City of Lincoln

Ten Percent Design Study for a Waste Fueled Gas Production Process to Produce Heat and Electricity in a Fuel Cell to Power the City of Lincoln Wastewater Treatment and Reclamation Facility

HERWIT
Engineering

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Placer County Air Pollution Control District

Councilman Kent Nakata

Director

Lincoln
All-America City
2006

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Section 1: Background

1.1 Introduction

The City of Lincoln has received a grant from the Placer County Air Pollution Control District (PCAPCD) to study how the Lincoln Wastewater Treatment and Reclamation Facility (WWTRF) can utilize community waste for the production of energy, to power the WWTRF. The study will provide a 10% design, along with an investigation of waste to fuel gas production processes to produce heat and electricity by way of a fuel cell.

There are a number of waste to energy studies for wastewater plants in circulation. Most of these studies investigate the utilization of existing digester capacity to commingle primarily food waste with wastewater biosolids. These processes produce methane utilized for onsite generation of heat and electricity utilizing internal combustion engines. The WWTRF does not currently utilize digesters, so any anaerobic process would require development of digestive capacity. This study will also evaluate available thermal processes that produce syngas that can be utilized much like methane.

1.2 Background

In 1989 California passed Assembly Bill 939 (AB 939). AB 939 required by the year 2000 that all communities divert 50% of solid waste from disposal in a landfill. This law set in motion the establishment of reduction, reuse, and recycling programs. The 50% diversion standard is under political pressure to be increased to 60% and even 75% diversion.

Political pressures of global warming combined with the cost and use of foreign sources of energy, in combination with diversion requirements has set the stage for locally sourced, carbon neutral, energy production.

Very little of the waste generated in Lincoln today is used for energy production. There are only two known sources; the first, wood waste is diverted at the Western Placer Waste Management Authority (WPWMA), Material Recovery Facility (MRF) for eventual combustion in a biomass plant. The second, methane captured from the anaerobic breakdown of organic matter within the WPWMA landfill. The latter has significant quantities of fugitive emissions due to the breakdown of organics before the effected landfill cell can be sealed, and perforations and leaks in the final cover.

By quickly capturing and processing putrescible waste in a state-of-the-art waste to energy facility, fugitive emissions will almost totally be eliminated. Also residual materials can be used for beneficial use. Such a process will eliminate the potential long term liability associated with a community landfill.

Food waste comprises about 20% of the residential waste stream to the WPWMA landfill. Diversion of this waste will significantly impact State required solid waste diversion. It has also been shown that the net financial result can be very positive.

Lincoln is in a strong position to develop a waste to energy program. The City owns the WWTRF and owns and operates the solid waste collection of residential and commercial waste. The City has not signed the WPWMA Flow Control Agreement. As such the City is free to transport waste to facilities other than the WPWMA.

Starting as early as 2001, the City has investigated a combined heat and power (CHP) system for powering the WWTRF, and providing heat to dry WWTRF biosolids. In 2008 the first phase of a CHP system was completed at the WWTRF with the commissioning of the Active Solar Dryer.

This biosolids solar drying system can utilize waste heat from the power generation component of a CHP system that is yet to be installed.

1.3 Acknowledgements

This Study was prepared by Herwit Engineering, with assistance from the following individuals organizations, and companies:

City of Lincoln
Paula Balwin
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Western Placer Waste Management Authority
Eric Oddo

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AES
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Placer County Air Pollution Control District

Pacific Gas and Electric

Section 2: Reference Search

A number of reports have recently been published discussing waste to energy. Pertinent reports are discussed here, with relevant information contained in the body of this report. Copies of all discussed reports are included in Appendix A. Most of the available information pertains to the East Bay Municipal Utility District (EBMUD) food waste to energy operation.

2.1 U.S. Environmental Protection Agency Region 9

U.S. Environmental Protection Agency Region 9
Anaerobic Digestion of Food Waste
March 2008
Prepared by:
East Bay Municipal Utility District

US EPA Region 9 commissioned EBMUD to investigate the use of excess wastewater treatment plant digester capacity to process a portion of California's annual 5.9 million tons of food waste. EPA's interest is to divert waste from landfills and to avoid the production of methane that can escape to the environment. The report states that methane is a "potent greenhouse gas".

At the East Bay Main Wastewater Treatment Plant food waste is currently being co-digested with primary and secondary wastewater sludge. Even though full scale food waste processing is occurring, due to operational issues bench scale testing of food waste was conducted to determine:

- Minimum MCRT.
- Volatile solids and chemical oxygen demand (COD) loading rates.
- Volatile solids destruction.
- Methane gas production.
- Process stability.
- Thermophilic and mesophilic operating temperatures.

The report summarizes study findings which include:

- Energy value of food produced by anaerobic digestion.
- Volatile solids destroyed.
- Biosolids produced.
- MCRT
- Volatile solids loading rate.
- Methane gas production rates.

2.2 California Integrated Waste Management Board

California Integrated Waste Management Board
Current Anaerobic Digestion Technologies
Used for Treatment of Municipal Organic Solid Waste
March 2008
Prepared by:
Department of Biological and Agricultural Engineering
University of California Davis

Due to the implementation of AB 939 the California Integrated Waste Management Board (CIWMB) has a vested interest in diverting as much mass as is practical from disposal in landfills, to beneficial use. This mandate combined with the goals of AB 32 has turned the CIWMB attention from diversion, to diversion with reduction in the production of greenhouse gasses resulting from the degradation of municipal solid waste (MSW).

Due primarily to government support, there are a number of non-thermal waste to energy facilities operating in Europe. Thermal or transformation processing of MSW is not encouraged by the CIWMB. This report investigates a number of anaerobic processes currently deployed to convert MSW to methane.

The State of California has in the past encouraged composting of various segments of the MSW waste stream. Composting is an aerobic process that generally consumes large quantities of energy and produces volatile organic compounds (smog precursors and greenhouse gasses) that are released to the environment. For these and other reasons anaerobic processing of the organic fraction of municipal solid waste (OFMSW) may evolve to be the preferred diversion method of the CIWMB.

This report in part investigates the advantages and disadvantages of the following anaerobic process categories and specific processes within each category:

Single-Stage Wet Systems

- Waasa
- BIMA

Single-Stage Dry Systems

- Organic Waste Systems (Dranco Process)
- Waste Recovery Systems, Inc. (Steinmüller Valorga Process)
- Kompogas AG

Multi-Stage Digesters

- Biotechnische Abfallverwertung Gmbh & Co. KG (BTA)
- Linde-KCA-Dresden Gmbh
- Super Blue Box Recycling (SUBBOR)
- WEHRLE Umwelt GmbH (Biopercolat)

Batch Digesters

- Biocel
- Sequentail Batch Anaerobic Composting (SEBAC)
- Anaerobic Phased Solids (APS) Digester
- BioConverter

The CIWMB encourages investors and city planners to investigate and implement anaerobic digestion (AD) of MSW. This report provides significant information regarding experience of the European community.

2.3 East Bay Municipal Utility District

East Bay Municipal Utility District
Producing Green Energy From Post-Consumer Solid Food Wastes At A Wastewater Treatment Plant Using An Innovative New Process
2008
Produced by:
East Bay Municipal Utility District

It is recognized that a number of AD, MSW to energy systems did not properly evaluate the challenges presented with material handling of the organic fraction of municipal solid waste (OFMSW). EBMUD's food waste introduction to excess digester capacity at the Main Wastewater Treatment Plant was delayed due to contamination in the waste stream. Even though food waste was source separated it still contained unacceptable levels of contamination which included, metal and metal utensils, ceramics, plastics, rock and other inorganics. Even though these materials will not interfere with biological activity of the AD process, they have the potential to damage and disable mechanical systems.

This report essentially follows up on, and takes an operational view of the U.S. EPA Region 9 Report prepared by EBMUD titled **Anaerobic Digestion of Food Waste**. EBMUD was compelled to develop their own materials handling and processing system to protect down stream equipment. EBMUD has filed for a process patent of their "front end process" to remove contamination, and perform size reduction of delivered food waste.

The report also evaluated operational performance of EBMUD's full scale AD Food Waste system.

2.4 78th Annual Water Environment Federation Technical Exposition and Conference

78th Annual Water Environment Federation Technical Exposition and Conference
Overview of Anaerobic Treatment: Thermophilic and Propionate Implications
Written by:
R. E. Speece, Saroch Boonyakitsombut, Moonil Kim, Nuri Azbar and Pepi Ursillo
October 29 – November 2, 2005

This paper investigates anaerobic reactor performance of both thermophilic and mesophilic systems based on four factors:

1. Reactor Configuration
2. Inorganic nutrient supplementation.
3. Substrate characteristics.
4. Role of microbial consortia proximity.

It was found that reactor removal efficiency was considerably improved utilizing an intact up flow anaerobic sludge blanket process. Efficiency was reduced with homogenized slurry blanket, and significantly reduced when completely stirred. The paper suggests that this effect is the result of proximity of acenogen and methanogen bacteria to each other. The closer the proximity, combined with the ability of the acenogen and methanogen bacteria ratios to self adjust, is a critical component of reactor performance. These criteria are primarily based on reactor configuration.

The paper concludes that the best performing anaerobic reactors are ones that promote development and sustainability of self regulating consortia of acenogen and methanogen bacteria. If consortia is broken up, as in a complete mix reactor, performance is significantly impacted. The key to anaerobic reactor performance is the presence of intact granules of bacteria.

2.5 City of San Rafael and Central Marin Sanitary Agency

City of San Rafael and Central Marin Sanitary Agency
Methane Capture Feasibility Study
Produced by;
Kennedy/Jenks Consultants
December 2008

It is estimated that half the solid waste collected in central Marin County is food waste. This food waste is being transported and disposed in the Redwood Landfill in Novato. The study assumes that in the landfill the natural degradation of food waste releases methane and carbon dioxide to the atmosphere. The release of these gasses is contributing to the County greenhouse gas emissions.

The key objectives of the study are to:

- Identify the quality and characteristics of available food waste.
- Identify other agencies that have implemented food waste to energy programs.
- Determine requirements for pretreatment of food waste.
- Identify required modifications to the Central Marin Sanitation Agency
- Wastewater Treatment Plant anaerobic digesters.
- Determine the methane and solids production from food waste digestion.
- Develop project costs and the expected payback period for the project.
- Identify permitting issues for the project.

This study utilized the experience of EBMUD and the subsequent reports as a primary tool to evaluate a Central Marin Sanitary Agency food waste to energy system.

2.6 Los Angeles County

Los Angeles County
Conversion Technology Evaluation Report
Phase II Assessment
Executive Summary
Produced by;
Alternative Technology Advisory Subcommittee of
Los Angeles County Department of Public Works
Solid Waste Management Committee/Integrated Waste Management
Task Force
October 2007

Los Angles County has conducted a study of potential solid waste conversion technologies for use in the County. The report acknowledges the operational use of conversion processes in Europe, Japan, Israel, and other countries in Asia.

The report technically evaluates five preferred companies that offer to provide full scale conversion processes. The processes evaluated are:

- Anaerobic Digestion
- Thermal Depolymerization
- Pyrolysis
- Pyrolysis/High Temperature Gasification
- Low Temperature Gasification

The report includes an evaluation of the potential to develop a project for processing of County solid waste. This evaluation includes, environmental, permitting, funding, and incentives.

