From Waste to Energy:

A Conceptual Analysis of Anaerobic Digestion at the Saratoga County Sewer District No. 1 Plant

Laura Adelman

Davide Gill-Austern

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Capstone Faculty Advisor: Professor Karen Kellogg

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1. INTRODUCTION

1.1 National Wastewater Treatment Concerns

Increasingly stringent standards at wastewater treatment facilities (WWTFs) once seen as universally positive must be revisited due to the unintended consequence of increased energy demands. In New York State alone, national water quality regulatory initiatives have the potential to increase electricity consumption at water and wastewater treatment plants by nearly 300 million kWh, or 10%, per year by 2018. This increase in energy demand comes from requirements for advanced treatments such as adding ultraviolet technology. Across New York State, advanced treatment installations lead to increases in energy demand ranging from a minimum of 34% upwards to 97% depending on the size of plant (NYSERDA, 2008). This increase in energy demand leads to economic and environment costs due to the high price and environmental deterioration associated with the use of fossil fuels as an energy source. The combustion of fossil fuels leads to the release of harmful greenhouse gasses and smog pollutants into the atmosphere including CO_2, methane, nitrogen and sulfur oxides.

Due to these intensive regulatory demands, coupled with outdated or obsolete infrastructure, energy costs currently comprise an average of 25-40% of New York State's WWTFs operating budgets (NYSERDA, 2008). Wastewater treatment facilities are frequently the largest consumers of energy within local city and community governments (Stillwell et al., 2010). Considering the energy sector as a whole, the wastewater industry alone consumes 3% of the United States electric power (EBMUD, 2010). Furthermore, the consumption of energy by WWTFs is likely to increase in the future as populations expand and stricter discharge requirements are instituted.

Considering the competing demands of meeting water quality regulations and operating within a limited budget, WWTFs must pursue an option that addresses energy demands without sacrificing water quality standards. According to the New York State Energy Research and Development Authority (NYSERDA), given the increased funding currently available for renewable energy projects, a feasible solution addressing rising WWTFs' quality standards as well as reducing energy demands comes through the use of an anaerobic digestion system (Statewide Assessment, 2008).

1.2 Anaerobic Digestion

Anaerobic digestion is a biological process in which bacteria digest or break down biomass in the absence of oxygen, or an anoxic state. This process produces two outputs, a solid byproduct (digestate) and a gas principally composed of methane (CH_4) and carbon dioxide (CO_2), otherwise known as biogas (WASTE, 2005). Methane, which composes roughly 50-80% of biogas, is the principal component of natural gas. Natural gas is a fossil fuel that forms over millions of years from the anaerobic decomposition of organic materials. Both methane and natural gas are produced by the same types of anaerobic bacteria. These microorganisms existed long before photosynthesis. Natural gas, or pure methane, has a heat energy content of approximately 1,000 British Thermal Units (Btu) per cubic foot. Biogas has an energy content of 10 Btu per percentage of methane, thus biogas composed of 60% methane yields 600 Btu per cubic foot. Biogas is commonly burned in a boiler or combined heat and power (CHP) application to generate electricity and heat. Digestate, the remaining material after methane has been extracted from the digested biomass, contains nutrients such as phosphorus and potassium, making it possible to refine this product into fertilizer (U.S. Department of Energy, 2011). Thus, anaerobic digestion can act as a source of renewable energy, reduce the amount of waste sent to landfills and provide a valuable secondary product in the form of a soil conditioner.

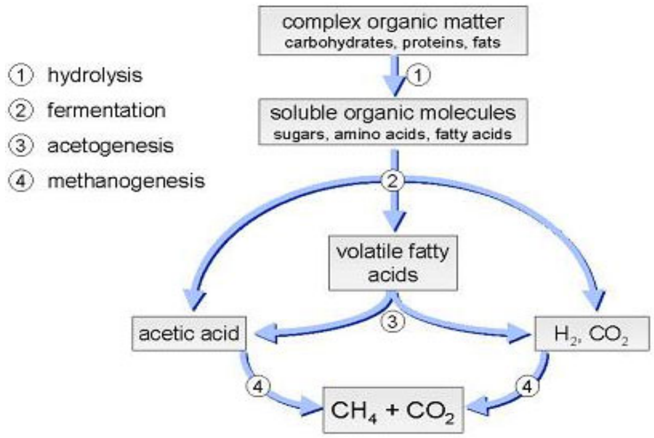
Anaerobic digesters (AD) are often installed where industrial or agricultural operations create a significant waste stream. Currently, AD systems are predominantly used at WWTFs and livestock operations; however, almost any organic material can be processed by anaerobic digestion. Potential feedstocks include biodegradable waste materials such as food and beverage waste, paper and pulp waste, grain industry and crop residues, forest residues, primary and secondary mill residues, animal manure and sewage (WASTE, 2005). Digesters represent a way for an operator to convert a waste product into an economic asset, while simultaneously solving an environmental problem.

1.2.1 The Science of Anaerobic Digestion

Anaerobic decomposition is a biological process that occurs in natural environments ranging from swamps, waterlogged soils and rice fields, deep bodies of water, and in the digestive systems of termites and large animals (U.S. Department of Energy, 2011). The same process occurs in landfills, as garbage undergoes anaerobic decomposition over time, emitting methane. The process of capturing methane gas from landfills to generate electricity has been implemented across the United States for a number of years. Electrical power from landfills surpasses solar power in both New York and New Jersey. Capturing methane has a double benefit as it creates a usable form of energy while limiting the amount of methane released into the atmosphere, which is 20 times more potent and detrimental than carbon dioxide as a greenhouse gas (GHG) (Rather, 2008). In engineered anaerobic digesters, organic matter is digested in an enclosed anoxic chamber, where temperatures are maintained at elevated levels, typically 98^0 Fahrenheit, in order to accelerate the bacterial digestion process that occurs in landfills. Other critical environmental conditions such as moisture content and pH levels are "controlled to maximize microbe generation, gas generation and waste decomposition rates" (Broses et al., 2011).

Anaerobic digestion, the process in which bacteria break down organic molecules, consists of four basic steps as shown in Figure 1: (1) in the hydrolysis stage, decomposition or 'hydrolysis' breaks down organic matter into enzymes, usable-sized molecules such as sugar; (2) in the fermentation stage, acidogenic bacteria then convert the sugars and amino acids into carbon dioxide, hydrogen, ammonia, and organic acids; (3) in the acetogenic stage, acetogenic bacteria then convert these resulting organic acids into acetic acid, along with additional ammonia, hydrogen, and carbon dioxide; and finally (4) in the methanogenesis stage, methanogens convert these acids to methane and carbon dioxide, known as biogas (WASTE, 2005).

Figure 1: The Four-Phase Process of Anaerobic Digestion



Source: EPA, 2010

1.2.2 Anaerobic Digestion in the United States

In April of 2007, the EPA reported that more than 16,000 municipal WWTFs were in operation in the United States. The wastewater capacity of these WWTFs ranges from several hundred million gallons per day (MGD) to less than 1 MGD. Roughly half of the 1,066 facilities that have an influent rate greater than 5 MGD operate anaerobic digesters to process wastewater. Only 19 percent of these WWTFs, however, "utilize the biogas produced by their anaerobic digesters to generate electricity and/or thermal energy" (EPA). It is assumed that the WWTFs that do not generate electricity or thermal energy, flare their biogas, a process in which excess biogas is safely burned without emitting methane but is not used for any form of onsite electricity generation.

Table 1: United States Wastewater Treatment Facilities with Anaerobic Digestion and Off-Gas Utilization by Number

WWTFs by Wastewater Flow Rates (MGD)	Total WWTFs	WWTFs with Anaerobic Digestion	WWTFs with Anaerobic Digestion and Gas Utilization	Percentage of WWTFs with Anaerobic Digestion that Utilize Biogas
> 200	15	10	5	50
100 – 200	26	17	9	53
75 – 100	27	16	7	44
50 – 75	30	18	5	28
20 – 50	178	87	25	29
10 – 20	286	148	19	13
5 – 10	504	248	36	15
Total	**1,066**	**544**	**106**	**19**

Source: EPA- Clean Watersheds Needs Survey, 2004

1.2.3 Anaerobic Digestion in New York

Today, New York has approximately 590 WWTFs in operation. With a combined design flow, or capacity, of 3.7 billion gallons per day (BGD), New York WWTFs account for 10% of the nation's total wastewater treatment design capacity. A market characterization report conducted by NYSERDA in 2007 found that 145 WWTFs in New York had anaerobic digestion systems installed, representing roughly 75% of the state's total wastewater treatment capacity. In order to calculate the current electrical/thermal capacity and potential, NYSERDA sent out a survey to all 590 WWTFs. Of the 69 respondents, 17 reported their installed biogas-fueled generation capacity. NYSERDA estimates that these 17 facilities produce roughly 1.9 billion cubic feet of biogas per year (cf/yr), equating to 36% of the anticipated biogas production at the 145 WWTFs that have existing anaerobic digestion facilities. NYSERDA found that 60% of the respondents report that they "flare or vent some portion of the biogas" generated at their facility (See Table 2).

Based on this survey, NYSERDA estimates that the electrical production potential of the 145 WWTFs with existing anaerobic digesters is 24 megawatts (MW). If all 590 WWTFs in the state were to install anaerobic digestion facilities and electrical generation equipment, the electrical potential would rise to 31 MW, according to NYSERDA (Statewide Assessment of Energy, 2007). This rise represents a 22.6% increase in onsite energy production for the state of New York, thus lowering external energy demands with the potential to decrease the state's environmental footprint depending on the energy sources for electrical production.

Table 2: Biogas and Electrical Production Potential of NYS WWTFs

Category (Number of WWTPs)	Estimated Biogas Production (cf/year)	Theoretical Heating Value (MMBTU)	Electrical Production Potential [1] (kwh/yr)
Survey Respondents (67)	4,734,000,000	2.59 million	189,000,000
All WWTPs w/Existing Anaerobic Digestion Facilities (145)	5,191,501,000	2.86 million	209,000,000
All WWTPs (590)	6,672,065,000	3.7 million	268,600,000

[1] Based on an electrical conversion efficiency of 25%.

