity of waste production at each type of food service establishment.

3) Assess for the acceptance level among business owners for diverting organic waste streams to a community digester.

The following is an overview of how each sector was evaluated.

Restaurants

The outreach to local food service establishments provided valuable insight into business practices in Ann Arbor. Owners were willing to talk about the waste produced at their facilities and were, in general, open to further discussion. While most respondents said "Yes, we have food waste and would like a better solution", few owners knew the exact amount of food waste produced at their restaurants.

Seven restaurant managers were interviewed representing over 20 Ann Arbor food service establishments. Preliminary data collected showed that waste generation is highly variable between restaurant types, location, and practices. In spite of the small sample set, three important observations were clear:

Composting: Several restaurant owners already had a composting system implemented to divert pre-consumer "kitchen" waste. This is a particularly popular solution because both pre- and post-consumer waste can be included in the composting bin (including napkins and other paper products). One owner told us "*Don't take my composting away – I love it.*"

Space constraints: For restaurants in high density areas (downtown, for example) the practical consideration arose as to where to place a bin for segregated food waste. Restaurants already separate trash, recyclables (multiple bins) and (sometimes) cooking oil. For many restaurants, the physical space for a dedicated "food waste bin" is simply unavailable.

Low priority: Several restaurant owners estimated the total weekly production of food waste to be relatively marginal and did not see the cost of disposal as a major concern.

Rough estimates of waste production were collected from restaurant managers and compared with documented values from a variety sources. Food service establishments were categorized into three categories, Casual Dining – larger full service restaurants, Fine Dining – smaller atmosphere focused restaurants, and Fast Casual – restaurants not offering full table service, fast food – limited menu, quick service.

Interviews with several fast-food chains yielded little optimism about being able to divert food waste from these locations. Several responses from these organizations considered their waste handling operations to be "proprietary information," and were not open to discuss alternative opportunities at this time. However, our team did speak to a franchisee with 67 outlets for a national fast-food chain. This owner indicated that fast food is a highly efficient food delivery system, with very little pre-consumer food waste produced. The post-consumer waste is typically co-mingled with paper and plastic.

Grocery Stores

Several local area grocery stores were contacted about their options for surplus food and other organic waste streams. Community food donation is the first priority for these stores. Over 300 food donors in Washtenaw County coordinate with Food Gatherers to take surplus food. The remaining non-edible, food waste/vegetable clippings is generated in the produce department, with a rough estimate of 400 pounds per week from a large grocery store.

Shift managers could not confirm disposal costs but did articulate that the primary pathways for expired food (or near expired) involved donation, composting, or diversion to animal feed. This appears to follow a similar pattern to the BSR study sponsored by the Food Waste Reduction Alliance.[10]

One of the key questions we asked of grocery stores was "*Will your staff be able to segregate food clippings/residues without significant extra work?*" The managers we spoke with said that their staff would be eager to implement more sustainable solutions in their workplace with little additional effort. Another question dealt with the physical space needed for an additional food-waste bin to store food waste before pick-up. Managers said that groceries tend to have ample storage space near loading docks and in the back of stores. However, an important caveat is that the food waste must be stored separately from incoming food stuffs in order to maintain a hygienic environment for incoming food.

Cafeterias

Large cafeterias were also considered to be potential sources for food waste collection. Schools, hospitals, and community colleges were all possibilities. A key difficulty is the separation of pre- and post-consumer waste. As noted previously, post-consumer waste is typically co-mingled with napkins, straws, flatware and other items that would foul a digester. Composting is the preferred solution for post-consumer food waste for this reason.

Figure 7: Composting tubs at WCC

Washtenaw Community College (WCC) was considered to be potential large source of food waste. However, our interview with the Recycling Operations Manager determined that WCC has already made a significant investment in composting equipment, and they plan to divert their pre-and post-consumer food waste into a compost system. WCC has installed two Green Mountain Technology Earth Tubs™ [ii] for composting (see Figure 7). These Earth Tubs™ can process up to 100 lbs per day of food scraps when mixed with a bulking agent such as wood shavings. The composted material will eventually be used as fertilizer for a neighboring greenhouse.

As with most institutions, segregation of pre- and post-consumer food waste remains a challenge for WCC and other cafeteria services. Our team was not successful in determining the available food waste from local public schools; however, other studies show that school food waste is typically both pre- and post-consumer. Given the modest timeframe for this effort, the focus was turned to larger sources of food waste such as food processors, restaurants and the University of Michigan.

Food Processors

The ideal source for food waste for biodigestion is sourced from local food processors. Food waste (or food residue) from the food production process is typically:

- Available in well-defined, consistent quantities (by product of the food production process),
- Well-characterized in terms of nutrient qualities, and
- Likely to be supplied via long term contract.

To identify the food processors near a proposed Ann Arbor Biodigester, a list of 1800+ active food processors was obtained from the Michigan Department of Agriculture and Rural Development (MDARD). Because most food processors must be permitted to dispose of food materials, the MDARD will issue permits based on the material type and quantity.

This long list was then narrowed down by first removing all "Limited Wholesale Food Producer" license type.[iii] Secondly, a 25 mile radius

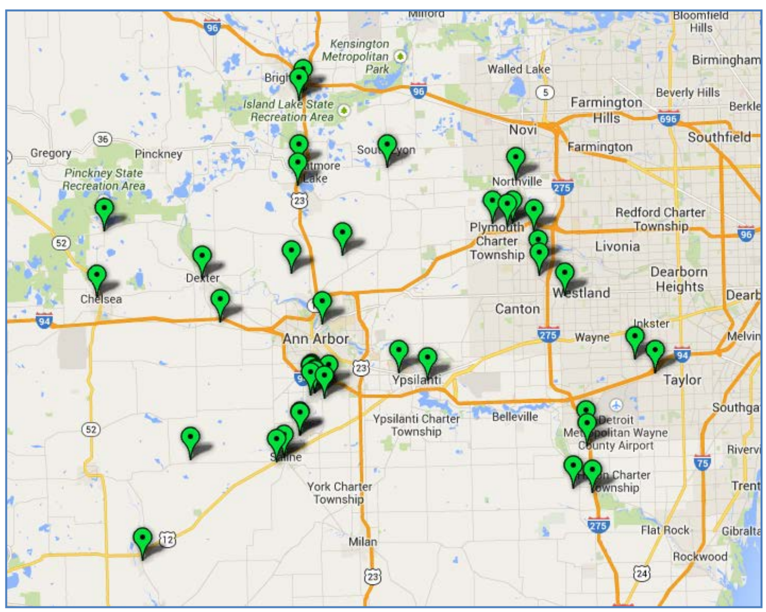

Figure 8: Wholesale food processors within 25 miles of Ann Arbor

[ii] http://compostingtechnology.com/products/compost-systems/earth-tub/

[iii] Limited Wholesale Food Producers are defined as $25,000 or less in annual gross wholesale sales

was used to sort by travel distance to Ann Arbor.[iv] The remaining list of 38 processors was vetted by investigating the company websites or by personal phone calls to determine available material.

Our interviews showed that the food processors shown in Figure 8 are only modest producers of food residue/waste. The largest producer was a bagel manufacturer that disposed of 100 to 500 lbs of dough per week. Nearly all companies co-mingle their food waste with trash in a dumpster, and the material is picked up at regular intervals their trash hauler.

As was the case with grocery stores, food processing companies wanted to be sure that the organic materials were quickly removed from the building (to maintain cleanliness) and periodically removed from the site.

The food processors that were interviewed identified the following important opinions about food-waste diversion to a biodigester:

- Nearly every processor we contacted was supportive of the idea of enhanced food-waste diversion, and indicated a willingness to participate in a City program (if implemented).
- While co-mingling food waste with trash for the landfill was considered a poor approach, processors reluctantly do so because it is easy and cost-effective. Optimizing disposal is simply not a core requirement for any company's success.
- Current cost of disposal was not a particular concern, likely because of the small quantities of food waste.
- Low quantities of food waste from processors is based on the fact that companies need to be efficient, and waste material has been engineered out of their production processes.

In summary, the food processors within a reasonable distance of Ann Arbor (approximately 25 miles) produce only small quantities of material. Ideally, a large food processor would be situated near the biodigester, with all the food waste efficiently diverted to the digester on a continual basis. At the current time, however, this notional "large" food processor does not yet exist in the Ann Arbor region.

4. Estimation of Available Food Waste

Given the low quantities of food waste from local food processors and grocery stores, this Study focused on estimating available food waste from two key sources:

- Restaurants and food services within Ann Arbor proper, and
- University of Michigan.

Each source is capable of providing pre-consumer food waste that does not conflict with their existing composting of post-consumer food waste. This will result in a very conservative

[iv] A filter of 50 miles was originally used but returned over 200 processors, mostly from the Detroit-metro area, a shorter range filter was necessary before conducting a more targeted outreach.

estimate on the food waste, with any additional quantities from other sources a bonus to the overall system.

Restaurant Food Waste – Statistical Estimate

A statistical estimate of restaurant food waste was based on a database of 275 Ann Arbor food service establishments using a series of Monte Carlo simulations. This approach is used routinely in engineering and science for determining quantities or instances for a large dataset with a small number of samples within that dataset. The results of the Monte Carlo simulation were then compared to the results of food sorts from other cities in the US in order to validate the results.

Table 1: Food waste generation by restaurant type

Ann Arbor Food Waste Generation Survey by Restaurant Type				
		Generation [lbs/week]		
	Sample Size	Lower Range	Average	Upper Range
Casual Dining*	8	500	1000	2000
Fine Dining**	3	250	500	1000
Fast Casual***	2	90	180	280
*4 yd dumpster 3x week collection @ 80% food waste and 245 lbs yd				
**4 yd dumpster 2x week collection @ 80% food waste and 245 lbs yd				
***Based on 50 lbs / day estimate @ 80% food waste				

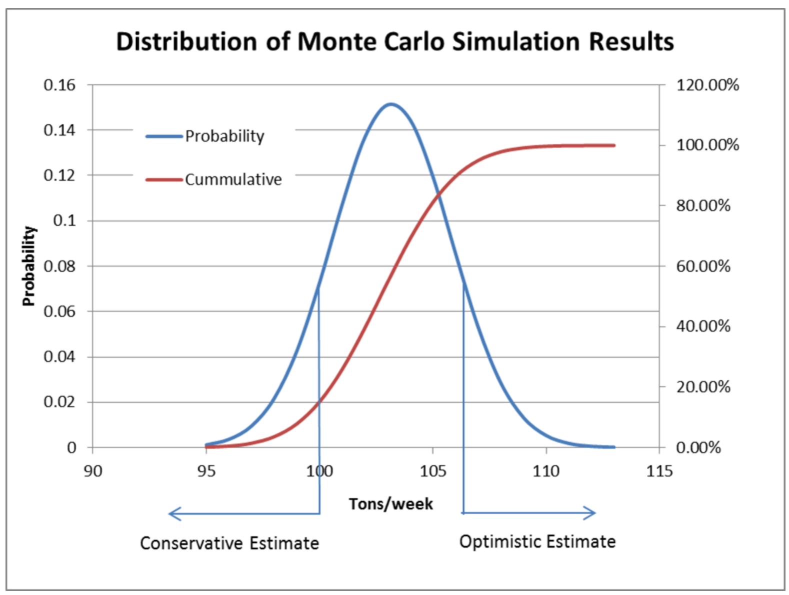

Figure 9: Results of Monte Carlo Simulations on food waste.

To construct the Monte Carlo simulations, each food service establishment was geographically referenced and assigned a category; Casual Dining, Fine Dining, and Fast Casual. The 275 restaurant database is not an exhaustive list of restaurants in Ann Arbor however, for the purpose of the simulation, it was considered to be representative of 90-100% of the total food service population in Ann Arbor.[v] For each simulation, a randomly generated food waste production value (in lbs) between the lower and upper range established in Table 1 was assigned to each restaurant. The randomly generated values for all restaurants were summed together to produce a simulation total. The simulation was then run 1000 times. The results are shown in Figure 9, where the peak of the probability distribution represents the amount of food waste (103 tons/week) that is statistically most likely to be available. The

[v] There are potentially more sources of food waste production; however, the researchers felt that considering the 275 restaurant database as 100% of the population allowed for a conservative estimate.

distribution of food waste availability follows a normal distribution ("bell curve"), which is consistent with a large number of samples generated by the Monte Carlo procedure.

To get a sense for how accurate this statistical approach is, a number of other reports/surveys were compared to the Monte Carlo results[11] [12] [13] [14]. This data is shown in Table 2. Results for these surveys show that for 800 meals/day, the upper range for available food waste will be approximately 2000 lbs/week. This compares favorably to the upper range from the Ann Arbor data for "Casual dining" (see Table 1), yielding confidence that the upper and lower values for the Monte Carlo analysis were selected correctly.

Table 2: Comparable food waste data from other studies and surveys (see text above for references.)

Restaurant Waste Production Comparison Table			
Source	Metric	Upper Range Conversion Factor	Comparison
Recycling Works Massachusetts	0.5 lbs/meal	800 meals/day* x 5 days/week	2000 lbs/week
EPA Food Waste Management Cost Calculator	0.5-1.5 lbs/meal	800 meals/day x 5 days/week	2000 – 6000 lbs/week
The Rosenthal Group (incl all discarded waste)	1.5 lbs/meal	800 meals/day x 5 days/week x 30%**	1800 lbs/week
Cascadia Consulting Group	2,900 lbs/employee/yr	2,900 lbs / 52 weeks/yr	30 employees = 1600 lbs/week 50 employees= 2800 lbs/week

The results of the Monte Carlo simulation are considered to be representative of the food waste in Ann Arbor restaurants, but conservative.

Important Note: The most accurate method for determining available food waste is to conduct a food sort from a series of restaurants, including sufficient restaurants in the effort so that the sample size is statistically valid.

Geographic Location of Food Waste in Ann Arbor

The results from the Monte Carlo simulation were further broken down into geographical areas within Ann Arbor. Per the recommendations of City staff, this study did not include food establishments outside Ann Arbor city limits on the thesis that access to outside food waste could not be guaranteed to the City. Inside the City, however, the possibility of franchising the collection of food waste exists. This would offer a steady supply of food waste to the biodigester, which is a critical requirement for successful operation. In future studies, food waste outside Ann Arbor proper should also be considered, along with an assessment of how to incentivize the delivery of that material to the biodigester.

Figure 10 shows the geographic area and relative waste production estimates for restaurants in Ann Arbor proper. The physical location of restaurants is shown in the map on the left, and a "heat map" of food waste concentrations is shown on the right.