Section 3: Potential Feedstock Sources

The City is a member of the Western Placer Waste Management Authority (WPWMA). The City delivers or has delivered all residential and commercial solid waste to the WPWMA for processing in the WPWMA dirty material recovery facility (MRF). The City has a Debris Hauler Franchise Ordinance witch controls the point of disposal of all solid and septic waste generated in the City. The City has no obligation to the WPWMA to dispose of waste at the MRF. The City has not signed the current flow control agreement with the WPWMA.

The City ultimately controls the hauling and point of disposal of the vast majority of solid and septic waste generated in the City.

3.1 Wastewater Treatment Plant Biosolids

The City of Lincoln owns an extended aeration, activated sludge wastewater treatment plant (Plant). The Plant does not have any anaerobic digesters. At this time biosolids are removed from the aeration basins, collected and concentrated in standard gravity clarifiers, then stored in an aerated sludge holding basin. Periodically biosolids are pumped from the sludge holding basin for processing through a centrifuge where they are concentrated to about 20% solids.

With the original Plant design, after dewatering in the centrifuge, the material was pumped to trucks for transportation and disposal. Those solids have traditionally been disposed of at Forward Landfill, near Manteca, California. The roundtrip haul distance is 140 miles and the total disposal cost with trucking was $59 per wet ton. Recently an alternate disposal location at the Ostrium Road Landfill has been found at a total disposal cost of $29 per wet ton.

The City has constructed the first phase of a combined heat and power (CHP) system for the Plant. This phase is comprised of an "Active Solar Dryer" which uses solar energy to dry centrifuged biosolids from approximately 20% solids to as high as 90% solids. This process is seasonally dependent and produces the highest solids during the summer period. Ultimately the City planned to install natural gas power fuel cells to provide electric power to the Plant. Waste heat from the fuel cells was to be used to supplement solar energy in the Active Solar Dryers during the winter periods and to increase the overall capacity of the dryers. This plan has been placed on hold, with no schedule to complete the full project.

The biosolids produced by the plant have been found to contain up to 85% volatile solids. The volatility of the solids has produced an odor problem that is diminishing the operational viability of the Active Solar Dryers.

Wastewater treatment plant biosolids have been used for fuel to produce power in both thermal and non-thermal processes. The City has investigated a thermal process for disposal of biosolids (discussed in Section 4.1). Up until this point the City has not investigated the use of biosolids to produce energy through non-thermal processes.

At this time the Plant produces, on average, 5,100 dry pounds of biosolids per day. These biosolids release an unknown volume of green house gasses to the environment as a result of their processing, transportation and disposal. Both thermal and non-thermal processing of biosolids to destroy volatile solids would have the potential of significantly reducing the volume of greenhouse gasses released to the environment. The volume of greenhouse gasses resulting from disposal in a landfill would be significantly reduced as well.

The reason the Plant does not presently have anaerobic digesters is primarily monetary. Capital cost to construct traditional continually stirred (CSTR) wastewater treatment plant digesters is extremely high. To avoid this capital cost, the City has a higher operations cost associated with handling and disposal of approximately twice as much wastewater biosolids. If digesters had been constructed, the operational costs of the plant would be lower due to the reduction in solids disposal and the potential energy production.

The Thunder Valley Casino owns and operates its own wastewater treatment plant. This facility produces 10 wet tons of biosolids per week at a solids concentration of 14% solids. This volume could be diverted to the City for additional processing.

3.1 Food Waste

The CIWMB reports that 16% of total MSW is food waste. In the Draft 2008 City of Lincoln, Solid Waste Electronic Annual Report, the CIWMB estimates that Lincoln disposed 26,000 tons, with a diversion of about 60%. This results in a total waste production of about 65,000 tons per year. If the City were able to mine the food waste from MSW there would be an estimated 28.0 tons per day.

Based on observations in the City of San Jose, if just the 2" minus portion of the MSW was separated, about half the food waste could be captured for processing (14 tons).

The WPWMA currently has a program to keep restaurant waste out of the MRF. The City currently does participate in this program which in 2008 resulted in 165 tons of restaurant waste being direct hauled to the landfill, with no processing for the collection of recyclables. If the City were to expand this program to all restaurants there would be the potential to divert approximately 3 tons of food waste per day. This total would be included in the City wide 28.0 tons per day.

By far the largest point producer of food waste in the Lincoln area (within the sphere of influence, but not in the City) is the Thunder Valley Casino. In a recent facility tour Skip Elliott, Operations Manager for Thunder Valley Casino, estimated they dispose of 10 tons of food waste per day. This volume is not included in the City wide total.

3.2 Fats Oils and Grease

Based on 2006 data,[1] there are 19 Lincoln food establishments with grease interceptors, and 20 restaurants with grease traps. The average interceptor is 1500 gallons and is serviced once every 3 months. The grease occupies about 10% of the total volume. The average grease trap serviced volume is only 10 gallons, and they are serviced on average once a month. The grease is about half the total volume.

In the City of Lincoln the total volume of pure grease collected annually is about 11,500 gallons or 70,000 pounds. The total volume of very high COD water collected with pumping is 330,000 gallons. COD is estimated at 50,000 mg/l.

In addition, the Thunder Valley Casino produces 1,500 gallons of pure grease and oil each month from kitchen traps. This volume could be diverted to the City for processing. It is assumed that, due to daily pumping, the volume of grease currently captured in the Casino interceptor system is too dilute to be processed by the City.

3.3 Landfill Gas

[1] International Engineering Services, Industrial Discharger Survey

The WPWMA operates the landfill that services South Placer County. The landfill does have a cap with gas collection. At this time the WPWMA has a contract with a private party to generate electricity from produced landfill gas. Per Eric Oddo, Engineer for the WPWMA, there is no excess gas now, or anticipated to be in the future.

3.5 Greenwaste

In calendar year 2008 the City was credited with 6,342.40 tons of greenwaste disposal at the WPWMA. Of this, 4,136.33 tons were the result of the City residential collection program. The balance was a combination of commercial and residential self-haul.

The City has very good control of movement and disposal of City produced greenwaste. Greenwaste could be considered a significant fuel source. Unfortunately, the characteristics and volume of greenwaste change throughout the year.

3.6 Municipal Solid Waste (MSW)

As previously discussed in Section 3.2, in 2008 the City disposed of 26,000 tons of MSW in local landfills. Thiss Data is summarized in Figure 1. Also previously discussed in Section 3.2, the organic fraction of MSW can be mined for conversion to energy. Also there is a large component of MSW that is combustible and able to produce energy through a number of thermal conversion processes.

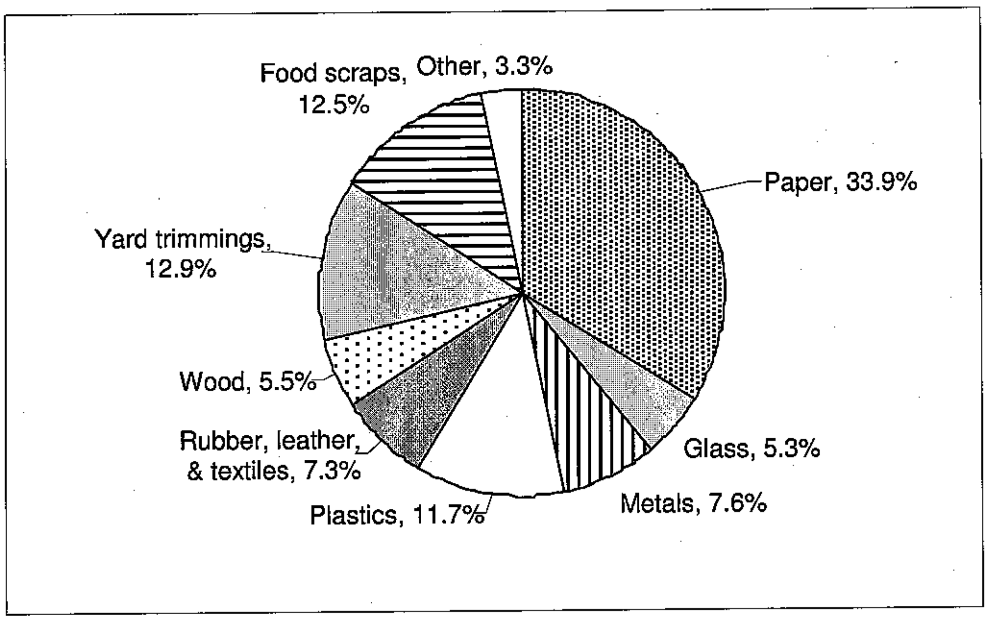


Figure 1. *National Waste Characterization of Municipal Solid Waste.*

The City has previously investigated thermal conversion of MSW for energy at the WWTRF. There are a number of reasons a MSW project was not pursued. One of the more significant reasons was the City did not have access to a large enough volume of MSW to make the project financially viable. At the time of investigation, the smallest project would require a minimum of 100 tons per day. Even now the City is considerably short of that volume averaging 71 tons per day.

Section 4: Waste to Energy Process Options

Worldwide there are three core processes for conversion of waste to energy. Thermal conversion with oxidation is by far the most prevalent, followed by thermal conversion without oxidation, and biological conversion.

4.1 Thermal Process

On July 22, 2009 the CIWMB held a public meeting to discuss the Draft Final Project Report Titled "**Life Cycle Assessment and Economic Analysis of Organic Waste Management and Greenhouse Gas Reduction Options.**" In that meeting it was stated that thermal technologies such as gasification and hydrolysis that process MSW, at a commercial scale, do not presently exist in the United States. These are emerging technologies that still require significant operational data before environmental and regulatory barriers will allow their development in California.

Over the last several years there has been a number of thermal, non-incineration/non-burn technologies proposed to process MSW. The City has met with one such technology provider, and has seriously entertained this option. Incineration, or burn processes can release dioxin (polychlorinated dibenzodioxins (PCDDs)) to the environment through oxidation of chlorinated compounds, such as the burning of PVC plastics. Dioxins will bioaccumulate in fatty tissues, so over time even small exposures may eventually reach dangerous levels. In humans dioxin accumulation can produce cancer, nervous system disorders, diabetes and endometriosis. For these reason incineration is not considered an alternative.

Non-burn thermal processes include:

- **Pyrolysis** operates at temperatures > 300°C. This is the basic process involved in the burning of wood and other organic compounds. As organics are heated in non-oxygenated environments a gas comprising partly of H_2 and CH_4 is produced. The visible flames of burning wood are not due to combustion of the wood itself, but rather of the gases released by pyrolysis. The process is rather crude resulting in very low grade gas products.

- **Gasification** operates at temperatures > 700°C. There are four basic types of gasification reactors, counter-current fixed bed ("up draft") gasifier, co-current fixed bed ("down draft") gasifier, fluidized bed reactor, and an entrained flow gasifier. All the processes operate with a controlled volume of oxygen and/or steam to produce synthesis gas or syngas. The main fuel produced is H_2.

- **Plasma Arc** operates at temperatures in the range of 2800°C to 4400°C. This process will break waste down into its primary elements where complex molecules are separated into individual atoms. The result is a syngas, which at a later stage can be refined into various fuels.