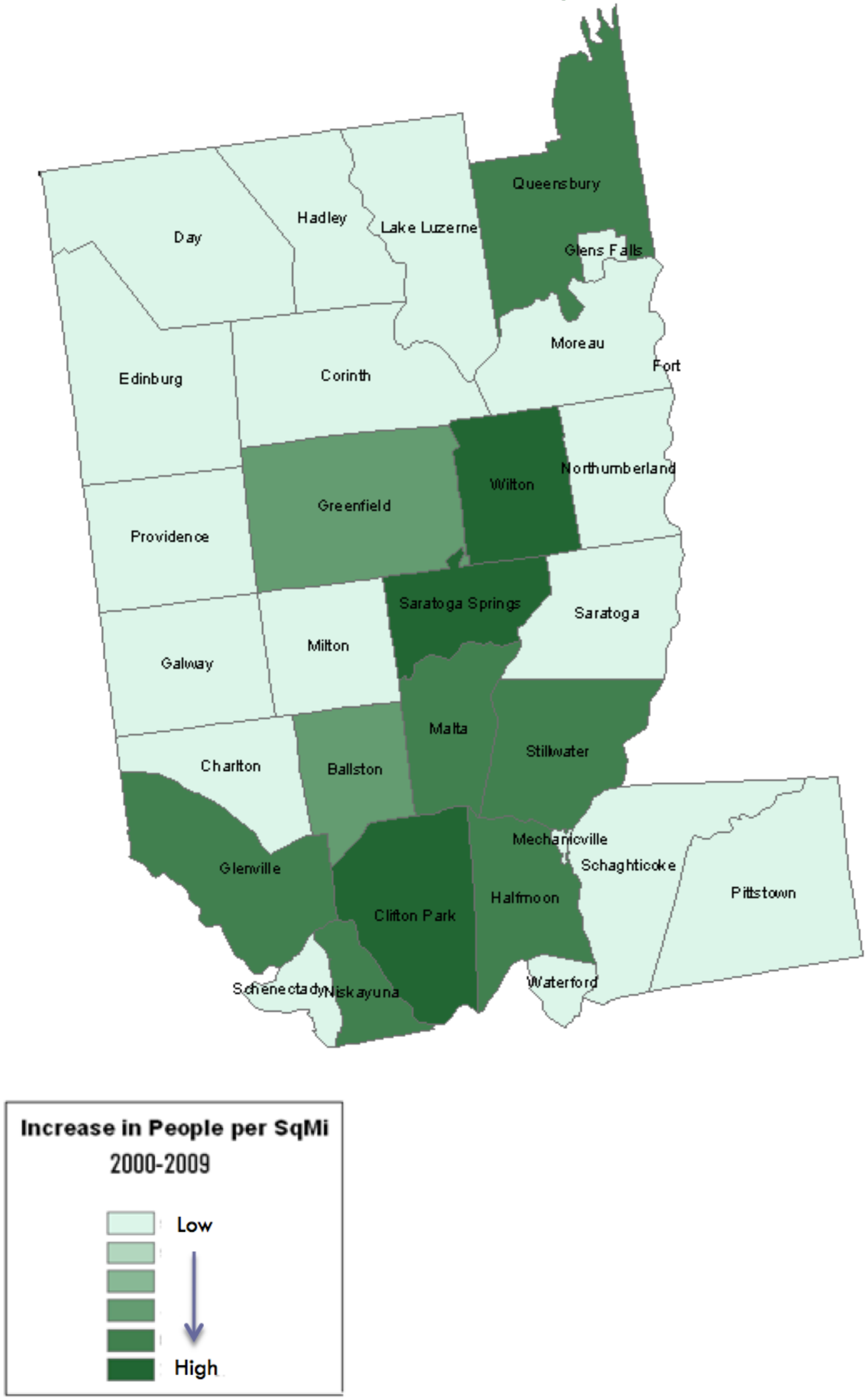
Source: NYSERDA, Statewide Assessment, 2008

1.3 Current Wastewater Treatment Practices in Saratoga County

Saratoga County includes the Saratoga Lake watershed, a 240-square mile area that includes 11 townships. The tributaries within this region empty into Saratoga Lake, a 5.8 square mile body of water (SLIPID, 2002). The County Sewer Plan regulating Saratoga County first came into effect in 1977 through the creation of the Saratoga County Sewer District #1 (SCSD) plant, successfully stopping the discharge of raw sewage into Saratoga Lake (Aulenbach et al. 1976). In the decades since this plan, the sewage district has expanded into more rural areas using onsite septic systems that are periodically emptied and disposed of at the WWTF (SLIPID, 2002). The current service area of the SCSD plant encompasses a radius of over 100 miles including over 80 pump stations (Duff, 2011). The plant processes a wide range of waste products, including municipal, dairy, and industrial wastes through aerobic processing.

Within New York State, regions experiencing higher than average growth rates, such as Saratoga Springs, must prepare for increased energy demands and the necessity of improved waste management programs (Saratoga County, 2008). Saratoga Springs has experienced some of the greatest population density growth in a 26 county region surrounding Saratoga Springs (See Figure 2). With Global Foundries, a large scale chip manufacturing industry, developing its headquarters in the nearby county of Malta, population density increases can be expected to increase both in Malta itself and Saratoga Springs due to close proximity.

Figure 2: Population Density Increases from 2000-2009



Source: US Census Data 2000 and 2009

2. RESEARCH GOAL

Considering the competing demands of clean water supplies, sustainability, and cost reduction, our capstone research goal focuses on anaerobic digestion as one possible solution for Saratoga County. Our study culminates in a conceptual analysis of the feasibility of an anaerobic digester at the Saratoga County District #1 (SCSD) WWTF. Our study focuses on examining the Gloversville-Johnstown Joint Wastewater Treatment facility as a successful case study and applying lessons learned and best practices to the SCSD plant. We will do so by studying the energy content of existing input materials to the plant as well as potential additional sources of organic waste. We will use this data to examine whether an anaerobic digestion system will be feasible based on expected payback period and social incentives to participate.

3. METHODS

The majority of our research was collected through primary source interviews and access to annual reports. Using interviews as our method of research allowed us to elicit explanations of social behaviors by understanding the detailed "why" and "how" of the waste management issues (Patton, M.Q. 2002). Interviews enhanced our project by providing specific examples of potential locations, demonstrated level of interest of those involved, and led to site visits allowing us to better envision the possibility of an installation within the Saratoga Lake Watershed. As an interview based conceptual analysis, the triangulation of results examining different perspectives provided the most realistic analysis of installation. The International Development Research Centre highlights the importance of triangulation in qualitative research by stating that it "validates and improves confidence in research findings" (2010). As interviewing can be the most complex form of data collection, we followed the recommendation of past qualitative research studies to tape our interviews and record transcripts as soon as possible following the interview (Interviews, 2006). The process of recording and transcribing leads to reliable and accurate results in our qualitative study.

For background information, we began by speaking with Kathleen O'Connor of the Albany office of NYSERDA to better understand the science behind anaerobic digestion as a renewable energy option. From this conversation, we identified local facilities that have successfully installed anaerobic digestion systems. This conversation took place on Wednesday, December 8, 2010, in the Dana Science Center on the campus of Skidmore College. We also held a follow up interview on Thursday, February 10, 2011 to discuss revisions to our original project proposal and an interview on Tuesday, April 12, 2011 to discuss potential funding from NYSERDA and other entities.

The most successful case that O'Connor mentioned was the Gloversville-Johnstown Joint Wastewater Treatment Plant (GJJWWTP). Based on the documented success of this plant and its involvement with NYSERDA, we interviewed George Bevington, manager of the GJJWWTP. Using interviews as our method of data collection allowed us to gain perspectives on the hurdles faced in installation and operation. Our interviews took place on Thursday, February 4, 2011 and Thursday March 24, 2011 at the GJJWWTP facilities. These interviews were tape recorded for accuracy in transcribing, and our visits included a tour of the plant.

After our second conversation with Bevington, he recommended that we work with Rob Ostapcuzk, Senior Environmental Engineer, and Malcolm Pirnie, with the Water Division of Arcadis, a consulting firm working for the GJJWWTP. We interviewed Ostapcuzk on Saturday, March 26, 2011 and Sunday, April 3, 2011 to define the scope of our research and identify a potential partnership with him and his work on the SCSD Board. This interview was informal, but taped for our transcribing purposes, and notes were taken at the time of interview.

From this conversation, we identified sources with the greatest potential as input materials for an anaerobic digestion system at the SCSD plant. The food sources we identified included local colleges and universities, local food and beverage processors, and smaller wastewater treatment plants nearby. Focusing on Skidmore College as an example college from which to extrapolate data, we interviewed Riley Neugebauer, the sustainability coordinator of Skidmore College, on March 28 2011. From this conversation we received data on the food waste audit conducted at Skidmore College which we extrapolated to local colleges with similar percentages of undergraduates living on campus. To determine food waste per student we divided total food waste per week by the number of undergraduate students. While we realize that Skidmore's staff, faculty, and visitors also produce waste in the dining hall, we had to make the assumption that calculating food waste per student would give an accurate representation when extrapolated to larger schools. This calculation may be skewed due to the fact that first and second year students living on campus at Skidmore are required to purchase unlimited meal plans which may increase the frequency of visits to the dining hall, thus increasing the amount of food waste per person generated. As a small campus, Skidmore students may eat in the dining hall at a varied rate to those students attending larger schools, a factor we could not account for in our calculations.

To understand the social feasibility of an installation project, we interviewed Sue Duff, Chief Operator, and Jim Dipasquale, executive director of the SCSD Sewer Treatment Plant throughout February and March 2011 over the phone and visited the plant on April 21, 2011. From these phone interviews and our plant visit, we were able to request detailed information on the plant's current operations including flow rates, sludge composition, and financial data. By having multiple informal phone interviews, we also were able to gauge the directors' levels of interest in anaerobic digestion and learn about future plans for the plant.

In order to calculate the potential electrical and thermal energy output of the SCSD plant, we used calculations based on industry and historical standards as advised by Rob Ostapczuk. While not precise, these equations give a rough estimate of the potential electrical and thermal generation based on current waste and the addition of offsite feedstock. In Ostapczuk's work creating conceptual analyses and feasibility studies, the accepted margin of error ranges from 30-50% as compared to a final feasibility study with 15-25% margin of error (Ostapczuk, Personal Interview, 2011).

4. CASE STUDY: GLOVERSVILLE-JOHNSTOWN SUCCESS STORY

"The initial purpose of installing the AD system was just to deal with the sludge issue but now we are looking at the question of whether we can become completely sustainable based on the energy created from the digesters."

- George Bevington, Manager, Gloversville Johnstown Joint Wastewater Treatment Facility

4.1 Plant History

Located 35 miles from Saratoga Springs, the Gloversville Johnstown Joint Wastewater Treatment Plant (GJJWWTP) installed its first anaerobic digestion system in 1900 to handle the intense content of waste from the local leather industry due to its high biological oxygen demand (BOD). Waste with high BOD levels can overwhelm an aerobic system, decreasing the capacity of waste the plant can handle. By installing anaerobic digesters that thrive on high BOD substances, the plant could function far more efficiently without altering its inputs from the leather industry (Bevington, Personal Interview, 2011).