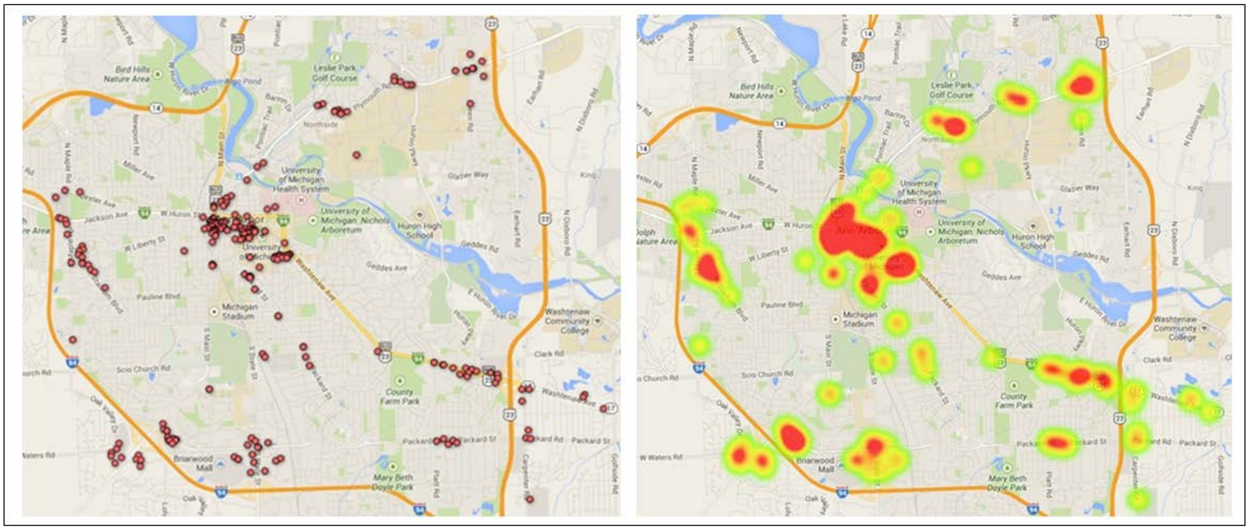

Figure 10: Geographic location of food service establishments in the restaurant database; geo-code (left) and heat map of food concentrations (right).

The data in Figure 10 can be further combined to identify “food waste corridors” in the City of Ann Arbor. Figure 10 shows a breakdown of the restaurant database according to location, with estimations of the food waste available from each “corridor In general, the Downtown area is the largest source of food waste, with the other areas roughly equal in food waste generation.

The estimate of 100 tons per week is the value of food waste production used this Study’s computer modeling (described in later sections of this report).

Weekly Food Waste Generation (tons/week)			
Area	Low	Med	High
Downtown	39	45	50
South Ann Arbor	12	16	19
Packard/Washtenaw Corridor	12	15	19
West Ann Arbor	7	9	12
Plymouth Road Corridor	7	9	12
South University	6	8	10
Totals	83	103	122

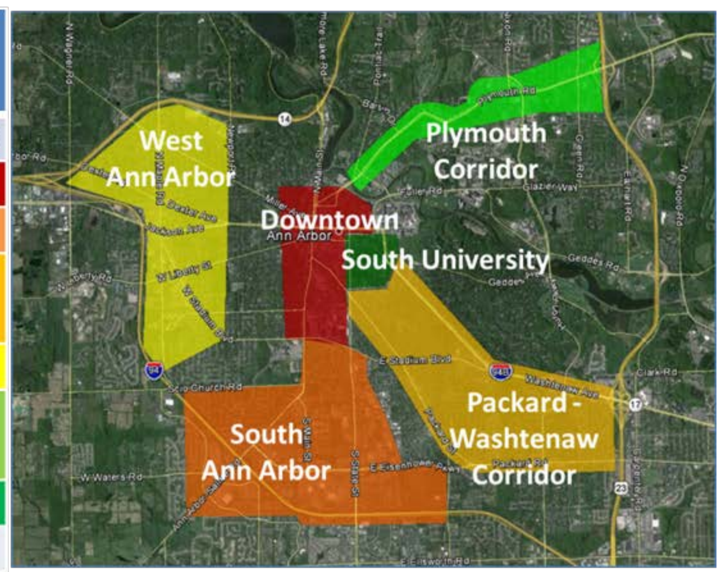

Figure 11: Restaurant Food Waste Generation by Corridor with map of corridors in Ann Arbor

University of Michigan

The University of Michigan conducted a refuse sort in 2013 for the waste generated at several of the University's cafeterias, and also at on-campus food service locations and special events. The data in Figure 12 represents pre-consumer food waste only, which is therefore an accurate representation of the available materials from the University of Michigan for biodigestion[vi].

2013	UM Food Waste [tons/wk]			
	Housing	Other	Events	Totals
Jan	3.3	0.2	0.0	**3.5**
Feb	4.7	0.3	0.5	**5.5**
Mar	3.1	0.2	0.6	**3.9**
Apr	3.5	0.2	1.8	**5.5**
May	0.7	0.3	0.1	**1.2**
Jun	1.3	0.2	0.0	**1.5**
Jul	1.9	0.2	0.0	**2.2**
Aug	1.0	0.2	0.0	**1.3**
Sep	4.7	0.6	1.8	**7.1**
Oct	5.3	0.7	1.3	**7.3**
Nov	5.4	0.8	1.8	**8.1**
Dec	3.2	0.6	0.7	**4.5**

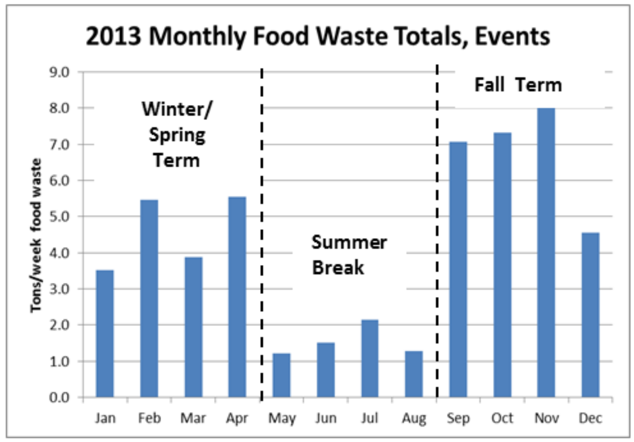

Figure 12: Pre-consumer food waste from the University of Michigan was tallied in 2013.

As with most schools, the available food waste from University of Michigan is synchronized with the school calendar. Summer quantities drop to very low values, and peak values are seen in the Fall and Spring terms. The average pre-consumer food waste from the University of Michigan is calculated to be 4.3 tons/week, with a high value of 8.1 tons/week in November and a low of 1.2 tons/week in May.

Composting vs Biodigestion – Target Pre-consumer waste for Biodigestion

Several of the restaurants interviewed had already established popular composting programs for much of their pre- and post-consumer food waste. From the restaurants interviewed, up to 20% of restaurants in the downtown area may already be diverting food waste to compost.[vii]

A significant challenge is to strip to non-digestable materials out of the total waste stream, and to segregate all materials before transport to either the composting facility or the biodigester. For practical considerations, it is recommended that only pre-consumer food waste be targeted as the feedstock for the biodigester. Pre-consumer waste is typically generated in kitchens where staff can be trained on the correct materials to segregate. Interviews with restaurant owners indicated that this would be a trivial change to the kitchen's workflow, with employees generally willing to support most sustainable disposal options.

[vi] Data courtesy of Ms. Tracy Artley, Sustainability Coordinator for the University of Michigan.

[vii] This percentage could be a result of a biased sample set. It was the experience of the researchers that environmentally focused businesses were more likely to discuss and engage in conversation about their business's waste diversion efforts.

5. Non-Food Waste Biodigester Feedstocks

For maximum stability of the ecosystem inside the biodigester, a diverse offering of feedstocks should be fed to the organisms in the digester vessel. In the same way that humans and animals benefit from a diverse diet with carbohydrates, proteins and fats, the methanogenic organisms in a biodigester are enhanced by the addition of secondary feedstocks other than food waste. (These secondary feedstocks are typically referred to as "co-feedstocks".)

For the Ann Arbor Biodigester, the selected co-feedstocks were:

- Fats Oils and Grease, or FOG (from grease traps in restaurants in the Ann Arbor region)
- Sludge from the Ann Arbor Waste Water Treatment Plant

FOG Co-feedstocks

Fats, oils, and grease (FOG) are generated as part of our daily lives. FOG is produced from residential, commercial, and industrial processes. FOG in the Ann Arbor area is generally broken down into two major categories[viii]:

Brown Grease: flotatable FOG, settled solids (food particles) and associated wastewater retained by grease traps and inceptors. Brown grease is also commonly known as grease trap waste (GTW).

Yellow Grease: inedible or spent FOG removed from Food Service Establishments (FSEs). A major source of yellow grease is deep frying.

Depending on its source, FOG may or may not have a market value. In general, the higher purity of the FOG, the higher value it has for reuse. For example, yellow grease is commonly recycled for reuse at FSEs or collected for biodiesel manufacturing. Of the two major sources of FOG, grease trap waste is most available for the use in an anaerobic digester. Brown Grease is generated through the preparation, serving and cleanup of food. As such, the FOG is discharged through sinks and drains that are connected to the sanitary sewer. Because it is co-mingled with kitchen wastewater, GTW is typically considered to be a waste product with little to no value; however, due to its high energy potential per unit volume and the form that it is collected; GTW is very desirable for use in a biodigester.

Figure 13: Typical Grease Accumulator near the kitchen sink

[viii] Another source of grease is the biodiesel manufacturing process, where the glycerin byproduct is an outstanding co-feedstock in a biodigester. However, the closest biodiesel facility is in Sandusky MI, which is too far to be considered a viable glycerin supplier.

Grease trap waste (GTW): Grease trap waste (GTW) is accumulated in grease traps and interceptors where non-residential food preparation activities are performed. Grease traps and interceptors work on the principle that FOG is less dense than water and therefore will accumulated on top of the water, much the same as an oil slick after an oil spill. Periodically, the grease traps are cleaned. Cleaning of the grease trap is performed by the skimming or vacuuming of the grease that is floating on top of the water into a truck. The collected grease is then taken off site for disposal.

Table 3: Grease trap waste characterization

Parameter	Results on Wet Weight Basis
Total Solids (%)	6.0
Total Volatile Solids (%)	88
Fats, Oils & Grease (%)	1.1
pH (SU)	4.4

Disposal of the GTW is typically performed through landfilling. Due to the high water content of GTW, landfills in Michigan cannot accept GTW without modifying it through a process called "solidification". Typical characteristics of GTW are provided below in Table 3[ix].

Access to Grease Trap Market

Grease trap waste is collected by companies that specialize in grease trap and interceptor cleaning. They have specialized trucks that are able to vacuum the GTW from the establishment's collection point. The companies have specific knowledge of the regulations for cleaning, transportation, and disposal of the GTW. Examples of companies in the Ann Arbor area that perform such services include:

- Dover Grease Trap – Fraser, MI
- Power Vac of Michigan, Inc., Novi, Mi
- Great Lakes Grease, Detroit, Mi
- Rooter-Man, various locations in south east Michigan
- Roto Rooter, various locations in south east Michigan

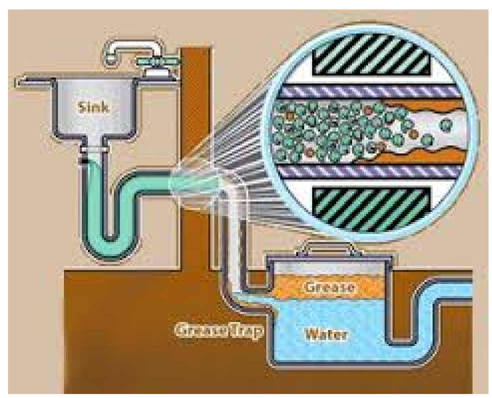

Figure 14: Under sink grease trap

FSEs depend on these types of companies to periodically clean grease from their collection points and dispose of it. Without periodic cleaning of grease traps and interceptors, FSE would likely experience sewer backups and or surcharge fees from the local sewer authority. As GTW material is centralized by various collection and disposal companies, the most efficient way to understand the quantity of GTW that is available is to speak directly with these companies.

Another route that may be taken is to speak with the disposal site that ultimately handles the GTW, however, these sites are less likely to collaborate with inventory studies as they are profiting from the disposal of the waste and would not support any diversion.

[ix] Taken from The Pumper, March 2000.

Current cost for GTW disposal is approximately 20 to 30 cents per gallon. Based on the experience of Swedish Biogas in accepting FOG materials at the Flint WWTP, tipping fees of 10 to 15 cents per gallon should be attainable depending on the overall logistics of transportation.

Important Note: The sustainable disposal of Grease Trap Waste is an additional selling point that collection companies can offer Food Service Establishment for green branding.

Sludge from the Ann Arbor WWTP as a co-feedstock

The additional of waste water treatment plant (WWTP) sludges to a digester can provide many benefits. They include:

- Improved digestion via the addition of necessary trace elements and nutrients.
- The creation of stabilized material that meet the standards to CFR 40 Part 503 for reuse.
- A reduction of lime stabilization costs, and also in the expense to landfill the digested material.

Perhaps the major advantage of digesting sludge is that *biodigestion naturally reduces the total amount of material by nearly 40%*. This means 40% lower disposal charges will decrease by approximately 40%, offering the WWTP a very large savings in disposal costs.

The Ann Arbor Wastewater Treatment Plant (WWTP) receives and treats approximately 19.0 million gallons of wastewater per day from the City of Ann Arbor, Pittsfield, Scio, and Ann Arbor Townships. The facility has a total treatment capacity of 29.5 million gallons per day. Sewage sludge is generated at two major locations within the flow regime of the plant:

1) Primary clarifiers where primary sludge is separated from incoming wastewater,

2) Secondary clarifiers where activated sludge is collected and pumped to holding tanks and then thickened to 6% total solids using a gravity belt thickener.

Based on the preliminary data provided by City staff, the quantity and characteristics of sludge that is available is provided in Table 4.

