Food to Fuel: Anaerobic Digestion at the Rutgers New Brunswick Campus

The food waste at Rutgers New Brunswick can be converted to bio-fuel through the means of anaerobic digestion.

Tag words: Anaerobic Digestion, food waste, natural gas, Rutgers, New Brunswick

Authors: Lauren Landgrebe & Danielle Voss with Julie M. Fagan, Ph.D.

Summary

Rutgers currently spends more than $100,000 per year to get rid of leftover food at its four dining halls. A local pig farmer, Steve Pinter of Pinter farms is paid to haul away about 10 tons of food waste per day from the four dining halls, which he reportedly feeds to his pigs. Although it is a good thing that the food waste does not end up in a landfill contributing to the greenhouse gas emissions, we believe that we are paying to throw away a useful commodity. By implementing an anaerobic digestion chamber on campus this food disposal fee will no longer be required. The philosophy behind the anaerobic digester is that the leftover will be converted to natural gas that can be utilized by Rutgers. This is achieved by specifying conditions within the chamber that are optimal for specific microorganisms that breakdown the leftover foods and convert them to gas. The process is akin to composting. The starting cost to implement the chamber will be outweighed over the span of a few years by the amount the University saves by not paying the pig farmer. This does not include the savings from the utilization of the fuels generated by this process or the environmental benefit of the chamber.

The Issue: Food waste

Food waste is a problem that many people feel is a bit taboo. Perhaps people prefer not to discuss food waste because it poorly reflects on the entire population however the time has come to give it serious scrutiny. Currently, there is a scramble to research any possible forms of renewable energy due to the waning supplies of fossil fuels and growing concern for the environment. Food waste is one renewable resource that many have not given a second look. Organic food wastes have potential to be converted into fuel and other products in a number of ways through recent technological innovations. There is always a steady supply of food waste that goes by the wayside in landfills and generates gases that are harmful to the atmosphere. In fact in 2000 each New Jersey Resident generated about 310 pounds of food waste a year (Hayes and Adelaja 2004). The current population of New Jersey is 8,682,661 (US Census 2010) and with some simple multiplication it is easy to see that over a million tons of food waste is generated annually across the state. A microcosm of this issue can be observed by looking at how Rutgers University and the city of New Brunswick handles its food waste.

Rutgers University in New Brunswick currently handles the food waste generated by it dining halls and catering service by paying Steve Pinter, of Pinter Farms, to remove the waste (EPA 2009). Rutgers University also pays for the maintenance of the pulverizing machines and refrigeration units that are required to pre-process the food waste that Pinter removes. Overall Rutgers is paying a high price for this farmer to remove what could be a valuable resource. The food waste that is generated by the Rutgers New Brunswick dining facility and catering services can be recycled along with other organic wastes generated by the University to create new energy. In other words the biomass produced by the University can be converted to bioenergy through the means of anaerobic composting.

The AD processes involves an airtight vat that contains the biodegradable composting material, and over a few days anaerobic microorganisms, organisms that survive in low or oxygen depleted environments, digest the material and produce natural gasses. (Doelle, 2001; EPA, 2008; Friends of the Earth, 2004). This form of composting helps the environment by reducing the amount of organic waste which has the possibility of being thrown into a landfill, the sea, or an incinerator along with lowering the green house gas emissions by trapping what would normally be released into the atmosphere by the waste. This natural gas, prominently methane and carbon dioxide, can be stored and used in place of lighting and cooking energy. Approximately 730 - 1,300 kWh of energy is produced per dry ton of food waste applied. (Doelle, 2001; EPA, 2008; Friends of the Earth, 2004).

The Service Project: Proposal

For the service project we submitted a proposal to the 2009-2010 Rutgers Energy Innovation Contest along with the help of Dr. Julie Fagan for the implementation of an anaerobic digester on the Rutgers New Brunswick Campus. The REI competition involves a submitted proposal of a new and innovative idea to help decrease the Rutgers student body's energy consumption. The proposal consisted of costs and energy savings analysis, a timeline of the cost benefits, implementation suggestions, and how the costs and energy savings were calculated. For a full version of the proposal and the poster see Appendices section.

