

**APPENDIX E**  
**ASSESSMENT OF EMERGING SOLID WASTE**  
**MANAGEMENT TECHNOLOGIES**

## 1.0 INTRODUCTION AND DEFINITIONS

As part of the New SWMP process, the City of Albany is identifying and evaluating solid waste management technologies that could potentially reduce the amount of solid waste requiring landfill disposal. The SWMP will consider both established and emerging technologies for possible inclusion in the region's long-term solid waste program.

This assessment of emerging solid waste management technologies was prepared as part of the SWMP. This comparative evaluation is not intended to result in the selection of any particular technology or any particular company. Rather, it is intended to facilitate a conclusion about whether continued consideration of one or more of these technologies is appropriate as an on-going element of the New SWMP.

For the purposes of this evaluation, "emerging" solid waste management technologies are defined as technologies with the potential to provide commercial-scale, effective means of municipal solid waste processing and disposal, but which currently have little or no commercial application in the United States. Technologies that have only recently been introduced to the U.S. in a demonstration or commercial capacity qualify as emerging. Emerging technologies with existing commercial applications in other countries, but which have not been implemented in the U.S., are also included in this analysis.

Proven technologies with widespread commercial use in the U.S. are not included in the definition of emerging technologies. Waste-to-energy facilities (including both mass-burn and mechanically processed refuse derived fuel), stand-alone material recovery facilities (MRF), composting facilities for organic waste and conventional landfills do not qualify as new or emerging technologies, and are not included in this assessment.

This analysis includes information provided by respondents to a Request for Information, as further described in Section 2.0, as well as information about other new and emerging technologies derived from recent studies conducted in other jurisdictions and from other sources. A summary description of the details of many of the emerging technologies is presented in Section 3.0, where they are characterized by type of process and other factors. Information provided in the RFI responses is summarized in this section.

Section 4.0 describes some recent assessments of emerging technologies conducted by other jurisdictions who are evaluating these alternatives. Section 5.0 presents the findings and conclusions of this analysis in the context of the Capital Region Solid Waste Management Plan.

## **2.0 REQUEST FOR INFORMATION**

As part of this process, a Request for Information (RFI) was prepared and distributed to solicit preliminary statements of interest and background information from parties wishing to participate in the evaluation process. The availability of the RFI was advertised in national publications (Waste Age and Waste and Recycling News) and began being distributed on February 16, 2009. Responses were requested on or before March 27, 2009.

Interested parties were invited to provide basic information regarding their sponsored technologies, including measures of actual or anticipated performance in each of the following categories of criteria:

- Experience of Project Sponsors
- Facility Sizing
- Costs of Ownership and Operation
- Environmental Impacts
- Readiness and Reliability
- Beneficial Reuse of MSW Byproducts
- Residues Requiring Landfill Disposal

A copy of the RFI is presented in Appendix A.

Fifteen (15) companies provided submittals in response to the RFI. Table 1 provides a summary of the RFI respondents.

**Table 1 –Summary of Respondents to RFI**

Name	Primary Treatment Type	Primary Product	Reference Facilities	Comment
Biogold	Thermal	Electricity or Biofuel/gasification	No MSW reference facility	Produces electricity and/or ethanol biofuel, depending on market for these commodities.
Carbon Diversion, Inc.	Thermal	Electricity from pyrolytic syngas	50 tpd facility in Dunlop TN	
Casella Waste Systems, Inc.	Mechanical/Thermal	Electricity from pyrolytic syngas	3 reference facilities for single stream. WTE demonstration unit under acceptance testing.	Final element of a 4 stage approach. Single stream recycling and processed waste feedstock in previous stages
Covanta Energy Corp.	Thermal	Electricity from Mass Burn	5 operating facilities in NY, 15 others in Northeast US.	Export to existing WTE facilities through B-3 transfer station in Columbia County.
Dongara Pellet Factory	Mechanical	Solid Fuel Pellets	110,000 tpy facility in Woodbridge, ON.	Fuel pellets are to be used for energy production.
Ecodeco	Biological/Mechanical	Solid Fuel Product	Several facilities in, Italy, Spain and U.K.	Solid Fuel product could potentially be used to generate electricity.
Energy Answers International	Mechanical/Thermal	Electricity from Processed Refuse Fuel	3,000 tpd SEMASS facility in Rochester, MA	Company was affiliated w/ reference facility from 1988 - 1996
Green Conversion	Thermal	Electricity from Mass Burn	1,100 tpd facility in Hamburg, GE	

