12.0 ALTERNATIVE TECHNOLOGIES – TOWN OF CHAPEL HILL BENCHMARK

The objective of this task was to review the Town and regional solid waste systems and known waste-to-energy (WTE) and waste conversion (WC) technologies to establish a long-term strategy and benchmark system requirements necessary to engage identified feasible technologies. This section of the report identifies key system and technology metrics by which the Town may best position itself to take full advantage of WTE and WC technologies as they may emerge.

During the course of our study, SCS relied on recent information and data collected by Orange County, North Carolina in its solid waste master plan[19], an alternative energy analysis conducted by the University of North Carolina[20], and a recent summary report of waste conversion technologies by the Applied Research Foundation of the Solid Waste Association of North America[21]. In addition, SCS has been monitoring the progress of WTE and WC technologies over the past few years through a series of presentations, trade journal articles, and books[22]. Thus, much of the initial discussion in this section is briefly focused on background, history, and the current status of these technologies. This is then followed by a benchmarking of the Town against the current status of these technologies and recent developments.

12.1 REASONS TO SELECT A WTE OR WC TECHNOLOGY

One of the first questions the Town must answer is what technology will be chosen to convert its solid waste into energy. This includes consideration of factors (which will be discussed later) such as: available energy and materials markets; the size of the Town's waste flow; site availability and location; capital and operating costs; ownership and financing considerations; and the level of risk to be assumed by the Town or the facility operator.

In evaluating whether or not one technology better suits its needs than another, the Town may often discover conflicting goals and values within both the community and within the target WTE/WC project. For example:

- A particular technology may produce the greatest amount of energy for the Town's waste, albeit at high projected capital and operating costs.
- Engaging in WTE or WC technology may impact historical success in other recycling or waste diversion practices (i.e., directing organics from a composting operation to a digester technology).

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19 GBB, Alternative Waste Processing Technologies Assessment, August, 2008.
20 Affiliated Engineers, Alternative Energy Analysis, July 2010.
21 Applied Research Foundation, Solid Waste Association of North America, Waste Conversion Technologies, December 2011.
22 Marc J. Rogoff and Francois Screve, Waste-to-Energy Technologies and Project Implementation, Elsevier, June 2011; Marc J. Rogoff, Bruce Clark and Amanda Moore, "Solid Waste Déjà vu: Waste-to-Energy Plant Technologies Break New Ground", APWA Reporter, March 2009.

- A refuse-derived fuel (RDF) technology may impact waste generation minimization efforts with the need to generate more waste for fuel.

The selection of a technology, therefore, is not a simple one, but one which can require tradeoffs between one goal with others. Since the risks associated with WTE and WC technology can be substantial, it is critical that the Town recognize and minimize these risks as best it can. The following criteria can be utilized to assess the relative risk of a particular WTE or WC technology:

- **Degree and Scale of Operating Experience.** The technology must be proven. Most existing technologies, other than conventional mass-burn technology, have only been proven in pilot or laboratory operations, or with raw materials other than municipal solid waste. Other technologies have only been commercially operated in small facilities and the scale up to larger sized plants may result in unforeseen problems.

- **Reliability to Dispose of Municipal Solid Waste.** The technology selected must be capable to dispose of solid waste in a reliable manner without frequent mechanical downtimes resulting in diversion of such waste to landfills.

- **Energy and Material Market Compatibility.** The technology must be capable of recovering energy and materials for which markets are available and viable.

- **Environmental Acceptance.** The technology must meet all permitted environmental requirements established by regulatory agencies.

- **Cost to the Town.** The technology must dispose of the Town's solid waste at a price it is willing to pay given alternative means of disposal.

12.2 CLASSIFICATION OF TECHNOLOGIES

For the purpose of this report, SCS has divided the processes for disposal of municipal solid waste into two main categories:

- Conventional WTE Technology
- Alternative WC Technologies

The conventional WTE technologies include mass-burn incineration and smaller, modular units where unprocessed MSW is fired in a boiler or chamber where the heat is recovered in a series of tubes filled with water or in a heat recovery boiler where the heat is recovered in the form of steam or electricity. Alternatively, shredded MSW with some form of metals recovery can be fired in a chamber either in a dedicated boiler made of water tubes or on a fluidized bed of sand with the energy recovery in the form of steam or converted to electricity.

Alternative conversion technologies can be defined as:

- Alternatives to landfills and standard combustion-based WTE plants
- Potential to produce by-products and chemicals that could be useful

- Compatible with municipal recycling activities
- Potential for less environmental impact

12.3 CONVENTIONAL WTE TECHNOLOGY

12.3.1 Basic Combustion System

The combustion of solid waste is accomplished in a furnace equipped with grates. A solid waste combustion system with energy recovery includes:

- Some type of structure to house the furnace and its appurtenances;
- A "tipping floor" where the solid waste from collection and transfer vehicles is deposited;
- A storage pit or floor to store the solid waste delivered (solid waste combustion is a 7 days per week, 24 hours per day operation; storage space is provided to enable this continuous operation);
- A charging system (normally overhead cranes) which mixes the various solid wastes received to develop a somewhat uniform material and then lifts it from the storage pit or floor and feeds (charges)the furnace;
- One or more furnace subsystems (sometimes referred to as combustion trains), which receive and burn the solid waste;
- A grate unit to move the solid waste through the furnaces; the most common grate designs are:
  - **Reciprocating Grate.** This grate design resembles stairs with moving grate sections which push the solid waste through the furnace.
  - **Rocking Grate.** This grate design has pivoted or rocking grate sections which produce an upward and/or forward motion to move the solid waste through the furnace.
  - **Roller Grate.** This grate design has a series of rotating steep drums or rollers which agitate and move the solid waste through the furnace.
- Air pollution control subsystems to clean up the combustion gases; and,
- An ash handling subsystem to manage the fly ash and bottom ash produced from the combustion of solid waste.

12.3.1.1 Stages of Combustion

Solid waste normally has a moisture content of 20 to 25% by weight. In order to successfully burn solid waste in a furnace, this moisture must be evaporated. Generally, most solid waste combustion units have three stages of reaction:

- **Drying.** Moisture driven off.
- **Ignition.** Solid waste ignited.
- **Burnout.** Solid waste is gradually moved through the furnace by the grate subsystem where the combustible organic fraction of the solid waste is burned out.

Successful combustion of solid waste is accomplished by controlling the "3 Ts of Combustion"- Time, Temperature and Turbulence.

- **Time.** The period taken for solid waste to pass from the charging hopper until the bottom ash is discharged at the end of the grate subsystem (usually 45 to 60 minutes).
- **Temperature.** Usually exceeds 1,800°F (980°C) within the furnace and is directly proportional to the residence time. If there is insufficient time in the furnace, the combustion reaction cannot proceed to completion and temperature declines.
- **Turbulence.** Provided by the grate subsystem moving the solid waste downward through the furnace to expose it to and mix it with air.

Normally, solid waste combustors reduce the original weight of the solid waste by 75+% and the volume by 85 to 90%.

Combustion is aided by the introduction of air at two locations in the furnace. Air is introduced underneath the grates (underfire air) to increase the agitation and turbulence within the furnace and help cool the grates. Air is also introduced above the burning solid waste (overfire air). Overfire air ensures that there is adequate oxygen available to completely oxidize and burn the entire combustible fraction of the solid waste. Overfire air also aids mixing of the combustion gases thereby ensuring complete oxidation and destruction. Combustion gases (also called flue gases) move from the furnace through the flues and the air pollution control systems and are eventually discharged out the stack into the atmosphere.

12.3.1.2 Waste-to-Energy Solid Waste Combustors

In a WTE solid waste combustor, the energy released from combustion in the form of heat is used to generate steam in a boiler. The common method of capturing this released energy is either through refractory or waterwall furnace systems. The major difference between these two designs is the location of the boiler.

- **Refractory Units.** This design consists of boilers located downstream of the combustion (furnace) chamber. The hot combustion gases pass through the boiler tubes to create steam.

- **Waterwall Units.** This design has the furnace constructed with water tube membrane walls to recover the heat energy directly from the furnace unit. Waterwall designs are more commonly used because their thermal efficiency is higher than refractory units.

Boilers convert the heat released to steam, which can be used to either generate electricity or for industrial steam applications (if a customer is nearby). Turbine-driven generators driven by the steam generate electricity.

12.3.1.3 Products of Combustion

Other than the release of energy in the form of heat, the products of combustion of solid waste are fly ash and bottom ash. Each of these byproducts of combustion, air emissions, and ash, present further environmental permitting, handling, and disposal challenges for the WTE technology.

Fly ash is carried in the combustion gas, which also contains a number of contaminants, including acid gases, and other products of incomplete combustion. The gases are passed through a variety of air pollution control devices for cleanup before being discharged out of the stack into the atmosphere.

Bottom ash is the non-combusted material, which is discharged at the end of the grate subsystem. The bottom ash, as it is discharged from the grates, is still burning and is normally quenched by water. In the United States, the two ash streams, fly ash and bottom ash, are normally combined for management and disposal in a permitted MSW or industrial landfill. The two combined ash streams are commonly referred to as solid waste combustor ash, or just ash. In Europe, these two ash streams are not usually combined and are normally managed separately.