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Editorials:

Lauren's Editorial
(SO) To the Editor:
Title: More water less energy drinks

There is rising concern about the large consumption of energy drinks among young adults, adolescents and children in the US. The lack of knowledge of the potentially harmful effects of high levels of caffeine and carbohydrates in energy drinks and in a few sports drinks has proven to be detrimental. One of the reported cases involved the overconsumption of energy drinks which led to the death of an individual due to the dehydration and heart arrhythmia caused by the high caffeine content in energy drinks. Caffeine and carbohydrates are the two major components in energy drinks that provide the energy boost. The amount of caffeine in some energy drinks is way more than the recommended daily intake. Consumption of two to three cans of energy drinks per day may result in caffeine toxicity leading to heart arrhythmia, insomnia and dehydration. On the same note, high levels of carbohydrates in energy drinks may be antagonistic to diabetes and obesity.

Producers of these drinks should be responsible and perhaps indicate the side effects of overconsumption of energy drinks in the promotional advertisements and on the cans as well. In addition, they should post on each can/bottle the recommended daily consumption and content of caffeine.

Rather than drink energy drinks during or after exercise, it is better to consume water for rehydration purposes or if in the case of prolonged sweating periods resulting in electrolyte loss, sports drinks with zero calories may be used for rehydration and replenishment of the lost electrolytes. Supplements and consumables that promote good health should not take the place of healthful everyday good health practices like eating a balanced diet, getting regular exercise and respecting sleep, an often abused requirement of the human body.

(AK) To the Editor:
To: Managing Editor at Sports Illustrated for Kids Magazine Bob Der
From: Andrew Krajewski
Re: What should young athletes be drinking? Sports Drinks vs. Water

It has come to my attention that most parents do not know how to keep their child athlete properly hydrated after participating in physical activities. Most parents buy their child a sports drink such as Gatorade thinking it will keep their child hydrated and healthy. However, sports drinks are only effective when used properly. Most parents are clueless about the appropriate uses of sports drinks. Most sports drinks contain sodium, potassium, as well as other electrolytes. Although it is vital to replace these nutrients after exercise due to their importance in certain body processes, sports drinks also contain something children already get too much of, sugar.

Obesity and diabetes in children today has never been more prevalent. Sports drinks are partly to blame due to their misuse because parents do not have knowledge about healthy hydration habits for children. Although it is the parents' responsibility to read nutrition facts and find out exactly what is in these drinks, the fact of the matter is most parents do not and inadvertently put their child's health at risk. For prolonged intense workouts it has been shown that sports drinks are helpful in replenishing vital nutrients to help restore the body. However, water is the best choice for rehydration when a child is not put through intense prolonged workouts. Knowledge about this subject is the best weapon against fighting obesity and diabetes in children due to consuming high levels of sugar in their diets.

Sincerely,
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Danielle's Editorial

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Appendices

The Energy Conservation Contest Cover Page
Rutgers New Brunswick Undergraduate Students
Sponsored by: The Rutgers Energy Institute

Proposal Title: **Food to Fuel: Anaerobic Composting at Rutgers New Brunswick, NJ.**
Total number of pages (not counting cover pages): 8
Student Name: **Lauren Landgrebe**
Danielle Voss
Faculty advisor name: **Dr. Julie Fagan**
Title: **Associate Research Professor**

Summary of the proposal:

Disposal of food at Rutgers is handled in a questionable manner and could be more efficient. Rutgers currently spends close to $100,000 to get rid of leftover food at the dining halls. The food is taken by a pig farmer to feed his pigs; this does nothing to benefit the Rutgers community. By implementing an anaerobic digestion chamber on campus this food disposal fee will no longer be required. The philosophy behind the anaerobic digester is that the leftover will be converted to natural gas that can be utilized by Rutgers. This is achieved by specifying conditions within the chamber that are optimal for specific microorganisms that breakdown the leftover foods and convert them to gas. The process is akin to composting. The starting cost to implement the chamber will be outweighed over the span of a few years by the amount the University saves by not paying the pig farmer. This does not include the savings from the utilization of the fuels generated by this process or the environmental benefit of the chamber.