Due to the immaturity of thermal, non-burn technologies in the venue of MSW this option should not be considered for the City of Lincoln. In addition one could anticipate significant project opposition from environmental groups. This would lead to protracted environmental review and expense.

4.2 Anaerobic Digestion (AD)

In the seventeenth century Robert Boyle and Stephen Hale noted the release of flammable gas when disturbing sediments of streams, lakes and swamps. In 1808 methane gas was found to be present in off gassing of cattle manure. In 1859 the first anaerobic digester was built near Bombay India utilizing a process from England that produced gas for street lighting. Today around the world there are thousands of anaerobic digesters processing waste and producing energy. In Vietnam alone there are more than 20,000 AD systems used to process agricultural and household waste to produce gas for cooking in rural areas. This has significantly reduced deforestation resulting from cutting of firewood.

AD is a natural process. It is believed that bacteria used in various steps required to turn organic waste to methane have been on the earth from near the time of the origins of life. Manmade AD systems mirror natural processes with the intent of increased productivity.

The biological production of methane, or microbial methanogenesis, occur when four groups of microbes, acting synergistically, convert organic matter to primarily methane (CH_4) and carbon dioxide (CO_2). The four steps are:

1. **Hydrolysis;** is a chemical reaction where particulates are made soluble and large polymers converted into simple monomers.
2. **Acidogenesis;** is a biological reaction where simple monomers are converted into volatile fatty acids.
3. **Acetogenesis;** is a biological reaction where volatile fatty acids are converted into acetic acid, carbon dioxide, and hydrogen.
4. **Methanogenesis;** is a biological reaction where through the consumption of hydrogen, acetates are converted into methane and carbon dioxide.

This process is summarized in Figure 2.

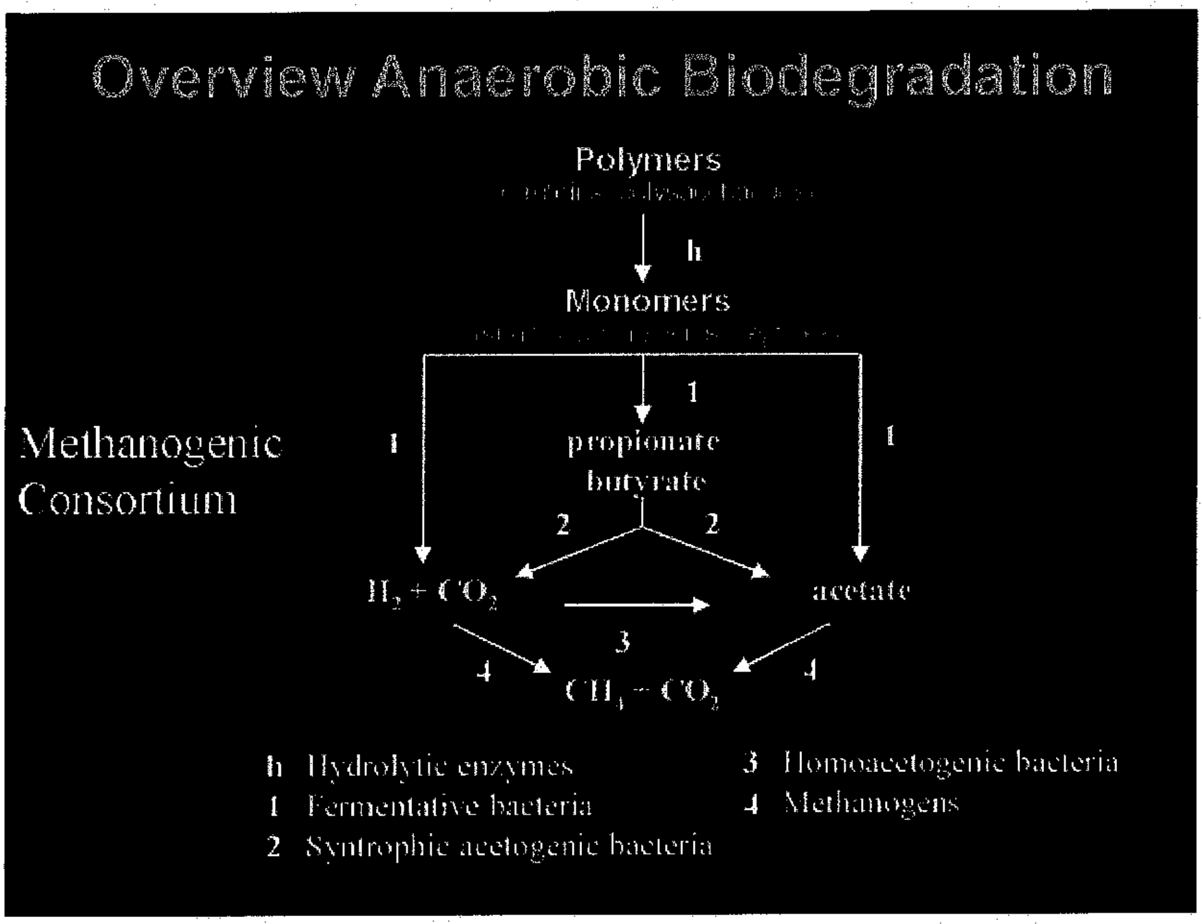


Figure 2. *From* *http://www.uasb.org/index.htm (accessed July 27 2009)*

If bacteria required to perform one of the steps is not present production of methane will not occur. If one or more of the bacteria are under populated that step will inhibit productivity of the system. Having proper bacteria populations, in correct ratios, will result in an optimized AD system.

Recent studies have shown that formation of bacterial consortia, in which small clusters of all required AD bacteria group together to form assemblages in their optimum ratio, will result in an optimized AD system. The basic challenge for AD system designers is:

- Methanogen bacteria repopulate much slower than the other bacteria. Therefore their population must be retained in the reactor and not lost with removal of other material.
- Consortia of bacteria are structurally very fragile. Very small acceleration of consortia will disassemble the bacterial cluster. When this occurs optimization is lost.
- Maintenance of a consistent environment where temperature, pH and feeding rates are maintained.

The success or failure of an AD system may well depend on the mechanical systems synergistic interface with the microbiology.

Because of its extensive experience and environmental acceptability, anaerobic digestion is considered the most feasible option for energy conversion for the City of Lincoln.

Section 5. Digester Technologies

In the most recent decade there has been a rapid expansion in anaerobic processes. Most of the development has come from Europe where there are significant government subsidies on both the input and output of AD systems. In the United States there has been a more muted development resulting from new regulatory requirements on dairy farming.

Of the various AD systems operating today, four have been identified as having potential for the City of Lincoln waste stream. One system is identified has having the greatest potential for success. The four systems are; continuously stirred tank reactor (CSTR), up flow anaerobic sludge blanket digestion (UASB), Induced Blanket Reactor (IBR), and Dry Digestion.

Of the available AD system some are able to process solid material, while others can only process soluble waste. Also, a very important factor is the ability of the AD system to operate at thermophilic temperatures of ~ 55°C. Thermophilic has intrinsic advantages over mesophilic digestion (~37°C), in terms of sanitation of the digestate and higher rates of decomposition.

5.1 Continuously Stirred Tank Reactor (CSTR)

CSTR digestive systems are the most widely used AD process for wastewater in the United States. AD/CSTR systems evolved from aerobic CSTR digestion processes. With both aerobic and anaerobic, CSTR development has incorporated ever increasing mixing energy. Aerobic systems required higher quantities of dissolved oxygen. Anaerobic systems were thought to require greater mixing velocity to force development of a homogeneous mixture. As previously discussed optimized anaerobic systems require formation and retention of consortia. Therefore mechanical mixing/agitation found in CSTR processes are counter productive.

The previously discussed Speece paper elaborates in depth regarding the issue of mixing and destruction of consortia. With mixing slow growing methanogen bacteria are lost with effluent. When this is combined with the loss of proximity of methanogen bacteria with the other bacteria in the anaerobic digestion process, hydrogen concentrations can increase effecting pH levels. These problems become more profound with CSTR operation at thermophilic temperatures.

Traditionally, the municipal industry has made up for the inherent inefficiencies of the conventional CSTR design by increasing the hydraulic retention time to 15 to 25 days. In addition, there are very few successful projects where conventional CSTR has been operated at a large scale at thermophilic temperatures given its instability and other process issues. As a result, the traditional CSTR municipal digester facility has very large tanks and mixing systems and is more capital cost and energy intensive then other digestion alternatives.

5.2 Upflow Anaerobic Sludge Blanket Digestion (UASB)

USAB digestion was developed in the Netherlands in the 1970s. The process was intended to treat very high strength wastewater. Since the 1970s UASB has become the process of choice for high strength liquid waste. The downside of UASB is it's intolerance of treating particulates.

The USAB system has no mechanical mixing. This allows bacteria consortia to be maintained. The consortia form a very powerful bed created by gravity settling in the reactor. Influent then flows up through this powerful bed allowing the slow growing methanogen bacteria population to be maintained.

The challenge with particulates in the USAB influent is that they interfere with the formation and retention of consortia. As a result, particulate containing water is treated in a two stage UASB system where the acidogenic and methanogenic processes occur separately. The acidogenic stage liquefies particulates and produces acids and H_2, which are then transferred to the methanogenic stage for transformation to methane. Each stage in the sequence requires separate management. Increased management and infrastructure requirements make the UASB system financially challenging when particulates in the wastewater required treatment.

Figure 3 shows and example of a USAB digester.