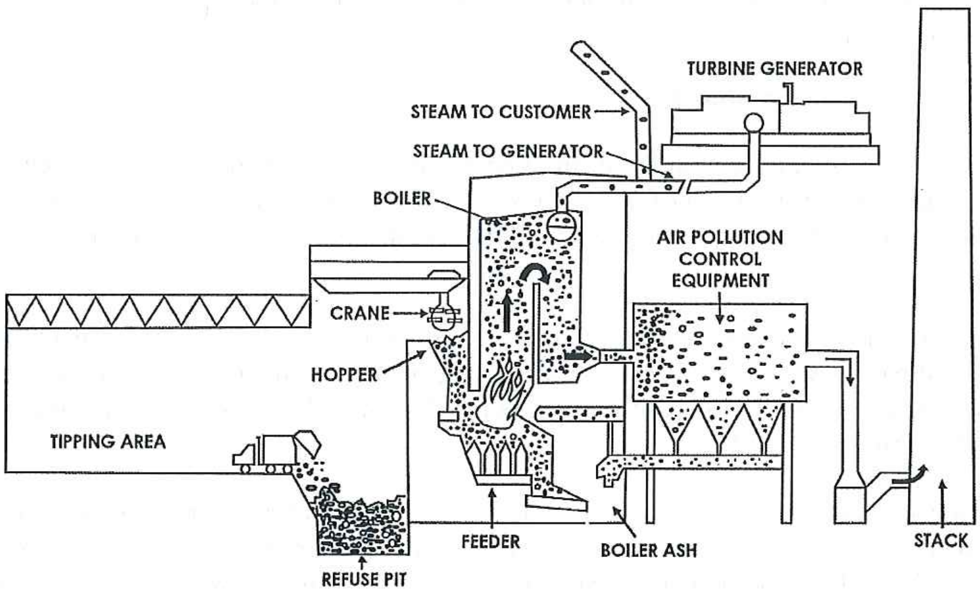
12.3.2 Mass Burning

"Mass-burning" refers to the generic name for the type of technology used to incinerate unprocessed solid waste, and thereby releasing its heat energy. The thermal reduction of solid waste through mass-burning has been a common procedure throughout the world. There are decades of experience in constructing and operating some 500 mass burn facilities in the United States and Europe. Such facilities were in operation as early as 1896 in Hamburg, Germany, converting solid waste into electricity.

12.3.2.1 Process Description

An illustration of a typical mass-fired, WTE facility is shown in Exhibit 12-1. Solid waste collection and transfer vehicles proceed into a tipping area where their waste is discharged into a large storage pit, which is usually sized to allow two to three days storage or stockpiling of refuse so that plant operations can continue over weekends and holidays when deliveries will not be accepted. There are some facilities which differ in design by utilizing a tipping floor with a front loader and belt conveyor system as their form of storage and feed system. In almost all facilities, however, the refuse is fed into the furnaces by means of overhead cranes manipulated by a crane operator. Much of the success of the operation depends upon the skill of the crane operator to remove large or unusual objects in the waste stream that would otherwise prove to be a problem if fed into the boiler. The operator is also responsible to observe the nature of the incoming waste so that materials with different moisture contents are gradually intermixed to try to get uniform moisture content.

Exhibit 12-1. Cross-Section of Typical Mass-Fired Waterwall Facility



The refuse is then discharged into refuse feed hoppers, which meter out the refuse into the combustion chamber, either by gravity feeding or by a hydraulic feeding device. In a majority of systems, the waste is then pushed onto an inclined, step-like, mechanical grate system which continuously rocks, tumbles, and agitates the refuse bed by forcing burning refuse underneath newly fed refuse. Generally, most systems have three zones of activity along the grates: drying, ignition, and burnout. Holes in each grate bar allow underfire air to pass through the grates resulting in cooling and, thus, preventing thermal damage to the grate system. The width of the grate and the number of grate steps is dependent not only upon the manufacturer's specifications, but also on the overall size of the WTE system. There are five basic moving grate designs:

- **Reciprocating Grate.** This grate resembles stairs with alternating fixed or moving grate sections. The pushing action may be in the direction of waste flow or in an upward motion against the waste flow.
- **Rocking Grate.** Pivoted or rocked grate sections produce an upward or forward motion, advancing the waste down the grate.
- **Roller Grate.** A series of rotating stepped drums or rollers agitate the waste and move it down the grate.
- **Circular Grate.** A rotating annular hearth or cone agitates the waste.

- **Rotary Kiln.** As an inclined cylinder rotates, it causes a tumbling action to expose unburned material and advance the waste down the length of the kiln.

Mass burn incineration produces ash resides amounting to 15 to 30% by weight and 5 to 10% by volume of the incoming municipal solid waste. Most facilities can produce an ash product that has less than 5% combustible material and 0.2% putrescible matter.

Recovery of ferrous and non-ferrous materials from the ash residue is possible in mass-burn systems. Many facilities have successfully utilized magnetic separators (with or without trommels) to recover ferrous material from the ash. Some systems have attempted to recover the remaining non-magnetic fraction in the ash, such as aluminum and glass, using various trommels, screens, jigs and fluid separators.

12.3.2.2 Operations Experience

Mass burning incinerators have been used in Europe and Japan for municipal solid waste disposal for nearly 30 years where their acceptance has been rapid and widespread. With over 500 facilities in operation worldwide in sizes ranging from 60 to 3,000 tons per day, mass fired incineration is the most thoroughly demonstrated technology in the WTE field at this time.

This technology was introduced into the United States in 1967 at the U.S. Naval Station in Norfolk, Virginia with the construction of a 360 ton per day waterwall plant to produce process energy for the Naval Shipyard. This plant was designed in America and equipped with American equipment. Later plants, which were constructed, were almost entirely designed using state-of-the-art European mass incineration technology. The National Resource Recovery Association publishes a semi-annual update of WTE activities in the United States. At the time of this comprehensive report, there are 98 WTE facilities using mass incineration technology. Based on our experience with these plants, SCS assumes that an experienced staff of more than 12 people, spread over three shifts per day, is required to continuously operate a mass burn plant of the size potentially applicable to the Town or region.

The introduction of European technology into the United States has not been without difficulties and several of the earlier constructed plants encountered some mechanical problems. These highly reliable and rugged European systems had been designed to burn solid waste that was somewhat different in composition than American wastes. Consequently, systems that had been designed for European conditions required designers to make adjustments in the grate areas and furnace heat release rates of American plants. In addition, the higher chloride corrosion of the superheaters in American plants meant that designers needed to change the metallurgy of these boiler tubes, as well as limiting the upper stream pressures and temperatures to minimize tube corrosion. Scale-up problems also had to be overcome since many of the European unites were designed for the 300 to 500 tons per day range. These problems have been corrected, and most mass-burn systems that have been constructed are still in operation today.

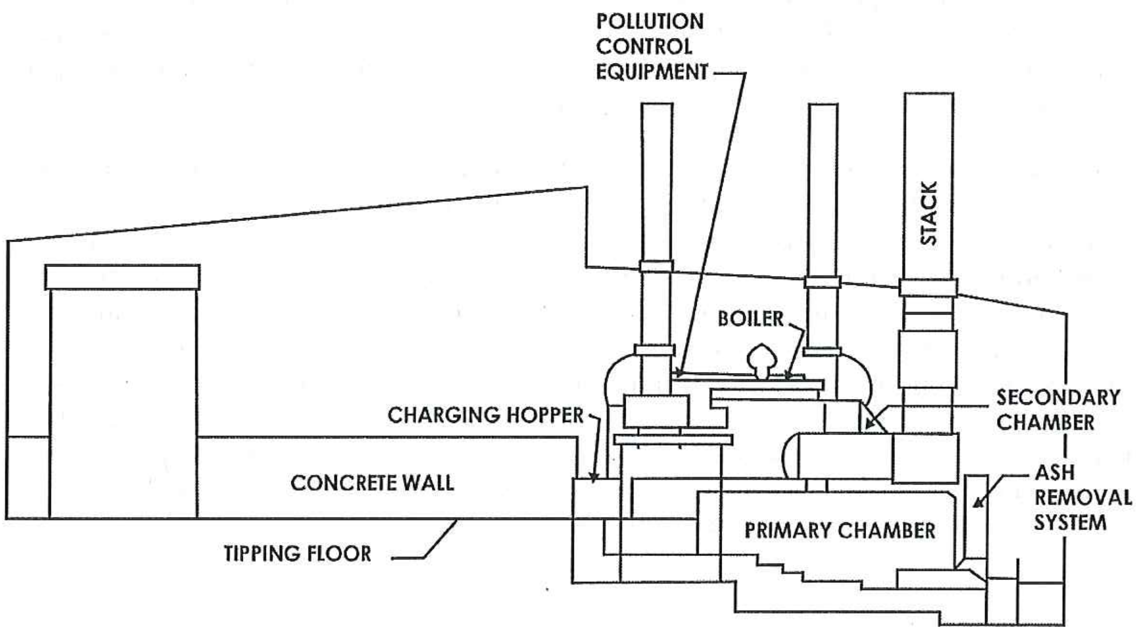
12.3.3 Modular Combustion

A modular incinerator is a type of mass-burning, WTE unit which is prefabricated on a standardized modular basis in a factory Such units are shipped to the site in modules, ranging in design capacity from 10 to 200 tons per day, where they are installed. Several modules can be grouped together at a single location. These "off the shelf" units can often be less costly to fabricate than the larger mass-burn facilities which require more costly field erection. Modular plants can also typically be constructed in some 15 to 20 months.

Modular incinerators have been designed and constructed in the United States with different process configurations. Some units have been designed to incinerate solid waste under excess air conditions with either refractory furnaces or waste heat boilers or with waterwall boilers. A majority of most units, however, have been designed to operate under starved air conditions with refractory furnaces and waste heat boilers.

A cross-section view of a typical modular combustion unit is illustrated in Exhibit 12-2. A majority of modular facilities have a tipping floor and utilize a front loader for simplicity in waste storage and feeding. Combusting takes place in either two or three stages. First, solid waste, which is delivered to the facility, is fed into the initial combustion chamber using a ram-type feeder. A moving ram slides back and forth over fixed steps within the chamber, causing the waste to tumble down one fixed section of the grate to the next fixed section. The waste is then transformed into a low-Btu gas which is then combusted in the secondary chamber, where auxiliary fuel is often fired under excess air conditions. A discharge ram on the back end of the combustion chamber feeds this incinerated waste into an ash quench bath.