In 1990, the price of electricity was low enough that the plant did not consider anaerobic digestion an economical or environmental asset but rather a practical solution to the current issue of waste management. As energy prices began to rise, however, the Gloversville-Johnstown WWTF began to face a crisis as the local leather industry, bringing with it the high BOD waste upon which the anaerobic digesters depended, closed down. Needing to sustain operations, the plant operators began seeking alternative sources of high BOD waste from neighboring communities and WWTFs. Luckily for the Gloversville-Johnstown WWTF, local, smaller WWTFs were often happy to redirect their high BOD waste to Gloversville as the waste was presenting issues for their aerobic systems. Receiving this trucked-in waste as a supplemental source allowed Gloversville-Johnstown to maintain the operations of the anaerobic digesters (Bevington, Personal Interview, 2011).

In another stroke of luck, a new Greek yogurt company, Fage Yogurt, was looking for a place to establish its first United States manufacturing plant. Partially due to promotion of the anaerobic digester's ability to process whey waste, Fage picked a location within 1 mile of the GJJWWTP. Due to this close proximity and the public status of the plant, the municipality funded a direct pipeline from Fage's manufacturing plant to the GJJWWTP, aiding in the convenience of waste treatment. The whey waste from this food processor has an average BOD of roughly 30,000 milligrams per liter (mg/L), as compared to the 100,000 mg/L found in waste from beer or fountain soda processing, or the 150 mg/L found in municipal waste from residential toilets (Bevington, Personal Interview, 2011).

Due to the addition of food waste as a feedstock, the GJJWWTP has been able to not only support the use of the original AD system but even replace this outdated technology with two new AD engines in a 2009 plant improvement project. Prior to this upgrade, the plant generated a small amount of electricity with smaller engines, but most of the biogas the plant flared the generated biogas from existing AD operations. The addition of two engines enabled the plant to begin utilizing the biogas to generate electricity. As a result, the plant's dependence on the electrical grid has declined due to its onsite electrical production.

4.2 The 2010 Upgrade to the Anaerobic Digestion System

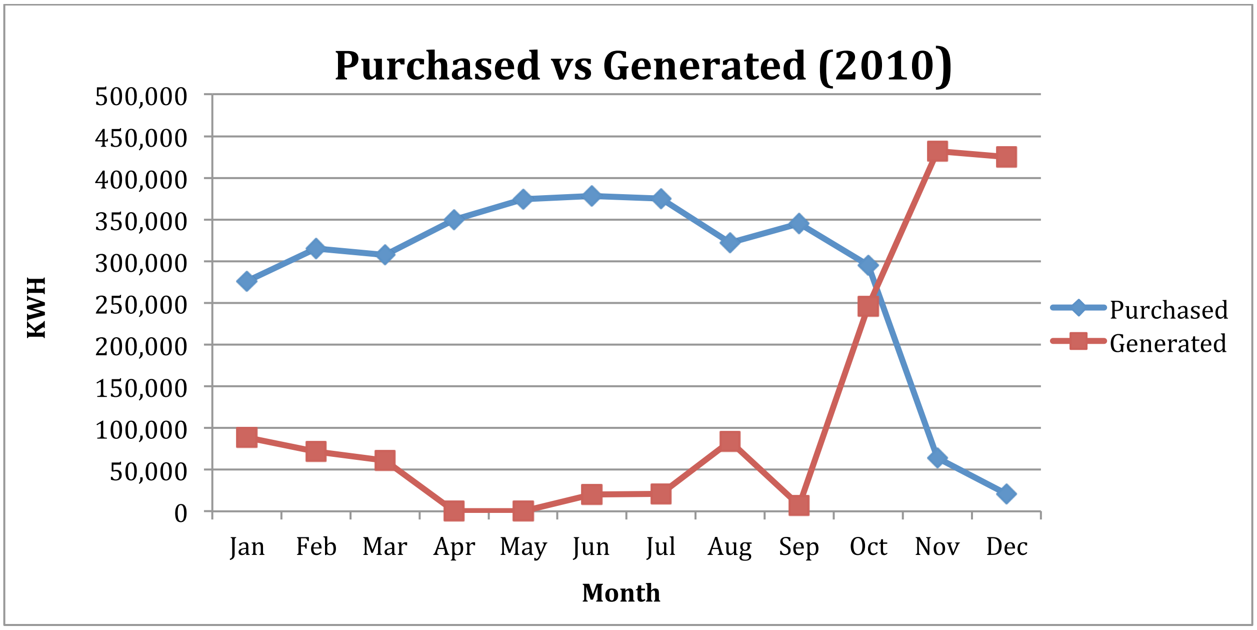
"I didn't choose to be in the energy business, but why the heck not?"

- George Bevington, Manager, Gloversville Johnstown Joint Wastewater Treatment Facility

Based on the success of the original anaerobic digesters, in 2010 Gloversville-Johnstown underwent an extensive upgrade project to expand capacity with the addition of two 350kWh engines to power the system. These engines function based on a combined heat and power (CHP) system. The heat that comes off of the engines, operating at 85% efficiency, is sufficient to keep the anaerobic digesters at a relatively constant 98 degrees Fahrenheit the temperature necessary for digestion processes to take place. Through this heat generation, the plant does not need to purchase natural gas from external sources for operation. The two engines combined create 700kWh of electricity to help run daily operations. For the year 2010, a total of 3.4 million kWhs of electricity was purchased, a higher than usual figure due to the months of downtime during installation. Since installation was completed, however, only a small fraction of energy must be purchased as the AD system produces an average of 7.8 million cubic feet of biogas per month, which generated approximately 401,401 kWh in March of 2010 (Bevington, Personal Interview, 2011).

This project, which cost $10.5 million to complete, was funded largely by federal and local grants. The Economic Development Administration (EDA) provided $2.2 million, NYSERDA provided $1.4 million, and the NYS Environmental Facilities Corporation gave a $6 million Green Innovation Grant, for a total of $9.6 million in funding. The Gloversville-Johnstown plant's manager Bevington admits that the funding the plant received was incredibly beneficial in terms of the short payback period. Due to the quantity and intensity of input materials, however, the plant would have needed to complete the upgrade project regardless of funding to remain operable. (Bevington, Personal Interview, 2011).

Figure 3: Gloversville-Johnstown WWTF -- Purchased Vs. Generated Electricity



Source: Gloversville-Johnstown 2010 Annual Report

4.3 Project Outcome

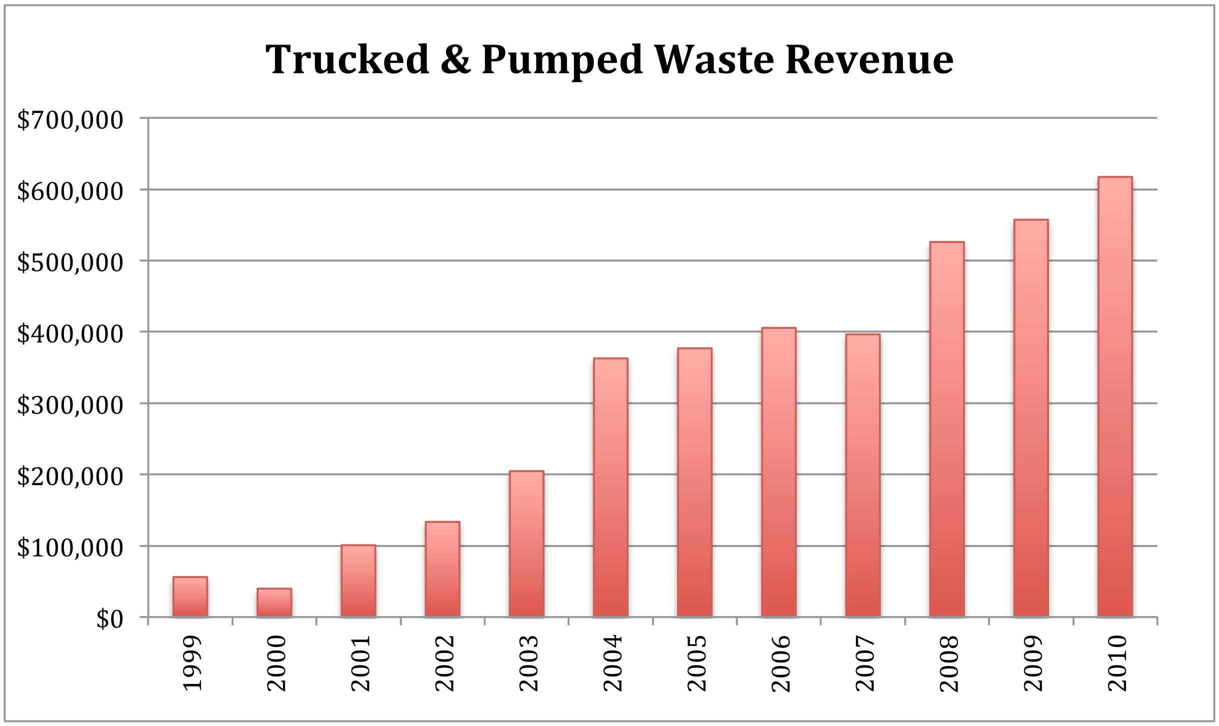
"I was initially a bit nervous we wouldn't have enough waste to power the digesters and the two engines, but in the past 5 months we have had enough or excess. Now, I'm almost kicking myself for not putting in three engines!"

- George Bevington, Manager, Gloversville Johnstown Joint Wastewater Treatment Facility

According to the 2010 Annual Report, the AD installation at the Gloversville-Johnstown plant proved economically successful and sustainable due to the increase in energy produced on site leading to a drastic reduction in electricity purchased. As shown in Figure 3, starting in October of 2010, once the system was fully operable, the plant began generating significantly more energy than was purchased. In addition to revenue earned by offsetting electrical costs, the plant increased revenues from trucked and pumped waste from $555,262 in 2009 to $815,275 in 2010 while simultaneously decreasing sewer rates to approximately 2-4 cents per gallon depending on the location of the user, a rarity for municipal WWTFs according to Bevington (Personal Interview, 2011). Due to its proximity and direct pipeline, Fage Yogurt pays only 2.2 cents per gallon to dispose of its waste, yet due to the energy value of its waste, contributes over 50% of the plant's trucked revenue and 25% of the plant's Operation & Manufacturing Revenue (See Figure 4) (Gloversville Johnstown Annual Report, 2010).