Table 4: Characteristics of sludge at the Ann Arbor WWTP

Description	Primary Sludge	Thickened Waste Activated Sludge (TWAS)
Quantity, dry tons per year	2,900	3,000
Quantity, avg dry tons per day	8	8.3
Total Solids, %	5.3%	6%
Volatile Solids, %	85%	75%

The City of Ann Arbor currently uses two processes for reuse and disposal of their biosolids:

Land Application: During allowable time periods of the year, sewage sludge is converted to 40 CFR Class B biosolids using alkalinity (lime) stabilization. The biosolids are then applied to agricultural lands as a soil amendment. A majority of the sewage sludge generated at the facility is handled in this way. Reuse of the biosolids in this fashion is heavily dependent on permissible weather conditions and availability of agricultural lands.

Landfilling: During time periods that land application of biosolids is not permissible, the sewage sludge is dewatered and sent to a landfill for disposal It was assumed that solids to the landfill and land application were at 27% and 7%, respectively

Biodigestion of Sewage Sludge

Biodigestion of sewage sludge can provide several benefits to a waste water treatment facility. Benefits include:

- 30 to 40% reduction in overall sludge volumes that require disposal/reuse
- Energy recovery through biogas production
- Obtainment of CFR 40 Class B biosolids without chemical (lime) addition
- Ability to co-mingle existing compost operations to achieve CFR 40 Class A EQ biosolids (soil amendment for unlimited use)
- Greater de-waterability as compared to waste activated sludge
- Nutrient recovery of phosphorus and ammonia
- Reduce odor control requirements as digestion takes place within closed vessel

Biodigestion is not without its drawbacks. The primary concern for the treatment facility would be any streams from the digester that would be diverted back to the treatment plant. The "recycle" stream would be rich in soluble phosphorous and nitrogen which may increase costs of processing.

Specific Benefits of Adding City of Ann Arbor Sewage Sludge

Discussions with the staff at the Ann Arbor WWTP identified two major benefits of processing some fraction of the incoming sludge into the digester. These include:

- Enhanced Biogas Production, and
- Reduction in disposal costs.

Enhanced Biogas Production: Based on the sewage sludge solids provided by City staff, estimates of biogas production were generated. A common range of biogas production from sewage sludge is between 12 and 17 cubic feet per pound of volatile solids destroyed. Actual biogas production is highly dependent on digester configuration, operation protocols, and actual feed stocks. It is beyond the scope of this study to determine the actual biogas production potential of the sewage sludges generated by the treatment plant. However, estimates from other digester operations can provide typical biogas production (See Table 5).

Table 5: Estimated biogas production as a function of volatile solids destroyed

Volatile Solids Reduction during Biodigestion	50% volatile Solids reduction	55% volatile solids reduction	Methane Concentration, %
	Biogas Production, ft^3/day	Biogas Production, ft^3/day	
12 ft^3/lb VS destroyed	156,403	172,043	65%
15 ft^3/lb VS destroyed	195,504	215,054	65%
17 ft^3/lb VS destroyed	221,571	243,728	65%

It is recommend as part of further study that laboratory testing be performed to determine more precise estimates of biogas production from the materials available from the WWTP.

Reduction in solids volume: As detailed above, a significant advantage of biodigestion is the reduction in the overall amount of material that has to be handled after the digestion process. Based on conservative rates of volatilization of organic solids, it is estimated the solids will be reduced from approximately 5,900 to 3,600 dry tons per year. The economic value of these biogas production and volume reduction will be detailed in the later section on Economic Modeling.

6. Bags and Bins

An underappreciated factor in biodigestion is the need to collect and store food waste before transportation to the biodigester. Typically, trash and waste is collected in plastic bags for transport to final disposal. This is a simple, reliable and robust solution, but unfortunately, bags based on petroleum feedstocks are not a sustainable solution. "Compostable" bags are made from corn starch and can break down in commercial composting operations, but are not "digestable" in a biodigester. The challenge is to find a solution for collection/storage of food waste that offers the convenience and reliability of a plastic trash bag, but fits into the flow of materials into a biodigester.

Other biodigesters have encountered the same problem, with a biodigester in Germany offering a very workable solution. Figure 15 shows the German approach that uses compostable bags to collect and transport food waste, but the bags are stripped away before digestion and routed to a composting operation.

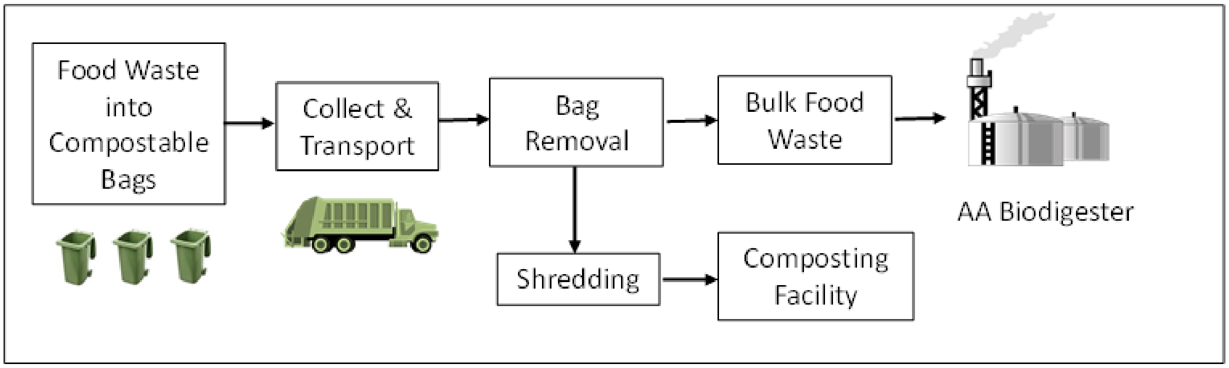

Figure 15: Use of compostable bags with a biodigester

The demands on bags for food waste are considerable. For example, restaurant workers will collect food waste in an internal container (see Figure 16) and then move it to a larger bin outside the facility. This bin will be collected once every 2-3 days, so any bag for food waste must be sturdy.

Figure 16: Rubbermaid Slim Jim is a ubiquitous trash container (23 gallon).

Using compostable bags in plastic containers makes the process of collecting food waste easier for the restaurant employees and cuts down on the smell and mess in the outside receptacles. However, to collect/store food waste, the bags must have the following characteristics:

Table 6: High Level Requirements for Food Waste Bags

Specification	Justification
Bags must be capable of containing liquids.	Food waste will be gooey and sludgy.
Bag must be able to withstand elevated temperatures.	Food waste may be warm or hot when it is disposed of.
Bags must be strong.	Food waste is dense, and may contain items that can pierce the bag and cause leakage.

Given the characteristics above, a listing of available compostable bags is shown in Table 7. All of these bags have BPI's seal for compostablility, which means that they meet ASTM 6400. Some of these are available through retail and some of them must be ordered from the manufacturer. Bags that are available for retail purchase are often more expensive than the bags that are ordered direct from the manufacturer in bulk. In addition, ordering bags from the manufacturer gives more options in regards to thickness, size, and shape.

Table 7: A sampling of compostable bags that meet ASTM 6400

Brand	Material	Thickness	Available Sizes?	How to aquire?	Price
BioBag	Derived from plant starches, compostable polymers	.88 mil	2-96 gallons	Retail or Direct	32G liner is $75.60 per case of 120 bags plus shipping
BioTuf	Ecoflex (polylactic acid, cellulose, lignin, starch, PHAs)	.88-1.2 mil	13-64 gallon	Direct or Distributor	$100 per case of 100 bags
Bag to Nature	Organic Biopolymers	Unknown	3-64 gallon	Retail or Direct	Retail price on (10) 33 gallon bags is $12.99
Xylobag	Lignin (byproduct of paper production)	.9-2.5 mil	33 or 45 gallon	Direct	$30.85 for a 25 bag roll

Food Waste Bin Requirements

The second important part of the consumer-end food waste collection system is the large receptacle sitting presumably out back behind the restaurant. This container will house the food waste after it is collected inside. This container will experience the multi-faceted weather of Michigan and also nuisance animals and insects in Ann Arbor. In addition to the environmental concerns, the containers must be user-friendly. Therefore, the following list of specifications has been developed for the food waste collection bin:

Table 8: High level requirements for food waste bins

Specification	Justification
Bin must be large enough to accommodate several days worth of food waste.	Food waste will be collected/picked up every 2-3 days.
Bin must be compact.	There is limited space in alleys behind restaurants.
Bin must be resistant to critters and insects.	Ann Arbor is host to many hungry creatures including, but not limited to, squirrels and raccoons.
Bin must contain odors.	Odors are especially challenging in summer.
One person must be able to put food waste bag into the bin.	A single restaurant employee will typically carry a bag of food waste outside to the bin.
Bin should be able to be cleaned easily.	Food waste may leak from the bags into the bin.

Few food waste bins on the market meet the specifications in Table 8 because food waste collection is a fairly immature movement. Some food waste collection systems use traditional dumpsters to collect food waste, just like the residential recycling bins of Ann Arbor, but colored green.

Commercial Food Waste Bins

A good example of a collection bin targeted to the food waste market is made by Taylor International, a UK-based company that designs metal rubbish and recycling containers.

The Taylor Food Waste Bin (see image below) is made of welded steel and has a 500-liter (about 130-gallon) capacity. It has a plastic lid with a lock that can be opened with a foot-pedal. It can be coated with acid resistant coating on the inside and painted on the outside. An ID chip can also be included in a Taylor Food Waste Bin. The Taylor Food Waste Bin costs about $780 US dollars plus freight costs. This is the price for up to 150 bins.

Figure 17: Taylor Food waste bin is targeted to the growing food-waste collection market.

The lock on the Taylor Food Waste Bin makes the opening resistant to critters, while the solid steel sides keeps them chewing in from the outside. Not only does the lock keep out critters, it also keeps out passersby who may try to put their trash in the bin behind a restaurant. The lid lock and side materials also help contain the odor. The foot pedal makes it easy for one person to easily put food waste into the bin. In addition, the top of the bin is at about waste height, so bags of food waste are easily lifted up and over the top lip. Because of the shallow depth, the bin is also easily cleaned. Traditional waste bins are deep, which may make them more difficult to clean.

7. Cost Model

To assess the magnitude of the financial benefit of a biodigester over time, our team developed several computer models to describe the financial viability of the biodigester over the short-term and the long term. These models were based on financial modeling tools used by our teammate Swedish Biogas to develop accurate bids for digester construction and operation of biogas plants in the US and Europe. The models were populated with data from several key sources:

- Data on available food waste
- Information from the Ann Arbor Wastewater Treatment Plant
- Existing disposal costs for solid waste (from the City of Ann Arbor) and
- Current financial terms available in the public and the private credit markets.
- Experience from actual digester operations in the US and Europe

For this Feasibility Study, several scenarios were modeled, varying key parameters such as:

- Available feedstocks (type and quantity),
- Financial terms (rates, terms), and
- Capital costs (including maintenance and operations costs.)

The ability to compare multiple scenarios can offer the City valuable insight to the potential pros and cons of digester facility over the life span of the project.

Modeling Assumptions

Location

Based on discussions with City staff, it was decided that for the purposes of modeling digester financial performance that the facility would be installed Near the Materials Recovery Facility on the south side of Ann Arbor (4150 Platt Road, Ann Arbor). While the scope of this Study did not require a Site Assessment, it was logical to select an existing location owned by the City of Ann Arbor. A specific location was also needed in order to calculate the logistics (travel time, mileage, and traffic patterns) of hauling sludge to the site from Ann Arbor WWTP on Old Dixboro Road.

Locating a biodigester near the Material Transfer Station offers a number of advantages:

- Available space for construction and operations,
- Close vicinity to the City's current compost site,
- Existing zoning for industrial use, and
- Adequate ingress and egress for waste hauling vehicles.
- •Supplement existing biogas generator as landfill to maintain full electrical production

Feedstock Loading

As part of the modeling effort, recipes for the biodigestion process were developed based on available feedstocks in the Ann Arbor area identified during the course of this Feasibility Study (See the Background Section for details.) Feedstocks included:

- Food waste from commercial businesses within the City of Ann Arbor. Food waste from the University of Michigan was also included.
- FOG from local grease-trap hauling companies
- Milk waste from local dairies ("Dairy Waste")
- Food waste or residues from food processing facilities ("Sugar Water")
- Primary and Thickened Waste Activated Sludge from the Ann Arbor WWTP

The quantity of each feedstock was based on two criteria:

1) Data from this Feasibility Study, which was then correlated with other feasibility studies/reports from similarly sized cities in the US.
2) Experience of Swedish Biogas in the Midwest region of the US; specifically, the amount of FOG, Dairy Waste and Sugar Waste is typical for the materials delivered on a regular basis a similarly sized biodigester in Southeast Michigan.

Discussions with City staff indicated that the inclusion of WWTP sludge was logical due to Ann Arbor's unique constraints on the existing Ann Arbor WWTP facility. As noted earlier, sludge is easily digestible and is a prime candidate as a buffer feedstock for the digester facility. Moreover, processing of sludge will offer the City cost savings because the digester will convert a significant portion of the sludge to biogas.

Parameters to Vary in the Model

A number of key parameters were varied in during the modeling process. These include:

Fraction of WWTP Sludge, (50% vs 100%)

Two different fractions of WWTP Sludge were considered:

1) The biodigester will accept 50% of the available sludge from the Ann Arbor WWTP.
2) The biodigester will accept 100% of the available sludge.

The non-sludge feedstock quantities remained constant for each scenario, however, the relative fraction of each non-sludge feedstock changed for each scenario.
Details on the two fractions are shown in Figure 18 and Figure 19.