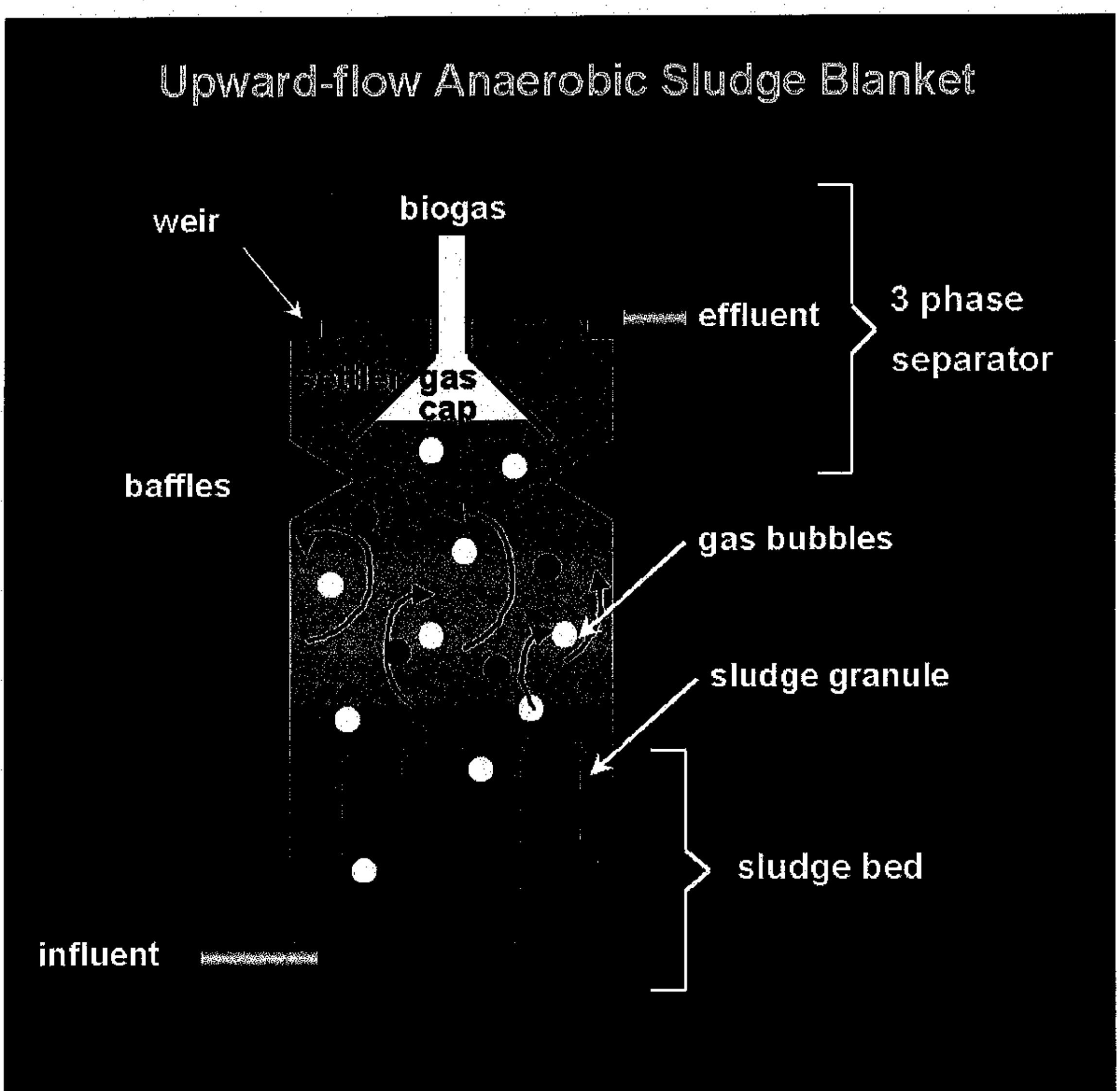


Figure 3. *Representation of an up flow anaerobic sludge bed (UASB) digestor. Sourced from http://www.uasb.org/index.htm (accessed 13 April 2009).*

5.3 Induced Blanket Reactor (IBR)

The IBR digestion process was developed by Utah State University for the treatment of dairy manure. In many ways it is similar to the UASB system, with the significant exception that it can process and digest particulates. This is made possible by development of a three phase separator at the top of the reactor. The separator provides a means to separate effluent from digested solids, while produced methane is allowed to separately exit the process. Undigested solids and bacteria consortia are returned to the process for additional treatment. Solids influent have been processed with concentrations as high as 25%, though typically the system is operated with 10% solids.

IBR influent solids provide a point for bacteria consortia to organize. Solids remain in the reactor until digestible matter is consumed. Bacteria consortia then remain in the reactor to provide digestion of new influent.

Figure 4 shows and example of an IBR Digester.

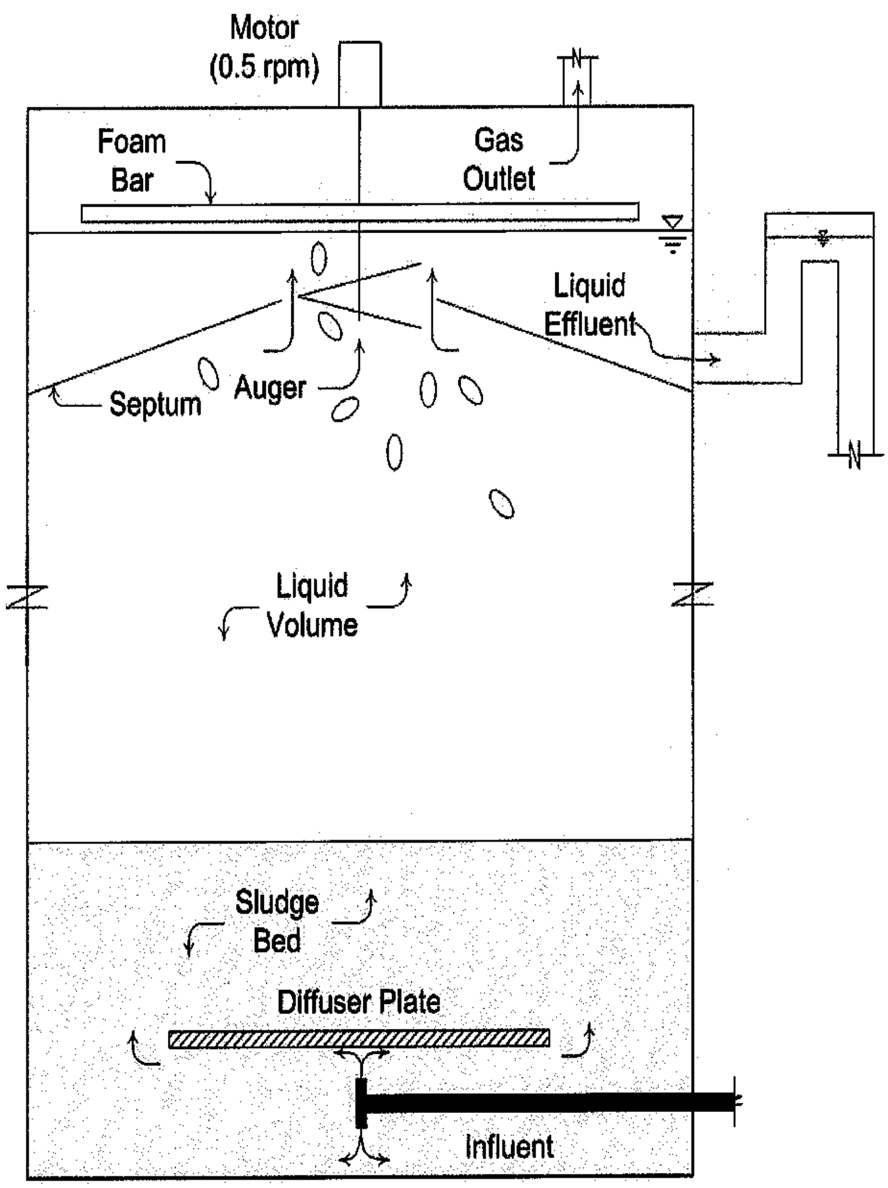


Figure 4. *Schematic of the IBR reactor (courtesy of Conly L. Hansen and Shaun Dustin), Utah State University.*

Both the IBR and the UASB can operate at thermophilic temperatures while maintaining consortia formation. For solid waste processing the IBR is the preferred technology due to processing of solids in a single phase.

5.4 Dry Digestion

Dry digestion is a complete departure from the previously discussed processes. The process is designed to primarily treat solids. Similar to aerobic composting a bulking agent must be used to promote percolation. The process starts when solid organic waste mixed with a bulking agent is placed in a sealed vault. The mass is then sprayed with a blend of anaerobic bacteria. Over the course of weeks the organic mass is partially converted to methane.

Figure 5 shows an example of a dry process. Unlike all the previous examples this is a batch process. Due to the requirement for a bulking agent, and the potential nature of Lincoln waste which would include wastewater biosolids, this process would not be effective.

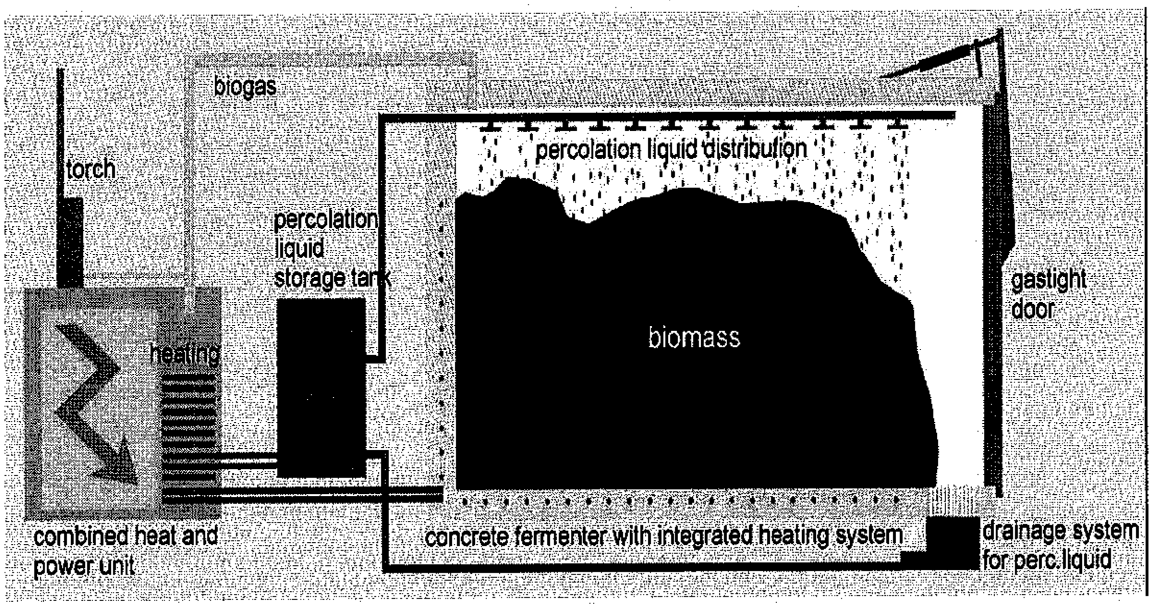


***Figure 5.** The Bekon process shown above is an example of dry digestion. The figure shows one of a series of vaults.*

5.5 Digester Technology Conclusions

For digestion of solid material, such as municipal sludge, food waste, and MSW, the IBR system appears to be the best option. The hydraulic retention time (HRT) is as low as 5 days as compared with 10-20 or more for the other systems. This coupled with the higher solids concentration handled by the IBR yields total tank volumes 1/4th or less the size of traditional municipal CSTR and USAB systems. Given that the UASB is not able to process solids, the IBR is the only system that can operate successfully at thermophilic temperatures while processing solids seen in municipal sludge and food waste.

As for capital cost and cost of operation, the IBR appears again to be the best alternative. The IBR requires no internal circulation pumping and limited heating. So in addition to smaller tank sizes the amount of support equipment is significantly less. The need for a digester control building to house this equipment has also been eliminated. The electrical energy usage is also about 20% of a conventional municipal CSTR system. As a result, the IBR digester system was the only system considered to have enough process and economic advantages to be economically viable at the City of Lincoln. As such, this was the only anaerobic digester alternative carried forward for detailed economic analysis.

5.6 Anaerobic Digester Process Analysis for IBR System at City of Lincoln

Process calculations to determine the vessel and equipment sizing as well as the material and gas flow rates, heating requirements and estimated gas productions were developed for the City of Lincoln based on the IBR anaerobic process. This analysis is summarized in Table 1.
In the analysis, the conditions considered included processing the existing sludge produced at the facility, and the impact on digestion of this sludge if fats, oils, and grease (FOG) is collected from the City and from the Casino and added to the sludge for digestion. Digestion of individual food waste sources from the City and from the Casino were also developed. Finally an ultimate project considering the digestion of the existing municipal sludge along with collected FOG and food waste from the City and the Casino was developed.