Based on the $1.5 million initial capital investment needed by the GJJWWTP after national and local funding was provided, the plant experienced a payback period of less than two years. This was made possible by stimulus funding coupled with a reduction in energy spending by $550,000 in the first year of AD operation, reducing the annual electrical bill from $600,000 to $50,000 (Bevington, personal interview, 2011). Without the available government funding, the project's payback period would have been 19 years, however, the plant is almost entirely finished paying the installation costs and poised to begin making a profit due to trucked revenues and its savings on electricity. Despite the fact that the facility is on average 95% energy independent, and produces upwards of 100% of its own energy, the plant has elected to remain attached to the local power company. Bevington explains this decision as strategic by avoiding the extensive and costly process of disconnecting from the local electrical provider. By maintaining a connection to the grid, the plant also has greater flexibility and dependability as in times of routine maintenance or emergency shut downs, the plant does not experience any changes in operation. In terms of digester load, even with the absence of the leather industry rather than searching for new feedstock, Gloversville-Johnstown now finds itself even turning away additional offers for waste as they have reached their capacity for the current AD system. Bevington mentioned in passing that due to the high level of biogas currently created and projected growth of waste volume, the plant could benefit from the installation of an additional engine within the next couple of years. This installation would enhance energy independence with the possibility of excess electrical production (Bevington, Personal Interview, 2011).

Figure 4: Annual Revenue from Truck and Pumped Waste



Source: Gloversville-Johnstown Joint Wastewater Treatment Plant 2010 Annual Report

4.4 Special Circumstances

"Anaerobic digestion is not needed everywhere, but where it can be used, the impact and savings are immense"

- George Bevington, Manager, Gloversville Johnstown Joint Wastewater Treatment Facility

The Gloversville-Johnstown plant experienced phenomenal environmental and economic benefits from the installation of an AD system. This phenomenal success can be attributed to specialized circumstances helping to make anaerobic digestion a profitable reality. The plant had a unique historic scenario in which switching to anaerobic digestion was a necessity rather than a strategic decision. Regardless of what funding opportunities were available, the plant needed to install an anaerobic digester in order to handle the high BOD waste that it was receiving at the time. The Gloversville-Johnstown plant also has the exceptional resource of Fage Yogurt located less than a mile from the WWTF making direct piping of waste materials possible. Due to the close proximity and high BOD content of whey, the Gloversville-Johnstown plant recognizes 59% of its trucked and pumped waste revenue from Fage alone, equating to roughly $900,000 towards the plant's annual revenue (see Figure 4). In terms of biogas generation, the high BOD content of Fage's whey waste makes Fage responsible for 95% of Gloversville's total biogas creation annually (Bevington, Personal Interview, 2011). Fage's unprecedented growth helped the Gloversville-Johnstown plant achieve its success.

In conversation with Ostapczuk regarding this success, he stated that Gloversville-Johnstown is only one out of five WWTFs nationwide that can effectively operate independently from the electrical grid. Despite these exceptional circumstances, each municipality has the opportunity to experience a similar payback period by pursuing the best available local options for feedstocks. Anaerobic digestion, as a localized renewable energy solution, must be customized to best suit the needs of an individual WWTF based on available feedstocks.

5. CONCEPTUAL ANALYSIS

"They [SCSD] have expertise, great resources, and a strong staff for anaerobic digestion installation but 'you don't think outside the box unless you have a problem"

- George Bevington, Manager, Gloversville Johnstown Joint Wastewater Treatment Plant

5.1 Saratoga County Sewer District #1 Sewer Treatment Plant Current Operations

"There is no economic incentive for us to change"

-Sue Duff, Chief Operator, Saratoga County Sewer District #1

Current operations at the SCSD #1 Sewer Treatment Plant rely on aerobic processes, using bubble aeration followed by sludge incineration. Once the sludge has been incinerated, the remaining ash is transported on an annual basis to a landfill in Seneca Falls, located 193 miles away from the plant. According to Sue Duff, Chief Operator the SCSD plant, "the landfill is local in the sense that it is still in New York State" (Duff, 2011). The SCSD plant produces an average of 1,200-1,300 tons of ash waste every year through incineration. Saratoga County has a contract with waste disposal companies such as New England Organics and Troy Soils that is renewed or changed every 3 years for the disposal of ash. In order to dispose of the ash, the SCSD plant pays a tipping fee of $50 per ton, amounting to an annual cost of roughly $60,000-$65,000. In addition to tipping fees, the plant faces steep energy costs in order to keep the incinerator running. The incinerator relies on oil, which is kept onsite. The plant's operations manager has been satisfied with the aerobic process followed by incineration stating that "beyond the cost of oil rising, it's a totally affordable process" (Duff, Personal Interview, 2011). With the cost of oil continuing to rise, however, current practices may prove unsustainable into the future.

5.1.1 Flow Rate and Composition

District 1 currently processes approximately 12-13 million gallons per day (MGD) of wastewater from a service radius of 100 miles, which includes 80 pump stations (see Figure 6). The amount of influent varies largely based on season, increasing in the fall and spring months. As shown in Table 4, between January 3rd, 2010 and March 23rd, 2011, the average daily flow was roughly 19.59 MGD. During this period, the influent had an average of 2.98% primary sludge solids and 84.99% of primary sludge volatile solids.

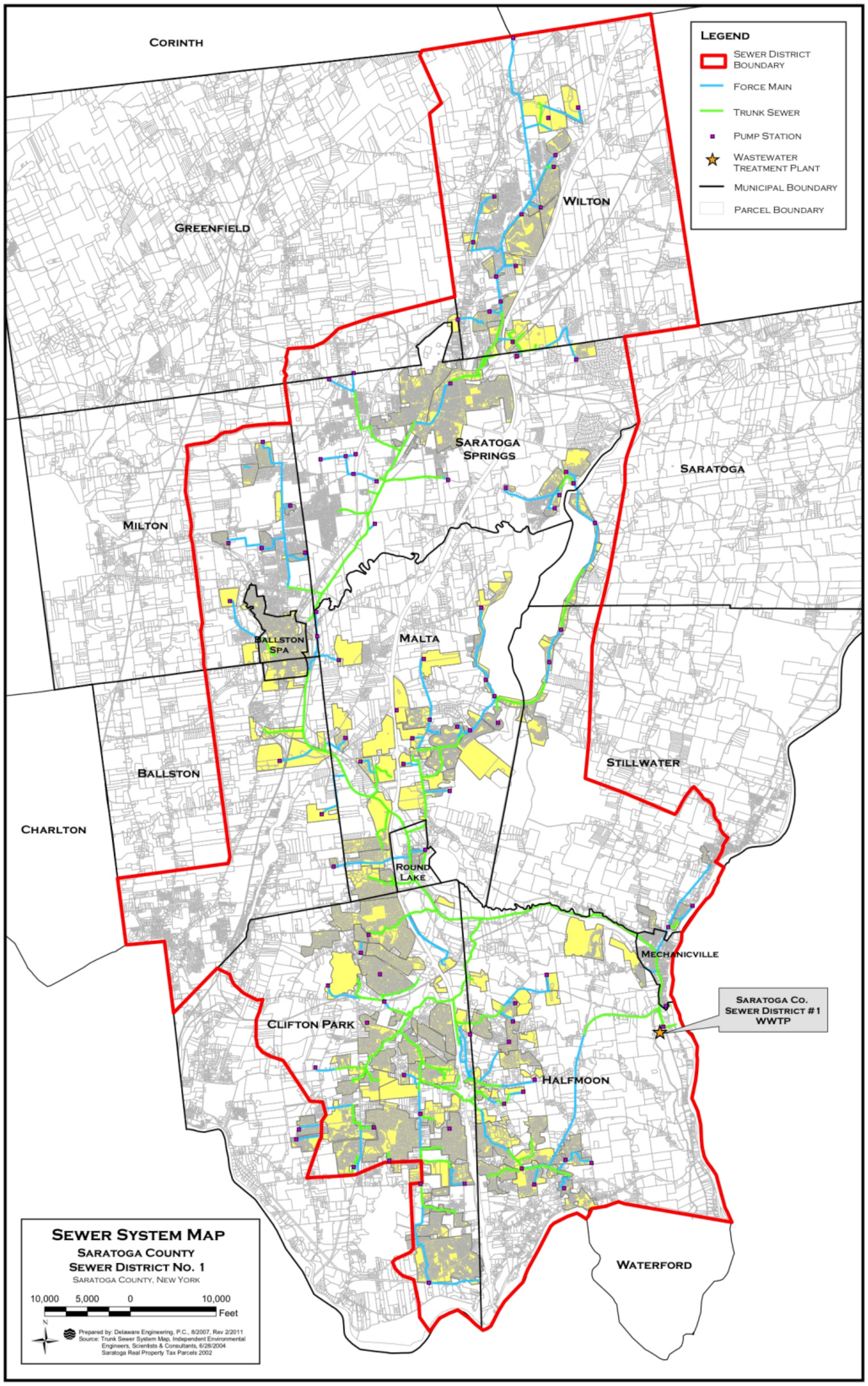
Table 4: Inflow Composition Averages

1/3/10-3/23/11	FLOW (MGD)	Primary Sludge % Solids	Primary Sludge % Volatile
Averages	19.588	3.291	84.411

Source: Saratoga County Sewer District 1 Report

The impact of Global Foundries, the new computer chip manufacturing plant in Malta, within SCSD's service area, will have an immense impact on the amount of inflow to the plant. The Global Foundries chip plant is currently the largest construction project in the nation and is projected to create 1,400 jobs (Fannin, 2010). County officials anticipate immense urban development in the region as new residences are constructed and businesses concentrate in the area (McCarty, 2010). Sue Duff estimates an increase of 3.1 MGD during the first stage of the Global Foundries project, and an additional 10 MGD when the project is completed, which will roughly double the amount of current influent. To handle this increase in waste, the plant has completed construction of a $55 million expansion.

Figure 6: Saratoga County Sewer District #1 Map of Service



Source: Sue Duff, Saratoga County Chief Operator

5.2 Sewer Rates

"Our rates are competitively low; they've just been the same forever"

-Jim Dipasquale, Director, Saratoga County Sewer District #1

Chief Operator Sue Duff explained that the sewer rates charged to the plant's users vary by location. Generally, the further away the user is from the plant, the greater the sewer rate. This variance in price structure is based on the number of pump stations that waste must pass through; the greater the number of pump stations used, the higher the sewer rate. Users are permitted to send a certain volume of influent to the plant at a flat annual rate; however, if users exceed this limit, additional steeper fees are charged. Jim DiPasquale admits that plant users Stewarts Dairy and Quadgraphics typically exceed their allotted BOD and must pay fees to accommodate this additional burden. Sewer rates are calculated based on a general formula for residential and commercial operations. Residential, commercial offices and restaurants are each charged $25 per unit of waste, units varying based on the operation. Residential units are determined by SCSD's scale of charges based on the number of pump stations used. The units for office spaces are calculated by multiplying square feet by 0.1 / 200 or 2 units for each bathroom, whichever number is higher. Units for restaurants are determined by multiplying the number of seats by 35 and dividing that number by 200 (SCSD, 2010). Annual fees vary greatly; the lowest rate is $190 per year for a facility or residential area with low intensity waste located close to the plant. For the year 2011, fees have increased by $40 per user to help compensate for the $55 million investment the municipality made in the plant's recent upgrade project.