Feedstock	Fraction of total	Vin [gpd]	Comment
Food Waste	11%	4329	Commercial businesses in Ann Arbor and University of Michigan
FOG	3%	1000	Sourced by FOG hauling companies
Dairy Waste	5%	2000	Available from local dairy
Sugar Water	3%	1000	Available from local food processor
WWTP Sludge	79%	30660	Transported to Biodigester from AA WWTP

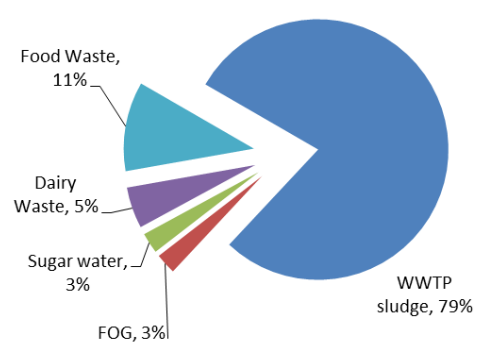

Figure 18: Feedstock menu using 50% of the available WWTP sludge

Feedstock	Fraction of total	Vin [gpd]	Comment
Food Waste	6.2%	4329	Commercial businesses in Ann Arbor and University of Michigan
FOG	1.4%	1000	Sourced by FOG hauling companies
Dairy Waste	2.9%	2000	Available from local dairy
Sugar Water	1.4%	1000	Available from local food processor
WWTP Sludge	88%	61320	Transported to Biodigester from AA WWTP

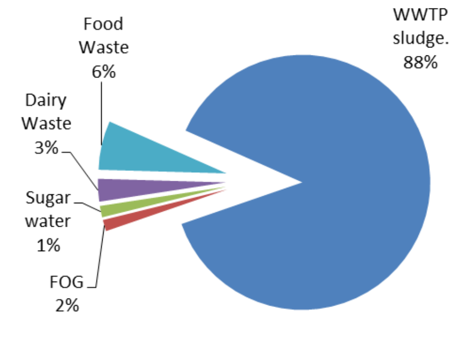

Figure 19: Feedstock menu using 100% of the available WWTP sludge

Facility Ownership - Public vs. Private

A key impact on the feasibility of any waste-to-energy facility is the funding source.

- Funding from private sources demand a shorter time period for the return on the investment, a higher carry cost of the capital, a higher discount rate, and a margin for profit.
- Publicly-financed facilities typically have a longer investment term, lower interest rates, and a lower discount rate.

Modeling was performed for both private and public ownership and funding. A public-private partnership was not included in the modeling but should be further investigated by the City. Table 9 shows the financial terms used in the computer model for public[x] and private[xi] investments.

Table 9: Financial assumptions for public and private financing of the project

	Investment Term	Interest Rate	Discount Rate	Payback
Public Financing	20 years	3.5%	2.1%	<10 years
Private Financing	10 years	12%	10%	< 5 years

Revenue from Electrical Generation, 5.5₵/kWh vs 9₵/kWh

Biogas produced from the digester is generally used as an energy source in three ways:

- Thermal power (i.e. heat generation in boilers), or
- Conditioned to be used as a natural gas replacement, known as biomethane[xii], or
- Electrical generation using a biogas powered electrical gen-set,

[x] The City of Ann Arbor (AA+ rating) is currently issuing tax exempt debt with the same terms as the US Treasury. We have assumed that public financing term and interest rate will match the US T-bill rate. See http://www.bloomberg.com/markets/rates-bonds/government-bonds/us/

[xi] Terms for private financing of biodigesters were determined via discussions with personnel at DTE Energy Trading (a non-regulated part of DTE Energy). Private investors typically seek shorter investment terms, shorter paybacks and a strong interest rate. The discount rate for renewable energy projects is estimated to be between 10% and 15%.

[xii] Biomethane can be injected into the natural gas utility grid or used as a cleaning burning vehicle fuel.

Thermal Energy: Extracting thermal energy from biogas is a viable approach; however, this is typically best done when a thermally intensive industrial process is located near the biodigester. This is not the case near the Materials Transfer Station, so biogas-for-heat was not considered.

Biomethane: Because of the lack of governmental policy for clean fuels in Michigan, the cost of biogas conditioning equipment, and the relatively low cost of natural gas, converting biogas to biomethane currently cannot economically compete against using biogas to generate electricity. Therefore, biomethane was not considered.

Electrical Generation: Electricity generated by biogas can be used in two ways:

1) Consumed on-site to meet existing electrical demand by City facilities.
2) Sold back to the grid via a Net-metering arrangement with Detroit Edison

The economic models for this Study assumed revenue from electrical generation.

Self-Consumption: City staff has indicated that cost of electricity purchased from Detroit Edison (local utility) at the Wheeler site is approximately 9₵/kWh. Additional information from the City shows that the average electrical consumption at that site is in the range of 170 to 190 kW. This level of power production is well within the range of gensets currently available for biodigesters. It is not clear if the City could take full advantage of the 9₵/kWh for the electrical generation at the digester because of the lack of overall power consumption at the Wheeler site (net meeting). It is recommended that further investigation be performed to determine the actual rate that could be gained through the local utility.

Net-metering: It is understood that Landfill Energy Systems (operator of electrical generation system at the Ann Arbor Landfill) is paid approximately for the electricity generated from biogas collected at the City's landfill. While net-metering program revenue can change over time, it is safe to assume that 5.5₵/kWh is a realistic payment for biogas generated electricity.

Important Note: Although electrical generation from the Ann Arbor Biodigester would be eligible for renewable energy credits (RECs), the economic models did not account for them since RECs are not generally not available for sale in the State of Michigan. In addition, the models did not account for the sale of carbon credits. While some estimates put the available value of Carbon Credits at $6-7 per MtCO2e, these markets remain immature. Future economic models can include REC and Carbon Credit revenue if the market improves

Capital Expenses based on WWTP Sludge Fraction (50% vs 100%)

Capital costs for the Biodigester will also vary as a function of the amount of WWTP sludge accepted. For the model, the capital cost estimates were based on Swedish Biogas's past experience of design, building and installing digestion facilities both here in the United States and Sweden. Major differences in the capital expense between the models using 50% and 100% sewage were the size of the digester and electrical generation system. Power production for the 50% sludge-fraction case is assumed to be a 400 kW biogas-powered genset operating with 95% on-time. A 600 kW genset is assumed for the 100% sludge fraction case. Capital cost estimates for the two cases are shown in Table 10.

Table 10: Capital cost rollup for 50% and 100% sludge models

Order of Magnitude Estimation of Capital Expense 100% use of Available Sewage Sludge	
Description	Amount
Receiving Station	$223,000
Digester	$1,518,000
Dewatering	$552,300
Cogeneration (CHP) System	$954,500
Building	$525,000
Site Civil	$367,000
subtotal	$ 4,139,800
Contingency (25%)	$ 1,034,950
Design Engineering and Construction Management (8%)	$413,980
Project Management (3%)	$155,243
GC OH&P (7.5%)	$388,106
Total Estimated Construction Costs	**$ 6,132,079**

Order of Magnitude Estimation of Capital Expense 50% use of Available Sewage Sludge	
Description	Amount
Receiving Station	$223,000
Digester	$1,116,683
Dewatering	$452,300
Cogeneration (CHP) System	$704,500
Building	$525,000
Site Civil	$367,000
subtotal	$3,388,483
Contingency (25%)	$847,121
Design Engineering and Construction Management (8%)	$338,848
Project Management (3%)	$94,878
GC OH&P (7.5%)	$317,670
Total Estimated Construction Costs	**$ 4,987,000**

Important Note: It should be noted that conversations with waste water treatment plant management staff yield concerns on the practicality of the 50/100% diversion of sewage sludge. A main concern was the potential to have untreated sludge being left in supply pipelines at the plant and being co-mingled with treated sludge. If this were to happen, it would potentially cause an issue with Michigan DEQ biosolids regulations compliance. Staff did believe that it was an issue that would need further attention but did create an overarching obstacle that could not be overcome through amendments to operating protocol or additional infrastructure. It is recommended that this issue be included for further study if the City should decide to perform a higher level of analysis.

Model Inputs: Revenues and Expenses

The economic model incorporated a set of revenues and expenses for the on-going operation of the biodigester.

Revenue is generated in a variety of ways:

- Cost savings developed as part of the reduction of material inherent in the biodigestion process
- Monies generated from the receipt of tipping fees and
- Production and sale of electricity.

Expense values were developed from various sources that utilized historical data from actual digester capital and operating costs, current consumable material costs, and conservative labor expenses.

Revenues from External Waste Tip Fees

One of the critical ways that the biodigester remains viable is to earn tipping fees by accepting waste organic materials. For all versions of this analysis, the model assumed the following tipping fees:

FOG: $0.10/gallon, delivered to the biodigester via FOG haulers

Sugar water: $0.06/gallon delivered to the biodigester from food processor

Dairy Waste: $0.05/gallon, delivered to the biodigester from local dairy

A roll-up for the tipping fee revenues is shown in Table 11 and Table 12 for 50% sludge and 100% sludge, respectively.

Table 11: Tipping Fee Revenue when accepting 50% of WWTP sludge

Model, 50% WWTP Sludge	Total daily volume of substrate (gpd)	Total weekly volume (gal)	total yearly volume of substrates (gal)	tip fee per gallon of feedstock	Yearly tip Fee Revenue
WWTP sludge	30,000	214,623	10,950,000	$0.05	$528,950
FOG	1,000	7,000	365,000	$0.10	$36,500
Sugar water	1,000	7,000	365,000	$0.06	$21,900
Dairy Waste	2,000	14,000	730,000	$0.05	$36,500
Food Waste	4,300	30,100	1,569,500	$0.07	$113,000
Net	**38,989**	**272,723**	**13,979,500**		**$736,850**

Table 12: Tipping Fee Revenue when accepting 100% of WWTP sludge

Model, 100% WWTP Sludge	Total daily volume of substrate (gpd)	Total weekly volume (gal)	total yearly volume of substrates (gal)	Tip Fee per gallon of feedstock	Yearly tip Fee Revenue
WWTP sludge	60,000	429,246	21,900,000	$0.05	$1,057,900
FOG	1,000	7,000	365,000	$0.10	$36,500
Sugar water	1,000	7,000	365,000	$0.06	$21,900
Dairy Waste	2,000	14,000	730,000	$0.05	$36,500
Food Waste	4,300	30,100	1,569,500	$0.07	$113,000
Net	**68,300**	**487,346**	**24,929,500**		**$1,265,800**

Revenues from Waste Water Treatment Plant Sludge

One of the major advantages of the proposed model is that the Ann Arbor WWTP will see substantially decreased disposal costs if sludge is processed in the biodigester. Table 13 uses data obtained from the City staff at the AA WWTP to compare the current costs of processing sludge with the cost of diverting sludge to the biodigester. Table 13 assumes that 100% of the available sewage sludge is used as a feed stock for the digester facility.

For profitability calculations, the model considers the current WWTP operating cost as an avoided cost, and coverts this to a revenue input for the biodigester project. Specifically, $1,057,000 is considered revenue, and $573,700 is allocated as an expense to the biodigester, leaving a net gain of $483,300 annually by processing sludge at the biodigeser.

Table 13: Comparison of Annual Sludge Processing Costs

Cost Comparison for WWTP sludge processing for using landfill, land application, or anaerobic digestion [annual $]				
Description	Current WWTP Process		Proposed Process	Notes
	Landfill	Land Application	Biodigestion	
Dewatering	$186,600	$0	$107,000	Polymer purchases 7/1/2013-6/30/2014
Dewatering Equipment O&M	$35,000	$0	$25,000	Includes electricity and maintenance
Hauling to site	$214,000	$416,700	$212,000	From WWTP to Digester
Tip fee			$209,000	To compost site
Lime for Class B biosolids and odor control	$46,100	$125,000	$0	No lime required post-digestion
Michigan DEQ Biosolids	0	$34,500	$20,700	
Totals	$481,700	$576,200	$573,700	
Grand Total	$1,057,900		$573,700	
	Processing Costs for WWTP		Processing Costs for BioDigester	
Net Revenue Gain from Biodigestion	$473,300			

It should be noted that the City staff at the Ann Arbor WWTP were well versed on the potential cost savings via anaerobic digestion. However, the unique landlocked nature of the Ann Arbor WWTP facility on the Old Dixboro Road cannot accommodate this alternative approach, specifically tankage. For this reason, they were open to exploring alternative solutions.

Operating Expenses

Operational costs have been included in each version of the model and are shown in Table 14. Note that the costs associated with the recycle streams from dewatering digestate (and ultimately sent back to the City's waste water treatment plant) were not included in the models as an operational expense. It was assumed that because the majority of any recycle streams sent to the treatment plant would be produced as a result of digesting sewage sludge, a fee to the digester operation would not be assessed.

Table 14: Operational Expenses used in the Economic Model

Annual Operating Costs	
Description	Amount
Labor (operations, maintenance, admin, management)	$275,000
Raw Materials and Consumables (electricity, dewatering polymer, equipment parts, etc.)	$306,000
Internal Charges (sludge transfer to digester, lab testing, central cost allocation, etc.)	$313,000
External Charges (compost tip fees, external maintenance services, state biosolids fees)	$274,000
Long Term Equipment Replacement	$25,000
Total	$1,193,000

Modeling Approach

Figure 20 shows the step-wise approach taken to assessing the economic viability of the proposed Ann Arbor Biodigester.

1. The first step compared the Project Profitability using either 100% of the available sludge from the Ann Arbor WWTP (**Case 1a**), or 50% of the sludge (**Case 1b**).
2. The second step compared Project Profitability using public or private financing**, Case 2a** and **Case 2b**, respectively. The terms for public vs private are shown in Figure 8.
3. Finally, the model compared the Project Profitability using the revenue from two different electrical rates:
    - **Case 3**: An electric Rate of 9 ₵/kWh, which is the current rate paid at the Materials Recovery Facility, and
    - **Case 4**: An electric Rate of 5.5 ₵/kWh, which is approximately the rate paid by DTE Energy under a typical Net-metering arrangement.