Name	Primary Treatment Type	Primary Product	Reference Facilities	Comment
Nature's Fuel	Thermal	Electricity from pyrolytic syngas	86,000 tpy facility in Atwood, IN.	
NORTERRA Organics	Biological	Compost	20,000 tpy facility in Joyceville, ON.	SSOW only
Organic Waste Remediation	Thermal	Electricity from pyrolytic syngas	250 tpd facility seeking approval in CT.	
Plasco Energy Group	Thermal	Electricity from Plasma syngas	110 tpd demonstration facility in Ottawa, Canada	
Powers Energy	Thermal	Biofuel from gasification	2,000 tpd facility being developed in Lake County, IN.	
StarTech Environmental	Thermal	Plasma-converted Syngas	2 facilities under contract in Europe	
Taylor Biomass Energy	Thermal	Electricity/ gasification	Facility under development	

Five of the submittals provided information about technologies that are considered commercially proven, including mass burn waste to energy, mechanically processed refuse derived fuel (RDF), and the composting of source separated organic waste. The 10 remaining respondents presented information about new and emerging technologies for waste treatment with recovery of materials, energy or both. Information from these submittals was summarized and is presented in the discussion of emerging technologies in Section 3.0.

A more detailed summary of each submittal is presented in Appendix B.

## 3.0 EMERGING SOLID WASTE MANAGEMENT TECHNOLOGIES

### 3.1 Thermal Processing

Thermal processing technologies encompass a variety of processes that use or produce heat, under controlled conditions, to convert MSW to usable products such as recyclable materials and/or electrical output. The organic content of MSW is converted to energy, and the inorganic content is recovered as products such as metals.

Thermal technologies can potentially convert all organic components of MSW into energy (i.e., all carbon and hydrogen-based materials, including plastic, rubber, textiles, and other organic materials that are not converted in biological processes). Thermal processing occurs in a high-temperature reaction vessel; reactor temperatures vary among technologies, but can range from approximately 800°F to as high as 8,000°F.

Generally speaking, thermal processing of MSW consists of two primary steps (DSNY 2006):

*Pre-processing* requirements are typically minimal for thermal processing technologies. Many thermal technologies require no MSW size reduction or separation by component, although some do require waste to be shredded prior to processing. While recyclables such as metals can be recovered in a pre-processing step, many thermal technologies recover recyclable metals after the thermal conversion process.

In *thermal conversion*, the organic fraction of the MSW is converted to a gas form by processing at a high temperature within the reaction vessel. Gas products are typically composed of hydrogen, carbon monoxide and carbon dioxide gases, and may be called “syngas” or “fuel gas”, depending on the technology. The gas may be converted to electricity by using it as a fuel in traditional boilers, reciprocating engines and combustion turbines. Net electricity is reportedly on the order of 400-500 kWh/ton for most thermal processing technologies.

Processing temperatures, the means of maintaining elevated temperatures, and the degree of decomposition of the organic fraction of MSW, vary among thermal processing technologies.

Several types of thermal processing technologies have been or are being developed to a level of commercial feasibility, and are described in detail below.

### 3.1.1 Pyrolysis

Pyrolysis systems use a drum, kiln-shaped structure, or pyrolysis tube, which is heated using recycled syngas or another fuel or heat source. Existing pyrolysis systems can typically process up to 300 tpd of MSW; systems are modular and can be installed in parallel to increase throughput. MSW must be pre-processed to separate non-degradable materials, and the organic MSW content is essentially “cooked” in an externally heated oven at temperatures of 750°F to 1,650°F, *in the absence or near absence of free oxygen*. At high temperatures, the organic compounds volatilize and bonds thermally crack, breaking larger molecules into gases and liquids composed of smaller molecules, including hydrocarbon gases and hydrogen gas.

The temperature, pressure, reaction rates, and internal heat transfer rates are used to control pyrolytic reactions in order to produce specific products. Syngas products are composed primarily of hydrogen (H<sub>2</sub>), carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), and methane (CH<sub>4</sub>). The syngas can be utilized in boilers, gas turbines, or internal combustion engines to generate electricity, or alternatively can be used in the production of chemicals. Some of the volatile components of MSW form tar and oil, and can be removed for reuse as a fuel. The balance of the organic materials that are not volatile, or liquid that is left as a char material, can be further processed or used for its adsorption properties (activated carbon). Inorganic materials form a bottom ash that requires disposal, although some pyrolysis ash can be used for manufacturing brick materials.

Most pyrolysis systems are closed systems, and there are no waste gases or air emission sources. However, subsequent power generation using syngas does have air emissions that can be filtered through a stack and air emission control system. The volume of MSW feedstock entering a pyrolysis reactor can be reduced by as much as 90% (City of LA 2005).

Four of the RFI respondents have developed or are developing thermal processing facilities utilizing pyrolysis. These respondents are Carbon Diversion, Inc., Casella Waste Systems, Inc., Nature’s Fuel, and Organic Waste Remediation, LLC. A brief summary of these technologies or facilities, based on information provided in each of the RFI responses, is presented below.