I) Introduction

Food waste is a problem that many people feel is a bit taboo. Perhaps people prefer not to discuss food waste because it poorly reflects on the entire population however the time has come to give it serious scrutiny. Currently, there is a scramble to research any possible forms of renewable energy due to the waning supplies of fossil fuels and growing concern for the environment. Food waste is one renewable resource that many have not given a second look. Organic food wastes have potential to be converted into fuel and other products in a number of ways through recent technological innovations. There is always a steady supply of food waste that goes by the wayside in landfills and generates gases that are harmful to the atmosphere. In fact in 2000 each New Jersey Resident generated about 310 pounds of food waste a year (Hayes and Adelaja 2004). The current population of New Jersey is 8,682,661 (US Census 2010) and with some simple multiplication it is easy to see that over a million tons of food waste is generated annually across the state. A microcosm of this issue can be observed by looking at how Rutgers University and the city of New Brunswick handles its food waste.

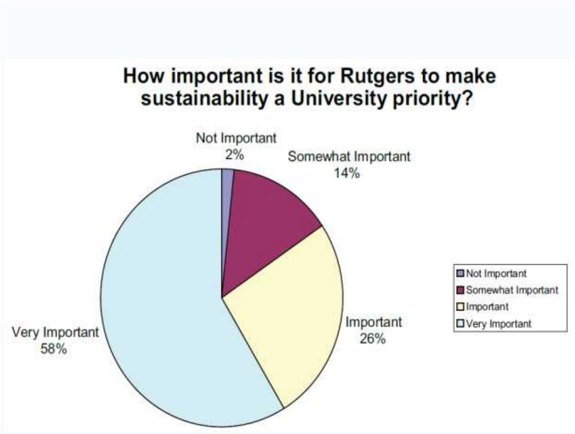
Rutgers University in New Brunswick currently handles the food waste generated by it dining halls and catering service by paying Steve Pinter, of Pinter Farms, to remove the waste (EPA 2009). Rutgers University also pays for the maintenance of the pulverizing machines and refrigeration units that are required to pre-process the food waste that Pinter removes. Overall Rutgers is paying a high price for this farmer to remove what could be a valuable resource. The food waste that is generated by the Rutgers New Brunswick dining facility and catering services can be recycled along with other organic wastes generated by the University to create new energy. In other words the biomass produced by the University can be converted to bioenergy through the means of anaerobic composting.

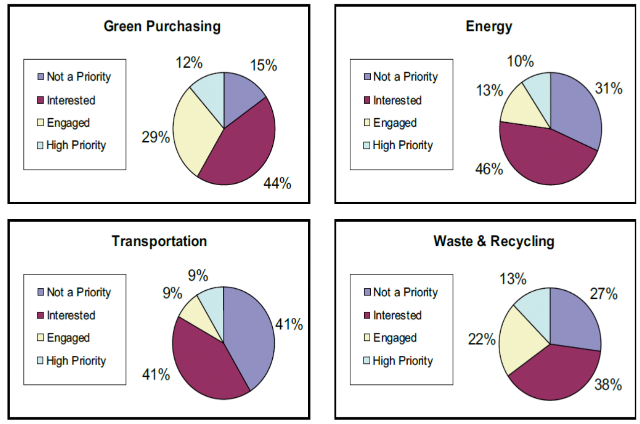
Looking at data from 2007, the population of the United States created more than 32 million tons of food waste. Almost all of the 32 million tons of the food waste was discarded into landfills across the US. Anaerobic digestion (AD) reduces food waste and landfill size while providing natural gas that can be used as an energy source. (Doelle, 2001; EPA, 2008; Friends of the Earth, 2004).