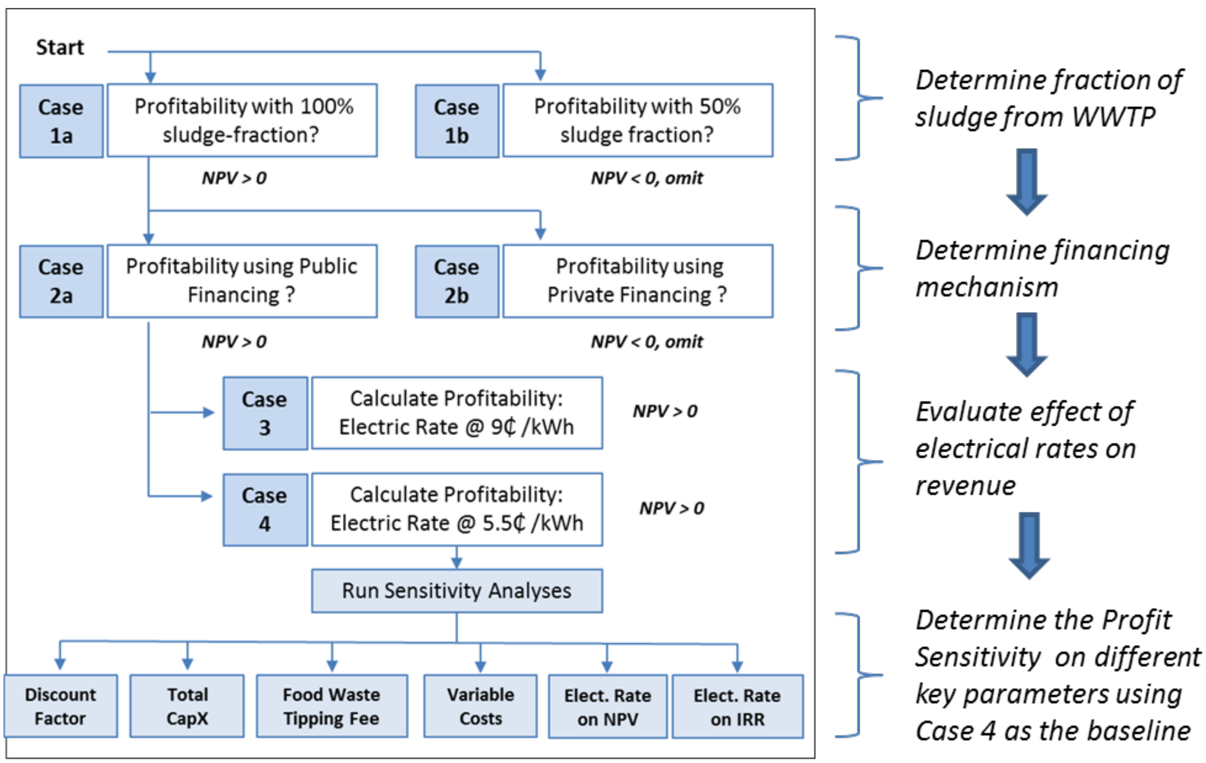

Figure 20: Modeling Flowchart

Model Results

Modeling **Case 1a** and **Case 1b** showed that only **Case 1a** (processing 100% of the sewage sludge) provided a favorable return of investment. For this reason, the balance of the modeling omitted the 50% sludge treatment option since the NPV was negative.

Comparing **Case 2a** and **Case 2b**, the model showed that only **Case 2a** (public financing) would provide financial viability. Project profitability was negative for private financing terms.

The results for **Case 3** and **Case 4** are shown in **Error! Reference source not found.**. Both cases have a positive NPV, with **Case 3** obviously earning more due to a more generous electrical rate. However, to assure that the modeling was not over optimistic, all subsequent modeling used Public financing with 5.5₵/kWh earned from electrical sales.

Important Note: Both **Case 3** and **Case 4** assumed the use of 100% of the available sludge fraction and the use of public financing for the bidigester project.
A graphical view of the project profitability is shown in Figure 21. Note that for all subsequent sensitivity analyses, the baseline is **Case 4**, using 100% sludge, public financing and 5.5 ₵/kWh for electrical revenue.

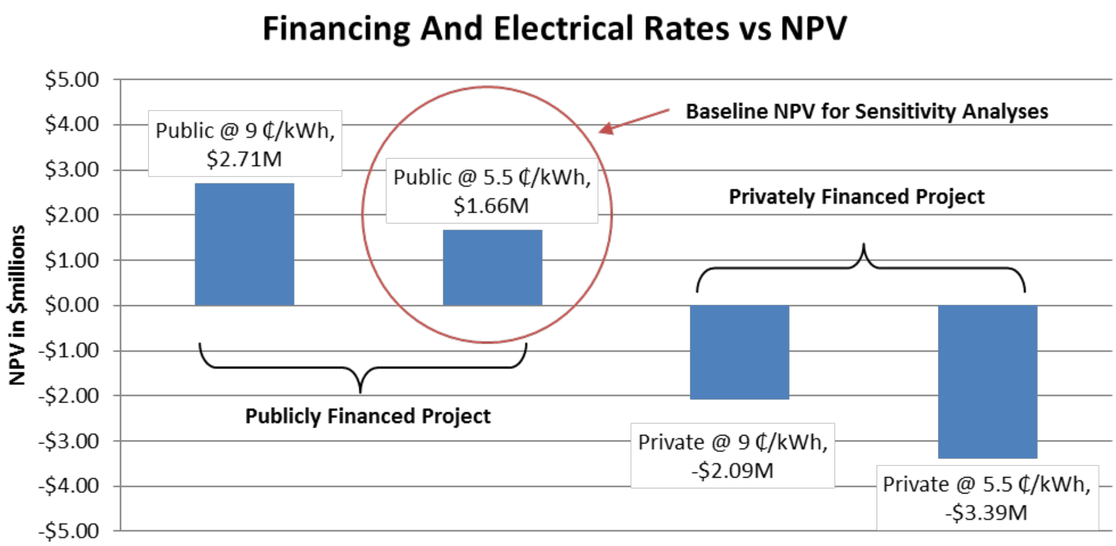

Figure 21: NPV vs Financing Method

Table 15: Model results for Cases 3 and 4

Case #	Type of financing	Fraction of sludge	Cost of Electricity ₵/kWh	Discount Rate, %	Cost of Money %	Term, years	Return on Investment, %	Internal Rate of Return, %	NPV
3	Public	100%	9 ₵/kWh	2.1%	3.5%	10	13.5%	6.06%	$2,705,235
4			5.5 ₵/kWh				15.6%	4.58%	$1,658,744

Financial Impact of Filtrate Disposal

One variable in the financial model required more in-depth analysis: namely, the potential cost of "dewatering" the material in the digester before final disposal (composting, landfilling or incineration.) Dewatering involves removing the excess water in the digestate using a filter press in order to separate the liquids and solids in the digested material. After dewatering, two components remain:

1. A cake-like (low moisture) solid material and
2. A nutrient rich, watery material called "filtrate".

The models for Case 3 and Case 4 assumed that the filtrate would be returned to the City's wastewater treatment plant through the sanitary sewer system. Since the raw sludge feedstock had already been paid for upon entering the WWTP via standard user fees, no cost was assigned to the material being sent to Ann Arbor WWTP. (The volume of filtrate generated at the biodigester from sewage sludge nearly the same as the treatment plant sees today.) It should be noted that the existing operations at the WWTP also create a filtrate stream through thickening and dewatering sewage sludge prior to its application to agricultural lands or landfilling.

City staff have indicated that inter-departmental budgeting at the City may not allow the transfer of filtrate between the biodigester to the WWTP at no cost. Therefore, two variations of Case 4 model were developed:

> ***Case 4b:*** In this variation, the biodigester would be charged by the Ann Arbor WWTP for accepting the filtrate from the non-sludge fraction of the feedstocks. The logic behind Case 4b is that the filtrate from the sludge had previously been accepted under a fee-basis at the head of the WWTP, but the other feedstocks had not been paid for. As Figure 19 shows, the fraction of non-sludge feedstock is approximately 12% of the total material.
>
> ***Case 4c:*** This variation modeled the biodigester paying the WWTP for the filtrate from all feedstocks (including sludge).

In both cases, the charge for filtrate accepted at the WWTP was $3.65/ccf.

Table 16: Financial impact of paying for filtrate sent to the Ann Arbor WWTP

Model Parameters:	Case	Case Variations	Internal Rate of Return, %	NPV
• Fraction of AA WWTP Sludge = 100% • Cost of Electricity, 5.5 ₵/kWh • Interest Rate = 3.5% for 10 years • Discount Rate = 2.1 %	4	Baseline Case 4, no payment for filtrate returned to WWTP	4.58%	$1,658,744
	4b	Pay WWTP for filtrate from all non-sludge feedstocks	4.29%	$1,450,888
	4c	Pay WWTP for filtrate from all feedstocks (incl. sludge)	1.95%	$-94,259

The results of Case 4, Case 4b and Case 4c are shown in Table 16. The financial performance of Case 4b is only slightly worse than Case 4a, but still profitable. Case 4c is not profitable (NPV<0).

Technical Note on Filtrate: The nutrient loading from the filtrate placed on the WWTP will be somewhat different than the filtrate from sludge. A biodigester converts proteins in the feedstock into available ammonium, and also transforms phosphorous into its soluble format (orthophosphate). Both of these nutrients may cause additional attention and treatment at the wastewater treatment plant; however, given the relatively small volume of filtrate in Case 4b, hydraulic and nutrient loading is not expected to negatively impact the wastewater treatment plant. City staff at the Ann Arbor WWTP can readily determine this impact.

As an alternative, the filtrate could be collected from the dewatering process, stored and land applied as a liquid fertilizer. In order to use land application as an alternative to composting, the biodigester would need to be configured to provide storage or alternative disposal methods (composting and or landfilling) during times of the year that land application is not permitted. Utilizing land application as a disposal alternative would increase the capital expense of the project by approximately $950,000 for an installation of a storage tank and a thickener.

It is recommended that further evaluation of filtrate disposal and or reuse be conducted as part of any future biodigester feasibility study.

Sensitivity Analyses

To determine the impact of specific parameters on the results of the model, a number of sensitivity analyses were calculated for the public financing with 5.5₵/kWh electrical sales. Selected variables include:

Sensitivity to Discount Factor

Table 17 shows the sensitivity of Case 4 to the Discount Factor. The baseline Discount Factor (Public Case) was selected to be 2.1%, which is typical for a project financed with tax-exempt bonds. Note that if the Discount Factor rises to 2.52%, the Net Present Value for the project will decrease by nearly 20%.

Discount factor's impact on profitability

Discount factor	1.68 %	1.89 %	2.10 %	2.31 %	2.52 %
Change, %	-20.0 %	-10.0 %	0.0 %	+10.0 %	+20.0 %
Net Present Value (NPV)	2,001,277	1,827,429	1,658,744	1,495,042	1,336,150
Change, %	+20.7 %	+10.2 %	0.0 %	-9.9 %	-19.4 %

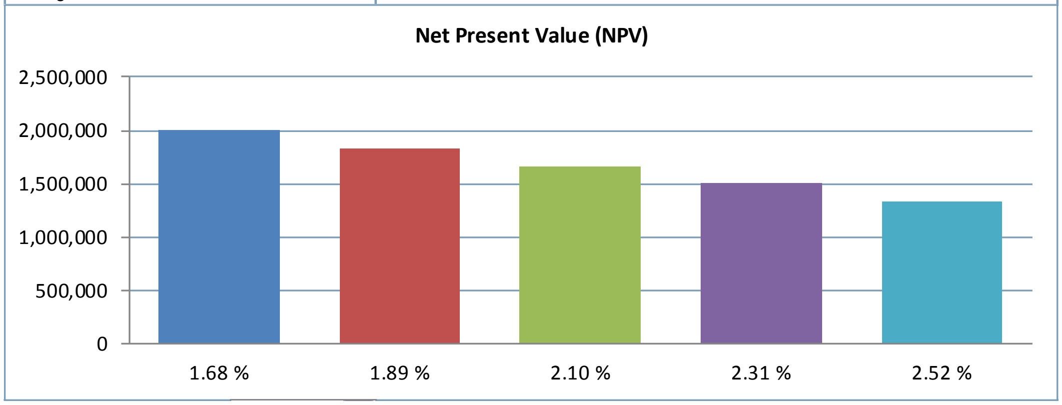

Table 17: Sensitivity to Discount Factor

Sensitivity to Total Investment

The total capital investment for Case 4 is calculated to be $6,132,079. The following chart shows the effect on Net Present Value of changing the capital investment by +/- 20%. The effect on profitability is significant, with a decrease of over 70% in the NPV if the cost increases by 20%

Total investment's impact on profitability

Total investment, USD	**-4,905,663**	**-5,518,871**	**-6,132,079**	**-6,745,287**	**-7,358,495**
Change, %	-20.0 %	-10.0 %	0.0 %	+10.0 %	+20.0 %
Net Present Value (NPV)	2,885,159	2,271,952	1,658,744	1,045,536	432,328
Change, %	+73.9 %	+37.0 %	0.0 %	-37.0 %	-73.9 %

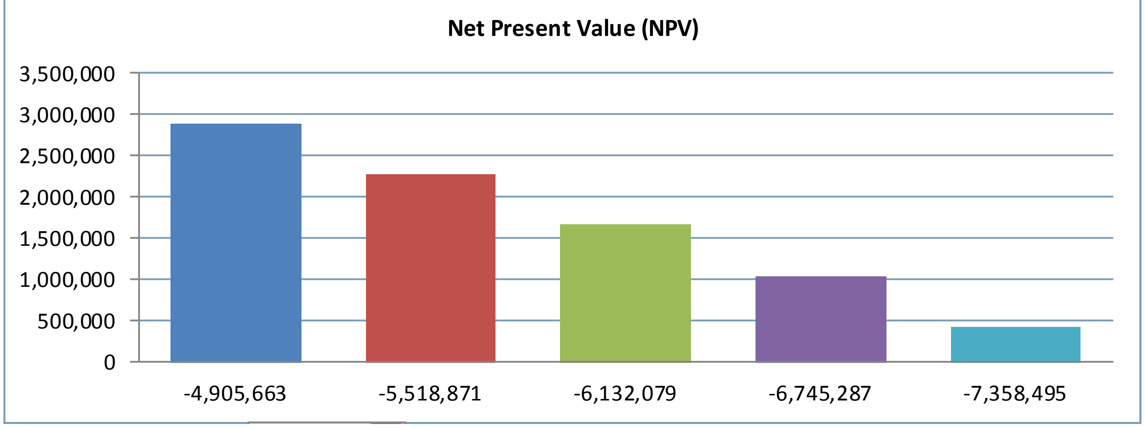

Table 18: Sensitivity to total capital costs

Sensitivity to changes in the Food Waste Tipping Fee

The tipping fee for the food waste delivered to the biodigester is assumed to be $21.80/ton. This is a 15% discount from the current transfer and disposal costs for City trash of $25.87/ton.