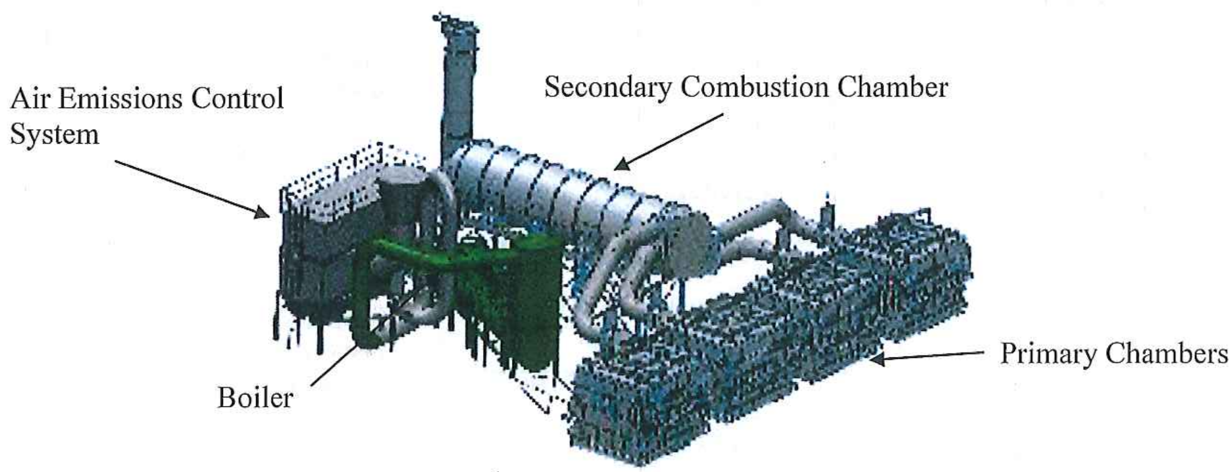
Exhibit 12-2. Cross-Section of Typical Modular Facility



The low-Btu gases produced by the combustion process in the first chamber are typically introduced into a secondary chamber where they are burned at temperatures ranging from 1,800 to 2,000°F. Heat energy is recovered by convection in waste heat boilers in this secondary chamber, although waterwall boiler units for the primary and secondary chambers have been constructed.

In recent years, several manufacturers have entered the modular plant marketplace using a batch oxidation process (BOS – Exhibit 12-3). The batch process integrates slow gasification and long exposure time at moderate temperatures followed by turbulent oxidation of gases at high temperature. After the waste is loaded into the primary chamber and sealed tight, an auxiliary burner is ignited to raise temperatures to about 200°C. The interior temperature is then monitored with controls and maintained by allowing sub-stoichiometric amounts of air into the chamber during the gasification process. The combination of relatively low temperatures and only sub-stoichiometric amounts of air in the primary chamber during gasification do not disturb the gasification bed, which is said to minimize particulate emissions, heavy metals, and many combustion gasses. Depending on the waste type and system layout, the waste reduction process in the primary chamber will take approximately 10 to 15 hours.

Exhibit 12-3. Cross-Section of Batch Oxidation System, Modular Facility



Source: Waste2Energy, Inc., 2009

Emissions produced during the gasification process pass through to the preheated secondary chamber also called an "afterburner" where these emissions are thermally treated. As the gasses from the primary chamber enter a preheated secondary chamber, auxiliary burners and excess oxygen create a very turbulent high temperature environment (typically between 850°C and 1,200°C). For most applications within the European Union (EU) 850°C is the required minimum, though 1,100°C is required for halogenated wastes, and in North America, 982°C is usually required. Additionally, residence time in the secondary chamber is important for proper destruction of emissions from the primary chamber. In both the EU and North America, a minimum residence time of 2 seconds is required. Operation of these units is subject to stringent

USEPA and state air emission regulatory standards and permitting. Operating permit conditions typically require continuous air monitoring and routine reporting to demonstrate compliance.

There have been many more modular WTE incinerators constructed in the United States than either the mass-burn or refuse-derived fuel systems. In 1977, the first modular incinerator began operations in North Little Rock, Arkansas to produce steam for the Koppers Industry's Forest Products Division. Since that time, some 50 modular systems have been built in the United States (Exhibit 12-4), almost exclusively to produce process steam for neighboring industries. Some of these systems, for example, a plant in Fosston, Minnesota, have utilized the community's solid waste as a fuel to produce steam to a district heating loop during the winter, and electricity during the summer. Many of the newer facilities have incorporated electric production capability.

Exhibit 12-4. Comparison of Active Modular Combustion Facilities

Location	Startup	Design Capacity (tons/day)	Energy Generation	Capital Cost ($ millions)
Auburn, ME	1992	200	Steam	4.0
Joppa, MD	1988	360	Steam	10.0
Pittsfield, MA	1981	360	Steam	10.8
Alexandria, MN	1987	80	Steam/Electric (0.5 MW)	4.2
Fosston., MN	1988	80	Steam	4.5
Perham, MN	1986/2002	116	Steam/Electric (2.5 MW)	6.0
Red Wing, MN	1982	90	Steam	2.5
Fulton, NY	1985	200	Steam/Electric (4 MW)	14.5
Almena, WI	1986	100	Steam/Electric (0.27 MW)	2.7
Husavik Municipality, Iceland	2006	20	Steam	3.5
Scotget, Scotland	2009	180	Electricity	40.0
Turks and Caicos Island	2008	4	None	1.0
U.S. Air Force, Wake Island	2009	1.5	None	0.5
U.S. Department of Defense, Kwajalein Atoll	2007	32	None	5.0

Modular combustion units offer a lower capital cost and simplicity than the larger field-erected mass-burning systems for communities considering WTE systems. These systems are generally reliable and are backed by many years of successful operating experience. The newer batch oxidation systems (BOS) appear to offer substantially lower costs of operations and maintenance. For example, the manpower required to operate these systems is generally minimal with one worker required to load the primary chamber and discharge the ash stream within an hour. Many suppliers claim nearly complete burn out between energy recovery and recycling. The ash remaining is reported to be about 3 to 8% of the original volume (depending on waste composition). Lastly, these systems are modular and can be easily increased or decreased in size.

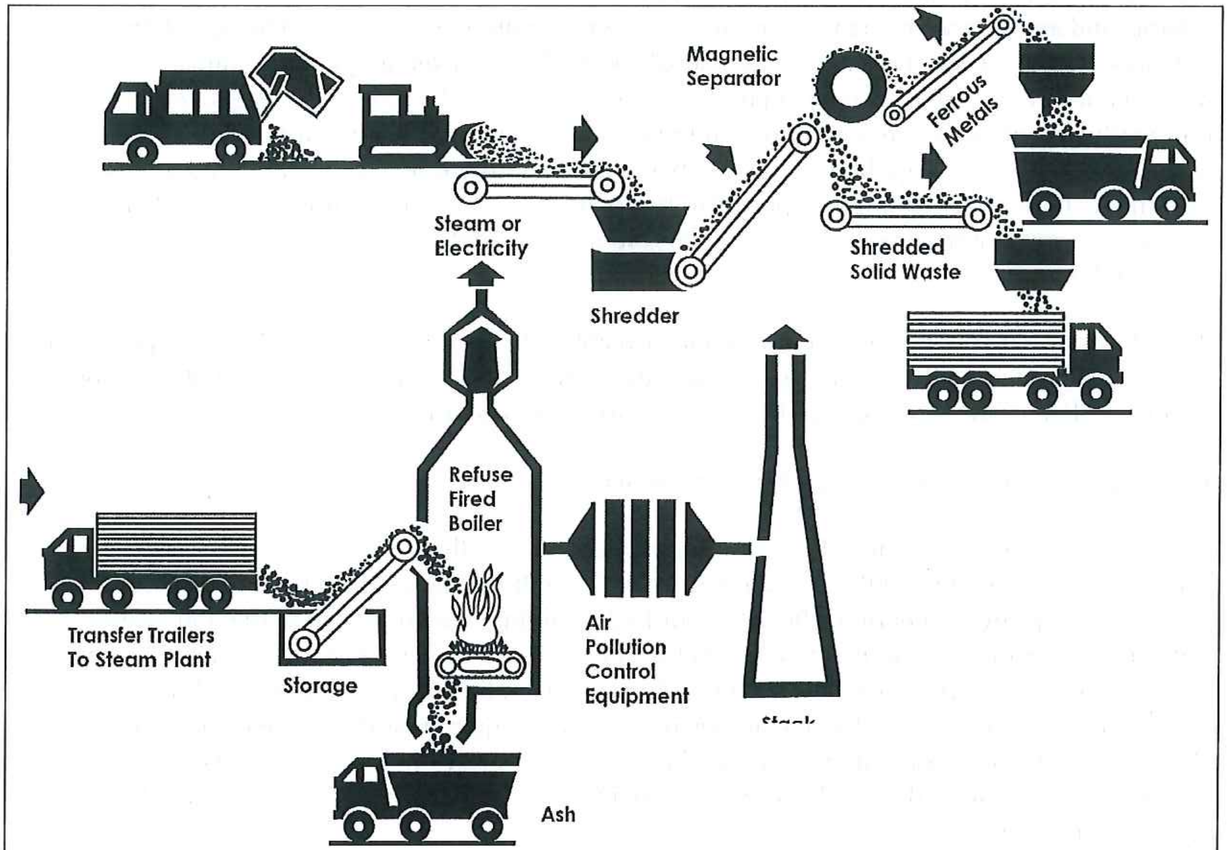
Based on our experience with similar modular plants, SCS would anticipate that an experienced staff of six (6) to nine (9) people, spread over three shifts per day, is required to continuously operate a plant of the size potentially applicable to the Town or region.

12.3.4 Refuse-Derived Fuel Systems

Several American corporations have developed technologies that pre-process solid waste to varying degrees to separate the non-combustibles from the waste stream. By undergoing processing steps of hammering, shredding, or hydropulping, the combustible fraction of the waste is transformed into a fuel, which can then be fired in a boiler unit specifically dedicated for this type of refuse-derived fuel (RDF), or co-fired with another fuel, such as coal, shredded tires, or wood chips. The fuel produced can thus be utilized in equipment that can have higher efficiencies than mass-fired units resulting in greater electricity or steam output. However, the front-end processing of the solid waste into a fuel has been one of the problem areas of this type of refuse disposal technology.

Since the early 1970's, there have been several dozen facilities which have been constructed in the United States to process solid waste into a RDF through the use of dry processing systems. Such dry processing systems are classified according to the type of products that can be produced: fluff RDF, densified RDF, and powdered RDF. A cross-section of a typical RDF system is illustrated in Exhibit 12-5.