Based on this process analysis, it was determined that the most flexible approach for the City of Lincoln is to develop the ultimate project in phases. Phase 1 is the base system of adding anaerobic digestion to the existing facilities to digest and reduce the solids going into the existing active solar dryers. Phase 2 is the addition of FOG collection from the city and the Casino to the Phase 1 project. Phase 3 is the addition of Food Waste Collection to the Phase 2 project. These phases were developed because they offer the most logical buildout of the facilities in terms of program development and they are also organized in the most economical order.

Due to the high overhead cost to develop each facility, it does not make economic sense to develop in smaller increments or to collect only a portion of the FOG or food waste from the City and Casino.

Table 1- Lincoln IBR Digester Process Analysis

Process Criteria	WWTRF Sludge (1)	WWTRF Sludge W/ FOG From City and Casino (2)	City Collected Food Waste	Casino Food Waste	WWTRF Sludge W/ Food Waste From City and Casino	WWTRF Sludge W/ FOG and Food Waste From City and Casino (3)
Digester Feed Criteria						
Dry Solids Feed (dry lbs/day)	5,100	6,037	1,512	5,040	11,652	12,589
Solids Concentration as Received	1%	1%	25%	25%	14%	13%
Weight Received (lbs/day)	510,000	603,682	6,048	20,160	536,208	629,890
Volume Received (gal/day)	61,151	72,384	725	2,417	64,294	75,526
Actual Grease Percentage		18%				
Maximum Grease Percentage of Sludge by wt		25%				
Gas Produced (cf/lb converted)	14	17	13	13	13.4	14.9
Gas Percent Methane (%)	62%	70%	65%	65%	64%	67%
Gas Heating Value (HHV) (BTU/cf)	620	700	650	650	637	672
Feed Solids Concentration	8%	8%	10%	10%	10%	10%
Digesters						
Diameter (ft)	13.5	13.5	13.5	13.5	13.5	13.5
Wet Side Water Depth (ft)	30	30	30	30	30	30
Digester Volume (cf/digester)	4,294	4,294	4,294	4,294	4,294	4,294
Digester Volume (gal/digester)	32,120	32,120	32,120	32,120	32,120	32,120
No of Digesters	3	3	1	2	5	5
Total Digester Volume (gal)	96,361	96,361	32,120	64,241	160,602	160,602
Influent Flow (gpd)	7,644	10,002	1,813	6,043	13,971	15,095
HRT (days)	12.6	9.6	17.7	10.6	11.5	10.6
Total Solids in (lb/day)	5,100	6,037	1,512	5,040	11,652	12,589
Percent VSS in (%)	80%	83%	90%	90%	86%	87%
VSS Destruction (%)	55%	71%	80%	80%	69%	76%
VSS Loading (lb/cf-day)	0.042	0.096	0.042	0.071	0.062	0.068
Methane Gas Produced, (cf CH4/dry ton)						
Residual Solids (lbs/lbs feed), (%)						
Converted Solids (lb/day)	2,244	3,555	1,089	3,629	6,961	8,273

Digester Remaining Solids (lb/day)	2,856	2,482	423	1,411	4,691	4,316
Digested Solids (%)	4.6%	3.1%	3.0%	3.0%	4.3%	3.7%
Digester Remaining Solids (gpd)	7,375	9,499	1,682	5,608	13,137	14,103
Tank Size for 3 Days Storage (gal)	22,124	28,498	5,047	16,824	39,410	42,308
Gas Produced (cf/day)	31,416	60,440	14,152	47,174	93,546	123,414
Higher Heating Value of Fuel (Therms/hr)	8.12	17.63	3.83	12.78	24.82	34.58
Total Fuel Flow (BTU/hr)	811,580	1,762,832	383,292	1,277,640	2,482,349	3,457,645
Incoming Sludge Temperature (F)	65	65	65	65	65	65
Digester Temperature (F)	135	135	135	135	135	135
Sludge Heating Requirement (BTU/hr)	185,938	243,301	44,100	147,000	339,850	367,174
Boiler Efficiency (%)	80%	80%	80%	80%	80%	80%
Input Fuel to Boiler (BTU/hr)	0	0	0	0	0	0
Remaining Fuel for Cogeneration (BTU/hr)	811,580	1,762,832	383,292	1,277,640	2,482,349	3,457,645
Remaining Fuel kW	238	516	112	374	727	1,013

Notes

1) This option was selected as Phase 1 for the economic analysis.
2) This option was selected as Phase 2 for the economic analysis.
3) This option was selected as Phase 3 for the economic analysis.

Section 6. Electrical Generation Technologies

The City originally considered Fuel Cells only for this analysis. However, after quantifying the available gas flows, it became clear the fuel cells would only be suitable for the largest Phase 3 portion of the project. Therefore, Internal Combustion (IC) Engines and Gas Turbines were also considered for Phase 1 and 2 of the project.

6.1 Internal Combustion (IC) Engines

Internal combustion engines have been used on digester gas for many years. They are also usually the lower cost alternative for electrical cogeneration. The biggest constraint to their use are the increasingly higher emissions standards promulgated throughout the different air districts in the State of California. Both Waukesha and Caterpillar make engines for digester gas service. The specific air emissions limits for Placer County will govern the exact engine that can be used.

6.2 Micro-Turbines

Micro turbines have been successfully installed on digester gas. These systems are small packaged gas turbines that actually rest on the bearings until it comes up to full speed when it lifts off and floats. They have the advantages of close combustion control and lower emissions than IC Engines. Capstone makes a 65 kW micro-turbine and 200 kW micro-turbine and Ingersoll Rand makes a 250 kW unit.

The main disadvantage of micro turbines is that they are designed to be started and left on and cannot load follow. This means that the micro-turbines cannot change power output and follow plant electrical load or gas production for the facility. To compensate for this they are usually undersized somewhat for the actual gas production for the facility and their control design is more complex.

6.3 Fuel Cells

Fuel cells generate electricity without using combustion based on chemically separating the methane molecules. There are two common types of fuel cells, phosphoric acid as manufactured by United Technologies Inc., and molten carbon as manufactured by Fuel Cell Energy, Inc. The molten carbon fuel cells from FCE have the highest energy efficiency of any system available at approximately 40% based on the higher heating value of the fuel. The phosphoric acid fuel cells cost less, but have somewhat lower efficiencies. Currently, United Technologies has stopped selling their older style fuel cell and is coming out with their second generation fuel cell for digester gas service. As a result, it is only possible to compare FCE fuel cells at this time. Therefore, the analysis was based on a 300 kW FCE fuel cell system.

In addition to economic advantages, the biggest advantage to fuel cells is that they have the lowest emissions output of any prime mover system. This has made them very desirable from a green environmental perspective and very easy to obtain an air permit for. They also produce the lowest amount of carbon dioxide, a greenhouse gas, of any of the prime mover options. As a result, the fuel cell projects have both PG&E incentive rebates through December 31, 2011 and federal tax credits available to encourage their uses. The City would not likely be able to take advantage of the federal tax credit and would need to complete the entire project no later than December 31, 2011 to take advantage of the PG&E rebate program.

6.4 Electrical Cogeneration Analysis for the City of Lincoln

To determine the governing conditions for the size of the electrical cogeneration system, gas production estimates were made and presented in Section 5.6. These estimates were compared to the average plant electrical usage each month and the monthly influent flow for the facility. The plant influent flow and power usage data are presented in Figure 6.

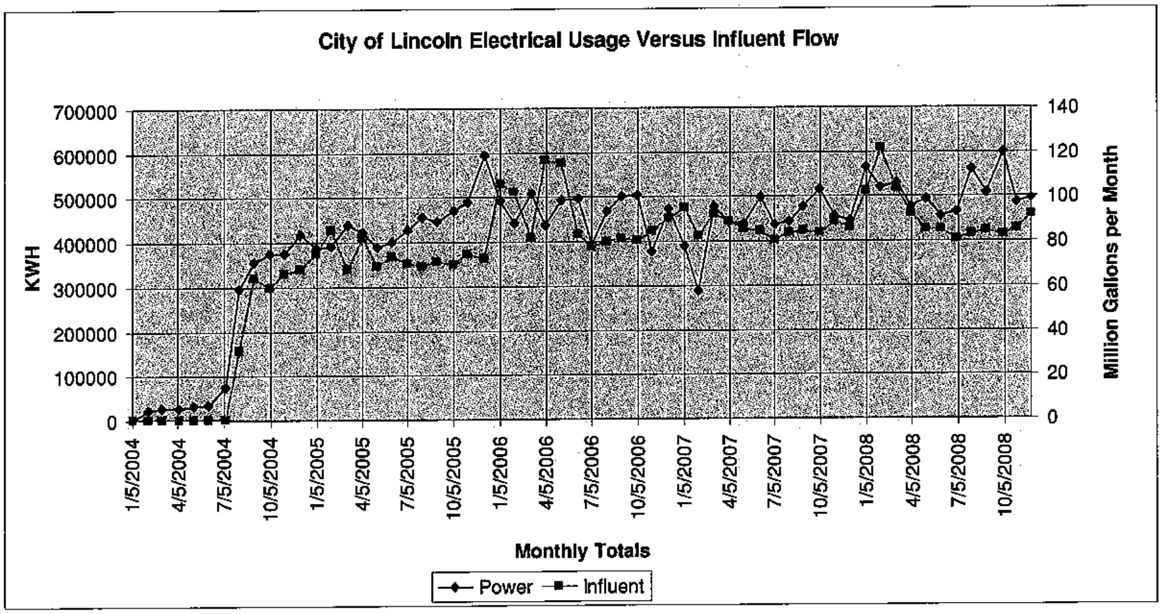


Figure 6. *City of Lincoln Monthly Electrical Usage*

Based on the total monthly power and influent flows in Figure 6, the average plant load varies from 625 kW to 833 kW and the influent flow is approximately 3 mgd. Cogeneration systems larger than 600 kW would therefore need to be curtailed during parts of the year to avoid an export situation to PG&E. Combining figure 6 with the analysis in Section 5.6, it is clear that none of the project alternatives produce enough gas to exceed the plant minimum usage of 625 kW. The electrical cogeneration choice is therefore limited by the gas production and not the electricity usage at the facility.

An economic comparison of the three electrical cogeneration alternatives for each project phase is presented in Table 2. From this table it is clear the larger systems are more economically viable than the smaller systems. This is because of the large overhead to install the initial system.

Based on this analysis, the best performing cogeneration option for each phase was carried forward to the overall economic comparison of the anaerobic digestion system in Section 7. For Phase 1 this was the micro-turbine. For Phase 2 and 3 this was the IC Engine.

The 300 kW fuel cell is a viable option if all 3 phases are constructed. However, all three phases would need to be constructed and the complete FOG and Food Waste Collection programs would need to be in place and fully operational by December 31, 2011 to produce enough gas to qualify for the PG&E rebate. Given the tight timeframe and the fact that the IC engines are a more economical alternative than the fuel cells, the IC engine option was carried forward for the detailed economic analysis.