Income variable´s impact on profitability

Variable		External Substrate - Food Waste Tip Fee, $/ton				
Change in value, %		**-20.0 %**	**-10.0 %**	**0.0 %**	**+10.0 %**	**+20.0 %**
Sample value	12/2016	17.5	19.6	21.8	24.0	26.2
Net Present Value (NPV)		1,291,240	1,474,992	1,658,744	1,842,495	2,026,247
Change, %		-22.2 %	-11.1 %	0.0 %	+11.1 %	+22.2 %

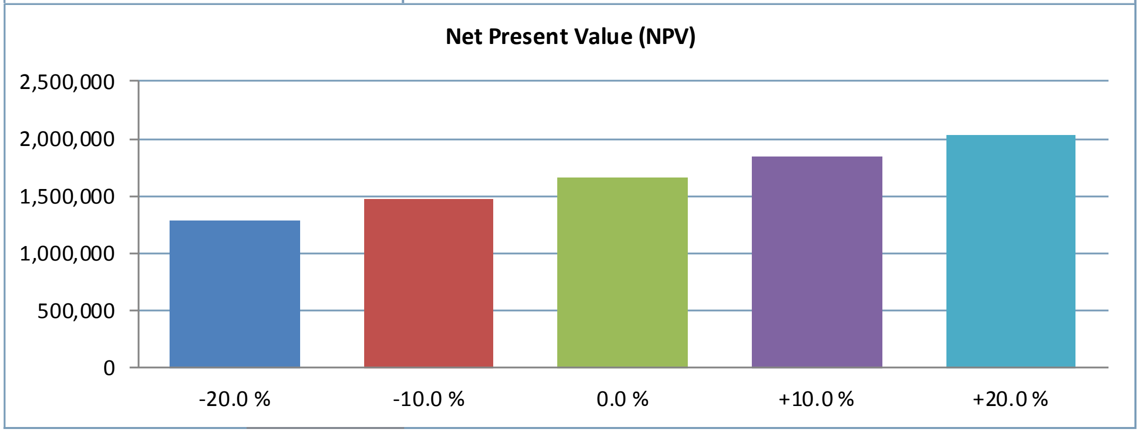

Table 19: Sensitivity to increases in Food Waste Tipping Fees

Discussions with City staff indicate that the current T&D costs escalate at 2.3% per year, and are likely to increase substantially when the current disposal contact expires in 2017. For this reason, the Sensitivity Analysis in Table 19 is particularly valuable.

Note that the food waste tipping fee is earned by the biodigester, not the landfill, and is therefore considered revenue in this model. As landfill rates escalate, so does the implicit value of the food waste increase to the biodigester's finances. An increase in 20% in landfill rates yields an increase in NPV of over 22%.

Sensitivity to Variable Costs

The effect of changes in the variable costs for the system is also substantial. Varible charges can come from two main areas: Raw Materials/Consumables used on a daily basis in the plant, and External Charges for items outside the plant. The model assumes that these costs escalate at the rate of inflation for the term of the model (nominally 2% annually.)

Variable Charges			
Raw materials and consumables		**External Charges**	
Dewatering Polymer	Equipment O&M	Trucking Fee for WWTP sludge	Building Maintenance (water, heat, repairs)
Electricity, kWh/yr	CHP maintenance	Lab Testing, $/year	City Central Cost Allocation
Electrical Rate	Gas Cleaning Costs	Centrate disposal fee	External Maintenance
Plant Electricity	Replacement of Long Term Equipment	State Biosolids Fee	

Table 20: Variable Costs in the Model

As Table 21 shows, the NPV is highly sensitive to changes in variable cost, where a 20% increase in total variable costs results in the NPV becoming negative (i.e. not economically viable.)

Variable cost's impact on profitability					
Change in Variable costs, %	**-20.0 %**	**-10.0 %**	**0.0 %**	**+10.0 %**	**+20.0 %**
Net Present Value (NPV)	4,992,950	3,325,847	1,658,744	-8,360	-1,675,463
Change, %	+201.0 %	+100.5 %	0.0 %	-100.5 %	-201.0 %

Net Present Value (NPV)

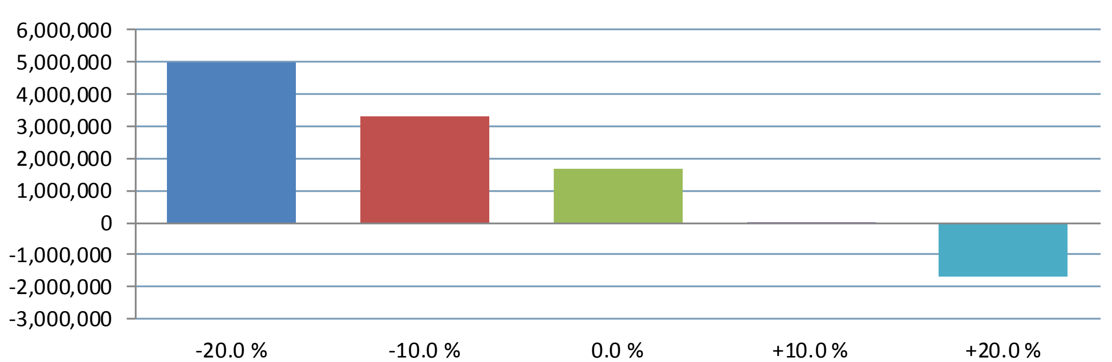

Table 21: Sensitivity to Variable Cost

Sensitivity of NPV and IRR on changes in electrical rate

The effect of earning more or less revenue from electrical generation is shown in Table 22 and Table 23. Table 22 shows the sensitivity of NPV on the electrical revenue, where $274,626 is the amount earned at 5.5₵/kWh.

Income variable´s impact on profitability					
Variable	Electrical Revenue				
Change in value, %	**-20.0 %**	**-10.0 %**	**0.0 %**	**+10.0 %**	**+20.0 %**
Sample value 12/2016	219,700.8	247,163.4	274,626.0	302,088.6	329,551.2
Net Present Value (NPV)	541,833	1,100,288	1,658,744	2,217,199	2,775,654
Change, %	-67.3 %	-33.7 %	0.0 %	+33.7 %	+67.3 %

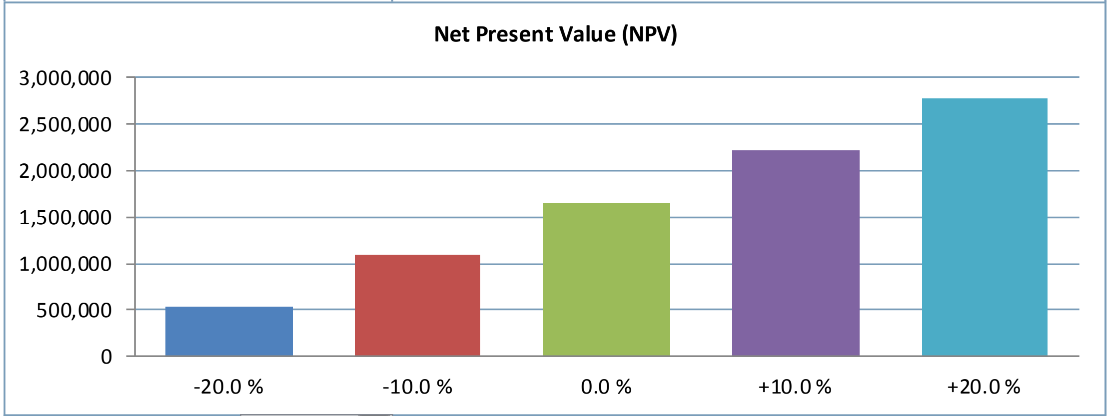

Table 22: Sensitivity to changes in Electrical Revenue

The sensitivity of the Internal Rate of Return is shown in Table 23.

Income variable´s impact on profitability					
Variable	Electrical Rate, $/kWh				
Change in value, %	**-20.0 %**	**-10.0 %**	**0.0 %**	**+10.0 %**	**+20.0 %**
Sample value 12/2016	0.044	0.050	0.055	0.061	0.066
Internal Rate of Return (IRR)	3.1%	3.9%	4.6%	5.3%	6.0%
Change, %	-32.4 %	-15.9 %	0.0 %	+15.3 %	+30.0 %

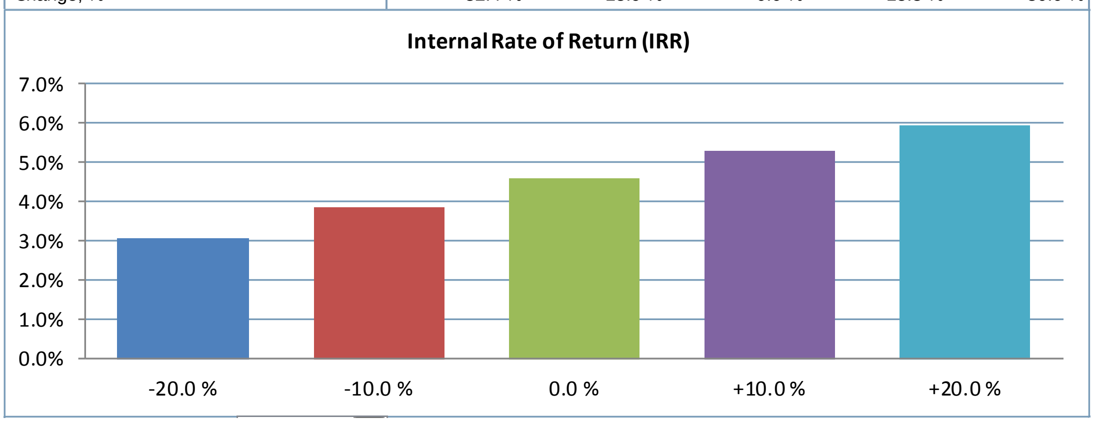

Table 23: Sensitivity of the system IRR to changes in electrical rate (Netmetering)

The Sensitivity Analyses on electrical revenue and rates show that the project has a high sensitivity to the revenue earned by electrical production. An increase in electrical revenue to nearly $330k will increase the system's profitability by over 67% Even a modest increase in electrical rates to 6.6₵/kWh will increase the project's IRR by 30%.

Conclusions: Economic Model

In general, the economic viability of the proposed Ann Arbor Biodigester relies on three critical factors. These are:

1) The availability of an adequate volume of WWTP sludge to achieve a sufficient economy-of-scale. Revenues to the biodigester come from the avoided costs of landfilling or land application of sludge, plus the elimination of expenses for lime, polymer and other required materials if treated sludge is land applied or landfilled.
2) The availability of public money to finance the project. With an estimated capital cost of over $6M, the cost of debt between public and private sources is substantial. Luckily, Ann Arbor has an excellent credit rating (AA+) and can borrow funds on the tax-exempt market at extremely good rates. (See Table 9.)
3) The availability of food waste and other organics to increase biogas production. As the sensitivity analysis on electrical revenue and rates showed (Table 22 and Table 23), the project's profitability has a moderately high sensitivity to revenue from electrical generation. This means that the more food waste/FOG/dairy waste, the better. These feedstocks have much higher biogas production potential than WWTP sludge, so additional quantities have a disproportionally positive impact on project revenue.

If these three factors can be met, then it is recommended that the City of Ann Arbor invest in the development of a biodigester system. The economic modeling in this Study shows that the City will benefit from a profitable waste-to-energy system, assuming the correct feedstock mix.

8. Sustainability Benefits of a Biodigester.

In 2011, Ann Arbor developed a Sustainability Framework project started in January 2011 with the goal of creating one unified vision of sustainability for the city. The Sustainability Framework includes 16 high level sustainability goals[xiii]. The following compliance matrix identifies how a biodigester can work to meet specific goals in the framework

[xiii] http://www.a2gov.org/sustainability/Documents/Ann%20Arbor%20Sustainability%20Framework%20051313.pdf

Framework Goal	Biodigester Feature	Comment
Sustainable Energy –Increase the use of renewable energy.	Biogas Production for heat, or to generate electricity in a gen-set. Biogas is a byproduct of material decomposition	Using biogas also destroys the methane in biogas. Methane is a powerful greenhouse gas.
Clean Air and Water - Eliminate pollutants in our air and water systems	The liquid fraction of the digested material is essentially pathogen-free after digestion.	Digesters are sealed, eliminating leakage of leachate into the groundwater under landfills.
Sustainable Systems - Plan for and manage constructed and natural infrastructure systems to meet the current and future needs of our community	The digested solids from biodigesters convert complex food waste material into readily accessible soil nutrients. Water can be used as a liquid fertilizer.	Digestion and composting are part of a continuous cycle of returning nutrients and water back to the environment.
Responsible Resource Use - Produce zero waste and optimize the use and reuse of resources in our community	.Biodigestion reduces the volume of material by as much as 40%. Digested solids can be used as a soil amendment.	Diversion of food waste is part of a larger strategy to put all waste products to beneficial use. Ultimately, zero waste goals can be achieved

Table 24: Sustainability benefits of biodigestion

The 2013 Solid Waste Resource Plan[xiv] contains a detailed list of key actions to execute to meet the 16 goals in the Sustainability Framework. One of the Key Actions under ***Responsible Resource Use*** called for the following:

> *"Research options to collect and process all food waste produced within the city, including but not limited to biodigesters. Include a review of options to potentially manage diapers and pet waste. Conduct a feasibility study of the ability of the City's compost facility, operated by WeCare Organics, to handle full-scale food waste composting. Complete feasibility study by January 2014. "*

The RFP 889 issued by the City of Ann Arbor in February of 2014 was focused on the use of a biodigester to process food waste, and this Feasibility Study by Quantalux is the resulting document. Previous work by our firm has researched the processing diapers and pet waste, and has concluded that both items are unsuitable for biodigesters:

> ***Diapers:*** Disposable diapers contain a range of materials, including plastic sheeting to prevent fluids from leaking. While biodigesters can safely process human waste, the plastic sheeting and plastic absorbent material is currently non-biodegradable, and will foul both

[xiv] http://www.a2gov.org/Documents/A2_WasteLessFive-YearPlan_APPENDIX_10-7-13.pdf

compost systems and biodigesters. Furthermore, the mixers in a biodigester will become clogged with disposable diapers.

Pet Waste: Biodigesters can also safely process pet waste, however, the litter that typically accompanies pet waste is made from diatomaceous earth. This clay-like material will settle in biodigester vessels, and will ultimately plug the system's pumps and vessels.

9. Conclusions and Next Steps

In conclusion, the deployment of a biodigester in Ann Arbor for food waste and WWTP sludge has the potential to be a good financial investment for the City, but only under certain conditions. These include:

Large Scale: The biodigester must be of adequate scale to be financially viable, and be publically financed using inexpensive monies available to a city like Ann Arbor with excellent credit. The issue of scale requires a judicious selection of available organic feedstocks for optimum performance, with large quantities of feedstocks needed for daily operation.

Diverse Feedstocks: Food waste is an excellent candidate feedstock because of its outstanding biogas production potential. The ideal source of food waste is a food processor because the supply of material is typically well-characterized, and can be delivered on a regular schedule. Large amounts of food waste are also produced in restaurants and at other institutions; however, the efficient collection of food waste from municipal sources is still in its relative infancy, with cheap landfill options remaining a barrier to deployment.