Exhibit 12-5. Cross-Section of Typical RDF System



Somewhat associated with RDF facilities are materials processing facilities, which include size reduction, screening and recovery systems, and then additional equipment to reduce the moisture in the resulting RDF to improve its heating quality. For example, in the Chemtex-Entsorga HEBIOT process ("high efficiency biological treatment") an aerobic digestion module is utilized to drive off the moisture from waste that has been shredded. This volume reduction technique reported reduced the incoming waste by 80% with the remaining 20% being disposed of in a landfill. In essence, except for this latter function, this process is very similar to "dirty" materials processing facilities used for volume reduction at many front-end processing facilities at RDF facilities. In Europe, there is a substantial market for such mechanical biological treatment plants offered by Ensorga, which has been driven by the European Union's Landfill directive that restricts the landfilling of biodegradable waste and stipulates a pre-treatment of MSW. Many of these facilities are co-located with cement mills, RDF power plants, or even coal-fired power plants.

Common disadvantages associated with such mechanical biological treatment plants include:

- Noise and odor associated with the dirty MRF processing;

- Air emissions from burning the RDF product;
- Concerns with contamination and quality of the resulting biological compost product; and,
- The need for additional infrastructure to utilize the generated power.

12.4 ALTERNATIVE WC TECHNOLOGIES

The alternative waste conversion technologies are numerous and can be grouped many ways, but for this discussion, SCS has grouped technologies by three major processes that include:

- Thermal
- Biological
- Bio-Chemical

Within these groups are many methods and technologies that have been developed to extract different benefits from the processed waste stream including;

- Gases for power production;
- Gases for feedstock for vehicular fuels;
- Basic chemicals for use as a raw feedstock;
- Compost/ soil amendments; and,
- Slag for use an alternative building material.

A brief description of the main technologies in each of the three groups is presented below with discussion as to potential relevancy to the Town and region, benefits, estimated costs, and potential advantages and disadvantages.

12.4.1 Thermal

The thermal technologies are based on taking the solid waste and processing it under moderate to very high temperatures in a closed reactor vessel, sometimes under pressure and with or without the introduction of air or steam. Depending on the particular process, traditional recyclables may be removed at the front end of the process or during the process stages. The predominant processes are pyrolysis-gasification and autoclaving.

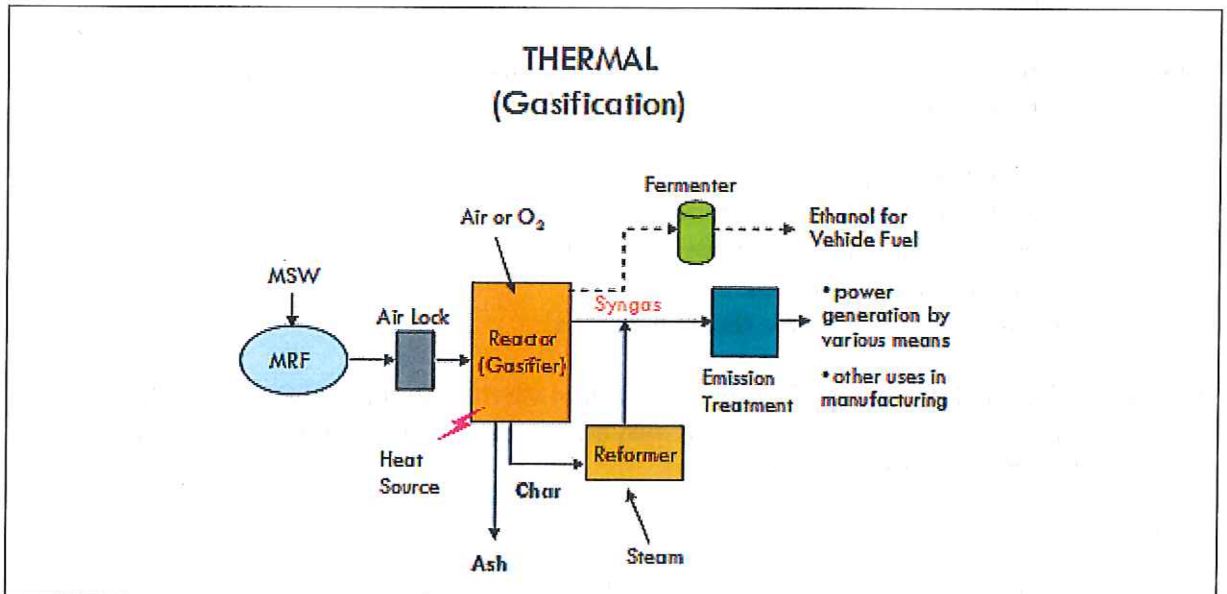
12.4.1.1 Pyrolysis - Gasification

In a pyrolysis process air is excluded from the reactor vessel and results in the waste decomposing into certain gases (methane, carbon dioxide, and carbon monoxide), liquids (oils/tar), and solid materials (char). The proportions are determined by operating temperature, pressure, oxygen content, and other conditions. Because there is little to no air or oxygen, the waste does not combust as it breaks down (there are no flames).

When the amount of air in the process is less than that required to support combustion, but greater than in a pyrolysis process, the process is termed *gasification*. This process is typically used to achieve a different balance of the gaseous by-products, mainly the production of a hydrogen (H)-rich gas with smaller quantities of carbon monoxide (CO), methane (CH_4) and carbon dioxide (CO_2). The refined gas, primarily H and CO, is termed *syngas* and has many direct applications such as powering a turbine to produce electricity and potentially for use as a feedstock to produce alternative vehicular fuel (ethanol), or other chemical compounds. Most of these processes require an external heat source under normal operating conditions. This is usually hot, clean air that captures heat from the downstream gas combustion process.

A basic gasification process is shown in Exhibit 12-6. Gasification processes have attracted much interest because the process is inherently more efficient than a combustion-based process, the syngas is a relatively clean energy source and the plant may generate less troublesome air emissions overall.

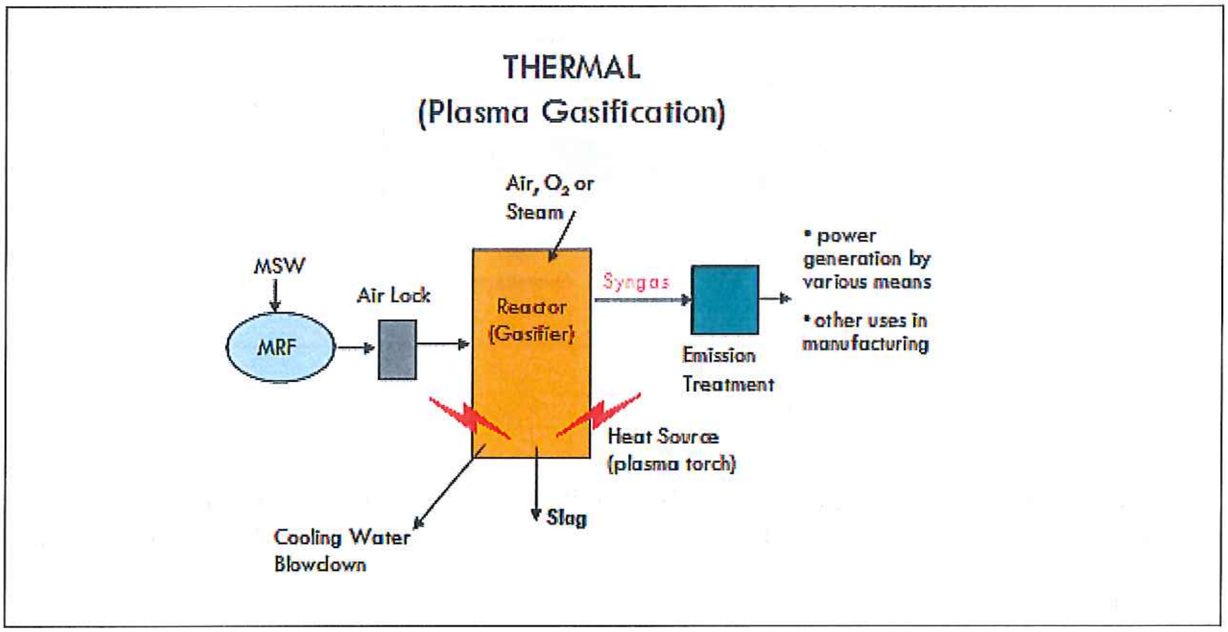
Exhibit 12-6. Basic Gasification Process



A relatively recent development for solid waste conversion using the gasification process, that employs a unique heating source, is known as a plasma arc converter. Although there are many variations, a typical plasma arc converter uses an array of plasma torches to generate temperatures in the reactor of more than 5,000°C. This extremely high temperature, coupled with a gasification environment has shown potential in small laboratory test units to achieve a very high efficiency in decomposing the organic fraction of the waste to syngas, while generating a slag material from the inert fraction. The slag has potential for use as a substitute ingredient in potentially many building materials, including concrete structural elements (e.g., wall panels and blocks, etc.) and asphalt.

A plasma is an ionized gas that results when a basic gas, such as nitrogen or air is passed through an electrical arc struck between two electrodes. The electrodes are constructed into a torch that directs the plasma arc. The intense heat created by the arc can be used to treat many materials, including MSW. Plasma arcs were commercialized in the metallurgical industry where the high temperatures produced in the reactor vessel (potentially up to 10,000°C) are used to create special alloys. Some of the electric power generated by the plant is siphoned off to power the torches. The basic plasma arc process is shown in Exhibit 12-7.