5.3 Energy and Budget

"The attitude of 'we're not in the energy creation business' is short sighted, no one can stay in business if they can't adapt to energy trends"

-Georges Alexis, Founder and President, ECO NRG Green Stream Energy Solutions

Now that the expansion project has been completed, the plant's energy demand has risen to approximately 900 kWh per month. The plant purchases this electricity from the local utility, for an annual cost of $1,144,089 for waste treatment alone. As shown in Table 5, the SCSD plant's average daily inflow is more than double the inflow processed by the Gloversville-Johnstown plant. Since SCSD does not generate electricity on-site, its electrical costs are 16.8 times higher than the Gloversville-Johnstown plant. Both plants also underwent large upgrade projects in the past 2 years; however, the cost of the Gloversville-Johnstown's project was $10.5 million, only $1.5 million of which the plant paid directly, while the Saratoga upgrade project cost $55 million, which the municipality paid in full (See Table 5).

Table 5: Physical and Chemical Inflow Comparison

WWTF	Treatment System	Average Capacity (MGD)	Cost of Last Renovation	Cost Paid by Plant	Annual Energy Costs
GJJWWTP	Anaerobic	5.6	$10.5 million	$1 million	$50,000
SCSD	Aerobic	12.5	$55 million	$55 million	$1,144,089

Sources: Personal interviews with operation directors George Bevington (GJWWTF), Sue Duff (Saratoga WWTF), and the GJWWTF 2010 Annual Report

The SCSD plant would not be able to install the same AD system as Gloversville due to differences in inflow and types of influent. The purpose of this conceptual analysis will be to identify the quantity and energy content of existing and potential sources of feedstock for the SCSD plant, in order to determine feasibility of installation of an anaerobic digester based capital requirements and cost savings.

5.4 Potential Feedstocks

"We started knocking on doors for waste, now we have to turn people away"

-George Bevington, Manager, Gloversville Johnstown Joint Wastewater Treatment Facility

An anaerobic digester can process a wide variety of organic waste, or feedstocks. However, certain feedstocks have a higher energy potential than others. Broadly, the more putrescible the material, the higher the potential yield in biogas. Food waste, both solid and liquid, is particularly attractive for AD systems based on its high chemical oxygen demand (COD) content. Food waste has a COD content ranging between 200,000 to 300,000 milligrams per liter (mg/L) (Zitomer, 2009). If the material has a higher COD content, then it will have a greater energy content to fuel for anaerobic digesters. Food waste has a relatively high COD loading, with a COD level of 1.25 lbs/ft^3/day or greater in comparison to 0.06-0.30 loading found in municipal wastes (EPA, 2010). As a result, food waste yields 376 cubic meters of methane of biogas per ton, three to five times the amount of methane generated from biosolids and fifteen times that of cattle manure (EPA, 2010). This high COD level makes food an environmental burden in landfills, due to elevated levels of methane emissions, but an asset to WWTFs if incorporated into an AD system as fuel.

The Gloversville-Johnstown plant relies on liquid waste from food, beverage and dairy processors. Due to the prevalence of higher education institutions, restaurants and grocery stores within Saratoga County, food waste proves an accessible form of waste, and potentially the key to success at the SCSD plant. As a result, our study focuses specifically on solid food waste as a potential feedstock for an AD system at the SCSD plant.

In a 2004 pilot project conducted in Oakland, CA, the East Bay Municipal Utility District (EBMUD) began redirecting solid food waste to its anaerobic digesters to supplement municipal and industrial wastes and found that "not only did the machines seem to work better with food, they also found that the food increased three-fold the amount of methane they were capturing" (EBMUD, 2010). With the maximization of biogas, the plant has been able to achieve immense cost savings that result from on-site electrical and thermal generation. The application of a combined heat and power (CHP) system has enabled EBMUD to utilize the biogas to heat its facilities, while generating the needed kilowatt-hours of electricity. Supplementing the existing influent with food waste proved to be EBMUD's ticket to economic success, as it now generates roughly 90% of its electricity on-site. Prior to co-digesting food, the anaerobic digesters only generated 40-50% of the plant's total electrical demand (EBMUD, 2010). The EBMUD model clearly demonstrates that the successful co-digestion of food waste is not limited to liquids, as processed at the Gloversville-Johnstown WWTF, but also includes food solids. Based on the EBMUD model, the installation of an AD system at the SCSD plant, with the incorporation of additional food waste (pre and post-consumer) from local sources could result in enormous economic and environmental benefits.

5.4.1 Local Colleges and Universities

In extrapolating from the success of the EBMUD model, our study chose to focus on the evaluation of food waste from college campuses. We chose this resource as college campuses have centralized dining operations, which produce significant waste streams. The existing literature on AD systems and their economic feasibility focus on an underlying idea that AD systems are the most successful at operations that create a large amount of waste. In building on this idea, we suggest that it is more economically practical to focus on diverting waste to a

WWTF from a few entities with a large waste stream, rather than collecting waste from numerous small sources. Logistically, it would be simpler, and hauling costs associated with collection and transportation would be minimized.

Competing with the need to decrease costs, higher education institutions are similarly under pressure to maintain high environmental rankings through improvements in sustainability associated with campus operations. A College Sustainability Report Card even assigns schools grades A-F based on initiatives on campus by category. These categories include administration, climate change and energy, food and recycling, green buildings, student involvement, transportation, endowment transparency, investment priorities, and shareholder engagement. By initiating a program in which campus food waste was diverted to a renewable energy system, colleges can improve sustainability rankings in the "energy" category without making a large financial investment. A 2009 survey of over 1,700 students at a diverse group of nine campuses by researchers at the College of William and Mary found that "current freshmen are two times more likely to choose their school based on sustainability concerns than the entering freshman class just 3 years ago" (AASHE, 2009). As a result, diverting waste for the generation of energy would enable local participating colleges to remain competitive in the world of higher education institutions attempting to attract a wider applicant pool.

5.4.1.1 Skidmore College

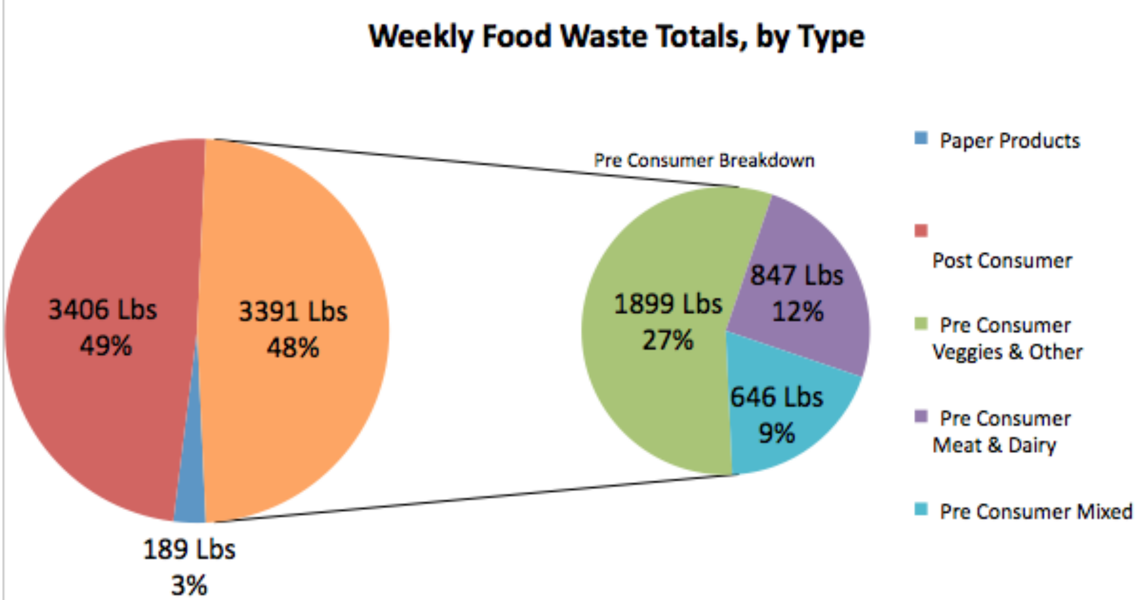
"Skidmore will enhance our ability to function as a socially and environmentally responsible corporate citizen…increase our emphasis on responsible planning for sustainable operation…and reduce the College's "environmental footprint."

-Skidmore College, Strategic Plan

In recent months, students and faculty members have begun addressing alternative options for food waste on campus by conducting an in-depth food waste audit at the campus' central dining hall. This audit reported a total of 6,986.5 pounds of food waste per week generated from the dining hall. As shown in Figure 8, of this weekly waste, 6,797.25 pounds or 97.3% came from pre or post-consumer waste.

Currently, Skidmore College sends the majority of its food waste from the Murray-Aikins Dining Hall to the SCSD plant via trash disposals. However, Rob Ostapczuk has indicated that by adding food waste to the existing stream of influent via pipelines, the energy potential of the waste is in fact reduced. If food waste were to be collected and inserted into the digester directly, the energy conversion would be significantly more efficient (Ostapczuk, Personal Interview, 2011). Further, the waste audit conducted by Skidmore College indicates that some of the food waste is currently thrown in the trash.

Figure 8: Food Waste by Type



Source: Skidmore College 2011 Food Waste Audit

As explained above, pre and post-consumer food waste is an ideal feedstock for anaerobic digestion systems due to its high energy potential and ability to maximize biogas production. Considering that half of the weekly food waste comes from pre-consumer products, the food audit also analyzed the source of the food waste, whether it came from the kitchen or the dining hall (Figure 8). The breakdown of sources of food waste shows that roughly equal amounts come from plate waste as opposed to waste generated in the kitchen. This finding shows that if the college wanted to regulate food waste based on behavior alone, simple outreach and education programs encouraging students to only take food they plan to finish would not be sufficient to address the roughly 49% of food waste coming from the kitchen's operations. A waste solution like anaerobic digestion would not require a change in current student, faculty, or kitchen staff behavior to achieve sustainability measures and reducing costs. In this case, the infrastructure would remain unchanged as the college currently sends all of its food waste via direct pipeline to the SCSD Plant. Alternatively, the college could choose to separate their food waste which would involve additional funding, but would allow for a more energy intensive input to the digester. Based on the relatively lower trucking fee to SCSD as compared to the landfill utilized by Skidmore College, this rise in cost may be negligible.