Sludge as a major feedstock: Diversion of a large fraction of the sludge from the Ann Arbor WWTP is a key source of revenue for the Biodigester. This is a viable approach since many wastewater plants across the US routinely use biodigestion to process their sewage sludge. Augmenting the Ann Arbor WWTP with a biodigester offers an alternative processing solution, and can offer both the City's WWTP and the Solid Waste group long-term savings in their disposal costs. This is particularly true if landfill or land application costs continue to escalate.

Sustainability: From a sustainability perspective, biodigestion is far superior to the current disposal for Ann Arbor's sludge (landfilling or land application). Biodigestion generates renewable energy, and also naturally reduces the amount of material for subsequent processing (to compost) or disposal.

Logistical challenges: Collection and transport of food waste is a challenging prospect due to its distributed nature, and the food waste's rapid decomposition. Efficient logistics systems will be needed to cost effectively gather and transport food waste from commercial locations such as restaurants.

Recommended Next Steps

This initial Feasibility Study shows the potential for a biodigester in the Ann Arbor area. The following items are recommended as key elements to include in any follow-on study:

- The ideal method for determining food waste totals is to conduct a rigorous food sort. A food sort for multiple restaurants is recommended in order to tally the available food-waste feedstock in a structured manner.
- FOG is a valuable feedstock for biodigestion, but is difficult to guarantee as a feedstock since multiple independent haulers mange the pickup and disposal of the material. A franchise model requiring all FOG within Ann Arbor city limits to be diverted to a common location (biodigester) should be explored.
- Similarly, a franchise model for the collection food waste produced within the city limit of Ann Arbor should be explored. A consistent supply of food waste and FOG to the digester will assure maximum biogas production, leading to enhanced financial stability and profitability.
- Further study is recommended to determine more precise estimates of biogas production from the sludge material available from the Ann Arbor WWTP.
- Commercial composting participation should be further evaluated to determine the fraction of food waste diverted to composting, and in turn, the fractions of pre-consumer food waste, and post-consumer food waste.
- A site assessment for the biodigester should be conducted to determine the optimum location based on available feedstocks. Another criterion for site selection will be any limits on renewable electrical production that may exist in Michigan's utility regulations.
- It is critical to determine how the cost-accounting structure at City departments will affect options for filtrate disposal.
- Future economic models should evaluate the addition of REC and Carbon Credit revenues. At the current time, these markets are uncertain. However, there are indications that limits on carbon producers may be imposed by the EPA, meaning that the positive carbon credits earned by the Ann Arbor Biodigester may (at some point) have significant monetary value.

Appendix A: Pro Forma for Case 4

A full 20 year Pro Forma listing for the Biodigester Case 4 (see Table 15) is listed in the Appendix A following the References.

10. References Cited

[1] "Municipal Solid Waste (MSW) in the United States: Facts and Figures 2012."*EPA*. Environmental Protection Agency, Web. 12 June 2014.

[2] "Analysis of U.S. Food Waste Among Food Manufacturers, Retailers, and Wholesalers." *FWRA Food Waste Reduction Alliance*. BSR, Apr. 2013. Web. 12 June 2014.

[3] Lawitts, Steven. "Commercial Food Waste Disposal Study." (2008): New York City Department of Environmental Protection, 31 Dec. 2008. Web. 12 June 2014.

[4] De la Houssaye, M. and A. White." Economics of New York City Commercial MSW Collection & Disposal and Source-Separated Food Waste Collection & Composting: Opportunities to Reduce Costs of Food Waste Collection & Recovery." 2008.

[5] Greer, Diane. "Commercial Food Waste Recovery In New York City." *BioCycle*., Dec. 2012. Web. 12 June 2014

[6] "Food Scraps Recycling." East Bay Municipal Utility District, Web. 12 June 2014.

[7] Hagey, Paul. "Utility District Ramps Up Food Waste To Energy Program."*BioCycle*. Nov. 2011. Web. 12 June 2014.

[8] "Executive Director Approval Of: Building Permit and East Bay Municipal Utilities District's Main Wastewater Treatment Plant (MWWTP) Land Use Master Plan Environmental Impact Report (EIR) and the First Addendum to the EIR for Recology's Organic-Rich Materials Preprocessing Facility 2020 Wake Ave (EBMUD Site)." Port of Oakland, 11 June 2012. Web. 12 June 2014.

[9] AECOM. "Food Waste Digester Phase 1 Feasibility Report." Dane County Dept. of Public Works, Solid Waste Division, June 2011. Web. 13 June 2014.

[10] "Analysis of U.S. Food Waste Among Food Manufacturers, Retailers, and Wholesalers." *FWRA Food Waste Reduction Alliance*. BSR, Apr. 2013. Web. 12 June 2014.

[11] "Food Waste Estimation Guide." *RecyclingWorks Massachusetts*. Web. 12 June 2014.
<http://www.recyclingworksma.com/food-waste-estimation-guide/#Jump06>

[12] "Food Waste Management Cost Calculator." *EPA*. Environmental Protection Agency, Web. 12 June 2014. <http://www.epa.gov/waste/conserve/foodwaste/tools/index.htm>.

[13] "Standard Waste Generated in Weight for Building/Business Type." The Rosenthal Group. Web. 12 June 2014. <http://www.the-rosenthal-group.com/Standard%20Waste%20Generated.pdf>.

[14] Cascadia Consulting Group. *Targeted Statewide Waste Characterization Study: Waste Disposal and Diversion Findings for Selected Industry Groups*. June 2006. Web. 12 June 2014. <http://www.calrecycle.ca.gov/publications/Documents/Disposal/34106006.pdf>.

City of Ann Arbor
Biodigester Feasibility Study
Case 4

INVESTMENTS (-) / REALIZATIONS (+)

Imputed depreciation	1/2016	12/2016	12/2017	12/2018	12/2019	12/2020	12/2021	12/2022	12/2023	12/2024	12/2025	12/2026	12/2027	12/2028	12/2029	12/2030	12/2031	12/2032	12/2033	12/2034	12/2035	Residual
Investments	**-6,132,079**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
Book value	6,132,079	5,544,143	4,956,208	4,368,272	3,780,337	3,192,401	2,604,466	2,016,530	1,700,635	1,430,079	1,159,524	888,968	618,413	347,857	77,302	0	0	0	0	0	0	0