Exhibit 12-7. Basic Plasma Gasification Process

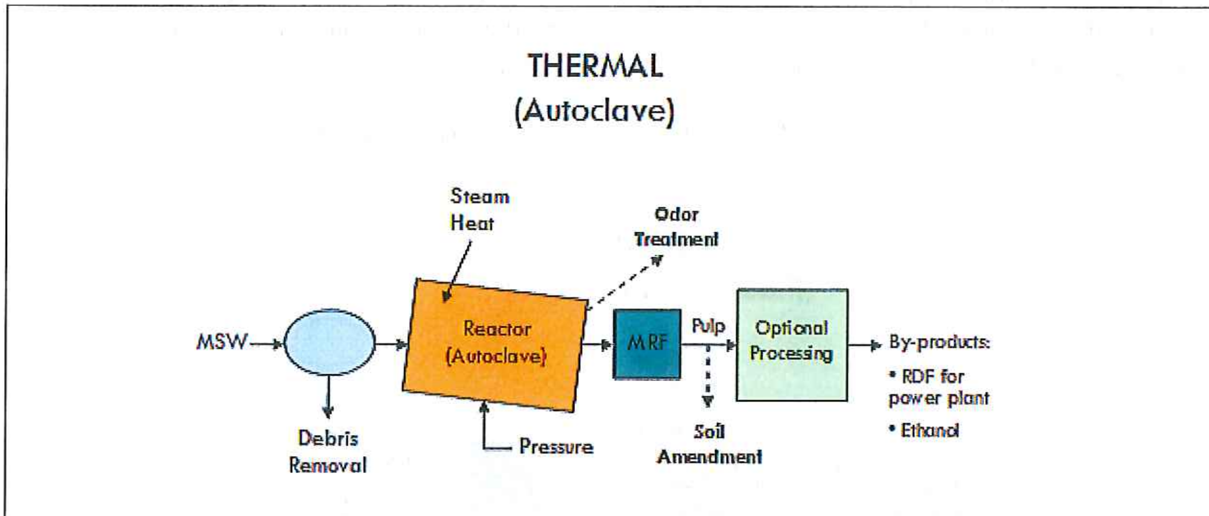


12.4.1.2 Autoclave

The basic autoclave process has been in commercial use for decades, primarily in the medical field for sterilizing instruments, some manufacturing uses and in the sterilizing of medical wastes. In an autoclave process for solid waste, mixed MSW is fed into a reactor vessel where it is subjected to heat, pressure and agitation. The reactor conditions cause the organic fraction of the waste (i.e., food scraps, fiber/paper products and vegetation) to break down into a pulp-like substance that potentially has reuse applications depending on the degree of post-processing selected.

The pulp has been demonstrated with a few systems to be a useful soil conditioner and also is being tested for use as feedstock for the production of ethanol, an alternative vehicle fuel and in the production of a RDF for combustion in power plants. The process also claims to provide a higher quality recyclable product. Plastic recyclable materials are softened and occupy less volume downstream. Product labels on glass, plastics and metals are totally removed and these materials also are cleaned and sterilized. A basic autoclave process is shown in Exhibit 12-8.

Exhibit 12-8. Basic Autoclave Process



12.4.2 Biological

There are two types of biological processes being utilized for WC. These include the anaerobic and aerobic process technologies. The following paragraphs briefly describe these technologies.

12.4.2.1 Anaerobic Process

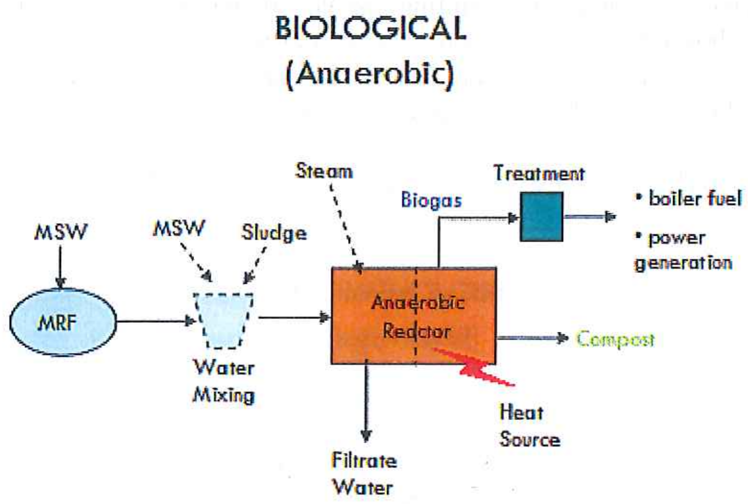
Anaerobic digestion is the bacterial breakdown of organic materials in the absence of oxygen. This biological process produces a gas, sometimes called biogas, principally composed of methane and carbon dioxide. The anaerobic process is often used to treat organic wastes other than nonsegregated MSW, and that is where it is used the most. This anaerobic process is used to digest sewage sludge (i.e., biosolids – produced from treated sanitary sewage), yard vegetation, agricultural wastes (both animal and plant) and some industrial waste sludge. The number of plants processing these materials is currently in the thousands worldwide.

The anaerobic digestion process occurs in three steps:

1. Decomposition of plant or animal matter by bacteria into molecules such as sugar.
2. Conversion of decomposed matter to organic acids.
3. Organic acid conversion to methane gas.

Depending on the waste feedstock and the system design, biogas is typically 55 to 75% methane. A basic anaerobic process is shown in Exhibit 12-9.

Exhibit 12-9. Basic Anaerobic Process



12.4.2.2 Aerobic Process

The aerobic process relies on a continuous supply of air to be mixed in with the waste material. Again, the waste is ground up into pieces. Recyclable materials are removed before this process. In a typical plant the waste is ground up and formed on an outdoor pad into long piles called windrows. The windrows are agitated a few times per week to allow all parts of the pile to be exposed to air. The agitation and aerating process can also be conducted in a vessel into which air is forced. The aerobic environment supports a different, but also common microorganism that, like the anaerobic process, feeds on the organic fraction of the waste. The waste is converted to by-products that include CO_2, water vapor and compost. Typically a site had to be located in a rural area; otherwise, the odors from the process could become a nuisance.

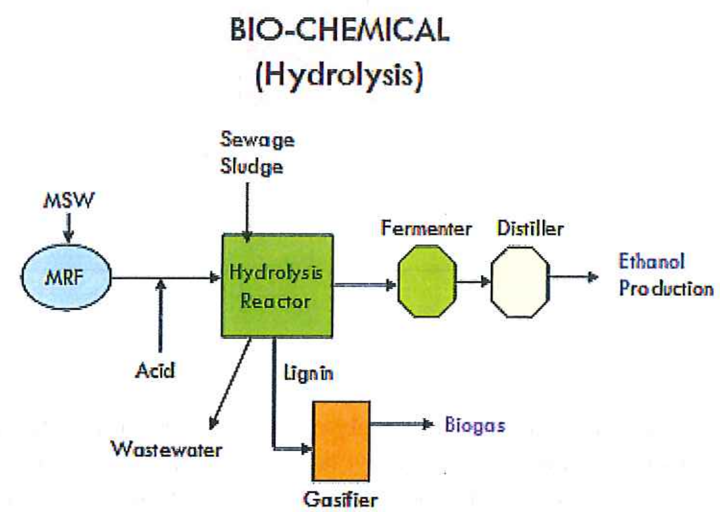
12.4.3 Bio-Chemical

The bio-chemical process is based on breaking down the cellulosic part of the organic fraction of the waste stream. This would include certain foods (e.g., vegetables, fruits), paper products and yard vegetation. Biosolids can also be added as a waste material. All other materials in the waste stream should be removed prior to the process.

In the process, following drying and shredding of the waste, the prepared waste stream is mixed with water and sulfuric acid in a closed reactor vessel. This causes a reaction that in conjunction with common bacteria already in the waste, breaks down the material into sugar compounds and a by-product known as lignin. There are some companies that are testing natural enzymes, instead of the strong acid chemical, to initiate this reaction.

The resulting sugar compounds and water are sent to a fermentation unit where yeast is added. The yeast reacts with the sugars to convert them to alcohol. The alcohol mixture is then heated and distilled to remove the solids. The resulting distilled alcohol (grain alcohol or ethanol) can be used as fuel. The lignin by-product is sent to a gasifier where it is used to produce heat for the drying process or can potentially be further processed for use as a fuel substitute in power plants. A basic bio-chemical process is shown in Exhibit 12-10.

Exhibit 12-10. Basic Bio-Chemical Process



12.5 STATUS OF COMMERCIAL OPERATING WTE AND WC FACILITIES

12.5.1 Waste-to-Energy

At the time of this report, there are about 1,300 WTE facilities worldwide. Large numbers are located in Europe (440) primarily because of the European Union's directive that requires a 65% reduction in the landfilling of biodegradable MSW. Asian countries (Japan, Taiwan, Singapore, and China) have the largest number (764) of WTE facilities worldwide. All of these countries face limited open space issues for the siting of landfills and have large urban populations. One of the largest current markets for WTE plant construction is in China, which is currently the fourth largest user of WTE worldwide.

In the U.S., there are currently 89 WTE plants (Exhibit 12-11) operating in 25 states managing about 7% of the nation's MSW, or about 85,000 tons per day. This is equivalent of a base load electrical generation of approximately 2,700 megawatts to meet the needs of more than two million homes, while servicing the waste disposal needs of more than 35 million people.

Exhibit 12-11. U.S. WTE Plants by Technology

Technology	Operating Plants	Daily Design Capacity (Tons per day)	Annual Capacity (Million tons)
Mass Burn	65	71,354	22.1
Modular	9	1,342	0.4
RDF – Processing and Combustion	10	15,428	4.8
RDF – Processing Only	5	6,075	1.9
RDF – Combustion Only(1)	5	4,592	1.4
Total U.S. Plants	94	98,791	30.6
WTE Facilities	89	92,716	28.7

(1) Plants that do not generate power onsite.
Source: Integrated Waste Management Services Association, 2010.

12.5.2 Waste Conversion

The following sections summarize existing information on commercial operating WC plants worldwide.

12.5.2.1 Plasma Arc Gasification

As shown in Exhibit 12-12, there are four operating plants utilizing MSW as feedstock. Only one of these, the Utashinai City plant, can be considered commercial; the others have been only operated as pilots or intermediately operated for testing purposes. A pilot plant in Ottawa, Canada is currently being tested by Plasco Energy and has only been intermediately operated with a maximum continuous runtime of 36 hours using a pre-sorted, post-consumer waste stream as feedstock. Plasco is currently in the process of converting this plant to commercial operations, having successfully negotiated an operating contract with the City of Ottawa.

Exhibit 12-12. Commercial Operating Plasma Arc Gasification Facilities

Location	Throughput (Tons per day)	Owner/ Operator	Technology Supplier	Start of Operation	Feedstock
Yoshi, Japan	25	Hitachi Metals, Ltd.	Westinghouse Plasma Corp.	1999	MSW
Utashinai City, Japan	200	Hitachi Metals, Ltd.	Westinghouse Plasma Corp.	2003	MSW
Mihami-Mikata, Japan	22	Hitachi Metals, Ltd.	Westinghouse Plasma Corp.	2002	MSW Biosolids
Ottawa, Canada	94	Plasco Energy	Plasco Energy	2007	Shredded MSW Shredded Plastics

Source: SWANA, Waste Conversion Technologies, 2011; SCS files.