This form of composting helps the environment by reduce the amount of organic waste which has the possibility of being thrown into a landfill, the sea, or an incinerator along with lowering the green house gas emissions by trapping what would normally be released into the atmosphere by the waste. This natural gas, prominently methane and carbon dioxide, can be stored and used in place of lighting and cooking energy. Approximately 730 - 1,300 kWh of energy is produced per dry ton of food waste applied. (Doelle, 2001; EPA, 2008; Friends of the Earth, 2004).

The AD processes involves an airtight vat that contains the biodegradable composting material, and over a few days anaerobic microorganisms, organisms that survive in low or oxygen depleted environments, digest the material and produce natural gasses. (Doelle, 2001; EPA, 2008; Friends of the Earth, 2004).

At the Rutgers New Brunswick location this would be a practical solution in the fight against global warming. Looking at a Rutgers 2007 Annual Report, there was a section on student interest on renewable energy and sustainability; more than a quarter say that it is important and more than half of the student population says that sustainable energy is very important. This would indicate that the student body would be more than willing to support our proposal of a sustainable anaerobic digestion composting system that would not only reduce the landfill size, but would reduce Rutgers New Brunswick's carbon foot print.

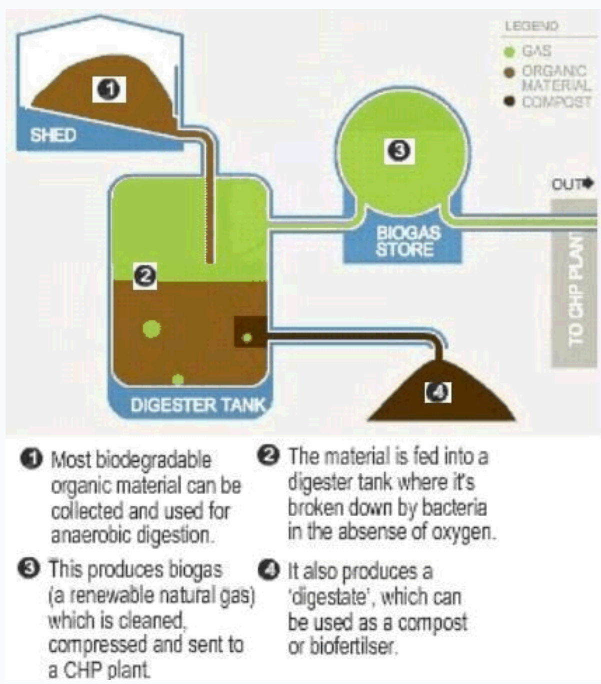




Images above found from Rutgers University Committee for Sustainability. Annual Report 2007

I) Models

The most common AD model in the US is primarily for manure and not necessarily for solid food waste, for this reason the research must look at places that have these digestion chambers in place such as the Europe. There are several companies in Europe that sell anaerobic digesters and a few that have North American companies as well. The companies that are most involved in the Northern American market include Dranco, Valorga, Arrowbi, BTA, and Kompogas (Kelleher, 2007). There are many types of food waste AD including a wet single and multi-step process, a dry continuous, sequencing, and multi step process. (AD Feasibility Study, 2004)



YouTube video found at Anaerobic Digestion 2010.

(The image above shows a basic understanding of a single stage AD for manure use.)