Table 2- Cogeneration Options Economic Analysis

Cost Item	Micro-Turbine			IC Engine			Fuel Cell		
	Phase 1 Anaerobic Digesters	Phase 2 FOG Receiving	Phase 3 Food Waste and FOG	Phase 1 Anaerobic Digesters	Phase 2 FOG Receiving	Phase 3 Food Waste and FOG	Phase 1 Anaerobic Digesters	Phase 2 FOG Receiving	Phase 3 Food Waste and FOG
Average Plant Electric Cost per kW	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12	$0.12
Gas produced (cf/day)	31,416	60,440	123,414	31,416	60,440	123,414	31,416	60,440	123,414
Higher Heating Value of Fuel (Therms/hr)	8	18	35	8	18	35	8	18	35
Total Fuel Flow (BTU/hr)	811,580	1,762,832	3,457,645	811,580	1,762,832	3,457,645	811,580	1,762,832	3,457,645
Electrical Revenue									
Cogen Size (kW)	65	130	250	125	175	350	N/A (1)	N/A (1)	300
Average Electrical Production (kW)	55	121	236	74	161	315			300
Cogen Availability	96%	96%	96%	95%	95%	95%			95%
Total Annual Electric Reduction (kW-hr)	462,335	1,014,968	1,984,077	614,140	1,336,038	2,619,235			2,496,600
Net Electrical Revenue ($/yr)	$55,480	$121,796	$238,089	$73,697	$160,325	$314,308			$299,592
Annual Costs									
Yearly Warranty and Service Contract Prime Mover ($/kW-hr)	$0.011	$0.011	$0.011	$0.025	$0.025	$0.025			$0.035
Yearly Warranty and Service Contract Prime Mover ($/yr)	$6,263	$12,527	$24,090	$27,375	$38,325	$76,650			$91,980
Yearly Warranty and Service Contract Gas Conditioning	$16,425	$22,995	$45,990	$16,425	$22,995	$45,990			$45,990
Subtotal Operations Costs	$22,688	$35,522	$70,080	$43,800	$61,320	$122,640			$137,970
Net Offset Revenue per Year	**$32,792**	**$86,274**	**$168,009**	**$29,897**	**$99,005**	**$191,668**			**$161,622**

Project Costs								
Total On Site Construction Cost	$ 530,000	$ 791,000	$ 1,374,000	$ 705,000	$ 847,000	$ 1,060,000		$ 2,385,000
Project Design and Construction Management	$ 53,000	$ 79,100	$ 137,400	$ 70,500	$ 84,700	$ 106,000		$ 238,500
Total Project Costs	$ 583,000	$ 870,100	$ 1,511,400	$ 775,500	$ 931,700	$ 1,166,000		$ 2,623,500
PG&E Self Generation Rebate Renewable Portion ($4.50/W) (2)								$ (1,282,500)
Total Project Cost	**$ 583,000**	**$ 870,100**	**$ 1,511,400**	**$ 775,500**	**$ 931,700**	**$ 1,166,000**		**$ 1,341,000**
Simple Payback Years	17.8	10.1	9.0	25.9	9.4	6.1		8.3

NOTES

1) Gas production is too small for a renewable energy Fuel Cell
2) This rebate expires 12/31/2011. The City would need all three phases constructed and all FOG and food collection in place and fully operational by 12/31/2011 to qualify for this rebate.

Section 7. Economic Analysis

7.1 Operational, Revenue and Capital Costs

For the analysis, operating costs were developed for the existing plant conditions impacted by the project for Phases 1 through 3. The existing plant conditions impacted by the project are the dewatering and solids disposal operations. Digesting the sludge will reduce the total amount of solids processed through the dewatering facility and disposed of. For the current condition, the active solar dryer is not used because of the serious odor issues encountered with its operation. The solids disposal costs are therefore more than what can be achieved with the dryer. Digesting the solids will remove the sludge volatility causing the odors and should restore this system to normal use with significantly less odor. This is accounted for in the analysis.

Table 3 presents the Lincoln Unit Cost data used for the economic analysis.

Table 3 - Lincoln Unit Cost Data			
Base Cost			
Polymer Cost	$	2.00	per lb active polymer
Electricity	$	0.120	per kW-hr
Operator Cost	$	70.00	per hour including benefits

Table 4 presents a summary of the process criteria used for each phase in the analysis.

Table 4 - Lincoln Process Criteria for Each Phase

Process Criteria	Existing Conditions	Phase 1 Anaerobic Digesters	Phase 2 FOG Receiving	Phase 3 Food Waste and FOG
Plant Flow Average Annual (mgd)	3.5	3.5	3.5	3.5
WAS Solids Loading dry (lb/day)		5100	5100	5100
WAS Solids Loading dry (lb/year)		1861500	1861500	1861500
WAS Solids Loading dry (tons/year)		931	931	931
Centrifuge Solids Loading dry (lbs/day)	5,100	2856	2482	4316
Centrifuge Solids Loading dry (lbs/year)	1861500	1042440	905758	1575373
Centrifuge Solids Loading dry (tons/year)	931	521	453	788
Centrifuge Feed Concentration (%)	1%	4.6%	3.1%	3.7%
Centrifuge Cake % Solids	20%	28%	28%	28%
Capacity of 1 Centrifuge dry (lbs/hr)	2200	2200	2200	2200
Capacity of 1 Centrifuge wet (gpm)	440	95	140	120

Table 5 presents the operating costs for the existing conditions and for each phase of the project.

Table 5 - Operating Costs for Each Phase

Operational Item	Existing	Phase 1		Phase 2			Phase 3			
	Dewatering	Digester System	Dewatering	Digester System	Dewatering	FOG System	Digester System	Dewatering	FOG System	Food Waste System
Number of Operating units	2	1	1	1	1	1	1	1	1	1
Polymer Usage										
lb polymer per dry ton of sludge	36	10	25	10	25		10	25		
lb polymer per year	33507	9308	13031	9308	11322		9308	19692		
Polymer Costs per year	$67,014	$18,615	$26,061	$18,615	$22,644		$18,615	$39,384		
Operational hours per week	16.2	168	9.1	168	7.9	168	168	13.7	168	168
Operating hp	350	18.7	350	18.7	350	5.1	18.7	350	5.1	34.0
Operating kW-hr/week	4243	2347	2376	2347	2064	639	2347	3590	639	4273
Electrical Cost per year	$26,474	$14,644	$14,825	$14,644	$12,882	$3,989	$14,644	$22,405	$3,989	$26,663
Operator hours per week	10	10	7	10	7	5	10	7	5	5
Operator Cost per year	$36,400	$36,400	$25,480	$36,400	$25,480	$18,200	$36,400	$25,480	$18,200	$18,200
Maintenance Costs per year	$20,000	$10,000	$10,000	$10,000	$10,000	$5,000	$10,000	$10,000	$5,000	$5,000
Process Operating Costs Per Year	$149,888	$79,659	$76,366	$79,659	$71,006	$27,189	$79,659	$97,269	$27,189	$49,863
	Existing		**Phase 1**			**Phase 2**				**Phase 3**
Total Net Operating Costs	**$149,888**		**$156,025**			**$177,853**				**$253,980**

Table 6 presents the annual disposal costs for the City of Lincoln for the Existing Condition and for each project phase. These costs include the cost to the City to dispose of the existing food waste collected by the City as well as the sludge from the wastewater treatment plant. The Existing phase for the treatment plant sludge does not credit sludge drying because the active solar dryers are not used as a result of the odor issues encountered with their operation.

Table 6 - Lincoln Annual Disposal Costs

Disposal Source		Existing	Phase 1	Phase 2	Phase 3
For City Collected Food Waste					
City Collected Food Waste (Wet Tons/year)		1104	1104	1104	0
Cost of Disposal	$35 per wet ton	**$38,632**	**$38,632**	**$38,632**	**$0**
For WWTP					
Solids Before Drying (dry lbs/day)		5,100	2,856	2,482	4,316
Average Sludge Percent Solids Before Drying		20%	28%	28%	28%
Average Sludge Percent Solids After Drying (1,2)		20%	80%	80%	50%
Solids After Drying (dry lbs/day) (2,3)		25,500	3,570	3,102	8,632
Solids Disposal tons per year (wet)		4654	652	566	1575
Ostrum Road Landfill					
Trucking and Tipping (4)	$29 per wet ton	**$134,959**	**$18,894**	**$16,417**	**$45,686**
Total All Disposal Costs		**$173,590**	**$57,526**	**$55,048**	**$45,686**

NOTES

1) Assumes waste heat from cogeneration or waste gas is burned and heat directed into existing Dryers.
2) Odor issues have curtailed the use of the dryers under the existing condition.
3) Installing anaerobic digesters will remove the sludge volatility and allow the dryers to operate with significantly less odor.
4) The disposal cost has recently been reduced from $59/wet ton when the dryers were constructed to $29/wet ton.

Table 7 presents the total City revenue, operations, and disposal costs for the existing condition and for each project phase.

Table 8 presents the capital cost summary for each project phase. A detailed cost break down of each project phase is presented in the appendix.

Table 9 presents the combined revenue and capital cost summary including the project simple payback periods.

Table 7 - Total City Revenue, Operations, & Disposal Costs

Costs	Without Cogeneration				With Cogeneration			
	Existing	Phase 1	Phase 2	Phase 3	Existing	Phase 1	Phase 2	Phase 3
Revenue from Grease Receiving (1)			($52,238)				($52,238)	
Net Revenue from Cogeneration (2)						($32,792)	($99,005)	($191,668)
Operating Costs	$149,888	$156,025	$177,853	$253,980	$149,888	$156,025	$177,853	$253,980
Disposal Costs	$173,590	$57,526	$55,048	$45,686	$173,590	$57,526	$55,048	$45,686
Total All Revenue and Costs of Operation	$323,478	$213,551	$180,664	$299,665	$323,478	$180,759	$81,660	$107,997
Net Savings Over Existing Condition		**$109,927**	**$142,814**	**$23,813**		**$142,719**	**$241,819**	**$215,481**

NOTES
1) Based on $0.15/gal of grease received
2) Based on best performing cogeneration option in this size range. Micro-Turbine for Phase 1 and IC Engine for Phase 2 or Phase 3.

Table 8 - Capital Cost Summary

Costs		Without Cogeneration				With Cogeneration			
		Existing	Phase 1	Phase 2	Phase 3	Existing	Phase 1	Phase 2	Phase 3
Base Project Cost			$ 2,335,000	$ 472,000	$ 1,498,000		$ 2,335,000	$ 472,000	$ 1,498,000
Project Cost for All Phases				$ 2,807,000	$ 4,305,000			$2,807,000	$ 4,305,000
Cogeneration Project Cost (1)							$ 583,000	$ 931,700	$ 1,166,000
Total On Site Construction Cost			$2,335,000	$3,279,000	$5,803,000		$2,918,000	$4,210,700	$6,969,000
Project Design and CM Cost			$233,500	$327,900	$580,300		$291,800	$421,070	$696,900
Total Project Cost			**$2,568,500**	**$3,606,900**	**$6,383,300**		**$3,209,800**	**$4,631,770**	**$7,665,900**
Annualized Capital Cost			**$206,103**	**$289,427**	**$512,213**		**$257,563**	**$371,665**	**$615,132**
Interest	5%								
Period (years)	20								

NOTES
1) Based on best performing cogeneration option in this size range. Micro-Turbine for Phase 1 and IC Engine for Phase 2 or Phase 3.