5.4.1.2 Additional Local Colleges/ Universities

In order to assess the availability of food waste from local colleges, we conducted a search within a 45-mile radius of the SCSD plant. The colleges and universities included in this radius with residential students include: Skidmore College, Union College, Rensselaer Polytechnic Institute, SUNY Albany, College of St. Rose, and Siena College. While we examined a 45-mile radius, each of the seven colleges we identified are no more than 21.3 miles from the SCSD plant. In order to estimate the amount of waste produced at each of these colleges, we extrapolated from the Skidmore Food Waste audit.

To calculate per capita food waste at Skidmore College, we divided the amount of waste per week by the total number of undergraduates living on campus, which equated to 3.074 pounds. We then multiplied this per capita waste with the number of students living on campus for each respective college to find the approximate total waste per week. After excluding a week for spring break, we found that each semester has roughly 14 weeks in which students are on campus. Thus, the calculated total annual food waste is the amount of waste during an academic year. We then divided the annual waste by 196 days (28 weeks multiplied by 7 days) to find the total daily food waste for each college. In our calculations, we make the assumption that food waste per undergraduate student living on campus for Skidmore College can be applied to the other institutions and that each school operates using a 28-week academic calendar.

According to our calculations, the combined food waste available within a 45-mile radius of the SCSD Plant within New York State is 58,251.17 lbs/week or 1,631,032.69 lbs/academic year assuming a 28-week academic calendar for all participating colleges and universities (see Table 8).

Table 8: Local Colleges

School	Undergrads	Grads	Total	Percent undergrad students on campus	# of Undergrads Living On Campus
Skidmore College, Saratoga Springs	2,674	0	2,674	85.00%	2,273
SUNY Albany, Albany	13,114	5,090	18,204	57.00%	7,475
Union, Schenectady	2,240	0	2,240	87.00%	1,949
RPI, Rensselaer	5,629	1,272	6,901	59.00%	3,321
College of Saint Rose, Albany	3,048	2,082	5,130	38.00%	1,158
Siena College, Loundonville	3,285	0	3,285	76.00%	2,497
Sage Colleges, Albany	749	150	899	37.00%	277
Total	29,990	8,594	39,333		18,950

Sources: *US News College Facts*

Table 9: Food Waste Extrapolation

School	Approx. Total Waste / Week (lbs)	Approx Waste Per Student (lbs/week)	Total Annual Food Waste	Total Daily Food Waste
Skidmore College, Saratoga Springs	6,986.50	3.07	195,622.00	998.07
SUNY Albany, Albany	22,978.09	3.07	643,386.48	3,282.58
Union, Schenectady	5,990.61	3.07	167,737.11	855.80
RPI, Rensselaer	10,209.09	3.07	285,854.58	1,458.44
College of Saint Rose, Albany	3,560.43	3.07	99,692.03	508.63
Siena College, Loundonville	7,674.55	3.07	214,887.36	1,096.36
Sage Colleges, Albany	851.90	3.07	23,853.13	121.70
Total	58,251.17		1,631,032.69	**8,321.60**

Sources: *Skidmore College 2011 Food Waste Audit*

5.4.2 Food Sector

"Stewarts consistently exceeds the allotted BOD limits and must pay additional fees for the burden this causes on our treatment system"

-Jim Dipasquale, Director, Saratoga County Sewer District 1

While we focused specifically on food waste from higher education institutes for our report, by no means would it be the only additional sources of high COD feedstock capable of fueling an anaerobic digester. Currently, Stewarts Dairy uses the SCSD plant for waste disposal. Dairy waste, primarily whey, has a particularly high COD content in comparison to traditional municipal wastes handled by the plant. In an interview with SCSD Chief Operator, Sue Duff, she mentioned that the high COD content of Stewart's has not proved to be an issue thus far. Despite this statement, the high COD level may eventually cause issues in processing as aerobic processes are not often designed to handle waste of this intensity. If a digester were to be installed, however, the dairy waste from Stewarts could prove a valuable asset to SCSD's operations by providing waste with a high energy content to help run the plant through thermal and electrical energy generated via combined heat and power engines.

Considering additional sources that do not already enter the plant via pipeline, the multitude of restaurants throughout Saratoga County, especially in downtown Saratoga Springs, could offer a daily stream of food waste. In the case of the Oakland, CA digester, a truck collects pre and post-consumer food waste from local restaurants, food handling facilities and grocery stores, and deposits it at the EBMUD anaerobic digester (EPA, 2010). If SCSD implemented a similar waste collection system, rather than decomposing in landfills, restaurant waste could supplement the anaerobic digesters, increasing efficiency and improving the sustainability footprint of local restaurants, many of which strive to achieve high rankings in the green food industry.

Local supermarkets including Price Chopper, Hannaford, and Wal-Mart's grocery section all represent additional opportunities to contribute to an AD system at the SCSD plant. Senior purchasing agent for Price Chopper, Linda Moffett emphasizes Price Chopper's commitment to corporate social responsibility, stating that, "Price Chopper has always been proactive in recycling and environmental management, and we currently recycle OCC, paper, plastic bags and shrink wrap" (BioCycle, 2008). Past commitment to organic waste management is embodied in the fact that Price Chopper was the first grocery chain to contract for composting. This prior commitment makes Price Chopper a strong potential candidate for future improvements through anaerobic digestion. With Price Chopper leading the way, other local branches of food suppliers such as Hannaford and Wal-Mart will need to follow suit in order to maintain a level of competitiveness in the green marketplace.

5.4.3 Other Potential Digester Inputs

In the case that the identified universities choose not to participate in a waste to energy program at SCSD, or if the plant seeks to further maximize biogas production, there are a number of other sources of waste that could serve as digester fuel including food and beverage processors, food handling facilities, industrial wastes, and other smaller wastewater treatment facilities. The SCSD plant currently processes high COD industrial waste from Cascade paper recycling plant, Quadgraphics and Esty Metals. Rather than putting a strain on current aerobic processes, by installing an anaerobic digester, the high COD content would serve as an asset to the plant by providing additional valuable feedstock for the digester to process. With the addition of Global Foundries to SCSD's network of users, the amount of high intensity industrial waste may continue to increase drastically, further justifying an effective system of treatment that benefits from, rather than becomes hindered by, high intensity industrial wastes.

Another possibility for additional sources of waste would be contracting to receive the sludge post-aerobic treatment from smaller WWTFs. Due to a lack of economies of scale, smaller WWTFs often do not have anaerobic digesters installed. As a result, they are forced to either incinerate or truck their remaining sludge to a landfill. Since post-aerobic sludge has a higher COD content than influent it could be a valuable feedstock for the SCSD digester. George Bevington has mentioned that the Gloversville-Johnstown plant has contracted with other WWTFs in the past to receive its sludge, proving that despite social challenges involved with waste treatment boundaries, this type of arrangement has proven to be successful at the Gloversville-Johnstown WWTF in the past.

6. MEETING THE TRIPLE BOTTOM LINE

6.1 Economic Assessment

"The take home lesson is that you need to spend money to save money, but the savings come quickly with anaerobic digestion."

- George Bevington, Manager, Gloversville Johnstown Joint Wastewater Treatment Facility

6.1.1 Revenue

Revenues for anaerobic digesters can come from any combination of the following sources: energy (electricity, heat, gas); secondary products (compost, liquid fertilizer, landfill cover); tipping fees (landfill disposal offset); additional feedstock material; and renewable energy credits (RECs).

In order to calculate the electricity potential of existing sludge at the SCSD plant and the incorporation of off-site food waste from the seven colleges we identified, we had to calculate the total volatile solids of each feedstock. Based on data received from the SCSD on primary sludge and WAS flow, we calculated the total volatile solids (VS) for 304 days[1] and found that there is an average of 14,665 pounds of VS per day, as shown in Table 10. In order to calculate the VS of food waste, we made the assumption that 4,160.8 pounds of food waste, or 50% of the seven colleges' food waste, would be diverted to the SCSD plant. With an average COD content of 350,000 mg/L, we calculated that the addition of food waste would generate 17,333 pounds of VS per day.

Table 10: SCSD Sludge vs. Food Waste

Parameter	SCSD Sludge	Food Waste	Total Waste
Volatile Solids (lbs/day)	14,665	17,333	31,998
Total Solids (lbs/day)	17,108	4,160	21,268
Total Solid Feed (%)	6	6	
Flow (MGD)	0.034	0.008	0.0425
Volatile Solids Reduction (%)	65	65	
Sludge Retention Time (days)	15	15	

Source: SCSD Historic Records, Ostapczuk 2011

A pound of VS generates between 12 to 18 cubic feet (cf) of biogas. Based on the 14,665 total VS per day that SCSD receives, and assuming that a pound of VS will yield an average 15 cf of biogas, we found that SCSD could produce 142,981.65 cubic feet per day (cfd) of biogas, the equivalent of roughly 300 kW a day as shown in Table 11. If SCSD were to incorporate the 4,160.8 total pounds of food waste into the digester, electricity production would more than double to roughly 654 kW a day or roughly 5.15 million kWh per year. In terms of cost savings relative to electricity, the plant would save roughly $236,198 annually with the digestion of strictly municipal sludge (see Table 11). However, with the co-digestion of food waste, cost savings would rise to approximately $515,376. Thus, the co-digestion of the 4,160.8 pounds of food waste per day would result in a 218.2% increase in annual savings.

[1] SCSD provided data on their influent between January 1, 2010 and March 23, 2011. With some days omitted, data for 304 days was made available.

Roughly 40% of the BTUs generated could be recovered to heat the anaerobic digester, as it needs to be maintained at 98 degrees Fahrenheit. While there is potential that there could be excess thermal energy of the 3.12 BTU/hrs generated annually, which could be used to heat additional facilities on-site, we are unable to quantify the extent to which excess heat would be available. As a result, we do not calculate cost savings relative to heat generation.