<u>Wet Single Step Process</u>

There is a wet single step process that is used for about a 10-15% total solid amount this requires the addition of water to dilute the solids to this percentage. This type is designed for a thicker type of manure and sewage and would not be appropriate for a food waste process. (AD Feasibility Study, 2004)

Wet Multi-Step Process

The multi-step continuous wet process including percolation, typically a percolation process is applied that is a solid and liquid two phase process. A pulper is applied to separate things too large to go through the liquid process. From here the solid phase is placed in an aerobic chamber to digest the solid pieces into liquid/pulp. The liquid from this part is digested and converted into CNG (AD Feasibility Study, 2004). The separate phases give optimal conditions for two types of microorganisms, allowing for the complete breakdown of the waste into biofuel. (AD Feasibility Study, 2004)

Dry Continuous Process

A dry continuous process is a digester that waste continues to be added. The total solid waste for this type of AD is about 25-40% which is still low for the amount of waste that would be used for food waste. This type of process is best used on manure and sewage waste and would not be an appropriate digester for the Rutgers campus. (AD Feasibility Study, 2004)

Dry Multi-Step & Sequencing Process

The dry multi-step is a continuous system that involves three separate digesters allowing different environments for different microorganisms to digest the waste. In a dry sequencing process there are a minimum of three digesters that are similar to the multi-step process, but without the continuous pump flow results in extremely laborious work and high maintenance costs. This dry-multi step process would be too much work for what would be an appropriate fit for Rutgers New Brunswick. (AD Feasibility Study, 2004)

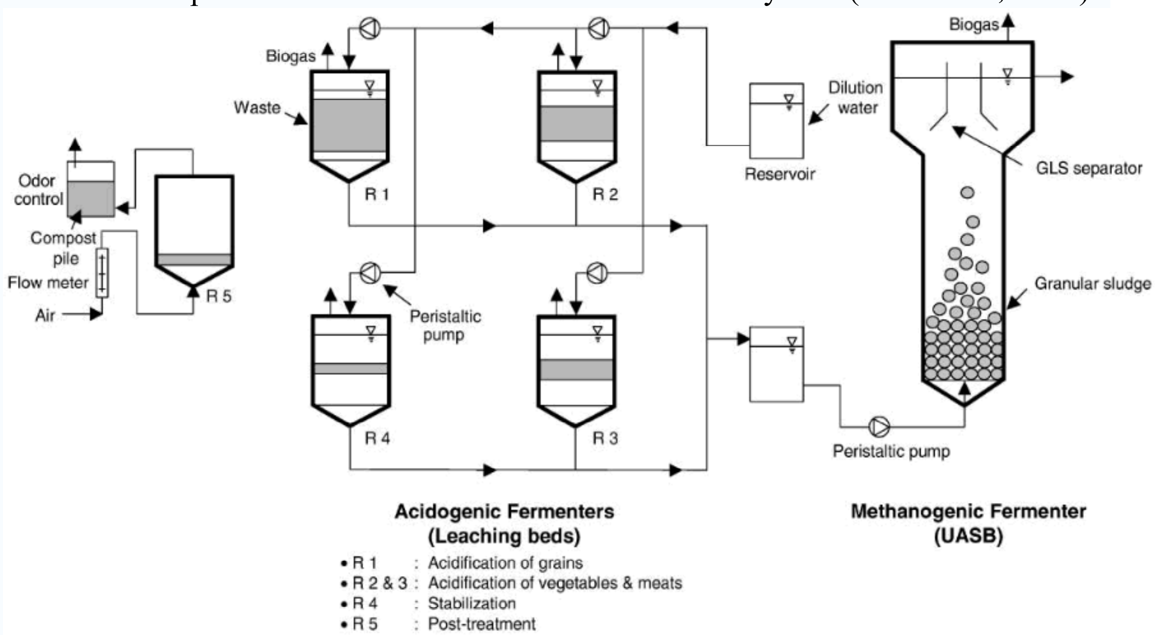
AD for Rutgers Campus

Out of all of the different types of anaerobic digesters the one most suitable for Rutgers New Brunswick campus is the multi-step continuous wet process with percolation; more specifically the mobile-pilot BTA-Plant sold by Canada Composting Inc (CCI). The BTA-Plant is a 10 ton anaerobic digester that includes eight different units including a pulper, a GRS/gas compressor container, the digester, a dewatering container, a process water tank container frame, a gas holder tank, a combined Heat and Power (CHP) container, and a control system. This specific type of plant is ideally used on about 1-2 batches per day and the water used in the process is generated from the removed recycled water obtained from the process making the only product that comes out of the digestion process the natural gas and the digested solids which can serve as a highly nutritious fertilizer, so there are also no unwanted bi-products from the digestion process.