12.5.2.2 Pyrolysis Plants

As shown in Exhibit 12-13, the use of pyrolysis technologies to process MSW has occurred mainly in Japan and Germany where these plants reportedly process about two million tons of materials per year.

Exhibit 12-13. Commercial Operating Pyrolysis Facilities Using MSW

Location	Throughput (Tons per Day)	Technology Supplier	Start of Operation
Toyohashi City, Japan	440 77 (Bulky Waste)	Mitsui Babcock	2002
Hamm, Germany	353	Techtrade	2002
Koga Seibu, Japan	286 (MSW and Biosolids)	Mitsui Babcock	2003
Yame Seibu, Japan	242 55 (Bulky Waste)	Mitsui Babcock	2002
Izumo, Japan	70,000 TPY	Thidde/Hitachi	2003
Nishiburi, Japan	210 63 (Bulky Waste)	Mitsui Babcock	2003
Kokubu, Japan	178	Takuma	2003
Kyouhoku, Japan	176	Mitsui Babcock	2003
Ebetsu City, Japan	154 38 (Bulky Waste)	Mitsui Babcock	2002
Oshima, Japan	132	Takuma	2003
Burgau, Germany	154	Techtrade	1987
Itoigawa, Japan	25,000 TPY	Thidde/Hitachi	2002

Source: SWANA, Waste Conversion Technologies, 2011; U.S. Department of Energy, 2011, "Draft Environmental Assessment for Oneida Seven Generation Corporation, Energy Recovery Project, Green Bay, WI.

There are no commercially operated facilities in the U.S., although a pilot facility was operated in Green Bay, WI using American Combustion Technology pyrolytic systems for testing purposes. Oneida Seven Generations, Inc. has plans to construct a pyrolysis facility using 148 tons per day of MSW and 61 tons per day of plastic waste in Green Bay, WI.

There were a number of full-scale MSW pyrolysis demonstration plants, which were constructed in the U.S. during the late 1970s and early 1980s by Monsanto and Union Carbide. These facilities were not commercially successful and were eventually shut down. Similarly, a 91 TPD MSW pyrolysis facility was constructed in New South Wales, Australia in 2001 by Brightstar Environmental. This facility incorporated the use of an autoclave process where the organic fraction was dried before being sent to a pyrolysis vessel. This facility operated for only 6 months and was shut down due to its failure to meet permitted conditions.

12.5.2.3 Anaerobic Digesters

There are nearly 240 anaerobic digesters (AD) facilities around the world with operating capacities greater than 2,500 tons per year. These plants process not only the organic fraction of the MSW waste stream but also organic waste from food industries and animal manure. Europe leads in the number of AD plants and total installed capacity principally due to the European Union Directive that requires member states to reduce the amount of landfilled organics by 65% by 2020. As shown in Exhibit 12-14, there are more than 120 plants processing the organic fraction of MSW in Europe of about 4.6 million tons per year. The principal technologies used around the world are provided by the following companies: Dranco, Kompogas, Linde, RosRoca, Valorga, BTA, and Cites.

Exhibit 12-14. European Countries With AD Facilities

Country	No. of Plants	Country Capacity (Tons per year)
Germany	55	1,250,000
Spain	23	1,800,000
Switzerland	13	130,000
France	6	400,000
Netherlands	5	300,000
Belgium	5	200,000
Italy	5	160,000
Austria	4	70,000
Sweden	3	35,000
Portugal	3	100,000
United Kingdom	2	100,000
Denmark	2	40,000
Poland	1	20,000
Total	127	4,605,000

Source: Levis, J.W., et. al., "Assessment of the State of Food Waste Treatment in the U.S. and Canada," Waste Management 2010 August-September 30 (8-9) 1486-94.

Currently, there is only one commercially operated AD facility in the U.S, which is located on the campus of the University of Wisconsin-Oshkosh. It processes about 6,000 tons of yard and food wastes per year. Further, an AD facility digesting source-separated organics has been commercially operating in Toronto, Canada for a number of years processing about 90,000 tons per year. A second AD facility is currently under construction in Toronto and should be operating within a year. Similar AD facilities have been authorized by Quebec City and Montreal with additional facilities funded in the Province of Quebec.

Based on our understanding of the AD process and results of numerous feasibility and pilot studies, SCS understands an AD operation of the size required to process the Town's waste would require as few as three (3) to four (4) staff.

12.6 BENCHMARK METRICS

12.6.1 Summary of Current Town Solid Waste Statistics

As described in Section 2, at the writing of this report, the Town generates and disposes approximately 17,000 to 18,000 tons per year of MSW and yard waste. Based on census data, population projections, and current disposal practices, this volume is anticipated to reach approximately 21,500 tons in 15 years and 27,400 tons in 30 years. These current and future generation and disposal statistics equate to a design operating range of 55 to 90 tons per day, assuming 6 days per week operations, while allowing 1 day per week for maintenance, repair, and residuals management. As described, the Town has historically paid a tip fee of $57 per ton to the Orange County Landfill, and anticipates lower tip fees with consideration of other disposal options.

12.6.2 Minimum Waste Throughput Processing Capacity

12.6.2.1 Waste-to-Energy

As depicted in Exhibit 12-2 in Section 12.3.3 above, WTE facilities require significant waste throughput to be economically viable. For traditional WTE technologies, SCS typically projects a daily throughput capacity of at least 100 to 300 tons per day required to substantiate siting a new WTE facility. Such a facility would most likely consist of multiple, smaller capacity modules, on the order of 250 to 100 tons per day or, several smaller facilities located in different areas, and in both cases providing an aggregate capacity. Collaboration and regionalization is a must to support such technologies.

12.6.2.2 Waste Conversion

Based on SCS experience, typical WC technologies, including thermal, biological, and bio-chemical are represented to operate on a comparatively smaller scale. Between these types, generally, thermal technologies require more significant waste throughput to be economically viable. Due to lesser equipment and energy requirements, biological technologies can generally support smaller waste throughput.

12.6.2.2.1 Thermal

By a wide margin, the greatest amount of recent activity in WC technology is with the thermal technologies, dominated by the plasma arc conversion process. This is mainly due to its potential for large power production and overall reduced air emissions.

The lack of an operational track record for both large-scale and small-scale WC technologies suggests to SCS that a WC technology plant should more likely be planned initially as a small pilot-plant. A pilot plant, in SCS's opinion, based on proven laboratory and mini-pilot scale technology, would be no more than about 100 tons per day with the potential for scale-up should the technology be proven at the pilot stage and with regional collaboration.

The point here being, based on SCS's experience, the scalability of thermal WC technologies may never exceed pilot scale without regional collaboration and population growth in Chapel Hill.

12.6.2.2.2 Anaerobic Facilities

In Europe, the anaerobic process has been used successfully to process MSW. The sizes of these plants reportedly range from 3,000 tons per year (TPY) to 182,000 TPY. Converted to a daily capacity, and assuming a 6-day per week processing schedule, these capacities range from 10 tons per day to 580 tons per day.

As noted in the paragraphs above, there are several operating AD facilities in North America in the size range potentially generated by the Town. These facilities are successfully processing from about 15 to 250 tons per day of food and yard wastes diverted from residences, restaurants and businesses and converted into methane that is used to produce power.

12.6.3 Summary of Readiness for Commercial Operations

Some, but not all of the alternative WC technologies are ready for commercial operation. Exhibit 12-15 summarizes the technologies discussed herein and whether, in SCS's opinion, they are ready for pilot plant or commercial operation on a scale necessary to serve the Town or Region.

Exhibit 12-15. Summary of Main Processes

Process	Pre-Processing	By-Product	Primary Product	Pilot Plant Readiness	Commercial Readiness
Pyrolysis	High	Ash	Syngas/Oil	Yes	No
Gasification	Medium	Ash/Slag	Syngas/Char	Yes	No
Autoclave	Low	None/Recyclables	Pulp	Yes	Yes
Anaerobic Digestion	Medium/High	Filtrate Water	Biogas/Compost	Yes	Yes
Hydrolysis	High	Waste Water/Ash	Ethanol	Yes	No
Aerobic Digestion	Medium/High	None	Compost	Yes	Yes
Plasma Gasification	Claims Low/High	Slag	Syngas	Yes	No

As depicted, each of the seven technologies have demonstrated pilot plant readiness either nationally or internationally; however, only three of the technologies appear ready for commercial scale operations. These three technologies are the biological processes and the Autoclave process. With the exception of the autoclave, each of these technologies requires pre-processing requirements to remove potential contaminants from the incoming waste stream.

12.6.4 Capital and Operating Costs

As described, due to the relatively recent development of the alternative WC technologies, there are few, if any, full-scale operational plants in the U.S. Thus, there are not reliable figures readily available for capital and operating costs.

Two large, relatively recent studies were conducted as part of a detailed review of alternative waste conversion technologies in the U.S. The on-going studies were sponsored by Los Angeles County California, as continuation of that region's program initiated in 2003 to further address the regions acute problems with energy pricing and availability, air quality, traffic congestion and reliance on landfills that had limited useful life. The original study screened 27 technologies in the initial phase (2005) and reduced the list to 5 "finalists" technologies in the subsequent 2007 report. The finalists are planning to build small-scale demonstration plants to prove their respective technologies.

Although there have been other large alternative technology screening/evaluation studies conducted (i.e., New York City, 2004), the L.A. County studies seem to have the most detailed information on projected U.S.-based plant costs and economics. Exhibit 12-16 summarizes the project economics for five finalist biological and thermal alternative WC technologies that were developed as part of the L.A. County study in 2007.