INCOME STATEMENT

USD	1/2016	12/2016	12/2017	12/2018	12/2019	12/2020	12/2021	12/2022	12/2023	12/2024	12/2025	12/2026	12/2027	12/2028	12/2029	12/2030	12/2031	12/2032	12/2033	12/2034	12/2035	Residual
Months per interval		12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	(12/2035)
Income specified:																						
Electrical Generation		449,388	458,376	467,543	476,894	486,432	496,161	506,084	516,206	526,530	537,060	547,801	558,757	569,933	581,331	592,958	604,817	616,913	629,252	641,837	654,673	
Generator Capacity, kW		600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	
Generator availability, %		95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	
Electrical Rate, $/kWh		0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.13	0.13	0.13	
+ Electrical Revenue		449,388	458,376	467,543	476,894	486,432	496,161	506,084	516,206	526,530	537,060	547,801	558,757	569,933	581,331	592,958	604,817	616,913	629,252	641,837	654,673	
External Tip Fees		208,364	210,189	212,060	213,977	215,942	217,957	220,022	222,138	224,307	226,531	228,810	231,146	233,541	235,995	238,511	241,090	243,733	246,442	249,219	252,065	
Grease Trap Waste Tip Fee, $/gallon		0.10	0.10	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.14	0.14	0.14	0.15	0.15	0.16	0.16	
Annual Volume Accepted, gallons		365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	
+ Annual Tip Fee		36,500	37,413	38,348	39,307	40,289	41,296	42,329	43,387	44,472	45,583	46,723	47,891	49,088	50,316	51,574	52,863	54,184	55,539	56,928	58,351	
External Substrate Tip Fee, $/gallon		0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	
Annual Volume Accepted, gallons		730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	730,000	
+ Annual Tip Fee, $/yr		36,500	37,413	38,348	39,307	40,289	41,296	42,329	43,387	44,472	45,583	46,723	47,891	49,088	50,316	51,574	52,863	54,184	55,539	56,928	58,351	
External Substrate Tip Fee, $/gallon		0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.10	
Annual Volume Accepted, gallons		365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	365,000	
+ Annual Tip Fee, $/yr		21,900	21,900	21,900	21,900	21,900	21,900	21,900	21,900	21,900	21,900	21,900	21,900	21,900	21,900	21,900	21,900	21,900	21,900	21,900	21,900	
External Substrate - Food Waste Tip Fee, $/gallon		21.82	22.366	22.925	23.498	24.085	24.687	25.305	25.937	26.586	27.250	27.931	28.630	29.345	30.079	30.831	31.602	32.392	33.202	34.032	34.883	
Annual Volume Accepted, tons/yr		5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	5,200	
+ Annual Tip Fee, $/yr		113,464	113,464	113,464	113,464	113,464	113,464	113,464	113,464	113,464	113,464	113,464	113,464	113,464	113,464	113,464	113,464	113,464	113,464	113,464	113,464	
WWTP Cost Savings		1,022,507	1,048,070	1,074,272	1,101,129	1,128,657	1,156,873	1,185,795	1,215,440	1,245,826	1,276,972	1,308,896	1,341,618	1,375,159	1,409,538	1,444,776	1,480,895	1,517,918	1,555,866	1,594,762	1,634,632	
+ Annual Lime Savings		171,163	175,442	179,828	184,324	188,932	193,656	198,497	203,459	208,546	213,760	219,104	224,581	230,196	235,951	241,849	247,896	254,093	260,445	266,956	273,630	
+ Annual Land App Savings		416,744	427,163	437,842	448,788	460,007	471,508	483,295	495,378	507,762	520,456	533,468	546,804	560,474	574,486	588,848	603,570	618,659	634,125	649,978	666,228	
+ Annual Landfill Savings		214,000	219,350	224,834	230,455	236,216	242,121	248,174	254,379	260,738	267,257	273,938	280,787	287,806	295,001	302,376	309,936	317,684	325,626	333,767	342,111	
+ Annual dewatering Polymer savings		186,600	191,265	196,047	200,948	205,971	211,121	216,399	221,809	227,354	233,038	238,864	244,835	250,956	257,230	263,661	270,252	277,009	283,934	291,032	298,308	
+ State Biosolids Fees		34,000	34,850	35,721	36,614	37,530	38,468	39,430	40,415	41,426	42,461	43,523	44,611	45,726	46,869	48,041	49,242	50,473	51,735	53,028	54,354	
Income	**0**	**1,680,259**	**1,716,635**	**1,753,875**	**1,792,000**	**1,831,031**	**1,870,991**	**1,911,901**	**1,953,784**	**1,996,663**	**2,040,563**	**2,085,507**	**2,131,522**	**2,178,632**	**2,226,864**	**2,276,245**	**2,326,802**	**2,378,564**	**2,431,560**	**2,485,818**	**2,541,370**	**0**
(cumulative financial year)		1,680,259	1,716,635	1,753,875	1,792,000	1,831,031	1,870,991	1,911,901	1,953,784	1,996,663	2,040,563	2,085,507	2,131,522	2,178,632	2,226,864	2,276,245	2,326,802	2,378,564	2,431,560	2,485,818	2,541,370	
Other operating income																						
Variable costs	0	-917,409	-940,850	-964,896	-989,565	-1,014,873	-1,040,837	-1,067,473	-1,094,801	-1,122,837	-1,151,601	-1,181,112	-1,211,391	-1,242,456	-1,274,330	-1,307,033	-1,340,588	-1,375,017	-1,410,344	-1,446,592	-1,483,787	0
Raw materials and consumables		-306,043	-314,199	-322,579	-331,190	-340,039	-349,132	-358,476	-368,078	-377,946	-388,088	-398,511	-409,225	-420,236	-431,554	-443,188	-455,146	-467,440	-480,077	-493,069	-506,425	
- Dewatering Polymer		106,853	109,524	112,262	115,069	117,945	120,894	123,916	127,014	130,190	133,444	136,781	140,200	143,705	147,298	150,980	154,755	158,623	162,589	166,654	170,820	
Electrcrity, kWh/yr		365,000	370,475	376,032	381,673	387,398	393,209	399,107	405,093	411,170	417,337	423,597	429,951	436,401	442,947	449,591	456,335	463,180	470,127	477,179	484,337	
Electrical Rate		0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.14	0.14	0.14	
- Plant Electricity		32,850	34,176	35,556	36,992	38,485	40,039	41,656	43,338	45,087	46,908	48,802	50,772	52,822	54,955	57,173	59,482	61,883	64,382	66,981	69,686	
- Equipment O&M		30,000	30,750	31,519	32,307	33,114	33,942	34,791	35,661	36,552	37,466	38,403	39,363	40,347	41,355	42,389	43,449	44,535	45,649	46,790	47,960	
- Misc		7,500	7,688	7,880	8,077	8,279	8,486	8,698	8,915	9,138	9,366	9,601	9,841	10,087	10,339	10,597	10,862	11,134	11,412	11,697	11,990	
- CHP maintenance		78,840	80,811	82,831	84,902	87,025	89,200	91,430	93,716	96,059	98,460	100,922	103,445	106,031	108,682	111,399	114,184	117,038	119,964	122,963	126,038	
- Gas Cleaning Costs		50,000	51,250	52,531	53,845	55,191	56,570	57,985	59,434	60,920	62,443	64,004	65,604	67,244	68,926	70,649	72,415	74,225	76,081	77,983	79,933	
External charges		-586,367	-601,026	-616,051	-631,453	-647,239	-663,420	-680,006	-697,006	-714,431	-732,292	-750,599	-769,364	-788,598	-808,313	-828,521	-849,234	-870,465	-892,226	-914,532	-937,395	
- Trucking Fee for WWTP sludge		300,000	307,500	315,188	323,067	331,144	339,422	347,908	356,606	365,521	374,659	384,025	393,626	403,467	413,553	423,892	434,489	445,352	456,485	467,898	479,595	
- Cake Disposal Cost (compost)		238,467	244,428	250,539	256,803	263,223	269,803	276,548	283,462	290,548	297,812	305,257	312,889	320,711	328,729	336,947	345,371	354,005	362,855	371,927	381,225	
- Lab Testing, $/year		5,000	5,125	5,253	5,384	5,519	5,657	5,798	5,943	6,092	6,244	6,400	6,560	6,724	6,893	7,065	7,241	7,423	7,608	7,798	7,993	
- Centrate disposal fee		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
- State Biosolids Fee		20,400	20,910	21,433	21,969	22,518	23,081	23,658	24,249	24,855	25,477	26,114	26,767	27,436	28,122	28,825	29,545	30,284	31,041	31,817	32,612	
- Building Maintenance (water, heat, misc repairs)		2,500	2,563	2,627	2,692	2,760	2,829	2,899	2,972	3,046	3,122	3,200	3,280	3,362	3,446	3,532	3,621	3,711	3,804	3,899	3,997	
- City Central Cost Allocation		7,500	7,688	7,880	8,077	8,279	8,486	8,698	8,915	9,138	9,366	9,601	9,841	10,087	10,339	10,597	10,862	11,134	11,412	11,697	11,990	
- External Maintenance		12,500	12,813	13,133	13,461	13,798	14,143	14,496	14,859	15,230	15,611	16,001	16,401	16,811	17,231	17,662	18,104	18,556	19,020	19,496	19,983	
Long Term Equipment Replacement		-25,000	-25,625	-26,266	-26,922	-27,595	-28,285	-28,992	-29,717	-30,460	-31,222	-32,002	-32,802	-33,622	-34,463	-35,324	-36,207	-37,113	-38,040	-38,991	-39,966	
- Long Term Equipment Replacement		25,000	25,625	26,266	26,922	27,595	28,285	28,992	29,717	30,460	31,222	32,002	32,802	33,622	34,463	35,324	36,207	37,113	38,040	38,991	39,966	
Other variable costs																						
Gross margin	**0**	**762,850**	**775,785**	**788,978**	**802,434**	**816,158**	**830,154**	**844,427**	**858,983**	**873,826**	**888,962**	**904,395**	**920,131**	**936,176**	**952,535**	**969,212**	**986,215**	**1,003,547**	**1,021,216**	**1,039,226**	**1,057,584**	**0**
(cumulative financial year)		762,850	775,785	788,978	802,434	816,158	830,154	844,427	858,983	873,826	888,962	904,395	920,131	936,176	952,535	969,212	986,215	1,003,547	1,021,216	1,039,226	1,057,584	
% (cumulative financial year)		45.4%	45.2%	45.0%	44.8%	44.6%	44.4%	44.2%	44.0%	43.8%	43.6%	43.4%	43.2%	43.0%	42.8%	42.6%	42.4%	42.2%	42.0%	41.8%	41.6%	
Fixed costs	0	-275,000	-281,875	-288,922	-296,145	-303,549	-311,137	-318,916	-326,889	-335,061	-343,437	-352,023	-360,824	-369,844	-379,091	-388,568	-398,282	-408,239	-418,445	-428,906	-439,629	0
Staff costs		-275,000	-281,875	-288,922	-296,145	-303,549	-311,137	-318,916	-326,889	-335,061	-343,437	-352,023	-360,824	-369,844	-379,091	-388,568	-398,282	-408,239	-418,445	-428,906	-439,629	
- Admin (25% utilization)		30,000	30,750	31,519	32,307	33,114	33,942	34,791	35,661	36,552	37,466	38,403	39,363	40,347	41,355	42,389	43,449	44,535	45,649	46,790	47,960	
- Manager (20% utilization)		50,000	51,250	52,531	53,845	55,191	56,570	57,985	59,434	60,920	62,443	64,004	65,604	67,244	68,926	70,649	72,415	74,225	76,081	77,983	79,933	
- Operator		78,000	79,950	81,949	83,997	86,097	88,250	90,456	92,717	95,035	97,411	99,847	102,343	104,901	107,524	110,212	112,967	115,791	118,686	121,653	124,695	
- Operator		78,000	79,950	81,949	83,997	86,097	88,250	90,456	92,717	95,035	97,411	99,847	102,343	104,901	107,524	110,212	112,967	115,791	118,686	121,653	124,695	
- Mechanic (50% utilization)		39,000	39,975	40,974	41,999	43,049	44,125	45,228	46,359	47,518	48,706	49,923	51,171	52,451	53,762	55,106	56,484	57,896	59,343	60,827	62,347	
Rents																						
Other fixed costs																						
Provisions, increase (-) / decrease (+)																						
EBITDA; Operating income before depreciation	**0**	**487,850**	**493,910**	**500,056**	**506,289**	**512,609**	**519,016**	**525,511**	**532,094**	**538,765**	**545,524**	**552,372**	**559,308**	**566,332**	**573,444**	**580,645**	**587,933**	**595,308**	**602,771**	**610,320**	**617,955**	**0**
(cumulative financial year)		487,850	493,910	500,056	506,289	512,609	519,016	525,511	532,094	538,765	545,524	552,372	559,308	566,332	573,444	580,645	587,933	595,308	602,771	610,320	617,955	
% (cumulative financial year)		29.0%	28.8%	28.5%	28.3%	28.0%	27.7%	27.5%	27.2%	27.0%	26.7%	26.5%	26.2%	26.0%	25.8%	25.5%	25.3%	25.0%	24.8%	24.6%	24.3%	
Depreciation	0	-587,936	-587,936	-587,936	-587,936	-587,936	-587,936	-587,936	-315,896	-270,556	-270,556	-270,556	-270,556	-270,556	-270,556	-77,302	0	0	0	0	0	0
EBIT; Operating income	**0**	**-100,086**	**-94,025**	**-87,879**	**-81,646**	**-75,326**	**-68,919**	**-62,424**	**216,199**	**268,210**	**274,969**	**281,816**	**288,752**	**295,776**	**302,889**	**503,343**	**587,933**	**595,308**	**602,771**	**610,320**	**617,955**	**0**
(cumulative financial year)	0	-100,086	-94,025	-87,879	-81,646	-75,326	-68,919	-62,424	216,199	268,210	274,969	281,816	288,752	295,776	302,889	503,343	587,933	595,308	602,771	610,320	617,955	
% (cumulative financial year)		-6.0%	-5.5%	-5.0%	-4.6%	-4.1%	-3.7%	-3.3%	11.1%	13.4%	13.5%	13.5%	13.5%	13.6%	13.6%	22.1%	25.3%	25.0%	24.8%	24.6%	24.3%	
Financing income and expenses	0	-227,500	-216,125	-204,750	-193,375	-182,000	-170,625	-159,250	-147,875	-136,500	-125,125	-113,750	-102,375	-91,000	-79,625	-68,250	-56,875	-45,500	-34,125	-22,750	-11,375	0
Financing income and expenses	0	-227,500	-216,125	-204,750	-193,375	-182,000	-170,625	-159,250	-147,875	-136,500	-125,125	-113,750	-102,375	-91,000	-79,625	-68,250	-56,875	-45,500	-34,125	-22,750	-11,375	
Interest Rate		3.50%	3.50%	3.50%	3.50%	3.50%	3.50%	3.50%	3.50%	3.50%	3.50%	3.50%	3.50%	3.50%	3.50%	3.50%	3.50%	3.50%	3.50%	3.50%	3.50%	
- Interest, $/A		227,500	216,125	204,750	193,375	182,000	170,625	159,250	147,875	136,500	125,125	113,750	102,375	91,000	79,625	68,250	56,875	45,500	34,125	22,750	11,375	
EBT; Income after financing items	**0**	**-327,586**	**-310,151**	**-292,629**	**-275,021**	**-257,326**	**-239,544**	**-221,674**	**68,324**	**131,709**	**149,844**	**168,066**	**186,377**	**204,776**	**223,264**	**435,093**	**531,058**	**549,808**	**568,646**	**587,570**	**606,580**	**0**
Extraordinary income and charges	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Realization profit (-loss)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other extraordinary income (-charges)																						
Income before appropriations and taxes	**0**	**-327,586**	**-310,151**	**-292,629**	**-275,021**	**-257,326**	**-239,544**	**-221,674**	**68,324**	**131,709**	**149,844**	**168,066**	**186,377**	**204,776**	**223,264**	**435,093**	**531,058**	**549,808**	**568,646**	**587,570**	**606,580**	**0**
Change in appropriations																						
Appropriations, increase (-) / decrease (+)																						
Income tax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Deferred tax																						
Minority interest																						
Net income for the period	**0**	**-327,586**	**-310,151**	**-292,629**	**-275,021**	**-257,326**	**-239,544**	**-221,674**	**68,324**	**131,709**	**149,844**	**168,066**	**186,377**	**204,776**	**223,264**	**435,093**	**531,058**	**549,808**	**568,646**	**587,570**	**606,580**	**0**
(cumulative financial year)	0	-327,586	-310,151	-292,629	-275,021	-257,326	-239,544	-221,674	68,324	131,709	149,844	168,066	186,377	204,776	223,264	435,093	531,058	549,808	568,646	587,570	606,580	606,580
% (cumulative financial year)		-19.5%	-18.1%	-16.7%	-15.3%	-14.1%	-12.8%	-11.6%	3.5%	6.6%	7.3%	8.1%	8.7%	9.4%	10.0%	19.1%	22.8%	23.1%	23.4%	23.6%	23.9%	
Return on net assets (RONA), %		**-1.7 %**	**-1.8 %**	**-1.9 %**	**-2.0 %**	**-2.2 %**	**-2.4 %**	**-2.7 %**	**11.6 %**	**17.1 %**	**21.2 %**	**27.5 %**	**38.3 %**	**61.2 %**	**142.5 %**	**1302.3 %**	**-**	**-**	**-**	**-**	**-**	**-**
Economic Value Added (EVA)		**-222,686**	**-204,279**	**-185,786**	**-167,207**	**-148,540**	**-129,786**	**-110,945**	**177,168**	**235,337**	**247,778**	**260,307**	**272,925**	**285,630**	**298,425**	**502,531**	**587,933**	**595,308**	**602,771**	**610,320**	**617,955**	**0**

WORKING CAPITAL

USD	1/2016	12/2016	12/2017	12/2018	12/2019	12/2020	12/2021	12/2022	12/2023	12/2024	12/2025	12/2026	12/2027	12/2028	12/2029	12/2030	12/2031	12/2032	12/2033	12/2034	12/2035	Residual
Change in working capital	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Net working capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CASH FLOW STATEMENT

USD	1/2016	12/2016	12/2017	12/2018	12/2019	12/2020	12/2021	12/2022	12/2023	12/2024	12/2025	12/2026	12/2027	12/2028	12/2029	12/2030	12/2031	12/2032	12/2033	12/2034	12/2035	Residual
Months per interval		12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	(12/2035)
Cash flow from operations																						
Income	0	1,680,259	1,716,635	1,753,875	1,792,000	1,831,031	1,870,991	1,911,901	1,953,784	1,996,663	2,040,563	2,085,507	2,131,522	2,178,632	2,226,864	2,276,245	2,326,802	2,378,564	2,431,560	2,485,818	2,541,370	0
Variable costs	0	-917,409	-940,850	-964,896	-989,565	-1,014,873	-1,040,837	-1,067,473	-1,094,801	-1,122,837	-1,151,601	-1,181,112	-1,211,391	-1,242,456	-1,274,330	-1,307,033	-1,340,588	-1,375,017	-1,410,344	-1,446,592	-1,483,787	0
Fixed costs	0	-275,000	-281,875	-288,922	-296,145	-303,549	-311,137	-318,916	-326,889	-335,061	-343,437	-352,023	-360,824	-369,844	-379,091	-388,568	-398,282	-408,239	-418,445	-428,906	-439,629	0
Extraordinary income & expenses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Income tax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Change in working capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cash flow from operations	**0**	**487,850**	**493,910**	**500,056**	**506,289**	**512,609**	**519,016**	**525,511**	**532,094**	**538,765**	**545,524**	**552,372**	**559,308**	**566,332**	**573,444**	**580,645**	**587,933**	**595,308**	**602,771**	**610,320**	**617,955**	**0**
Asset investments and realizations	-6,132,079	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Free cash flow (FCF)	**-6,132,079**	**487,850**	**493,910**	**500,056**	**506,289**	**512,609**	**519,016**	**525,511**	**532,094**	**538,765**	**545,524**	**552,372**	**559,308**	**566,332**	**573,444**	**580,645**	**587,933**	**595,308**	**602,771**	**610,320**	**617,955**	**0**
Discounted free cash flow (DFCF)	-6,132,079	477,816	473,801	469,831	465,903	462,017	458,170	454,362	450,591	446,856	443,156	439,489	435,855	432,251	428,678	425,132	421,615	418,123	414,657	411,215	407,795	0
Cumulative discounted free cash flow	-6,132,079	-5,654,263	-5,180,462	-4,710,631	-4,244,727	-3,782,711	-3,324,541	-2,870,179	-2,419,588	-1,972,731	-1,529,575	-1,090,086	-654,231	-221,980	206,698	631,830	1,053,445	1,471,568	1,886,225	2,297,440	2,705,235	2,705,235
Information																						
Financial cash flow																						
Financial income and expenses	0	-227,500	-216,125	-204,750	-193,375	-182,000	-170,625	-159,250	-147,875	-136,500	-125,125	-113,750	-102,375	-91,000	-79,625	-68,250	-56,875	-45,500	-34,125	-22,750	-11,375	0
Correction of income tax for financial items	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Long-term debt, increase (+) / decrease (-)	0	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	0
Changes in interest-bearing long-term debt	0	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	0
Long-term debt, increase (+) / decrease (-)	0	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	-325,000	
Long Term Debt	6,132,079	6,500,004	6,175,004	5,850,003	5,525,003	5,200,003	4,875,003	4,550,003	4,225,002	3,900,002	3,575,002	3,250,002	2,925,002	2,600,001	2,275,001	1,950,001	1,625,001	1,300,001	975,001	650,000	325,000	
- Amortization (15 years)		325,000	325,000	325,000	325,000	325,000	325,000	325,000	325,000	325,000	325,000	325,000	325,000	325,000	325,000	325,000	325,000	325,000	325,000	325,000	325,000	
Interest Over Contruction	367,925																					
Remianing Long Term Debt		6,175,004	5,850,003	5,525,003	5,200,003	4,875,003	4,550,003	4,225,002	3,900,002	3,575,002	3,250,002	2,925,002	2,600,001	2,275,001	1,950,001	1,625,001	1,300,001	975,001	650,000	325,000	0	
Changes in interest-free long-term debt																						
Changes in short-term borrowings																						
Equity, increase (+) / decrease (-)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total cash flow	**-6,132,079**	**-64,650**	**-47,215**	**-29,694**	**-12,086**	**5,609**	**23,391**	**41,261**	**59,219**	**77,265**	**95,399**	**113,622**	**131,932**	**150,332**	**168,819**	**187,394**	**206,058**	**224,808**	**243,646**	**262,570**	**281,580**	**0**