In this specific AD, the pulper is about $4m^3$ which is about 1,057 gallons of initial waste. This unit is located on a 20 foot frame that can easily be placed onto a flatbed or a truck for easy mobility. The GRS/gas compressor unit contains a sludge pump, grit removal system, a buffer tank (2,114.9 gallons), a compressor for pressure air, and a separate gas compressor unit. The digester tank (7,930.9 gallons) is coated on the inside with steel to prevent rusting or degradation of any type; the dimensions are 8m x 2.5m and the unit resembles a small concrete silo. During this stage of the digestion the tank is injected with gas which prevents settling of any sludge or scum.

Next is the solid liquid separation container; this simply a container to hold the liquid that is removed from the digestion process to be used as an effluent in future digestions. The equipment involved in this step is a feeding pump, buffer, separator, a flocculent system, and a control room for the operation of the whole digestion process. The solids that were separated from the liquid are placed into a solids bin. The process water tank (2,643.6 gallons) where the liquid removed from the sludge is placed until there is another batch of waste going through the digester. This liquid will be used as a buffer in the pulper process. The bio-gas holding tank (13,218.2 gallons) is a canvas reinforced plastic film bag that is under no pressure and is anchored between pylons. The flexibility of the bag allows the system to be transported easily. The CHP container includes a motor run on gas/diesel/vegetable oil (approx 60 kW) and is attached to a small laboratory including a cooler, a control unit, and operation panel. The produced electrical power from the digestion process may be used to heat the digester making this process self sustaining. The control panels on the pulper and the three containers include a local switch board that contains an SPS and an operational panel.

The image below shows a schematic of a multi-step sequential two-phase anaerobic composter that is similar to the BTA-Plant sold by CCI (Shin *et. al.,* 2001).



Each types of digester comes in a range of sizes. The companies that sell digesters to Northern American include Dranco, Valorga, Arrowbi, BTA, and Kompogas (Kelleher, 2007). The ranges in sizes are similar between the different types of food waste AD. (AD Feasibility Study, 2004) This chart below shows the price variation per yearly capacity (Integrated Waste Management Board Public Affairs, 2008).

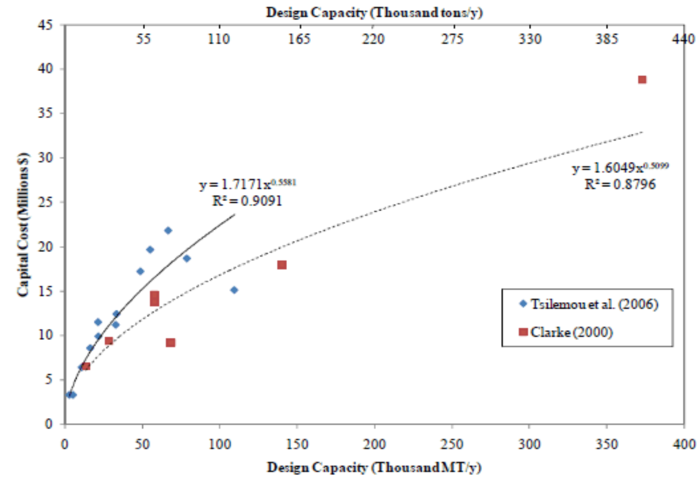


Figure 31. Capital cost curves for European MSW digesters
PPP and inflation-adjusted to 2007 dollars [120, 121].