Exhibit 12-16. Summary of Project Economics for Thermal and Biological Conversion Technologies(1)

Technology	(2)Annual Throughput (TPY)	Projected Design Capacity (TPD)	Capital Cost ($)	Capital Cost Per Ton ($/ton)	(3)O&M Costs ($)	Total Costs ($)	Estimated Annual Revenue ($)	Estimated Net Costs ($)	Calculated Tipping Fee ($/ton)	Tipping Fee Variation ($/ton)	Adjusted Tipping Fee ($/ton)
Biological (Anaerobic)	100,000	300	21,000,000	70,000	4,900,000	8,170,000	3,000,000	5,170,000	52	6	58
Thermal (autoclave)	51,100	200	35,000,000	175,000	9,000,000	13,100,000	8,400,000	4,700,000	92	0	92
Thermal (Pyrolysis Gasification)	80,000	242	30,140,000	125,000	5,580,000	7,740,000	3,280,000	4,460,000	56	2	58
Thermal (Gasification)	97,000	312	75,200,000	241,000	11,000,000	20,700,000	8,000,000	12,700,000	131	1	132
Thermal (Gasification)	138,000	413	56,600,000	137,000	8,260,000	14,200,000	6,300,000	7,900,000	57	12	69

(1)Excerpted and Summarized from the L.A. County, California Conversion Technology Evaluation Report, Phase II Assessment, dated October 2007.
(2)Tons per year (TPY), demonstration plant only.
(3) 1st year costs only, does not include annual debt service.

The costs and economic summaries were provided by the selected technology vendors, using some pricing assumptions for specific items provided by the planning committee and applicable to southern California only. The consultant retained by L.A. County conducted an independent review of the costs and economics provided by the vendors and concluded that the figures provided were, in general, reasonable estimates that matched with the independent assessment's conclusions.

12.6.5 Tipping Fee Survey

Exhibit 12-17 compiles costs from the 2005 and previously discussed 2007 L.A. County studies. The middle column are tipping fees summarized from the economic projections rendered in the 2005 study, which had similar pricing and cost assumptions as in the 2007 follow-on study. Tipping fees in the 2005 study ranged from $61 to $197 per ton for the eight vendors. Two plants exhibited tipping fees in the $50 to $70 per ton range, while six were higher than that.

Exhibit 12-17. Summary of Economic Data(1)

Technology	(2)Projected Design Capacity (TPD)	(1)Calculated Tipping Fee ($/ton)	(3)Calculated Tipping Fee ($/ton)
Biological (Anaerobic)	100	93	58
Biological (Anaerobic)	100	67	--
Biological (Anaerobic)	100	197	--
Thermal (Autoclave)	--	--	92
Thermal (Plasma-Arc)	100	172	--
Thermal (Gasification)	150	61	58
Thermal (Gasification)	300	186	132
Thermal (Pyrolysis-Gasification)	100	129	69

(1)Excerpted and Summarized from the L.A. County, California Conversion Technology Evaluation Report, Phase I Assessment.
(2)Tons per year (TPY), demonstration plant only.
(3)Adjusted Tipping Fee from Exhibit 12-16, based on Phase II Study.

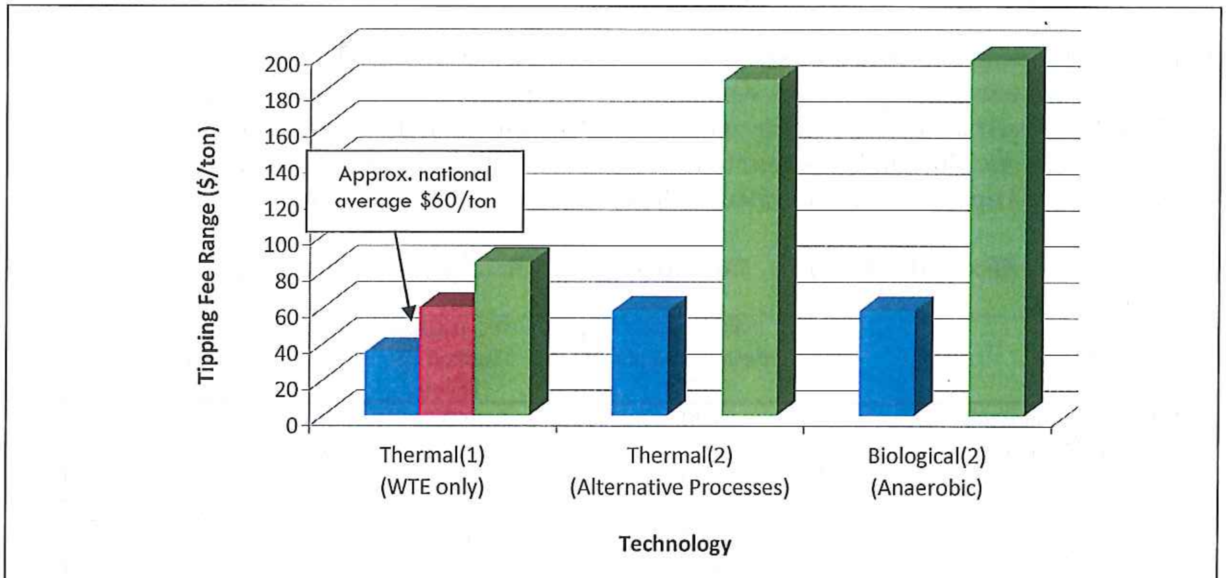
L.A. County considered a tipping fee in the range of $50 to $70 per ton, to be competitive with the tipping fees charged by the large regional landfills serving the area. Exhibit 12-17 indicates that two of the four thermal technologies and one anaerobic technology, provided costs that indicated the plant could offer a tipping fee in the $50 to $70 per ton range.

The difference in tipping fees from 2005 to 2007 probably reflects some differences in the pricing assumptions in individual studies including: proposed plant capacities were larger in 2007, and purchase pricing structure for the power produced was revised. It is also assumed that the market conditions for the development of these plants from 2005 to 2007 likely became more favorable as basic energy costs in the U.S. continued escalating.

12.6.6 Comparison to WTE Fees

Because conventional WTE plant technology has been in existence for decades, with hundreds of plants operating in the U.S. and abroad, comparative cost information is more established; although a completely new WTE plant has not been constructed in the U.S. in more than 10 years. Exhibit 12-18 presents a visual summary comparison of the tipping fees estimated for the alternative WC technologies in the L.A. County studies and the tipping fees for operating WTE plants. The graph shows that the appropriate "average" tipping fee for a WTE plant is about $60 per ton. The estimated "low" and "high" range is estimated to be from about $35 to $80 per ton, respectively.

Exhibit 12-18. Summary of Tipping Fee Range for Technologies



(1) Existing operating plants.
(2) Proposed demonstration, small-scale plants only. (8 plants total)

Legend
Low end
High end

The tipping fee ranges for alternative technologies are provided as a crude comparison to the WTE tipping fee. A large tipping fee range, from low to high, is evident. These plots reflect expected uncertainties and risks at the time of the studies, which would not be unusual for technology that is still in the development or pilot plant stages. Most WTE plants in the U.S. have a capacity anywhere from 500 to about 4,000 tons per day and this affords them a valuable "economy of scale" over the much smaller proposed alternative technologies.

Such a large range of tipping fees for alternative WC technologies may not actually be the case if a study were done today. Projected tipping fees are a function of many regional cost factors, including:

- Power production/ quality and quantity of syngas;
- Air emissions and treatment;
- Market for by-products;
- Downtime/ equipment reliability;
- Pre-processing requirements (sorting equipment, MRF, etc.);
- Operator experience;
- Financial contributions by vendor;

- Ancillary costs (transmission line, etc.); and,
- Contractual obligations.

However in SCS's opinion, these summary costs for alternative WC technologies suggest that tipping fee ranges are likely to be somewhat higher than a WTE plant, until enough of the plants are operating and hard costs are generated to validate that they can operate at a tipping fee comparable to a WTE plant.

12.6.7 Advantages and Disadvantages

All of the alternative WC technologies have some potential benefits and disadvantages. The over-riding aspect of all of the alternative WC technologies is that they are relatively new and thus do not have a "track record" from which one can derive hard conclusions related to actual, proven benefits and disadvantages. So, SCS can only postulate what the actual advantages, disadvantages, and economics might be. This exercise is based on assessing the information available from vendors, review of operational history for some very small-scale pilot plant facilities that may have operated intermittently, and evaluation of these technologies that are processing waste streams other than a normal mixed municipal solid waste.

Exhibit 12-19 summarizes the advantages and disadvantages of the alternative technologies and the WTE technology. We offer the following generalized conclusions, in addition to the comments in the table, about the viability of the technologies:

- **Biological (anaerobic).** Commercial scale proven at smaller capacities (i.e., 200 to 300 tons per day) in Europe. Developing a consistent market for the compost by-product is a major challenge and affects the operating economics. Only a few small scale plants are currently planned in the U.S.

- **Thermal.** Generally unproven at a commercial scale. One small pilot facility (85 tons per day) is operating in Canada. A complex process that must be optimized to provide the desired high-quality synfuel. There is much planning activity in the industry and in the next 5 years there will likely be some operational plants to better demonstrate the potential scalability and viability of these technologies.

- **Bio-Chemical.** Unproven at a commercial scale. A few plants have been planned, but have been delayed. Tied to the dynamic market for ethanol and competition with many other processes that do not use MSW.

Exhibit 12-19. Advantages and Disadvantages to Waste Processing Technologies

Process	Advantages	Disadvantages
Thermal – Pyrolysis / Gasification	Potential for high power production, high conversion	Untested, possibly high O&M costs, ash disposal
Thermal – Autoclave	Provide higher quality recyclables	Lack of market for compost
Biological – Aerobic	Proven, "low" tech. Emissions less of a concern.	Some odor; Lack of market for compost, low conversion
Biological – Anaerobic	Low emissions, low odor	Lack of market for compost
Plasma Gasification	Potential for high power production, high conversion	Untested, possibly high O&M costs, safety concerns, slag market (?)
Bio-Chemical (Hydrolysis)	Fuel production, biosolids processing	Untested, treats only cellulosic part of waste
WTE Plant	Proven large-scale technology	Large volumes of unusable ash, costly air emission control systems

12.7 RECOMMENDATIONS TO POSITION THE TOWN FOR POTENTIAL WTE AND WC TECHNOLOGIES

As the Town moves forward on its strategic planning initiative, SCS makes the following recommendations to help position the Town with relation to WTE and WC technologies:

- Many of the WTE and WC (thermal) technologies appear to be cost prohibitive with the current and projected MSW waste flow of the Town. The capital and pre-processing costs of these technologies, at the current time, appear to be cost prohibitive to reasonably recover the initial necessary investments compared to other solid waste management alternatives. It is our opinion, therefore, that regional efforts will be necessary to secure the desired waste flow to provide economies of scale for these technologies.