Table 11: Electrical and Thermal Production

	Municipal Sludge Only	Municipal Sludge and Food Waste
COD Load		20,320.09
Digester Size (MG)	0.51	1.19
Biogas (cfd)	142,981.65	311,981.65
Biogas (btu/hr)	3,574,541.36	7,799,541.36
Heating (BTU/hr)	1,429,816.54	3,119,816.54
Energy (kW)	299.59	653.70
Annual Energy (kWh)	2,361,977.40	5,153,763.39
Annual Savings ($)	236,197.74	515,376.34
Green RECs Revenue ($)	59,049.43	128,844.08
Annual Economic Benefit ($)	295,247.17	644,220.42

Source: Ostapczuk, 2011

In addition to the $515,376 in cost savings from electrical production, the SCSD plant can generate revenue through marketing green renewable energy credits (RECs). RECs represent the environmental and non-power attributes of renewable energy production. They can be sold to third parties, as they enable the owner of the certificate to claim that a portion of their electrical. States are increasingly allowing utilities to purchase RECs in order to meet mandated state Renewable Portfolio Standards (RPS). Rather than generating renewable energy themselves, it is often more cost effective to purchase the "claim" to renewable electricity generation (EPA, 2008). In New York, for example, utilities must obtain at least 30% from renewable sources by 2015 (NYSERDA, 2010). The Massachusetts Water Resources Authority's Deer Island Plant received $1 million in the fiscal year 2008 from selling its RECs (MWRA, 2010). The SCSD plant could receive REC revenue of 2.5 cents per kWh produced (Ostapczuk, Personal Interview, 2011). As a result, the plant could generate an additional $128,844 in revenue per year. Thus, with the electrical cost savings and additional revenue that would stem from an anaerobic digester, the total annual economic benefits that would accrue to

SCSD would equal roughly $644,220 a year as shown in Table 11.

However, even this figure may not accurately reflect the annual economic benefits. Since the anaerobic digester would substantially reduce the volume of influent that would need to be incinerated, fees associated with disposal and incineration would be reduced. As mentioned previously, the incinerator at the plant currently produces an average of 1,200-1,300 tons of ash each year. In order to dispose of this waste, SCSD pays roughly $60,000 to $65,000 in tipping fees annually. Thus, the reduction of waste volume by 65% and the amount of ash produced would lead to annual cost savings of $39,000 to $42,250. Further, since the incinerator relies on oil, a reduction in the amount of waste to be incinerated would result in lower energy costs. Jim Dipasquale estimates that in 2010, fuel for the incinerator and heat at the plant equated to a cost of roughly $460,000. While we cannot exactly quantify the decrease in fuel costs associated with a reduction in incinerator dependency, we can confidently conclude that the savings would be considerable. Further, an increase in oil prices in the future could magnify these cost savings. Between 1998 and 2010, crude oil prices have risen from $14.40 to $79.65 average per barrel (ProQuest Data Sets, 2010). According to the International Monetary Fund, this steady increase in oil prices indicates that global oil markets have entered a period of increased scarcity which may lead to "skyward" prices and intense demand increases (Jamaica Observer, 2011). Increasing oil prices would place an additional economic burden on SCSD and further incentivize the installation of anaerobic digester to lessen their dependence on incineration.

Alternatively, SCSD could add an additional process to treat the digestate, the remaining material after bacterial digestion, and convert it into organic fertilizer. The digestion of influent and food waste would yield 8.9 dry tons and 53.4 wet tons of digestate per day. If the plant were to recycle and compost this waste, it would eliminate the need to incinerate the digestate. With the incinerator obsolete, any costs associated with its operation would be eliminated. Fertilizer could be sold to third parties or provided to the contributing users of the plant, i.e. colleges and universities. The conversion of waste into fertilizer is described in greater detail in the next section.

6.1.2 Costs

In speaking with Rob Ostapczuk, Senior Environmental Engineer at Malcolm Pirnie, and Chris Alexopolous at Milton Caterpillar Power Systems, it was estimated that capital requirements for the project would equate to roughly $8.2 million. Of the $8.2 million in project costs, $1,452,000 would fund the purchase of two 350 kWh continuous power Caterpillar engines, which would generate electricity and heat on-site (Caterpillar Inc., 2011; see Appendix Item 2). With a project cost of $8.2 million and annual economic benefits of 644,220.42, the payback period would be roughly 12.73 years without taking into consideration potential funding opportunities and increases in the cost of electricity. As we have seen with the Gloversville-Johnstown WWTF, labor and operational costs do not increase dramatically as the AD process is relatively standardized and does not require a major shift in procedures.

If the plant opted to compost the remaining sludge from the AD process into fertilizer, it would have to construct additional facilities to further refine the sludge. Ostapczuk estimates that the plant would assume an additional project cost of $1 million for the installation, and labor costs of $56,250 ($45,000 for salary and $11,250 for benefits) for the individual managing the composting process (Ostapczuk, Personal Interview, 2011). As mentioned previously, however, composting the sludge would make the incinerator obsolete thereby eliminating costs associated with its operation. The inclusion of composting facilities would lead to total project cost of $9.2 million. It would be impractical to cite a payback period with the inclusion of a composting facility due to a number of cost savings that we cannot quantify at this time.

6.1.3 Funding Opportunities

Government incentives, which can include tax credits, grants, low interest loans and price supports are often a determining factor for the economic feasibility of an AD instillation. The Gloversville-Johnstown facility benefitted from the federal stimulus funding available through the American Recovery and Reinvestment Act of 2009. Tax credits for AD installations, under the stimulus package, are available until December of 2011. At this stage, however, substantial completion of the project by December seems unlikely. Due to the timeframe of the project, funding from local sources such as the New York State Energy Research and Development Authority (NYSERDA) or the New York State Environmental Facilities Corporation would be critical.

Past funding for similar projects reveals that there are a range of funding opportunities for renewable energy projects in New York State such as the proposed anaerobic digester at the SCSD plant. The first venue for grants for this project comes from NYSERDA's programs of production and performance grants. The production grant awards new renewable energy projects such as an anaerobic digestion installation based on the electrical capacity of the system. The first half of the grant is provided to the recipient when the materials for construction arrive on site and the second half of the funding is received when the project has been commissioned (O'Connor, Personal Interview, 2011). The production payment is structured such that a project receives $1,000 for every kW of electrical capacity installed. As shown earlier, with the production of 653.70 kW per day – the SCSD plant would install two engines with a total capacity of 700 kW. With $1,000 per kW, SCSD would be eligible for $700,000 in NYSERDA production funding.

In addition to production funding, NYSERDA also provides grants based on performance. The performance-based payments provide $0.10 per kWh of electricity produced in a year, assuming 80% engine efficiency. For our proposed 653.70 kW of utilized capacity, the equation would be 653.70 (kW) * 365 (days in a year) * 24 (hours in a day) * .8 (efficiency) * .1 (cents) = $458,112 per year. Plants qualify for performance-based grants during the first three years of operation. NYSERDA, however, has a cap on total production and performance-based grants at $1 million. This means that performance-based grants could not exceed $300,000 for this project. By reducing the total project cost by $1 million, the capital investment required would decrease to $7.2 million, cutting the expected payback period to 11.18 years. Based on our conversations with Bevington at Gloversville-Johnstown, Ostapczuk at Malcolm Pirnie, and O'Connor at NYSERDA, we feel confident that SCSD can expect to receive at least $1 million in funding for this project.

Last month, NYSERDA also offered an opportunity for a $2 million grant for projects aiming to reduce the energy and carbon footprint of municipal water and wastewater treatment systems in New York State (PON 2202, 2011). For this grant, NYSERDA invited proposals targeting the development or demonstration of innovative technologies associated with anaerobic wastewater treatment, energy-efficient nutrient removal from wastewater, and harnessing electric power from water and/or wastewater treatment systems/processes (PON 2202, 2011). Considering these eligibility requirements, an AD system at SCSD would qualify as it includes anaerobic wastewater treatment, improves plant energy efficiency, and utilizes a two 350kW combined heat and power engines based on the biogas generated from its AD system. The application deadline for this opportunity was March 17th, 2011, but assuming a similar opportunity will be available in the future, the original installation cost would decrease to roughly \$6.2 million, a payback period of 9.62 years, or a total project cost of \$5.2 million if SCSD also received production and performance funding, making the payback period for the project only 8.07 years.

The New York State Environmental Facilities Corporation (EFC) uses funding from the EPA to provide seed money for Green Innovation projects that spur sustainable green developments, build green capacity, and facilitate technology transfer throughout the state (NYSEFC, 2011). In order to be eligible for this grant, projects must demonstrate sustainable wastewater infrastructure in communities across the state. An AD system at SCSD would qualify for this funding. While exact grant amounts for the past year have not been disclosed by the EFC, the program has the capacity to fund either all or a portion of an eligible project depending on whether the recipient obtains a match from other local or state funding sources. Design grants from the EFC reach up to \$50,000, while construction grants have a cap at \$750,000 per project. While we cannot determine definitively the exact amount of available funding available,

6.2 Environmental Assessment

Converting from an incineration only system at SCSD to an anaerobic digestion system which produces biogas, would have an overall positive environmental impact through the generation of electricity, reduction in energy consumption, and reduction in the volume of food waste and ash sent to landfills. By generating electricity on-site, the amount of energy purchased from the local utility could potentially decrease by as much as 90 to 100% as shown by the success in Oakland, CA and Gloversville-Johnstown, NY. This reduction in consumption effectively means that fewer natural resources are needed to create the electricity supplied by the utility company. In upstate New York, this energy is likely derived from either natural gas or petroleum. Due to the environmental dangers of water and air pollution caused by the extraction and combustion of these fossil fuels, any type of reduction in the reliance on these forms of energy would benefit the environment. A movement to expand the use of anaerobic digesters and combined heat and power systems at WWTFs would work towards the State's 2009 Energy Plan goal of "15 by 15." The "15 by 15" goal was established by the Public Service Commission for its Energy Efficiency Portfolio Standard (EEPS), designed to reduce energy use by 15% by the year 2015 (NYS Energy Plan, NYSERDA, 2009). In this way, anaerobic digestion has the potential to reduce the SCSD plant's individual footprint while working towards larger regional goals for energy efficiency and sustainability.

The conversion of sludge into organic fertilizer pellets would have tremendous environmental benefits. The fertilizer could be sold or redistributed to contributing users or the local agricultural industry when possible. If the plant chooses instead to incinerate the remaining sludge from the anaerobic digester process, the quantity burnt will be smaller, resulting in lower annual ash creation, which needs to be disposed of at landfills. Currently, food waste is the second largest category of municipal solid waste (MSW) sent to landfills in the United States, equating to 18% of the total waste stream (EPA, 2010). Putting this figure of 18% in perspective, if only 50% of all food waste in the U.S. currently sent to landfills were instead processed using anaerobic digestion in a system of CHP, enough electricity would be generated to power approximately 2.5 million homes annually (EPA, 2010). Anaerobic digestion presents an opportunity to reduce this volume of waste, while simultaneously decreasing methane emissions at landfills. Thus, the diversion of waste from landfills to an AD system embodies a sustainable waste to energy program.

As a result of generating renewable energy from the biogas on-site, the proposed SCSD project would lead to a reduction of greenhouse gas emissions of 3,714,832.65 lbs a year of CO_2, or 1685.02 metric tons (Local Government Operations Protocol, 2010). The EPA estimates that on average passenger vehicles emit 5.1 metric tons of CO_2 each year (Greenhouse Gas Equivalencies Calculator, 2011). Thus, the reduction in CO_2 by an AD system at the SCSD plant would be the equivalent of removing 330.4 automobiles from the road each year. Unlike reducing cars on the road, this reduction in CO_2 emissions comes with no change in personal behaviors making it an easier and more realistic transition.