Table 9 - Combined Revenue, Operations and Capital Cost Summary

Costs	Without Cogeneration				With Cogeneration			
	Existing	Phase 1	Phase 2	Phase 3	Existing	Phase 1	Phase 2	Phase 3
Total Project Cost		$ 2,568,500	$ 3,606,900	$ 6,383,300		$ 3,209,800	$4,631,770	$ 7,665,900
Net Savings Over Existing Condition		$ 109,927	$ 142,814	$ 23,813		$ 142,719	$ 241,819	$ 215,481
Simple Project Payback		23	25	268		22	19	36

7.2 Carbon Credit Market

In 2001 the State of California created the California Climate Action Registry which has transitioned into the Climate Action Reserve (CAR). The mission of CAR is to address climate change through voluntary calculation and public reporting of emissions through transparent valuation of the US carbon market. It accomplishes this by establishing standards for development, quantification and verification of greenhouse gas (GHG) emissions reductions for projects in North America. CAR then issues carbon offset credits known as Climate Reserve Tonnes (CRT). CAR then tracks the transition of credits over time.

After CAR establishes CRT for a project the CRT can be sold or traded on the Chicago Climate Exchange.

Rules or protocols for the establishment of CRT in the venue of municipal sludge, food waste, MSW, and anaerobic digestion are still being established by CAR. At this time it would be difficult to estimate what the final protocol will be to establish an estimated value for various projects the City could consider. In the dairy protocol where cow manure is being processed into methane for production of electricity in an internal combustion engine, the CARs have a value approximately equivalent to four cents for every kilo-watt hour of electricity produced. There may or may not be a correlation to digestion of a portion of municipal sludge and food waste. Only when future protocols are established will that be answered.

In this report, the lack of clear protocols and a set economic benefit to the project for the reduction in greenhouse gases limits the analysis to what can be clearly economically quantified. As a result, the economic benefit of greenhouse gas reduction is not quantified or included in the economic analysis. The resulting projects considered show very long project paybacks without an economic credit for their greenhouse gas reducing benefits.

Section 8. Preliminary Design

8.1 Process Design Schematics

A process diagram for each phase has been prepared. Figures 7, 8, and 9 present the 10% design process schematic for each phase of the project.

8.2 Site Layout

Given the significant size reduction available with the IBR anaerobic digesters, the City of Lincoln can easily accommodate the digesters without impacting any areas reserved for future processes. The facilities would be located next to the existing dewatering building in the paved area originally considered for emergency storage and drying of sludge. This area was made obsolete with the addition of the active solar dryers.

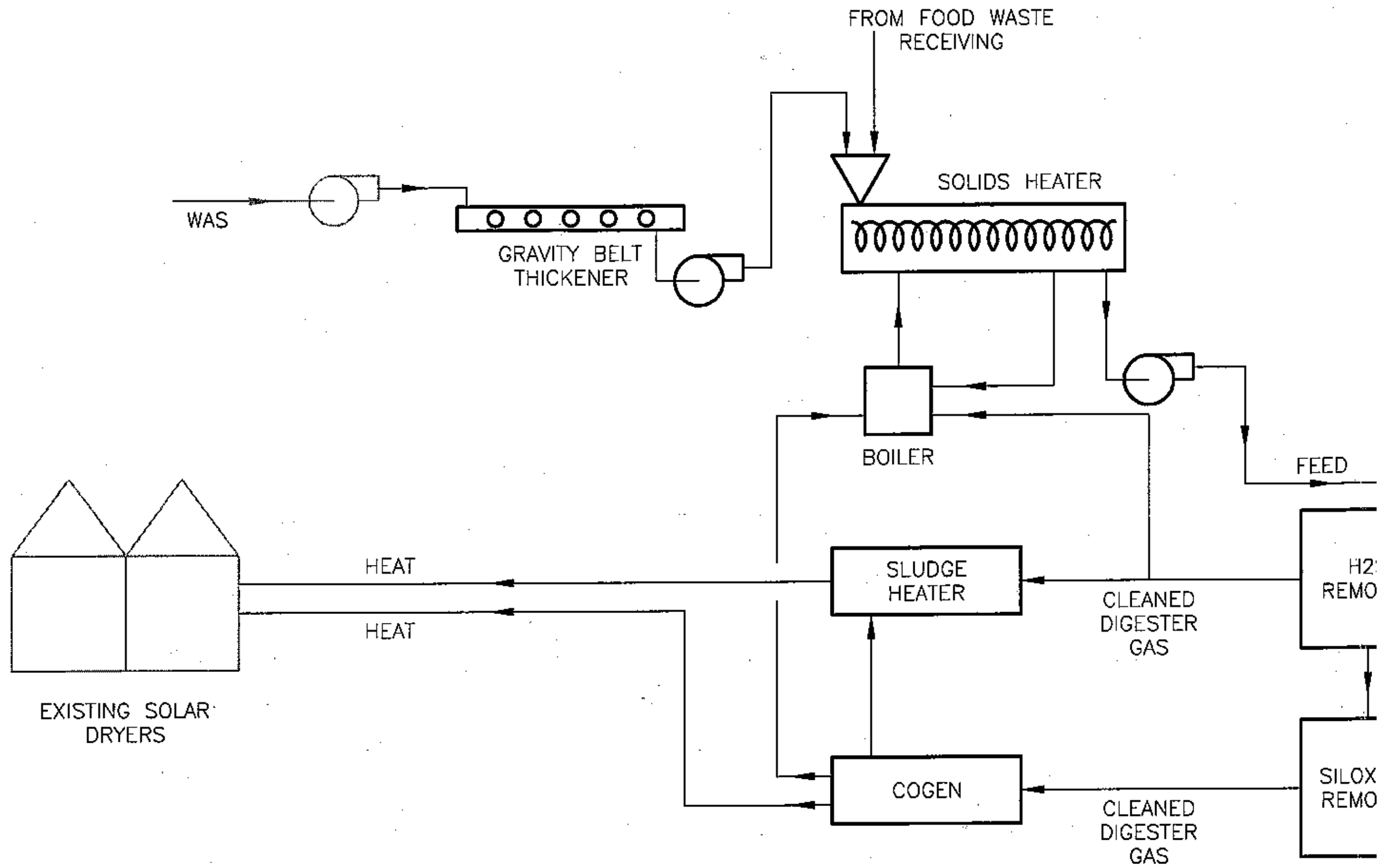
Figures 10, 11, and 12 present the site layout for each phase of the project.

8.3 Schedule

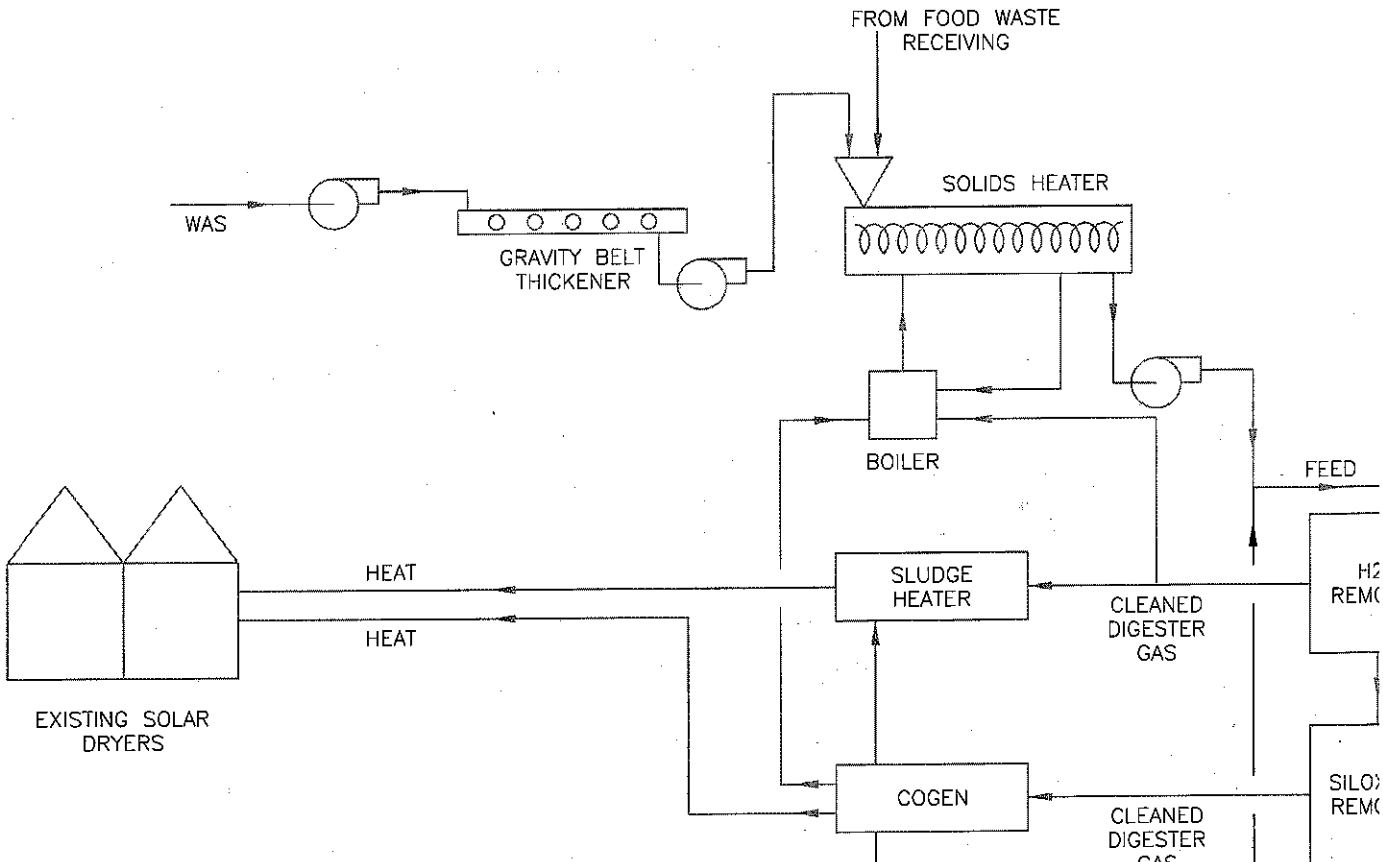
Based on the process design above. Phases 1 through 3 can be built sequentially or as a single project. Because Cogeneration projects are exempt form CEQA and the digester facilities would be contained on site with a significant benefit to greenhouse gas reduction, we do not anticipate anything more than a negative declaration for the project. As a result the project schedule can be compressed enough to complete Phase 1 by December 2010. The project schedule is shown in Table 10.