II) Application to Rutgers University New Brunswick Campus

There are many considerations that must be taken in the application of this type of anaerobic digester on the Rutgers New Brunswick campus. The main developmental challenge is finding an appropriate space on campus for the AD plant. The Livingston campus of Rutgers New Brunswick has a lot of open space and already has a compressed natural gas filling station for the cars that use this fuel. Thus it would be ideal for the plant to be built in this location due to its seclusion from residents and proximity to the compressed natural gas filling station. Currently there is very little regulation in place that limits the building of an AD plant. Local, state and federal authorities would have to be consulted to ensure compliance with all codes and laws. The area on Livingston campus that would be ideal is highlighted in the picture below. In addition to being remote, the plant is still accessible by trucks that could haul the food waste to the plant.

The hauling of the food waste is another consideration. Rutgers University already has a program instated that requires the separation of food waste; however, it does not have an organized transporting system. The implementation of an AD plant would require that Rutgers University have trucks haul food waste from its dining and catering facilities to the plant. This process is feasible because Rutgers already has a fleet of vehicles capable of moving the waste within the various campuses. The current system in place for the pick of waste by the pig farmer could be maintained only Rutgers University would move the waste instead. This operation also has the opportunity to be expanded to the city of New Brunswick; however, more equipment and planning would be necessary. A venture like this has already been successfully accomplished in Toronto Canada. They initiated their "green bin" program in 2008 and now boasts a waste diversion rate of 44% (City of Toronto, 2010). A program of that caliper would require a larger facility.

The success of the small scale Livingston campus could also pave the way for a large scale plant to be instituted on Cook campus. An area by the equine research farm is large enough for an AD plant with a larger capacity than the one that would be installed on Livingston campus. This area is in close proximity to route 1 that would allow for food waste from other areas to be brought to the facility. If the Livingston campus plant proves successful another AD plant on Cook campus would allow for the University to profit further from this process increasing its positive impact on the environment.

III) Cost benefit and timeline

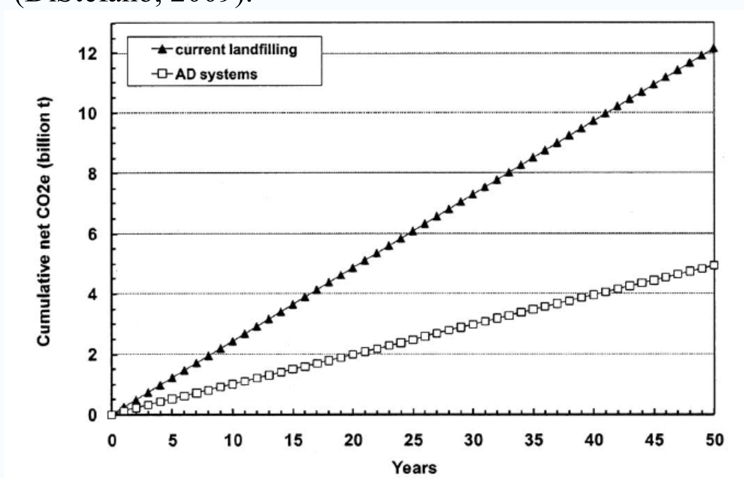
Financial

An AD plant proves to be a very profitable venture for Rutgers University. The initial cost of the described model plant would have an upfront cost of around $2 million (Canada Composting Inc). There would be maintenance, employee, hauling and general costs to the start up of the plant that would require a significant investment. The AD plant would however eliminate the cost of organic waste removal including more than just food. Any organic materials such as leaves, wood/green trimmings, paper products and other organics could also be digested by the plant. This would save the University around $142,354.40 per year (Recycling Data, 2008). The plant would also generate natural gas which can be used as fuel or electricity. One ton of food waste that is anaerobically digested under the condition of the BTA model can generate 100 to 200 m^3 of biogas (Clarks, 2009). This biogas can in turn be used as fuel for the fleet of CNG vehicles Rutgers University currently owns and can sustain the energy need by the plant itself. Excess gas can be sold or used as electricity.