- Consequently, we would recommend that the Town implement a "wait and see approach" as for WTE and WC (Thermal) technologies offered in the U.S. marketplace. As noted in this report, many of these technologies are currently unproven on the commercial scale in the United States. However, firms like Entsorga, Harvest Power, and Plasco are rapidly progressing in finalizing plans to commercialize their technology. Construction and subsequent observation of these plants will provide much needed detailed capital and operating information to support the Town's decision making.

- Based on its projected economy of scale and initial investment requirements, the WC technology that may be most applicable to the Town, at this time, would be anaerobic digestion. This technology has proven to be successful in the processing of organics and MSW both in Europe, and now in North America at the waste flow level generated by the Town. The technology allows for scalability if other neighboring localities decide to collaborate on the project in the future. The biogas produced could provide a valuable energy asset for Town facilities.

Capital needs required to construct and operate an anaerobic digester operations include: an organics receiving area(s), reactor chamber(s) (i.e., enclosed vessel), and processing equipment (i.e., wheel loader or conveyors). One initial challenge to implement this technology; however, is that the Town would need to initiate some form of separate organics collection, or post collection segregation, similar to what has been instituted by the City of Toronto. For example, under its "Green Bin Program," the City allows participants (residential and multi-family residents) to place organics (e.g., food wastes, soiled paper towels and food packaging, coffee grounds, etc.) out for separate collection along with refuse and recycling. The City provides roll-carts for residential customers while multi-family complexes are provided either bulk bins or roll-carts with residents given in-unit organics containers to collect their organics. The City has provided an extensive public education and outreach program. Should the Town consider a similar organics program, it is expected that organic wastes collection be carefully considered for its application towards and anaerobic digester operation.

- It is SCS's recommendation that the Town continue to pursue potential synergies between innovative technology vendors, local institutions of higher education, and professional associations to attract interest in fostering further feasibility studies and/or development of pilot studies. This recommendation is more fully discussed in the following section of the Report.

13.0 ALTERNATIVE TECHNOLOGIES – COLLABORATION WITH AREA INSTITUTIONS

13.1 UNIVERSITIES

Another waste management option for the Town is to pursue the implementation of Waste Conversion (WC) technologies in collaboration with area universities. Chapel Hill is located in the Research Triangle, so named in 1959 with the creation of Research Triangle Park, a research park between Durham and Raleigh. "The Triangle" is anchored by Duke University (Duke), North Carolina State University (NCSU), and University of North Carolina at Chapel Hill (UNC). Each university has its distinctive character and long-term sustainability program.

The following section briefly includes a general summary of current sustainability and solid waste management programs at the three universities and initial discussions with their sustainability directors to gauge the level of interest in collaborating with the Town on WC technologies. Several of the projects described below provide flagship examples of the possibilities that may spring from successful collaboration between WC technology vendors, university research resources, and private industry. Particularly, SCS believes collaborative resources within the Town are optimal for development of anaerobic digestion of organic waste with cooperation from UNC Chapel Hill, based on recent collaborative success in this technology by Duke.

13.1.1 Duke University

Duke has developed a Climate Action Plan that will guide the University towards carbon neutrality by 2024. As part of that effort, Duke University established The Duke Carbon Offsets Initiative (DCOI) to help meet the University's carbon neutrality commitment. The DCOI's mission is to develop local, state, and regional carbon offset projects that yield significant benefits beyond greenhouse gas emission reductions. Benefits the DCOI looks for in projects are additional environmental and public health protection, job creation opportunities, energy savings, and habitat protection.

For example, Duke University and Duke Energy have partnered to pilot an innovative system for managing hog waste that will reduce greenhouse gas emissions, generate renewable energy, and substantially eliminate a host of pollutants and issues associated with the waste from swine farms, including odors, ammonia, nutrients and pathogens. This system is located at Loyd Ray Farms, an 8,600-head swine finishing facility in Yadkin County, NC [23]. It is intended to serve as a model for other hog farms seeking to manage waste and develop on-farm renewable power.

The project involves the capture of methane generated by the hog waste. Hog waste generated at the farm is directed into a lagoon which acts as an anaerobic digester. The decomposing hog waste generates methane gas which is captured and collected under a plastic cover over the lagoon/anaerobic digester. The gas collected under the digester cover is used to power a 65-kW microturbine, the electricity from which is used to support the operation of the innovative waste

23 http://sustainability.duke.edu/carbon_offsets/Projects/loydray.html

management system. Any electricity not needed to power the anaerobic digester operations is kept on the farm to support normal farm operations. Like a traditional waste lagoon, the remaining liquid waste flows to an aeration basin which treats the water to address ammonia and other residual pollutants so that it can be re-used for irrigation and barn-flushing.

The project is also creating carbon offset credits through the documented and verified destruction of the methane gas. These carbon offset credits are shared by Duke University and Google. The project also produces renewable energy credits (RECs) which Duke Energy counts towards its NC Renewable Energy and Energy Efficiency Portfolio Standard (REPS) requirements for the generation of electricity from swine waste.

Discussions with Ms. Tavey McDaniel, the University's Sustainability Director indicated that they would welcome discussions with the town on potential collaborative research on waste-to-energy (WTE) and WC technologies.

13.1.2 University of North Carolina at Chapel Hill

SCS met with representatives of UNC to review their current solid waste programs and initiatives, and to identify possible areas of collaboration with the Town. In 2010, UNC initiated a study team to evaluate alternative energy technologies and make recommendations of viable options. As part of a long-term Climate Action Plan (CAP), the University has committed to end the use of coal on campus by 2020, and is evaluating the switch to biomass and natural gas.

13.1.2.1 Landfill Gas

Currently, UNC is partnering with Orange County to utilize landfill gas (LFG) supplied from the County's landfill. The initial phase of this project in 2010-2011 constructed a pipeline from the landfill to the power plant and modified UNC's existing boilers to co-fire coal and LFG. In future phases of this project, as part of upgrades to the University's power supply system, the University is constructing a new campus power plant to burn LFG with the gas transported via an extension of this pipeline from the landfill.

13.1.2.2 Biomass Feedstock Implementation

Furthermore, UNC has conducted pilot studies with their boilers to co-fire biomass in the form of torrefied wood pellets. The goal of these studies is to evaluate various feedstock, integrating the biomass processing and handling with boiler operations, and resulting energy potential. The results of these studies are under consideration and further studies are in discussion.

Based on these ongoing initiatives at UNC and the current state of many of the WTE and alternative WC technologies summarized in Section 12, collaboration with the Town to initiate another large-scale strategy (e.g., mass burn, or other thermal gasification technology) is in the near term unlikely. Furthermore, the University's existing boilers represent a useful life to the year 2040, at which time another technology may become feasible for consideration.

13.1.2.3 Anaerobic Digestion Potential

SCS initiated discussions with UNC staff to see if future collaboration opportunities would make sense for the Town. UNC staff confirmed UNC's desire to end its use of coal on campus and to move to renewable energy supplies. The current effort to burn LFG is one move in that direction. UNC is interested in looking at the feasibility of anaerobic digestion to process the university's food waste and biomass requiring disposal. They recognize a significant advantage of anaerobic digestion in reducing greenhouse gas emissions from the coal-fired boilers as well as providing renewable energy supplies.

Food waste is currently collected by Orange County at four campus locations (e.g., dining facilities) and hauled off campus to Brooks Contracting where it is composted in windrow piles. This existing operation is a key development towards a successful digester project in that source separation of organics and food waste is presently occurring and these operations do not need development. Furthermore, with the proven operations of firing LFG in the campus boilers, biogas generated by an anaerobic digestion operation may simply be fed into and blended with LFG in the existing pipeline, thereby reducing the need for a separate conversion unit associated with the anaerobic digestion unit. However, SCS's discussions with UNC staff recognized that siting an anaerobic digester operation at the landfill, near the campus power plant, or elsewhere on campus would likely present challenges. SCS recognizes that the development of the new Carolina North campus and construction of a second power plant to support this campus while utilizing the LFG presents a unique collaborative opportunity to include anaerobic digestion in the design of this infrastructure and its utilities.

UNC staff has noted that a few other academic communities have successfully implemented (or are evaluating) anaerobic digestion systems to manage their food wastes, and thus supporting sustainable, green campus operations to include: the University of Wisconsin and Michigan State University. Therefore, the interest in developing this technology is high. University staff believes other neighboring communities could partner on such a project. While implementing an anaerobic digester project to manage campus and Town organic and food waste would impact the current aerobic composting operations, UNC staff also recognize the addition of many other sustainable benefits including greenhouse gas (GHG) reductions, generating RECs and carbon offset credits, and promoting safety by eliminating long hauling.

13.1.3 North Carolina State University

NCSU houses a department of Waste Reduction and Recycling (WRR) which is also the name of one of the eight key focus areas for the Campus Environmental Sustainability Team (CEST). The goal of WRR is to divert university waste from the landfill through education, efficient processes and operational endeavors. Since establishing the office in 2001, NC State has seen WRR's efforts make tremendous improvements to the campus solid waste management program. As of 2010, the University has reportedly achieved a 45.45% diversion rate. The University has set a goal of 65% diversion rate by 2015, as outlined in the Sustainability Strategic Plan.

NCSU has a had a long history of solid waste recycling going back to 1975 when the University began hand sorting of campus recyclables. A campus-wide curbside recycling program was initiated in 1988, which involved a residence hall pilot program beginning in 1990 and yard waste recycling a few years after that. Currently, NCSU's organic materials (i.e., dining hall food waste, animal bedding, yard waste, etc.) are collected and composted by Brooks Contracting like UNC.

In January, 2011, NCSU broke ground on a $61 million performance contract with Ameresco, Inc., part of which will install an 11 Megawatt (MW) Combined Heat and Power (CHP) system in Cates Utility Plant. The CHP system, also called cogeneration, will pay for itself through energy savings over 17 years. The upgrade at Cates Utility Plant is expected to be completed in summer 2012.

Initial discussions with NCSU's Sustainability Director, Ms. Tracy Dixon, suggested that NCSU would be interested in partnering with the Town to consider and solicit applicable research grant and educational funding to initiate feasibility studies to involve the development of a WTE or WC technology (e.g., anaerobic digestion) in the region.