6.3 Social Assessment

The SCSD plant received funding for a reconstruction project in the summer of 2009 with the goal of "providing the highest-quality services to our residents" as stated by Supervisor Willard Peck (R-Northumberland), Chair of the Saratoga County Board of Supervisors' Law & Finance Committee (Saratoga County, 2009). This statement echoes the original mission statement of the Plant written in 1977, "Saratoga County Sewer District No. 1 will provide reliable sanitary sewer services in an efficient and cost effective manner that will protect public health, personal property and the natural resources of the residents of Saratoga County, New York" (McConkey and Nowak, 2009). Providing the highest quality services to residents could incorporate the installation of a waste to revenue system, embodied by anaerobic digestion.

While our study makes no assumption that Skidmore College will divert its food waste to SCSD, participating in this program would lead to positive publicity for the school. According to the College Sustainability Report Card, Skidmore receives an overall environmental grade of a B+, with only a B in "Climate Change & Energy" (Skidmore College Green Report Card, 2011). By participating in a waste to energy program, the school would stand to improve this ranking.

Despite the potential environmental and economic benefits of AD installation, plant operators seem hesitant to adopt new technologies due to the fear of taking on a new risk. Plant operators expressed concerns over the operation and maintenance of an anaerobic digester as none of their current staff have training in this specific field. Considering this hesitation based on financial risk, with proper assessment of available funding and training for plant operators, we believe the plant would consider anaerobic digestion as an option.

Obtaining new high COD feedstocks to supplement an AD system at the SCSD plant presents the potential for social conflict as municipalities do not typically compete for business. George Bevington, emphasized that WWTFs avoid "going in someone else's backyard" as they all function as public enteritis. Therefore, challenges exist when seeking sources of waste outside of one's district and service area. Bevington emphasized that WWTFs should be transparent and work with other municipalities to achieve common goals. Saratoga County's waste board should therefore meet with other WWTFs and town officials to make an arrangement, which is suitable to all parties. While this was done with little disagreement in the Gloversville-Johnstown case, this smooth transition cannot necessarily be assumed for Saratoga County as well.

7. CONCLUSION

Based on our conceptual analysis, the installation of an anaerobic digester at the Saratoga County Sewer District No. 1 plant represents long-term environmental, economic, and social benefits for not only the plant itself, but also its contributing users. Anaerobic digestion presents an opportunity to reduce the volume of waste sent to landfills, decrease methane emissions at landfills, while simultaneously generating a renewable source of energy. Economically, the project has a maximum potential payback period of 12.73 years, however with a multitude of state and federal funding opportunities this timeframe could be reduced drastically. After paying for the project's construction, the plant stands to gain an annual economic benefit of roughly $644,000, plus additional cost savings from eliminating the fuel intensive process of incineration. Further, this study focused exclusively on a set quantity of food waste from college campuses; however the incorporation of additional waste could allow the plant to achieve greater economies of scale. Thus, an increase in oil and electricity prices, new funding opportunities and the incorporation of additional feedstocks has the potential to reduce the payback period dramatically.

After proving the high likelihood of economic feasibility and the definite environmental and social benefits of installation, the only barrier preventing Saratoga from installing an AD system seems to be the perception of risk. As a municipal plant, SCSD cannot take on excessive economic risk, however, with the proper preparation of additional high intensity feedstocks the risk dims in the face of the tremendous benefits waiting. If SCSD can overcome this final barrier, they stand to maintain a long future as a sustainable wastewater treatment plant.

8. APPENDIX

Item 1: Overview of Benefits

Economic

- Transforms waste liabilities into a revenue stream
- Potential income from
    - Biogas (electricity, heat, gas)
    - Renewable Energy Credits (RECs)
    - Soil conditioner
    - Tipping fees
    - Tax credits

- Reduces the cost of sludge handling and ultimate disposal
- Renewable energy source
    - Increases self-sufficiency
    - Produces power at a cost below retail electricity.
    - WWTFs in some cases are able to sell electricity back to the grid.
    - Shields a WWTF from the impact of volatile and unpredictable energy prices.
    - Qualifies as a renewable fuel for green power programs.

Environmental

- Reduces greenhouse gas and other air pollution emissions
- Reduces the volume and weight of material being land filled
- Reduction in pathogens and bacteria
- Digestate reduces the need for artificial fertilizers
- Stabilizes organic material before disposal so that remediation occurs more rapidly
- A biomass-to-biogas facility reduces water consumption.

Social

- Improved public image
- Marketing and PR advantage for participating entities
- Potential to increase employee satisfaction and retention

Item 2 - Cost Estimate for Engines

Milton CAT

Power Systems Division

500 Commerce Drive **Phone: 518.877.8000**
Clifton Park, NY 12065 **Fax: 518.877.6840**

www.miltoncat.com

TO:
SKIDMORE COLLEGE
815 NORTH BROADWAY
SARATOGA SPRINGS NY 12866

ATTN: Dauive Gill-Austern
QUOTE #: 11-000748
DATE: 4/26/2011

PROJECT

Saratoga County Digest Gas Units

We are pleased to offer the following equipment for consideration:

Two (2) New Indoor Caterpillar Model G3508 Digester Gas Packaged Generator Sets. Each unit is rated 350 KW, Continuous power, 277/480 volt, 60 hertz, 1200 rpm, Three phase, 0.8 pf. Included is the following:

- Low Emissions Engine
- NSPS (Emissions Compliant)
- Permanent Magnet Generator
- Electronic Governor
- Jacket Water Heater
- Rubber Vibration Isolators (Loose)
- Initial Fill Lube Oil and Coolant
- 30 Gallon Lube Oil Reservoir
- Lube Oil Regulator
- Dual 24 VDC Electric Starting Motors
- Starting Batteries With Rack and Cables
- Charging Alternator
- Flexible Fuel Connector(s) – Code Compliant
- Engine/Generator Unit Mounted Electronic Modular Control Panel, EMCP Plus
  - Digital Volts, Amps, frequency, RPM, hour meter, tachometer, battery voltage, Water temperature and oil pressure.
  - Shutdowns for Oil pressure, overspeed, water temperature, over crank
  - Emergency stop switch
  - Engine control switch
  - KW, KWH, KVAR, PF, % KW, L-N voltages
  - Programmable protective relay alarms and shutdowns
  - Alarm horn
  - Low coolant level
  - Low coolant temperature
  - Run contacts
  - Common alarm
  - Engine failure relay
- Engine Gauge Panel
  - Oil pressure
  - Water temperature
  - Oil pressure differential
  - Intake manifold temperature
  - Service meter
  - Exhaust pyrometer and thermocouples for individual exhaust ports and right/left bank exhaust stacks
  - Intake manifold pressure
- 10 amp Battery Charger (Loose)
- Low gas pressure alarms

- Digester Gas Train
  - Low pressure system, 1.5 – 5.0 PSI
  - One (1) manual shut off valve
  - One (1) gas (digester) filter
  - One (1) gas dual solenoid shut off valve with position contacts
  - One (1) pressure transducer
  - Woodward tech jet metering valve
  - One (1) gas flex connector
  - Woodward EGS01 air fuel ratio controller
  - Woodword Proact actuator
- Stainless Steel Flexible Connector
- Critical Grade Silencer, Stainless Steel (Loose)
- Heat Recovery System
  - Exhaust heat recovery unit
  - Two (2) three way thermostatic valves
  - Engine process – jacket water plate and frame heat exchanger (1.65 million BTU/HR)
  - Stacked core heat dump horizontal type radiator for jacket water and aftercooler circuits with two (2) fans and thermostatic control and expansion tanks
  - Four (4) thermometers
  - Two (2) cooling system RTD's
  - Six (6) isolation valves
  - Coolant system flexible connectors
- Start-up and Test With Milton Cat supplied Load Bank
- Customer Training
- 1 Year Warranty from Date of Start-Up
- Three (3) Operation and maintenance manuals
- Spare parts

Budget Net Price, F.O.B. Job Site/Tailgate...$ 1,152,000
($ 576,000.00 per generator set)

Paralleling switchgear, utility paralleling with Generator #1 Breaker, Generator #2 Breaker and Feeder Breaker, utility grade protective relays. Includes generator paralleling controls and metering. Approximate overall dimensions of 30 feet long by 10 feet wide by 12 feet tall.

Customer interface connections as follows:
Customer process : 6 inch flanged Supply and Return
Radiator Jacket Water Loop: 6 inch flanged Supply and Return
Radiator Aftercooler Loop: 3 inch flanged Supply and Return
Natural Gas Connection: 3 inch
Digester Gas Connection: 3 inch

Budget Net Price, F.O.B. Job Site/Tailgate..$ 300,000.00

Payment Terms: With Credit Department Approval – Net 30 Days and 100% Paid Prior To Start Up

TOTAL Budget Net Price, F.O.B. Job Site/Tailgate...$ 1,452,000

Item 3: Calculations – Formulas

These following calculations were used in order to determine the economic feasibility of an anaerobic digester at the SCSD plant with the incorporation of existing influent with food waste from local colleges. We worked with Rob Ostapczuk in order to determine the appropriate calculations and potential cost savings and capital requirements. We then submitted these numbers to Chris Alexopolous with Caterpillar Construction in order to estimate the costs for engines.

Biogas (cfd) = (SDSD VS + Food Waste VS) * (65% VS Reduction) * (15 cf/lb VS)

Biogas (btu/hr) = Biogas (cfd) * 600/24

Heating = Biogas (btu/hr) * 40%

Fuel Requirement (BTU/BHP-hr) = 8,000

BHP = [Biogas (btu/hr)] / [Fuel Requirement (BTU/BHP-hr)]

Energy (kW) = bhp * 90% efficiency * 745/1000

Annual Energy (kWh) = Energy (kW) * 24 hours * 365 days * 90% runtime

Annual Savings ($) = Annual Energy (kWh) * 10 cents

COD Load = (SDSD VS + Food Waste VS) * 1.4 * 0.4536

Digester = (COD Load/4.5) * (264.17/1000000)

Capital Costs = ROUND (SCSD TS + Food Waste TS)* (365/2000)*2000,-5)
Assume $2000 per ton

Residuals (dry tons/d) = ((SCSD TS-SCSD VS)+(Food Waste TS)+(SCSD Average VS + Food Waste VS)*(1-VS Reduction))/2000

Residuals (wet tons/d) = Residuals (dry tons/d)*2000/(8.34*200000)*1000000*10/2000

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