The amount of biogas/natural gas equivalent to one gallon of gasoline is 3.587 m^3 (Gable S. and Gable C. 2010) and if the digester produces a conservative 100 m^3 per ton of food while processing around 10 tons per day that means daily the plant would produce the equivalent of 279 gallons of gasoline a day. The average cost of CNG per gallon equivalent ranges from $1.50 to $2.50 (US Department of Energy 2009). The overflow of unused gas can be sold by the university to generate a profit. The 12 CNG vehicles used by Rutgers University have fuel tanks roughly the size of 8 to 10 gallon of gas equivalents. Therefore much of the fuel would be leftover for sale or for use in meeting the power requirements of the AD plant. In fact if each of the vehicles were filled once a week that would leave a surplus of 1275 gallons of gasoline equivalents of natural gas per week. If all the surplus fuel was to be sold at a conservative price $2.00 per gallon gasoline equivalent it would generate $132600.00 per year. This revenue in combination with the savings from the avoided haul away costs would mean that the payback time for the small AD plant would be about 4 years. Overall the AD plant could be a self-sufficient entity requiring little man power to run, one full time operator, and with hauling costs minimized through the use of the CNG generated from the plant to power the transportation.

Environmental

The environmental benefits of an AD are significant. An AD reduces the size of landfills, methane emission from the landfills and vehicle emissions by eliminating the food waste that go into landfills, trapping the gas that is naturally put off, and using the gas in an efficient way. The AD will also eliminate leaf removal problems by incorporating the foliage into the digestion process. In the US the AD are used on manure and municipal solid waste and by digesting this alone would benefit the environment, but a food waste disposal system could decrease landfill size and green house gas emissions drastically. The following graph shows "comparison of projected nationwide net cumulative emissions for current landfilling and AD system implementation" (DiStefano, 2009).



While Rutgers does not seem to be contributing to these increasing landfill problems, we could be a leader in having the first AD chamber in New Jersey and the United States that incorporates waste other than sewage and manure. Items that can be put through an AD are food scraps, yard clippings, sewage and animal waste; while paper and cardboard can be digested, wood waste such as large branches and logs are unaffected by the digestion process.

If New Jersey used an AD instead of stuffing waste into landfills there would be many benefits. NJ's carbon foot print would be reduced by trapping and utilizing the green house gasses put off by the waste that would have been in landfills, NJ would save the money that would have been used for sewage waste processing plants and trash moving/hauling fees, and NJ could use gas created by the composting to fuel vehicles to replace fossil fuel usage. Each time food waste is thrown away into a landfill not only is this the same as throwing away viable energy and fuel, but this takes up valuable space and is extremely damaging to the environment that we plan to live in for the rest of our lives.

According to the Rutgers Green Purchasing website, the emissions put off from a compressed natural gas (CNG) car are only 10% of emissions put off by conventional cars that are run on gasoline. This could one day eliminate our dependence on fossil fuels and foreign suppliers (Rutgers Green Purchasing, 2010).

Rutgers purchased 10,500 gallon equivalents of CNG in 2008; compared to gasoline run vehicles this reduced carbon dioxide emissions by approximately 23 tons (Rutgers Green Purchasing, 2010). If the Rutgers New Brunswick/Piscataway campus was self sustaining in the fuel generated from the AD then this would send a powerful message to the rest of New Jersey and America. Continuing to use gasoline powered cars when the risks of global warming are clear and there is an obvious alternative is simply irresponsible.

IV) Conclusion

Anaerobic digestion is environmentally healthy and a practical solution to the rising problem of global warming and landfill dumping. Using an AD for food waste instead of selling the food to a pig farmer would:

-Reduce Rutgers' carbon foot print by incorporating more CNG vehicles

-Save the money that would have been given the pig farmer (over $120,000/yr)

-Eliminate leaf removal costs (about $500/year)

-The initial investment would be paid back within 4 years of the start of the project

-After 4 years the plant would generate a combined profit and savings that would amount to about $200,000 per year

-Rutgers would become a stepping stone for the rest of NJ to follow

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