Table 10 - Project Schedule

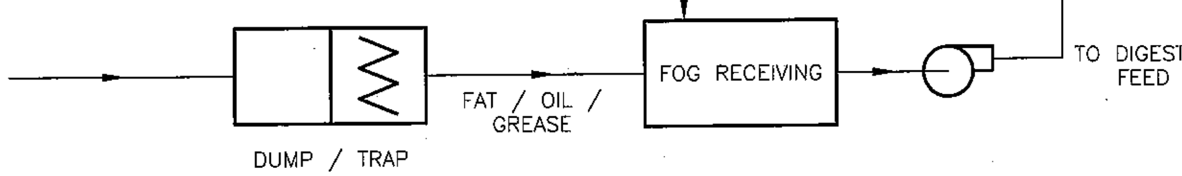
Item	Date
Phase 1 Project Approval	September 2009
Begin Engineering Design and CEQA Work	October 2009
Complete Design and CEQA Negative Declaration	April 2010
Project Bidding	May 2010
Order Long Lead Time Equipment	May 2010
Award Project and Begin Construction	June 2010
Complete Construction	December 2010



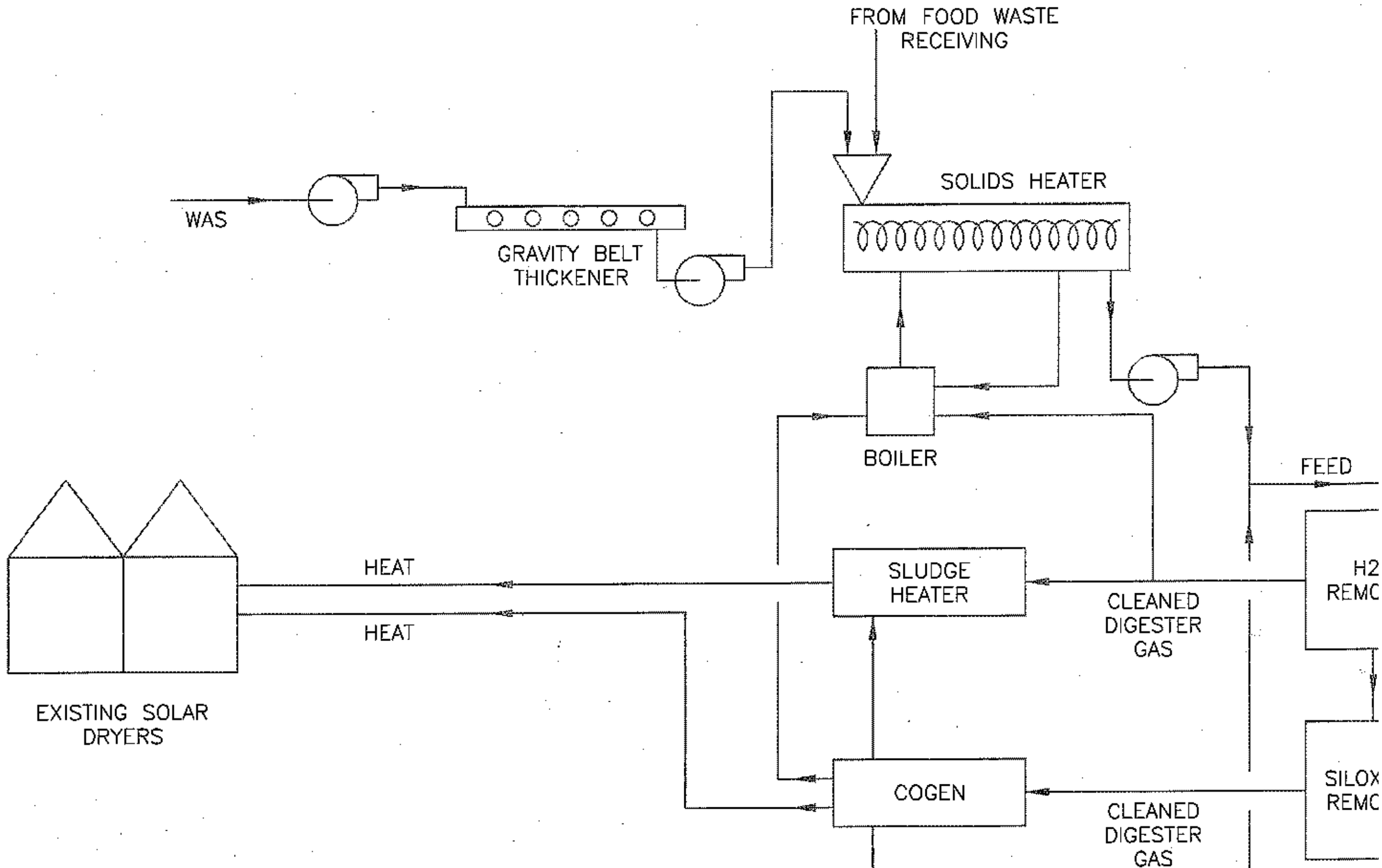
PHASE 1 - SOLIDS DIGESTION



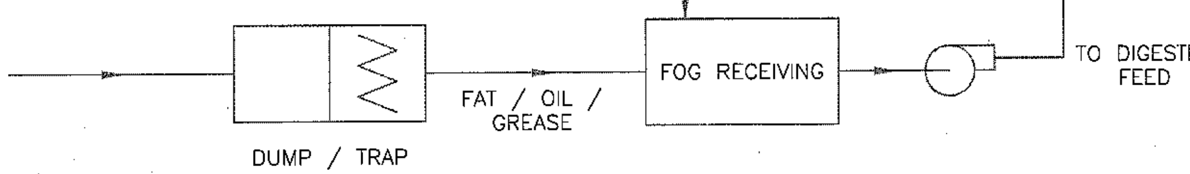
PHASE 1 - SOLIDS DIGESTION



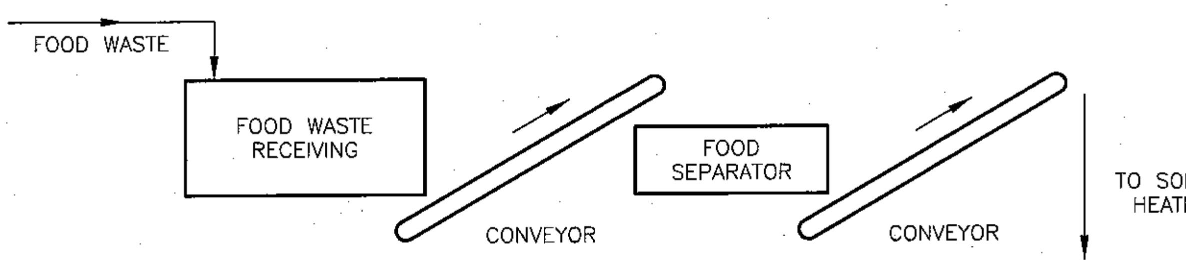
PHASE 2 - FOG RECEIVING



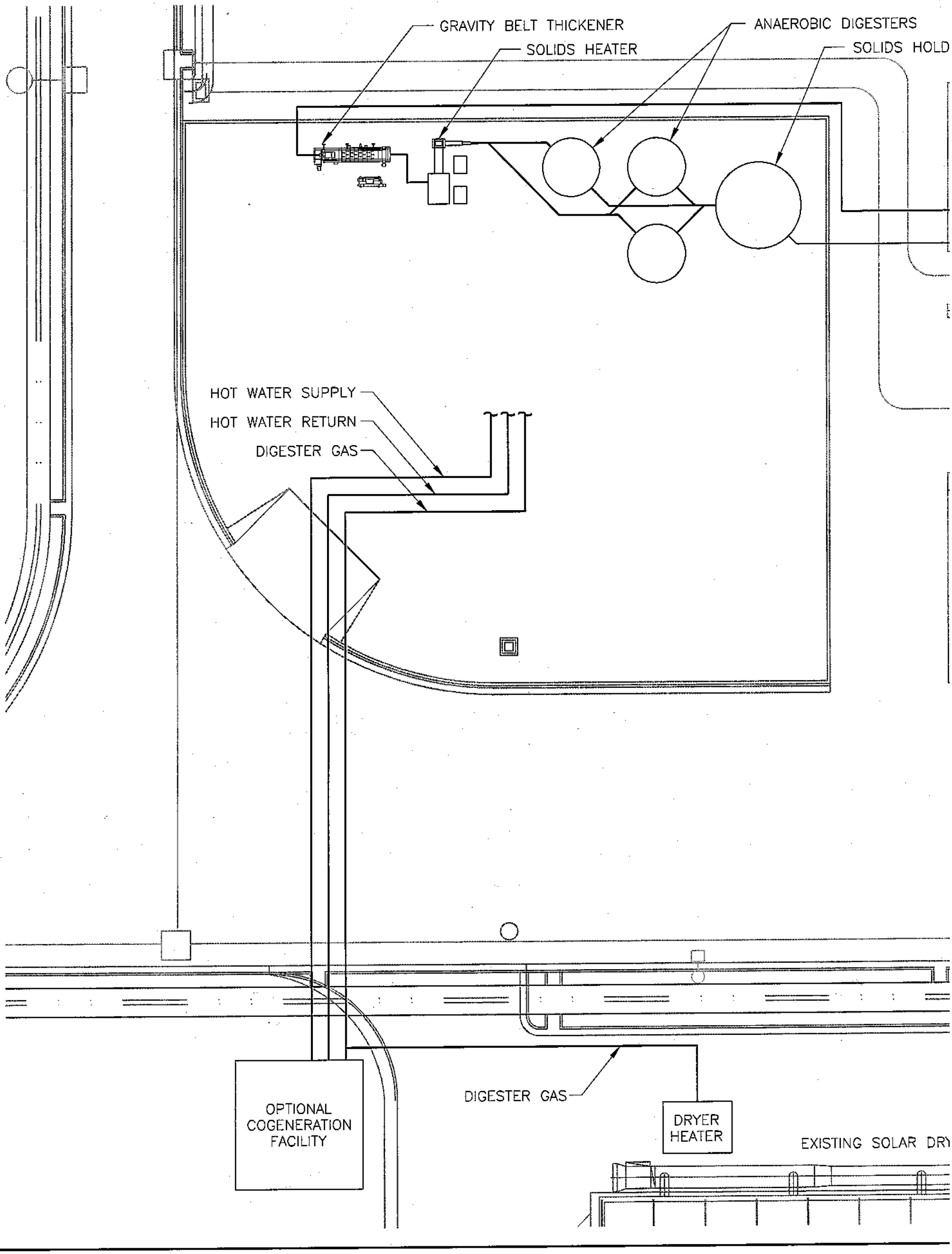
PHASE 1 - SOLIDS DIGESTION



PHASE 2 - FOG RECEIVING



PHASE 3 - FOOD WASTE RECEIVING


GRAVITY BELT THICKENER
SOLIDS HEATER
ANAEROBIC DIGESTERS
SOLIDS HOLD
HOT WATER SUPPLY
HOT WATER RETURN
DIGESTER GAS
DIGESTER GAS
OPTIONAL COGENERATION FACILITY
DRYER HEATER
EXISTING SOLAR DRY

Section 9. Recommendations

Based on the economics of the various projects, without the quantitative economic benefit of reduction in greenhouse gases, all of the projects have very long pay back periods of 19 years or more. These payback periods would be considerably shorter if the cost of solids disposal returns to the previous $59 per wet ton or if real values can be quantified for the reduction in green house gases. For instance, a return to $59 per wet ton for disposal would reduce the Phase 1 project payback from 23 years to 11 years. Until this time, significant weight will have to be given to the process needs of the City to justify the project. One potential process justification would certainly be the reduction of odors at the active solar drying facility. The extent to which the City can justify this project on odor reduction is not known given the Cities existing economic conditions and the political nature of the odor issues seen with the dryers. The City can choose to proceed or wait as needed.

If the City does wish to proceed with the project, then anaerobic digestion with the IBR system is recommended because of its significant cost and process performance advantages over a conventional municipal digester facility.