#### **Carbon Diversion, Inc.**

Carbon Diversion Inc. is a Hawaiian corporation that was formed in 2004. CDI creates small-scale systems that can process MSW to generate electricity and bio-char products. The company identifies a pilot plant and two commercial facilities, located in Hawaii and Tennessee. CDI will break ground on the first of three planned manufacturing facilities in April 2009, which will allow the company to produce and deliver its systems.

CDI has built a pilot plant at Campbell Industrial Park in Hawaii. The plant consists of three 1-ton processors, and the main product is a petroleum product in the kerosene range. A second system is located in Dunlop, Tennessee as part of a sustainable community development, and consists of two 3.5 ton/hr. units. The Dunlop facility is designed to operate 10 hours/day and generate 2 MW of electricity. Bio-char byproducts are bagged and sold under the Eterna Green trade name as a soil amendment. Work has begun on a third site in Hawaii; four additional sites have been identified at transfer stations in Hawaii, pending final bond passage with a start date in July 2009.

Incoming waste, including tires, animal waste and green waste, is pre-processed (briquetted) and fed into the processors. A pressurized partial pyrolysis gasification process is used to produce a liquid fuel and syngas, which are used to generate electricity. Bio-char can be used for water filtration or as a soil amendment. Units can be remote-started by local power providers, and can be used for emergency power generation if provided access to natural gas utilities.

More information about this RFI response is presented in Appendix B.

#### **Casella Waste Systems, Inc.**

Casella Waste Systems, Inc. is a vertically integrated resource management company that operates primarily in the northeastern U.S, and was founded in 1975. The company operates a number of collection divisions, transfer stations, disposal facilities, recycling facilities, and landfill gas to energy facilities. FCR, Inc. is a wholly owned subsidiary of Casella that designs, builds and operates recycling facilities throughout the U.S.

Casella proposes a four-phased waste management approach for the Planning Unit. The first three phases include a single stream MRF, a multimaterial processing platform to recover additional recyclables and manufacture engineered feedstock for co-firing in solid fuel boilers. These first three phases are considered conventional technologies. It is the fourth phase which is

considered an emerging technology because it includes the establishment of a waste-to-energy facility accepting the non-recoverable portion of the waste stream and thermally reducing it by means of pyrolysis and gasification. Syngas products would be used to produce electricity, liquid fuels or chemicals. Casella has a commercial demonstration unit currently in acceptance testing, which would serve as a reference facility upon completion; other reference facilities are operated by Eco Technology, a project partner.

More information about this RFI response is presented in Appendix B.

### **Nature's Fuel**

Nature's Fuel (NF) was founded in 2005 and is an Indiana Corporation; the company is owned by private equity investors. NF owns and operates one commercial facility in Atwood, Indiana, and is developing a second commercial facility in Huntington, Indiana.

The NF system uses a pyrolysis process to generate electricity, bio-oil, bio-char, and bio-gas. Bio-char residue can be used as a soil amendment or high-grade source of activated carbon. Bio-oil can be sold to blenders and used to reduce the sulfur content and viscosity of #6 heating oil.

NF operates an 86,000 tpy facility in Atwood, Indiana – this plant began as a solid fuel R&D facility and was converted into a full-production pyrolyzation operation in 2007. The Atwood facility does not accept MSW, but does accept wood waste, C&D waste, and other waste streams (plastics, waste oils, etc.) to produce sulfur-free bio-oil, high quality bio-char, and will begin to generate electricity later in 2009.

NF is in the process of developing a new facility in Huntington, Indiana that will accept MSW as feed stock. This facility will have an anticipated waste throughput of 200,000 tpy in Year 1, and will increase to 400,000 tpy by Year 3. Air permit approval is anticipated in July 2009.

Representatives of Nature's Fuel attended the SWMP Steering Committee meeting on August 18, 2009 give a presentation about their technology and facilities. As of that time, the facility planned for the Huntington Landfill was not yet operating. When it is operating the anticipated fee at Huntington will be \$20/ton. Nature's Fuel indicated they anticipate that biogas generated at the Huntington facility would be used to fire internal combustion engines, and they expected a facility processing 500,000 TPY to generate about 50 MW. At the presentation NF clarified that the operating facility in Atwood primarily accepts wood waste from recreational vehicle

manufactures including particle board, paints and sealants, laminates, and all kinds of wood and adhesives. That facility operates at 55,000 tons per year.

More information about this RFI response is presented in Appendix B.

### **Organic Waste Remediation, LLC**

Organic Waste Remediation, LLC (OWR) is based in Orlando, FL and offers the OWR Process for disposal of MSW. The OWR Process combines single-stream recycling and pyrolysis technologies, and includes three modules. The *Recycling Module* separates non-organic material into ferrous, aluminum, other non-ferrous metals and clear, green and amber glass, washed and delabeled with ceramics removed. Unrecycled organic material is shredded, dried and fed to the Remediation Module. The *Remediation Module* uses a pyrolysis process to break organic materials down into a relatively consistent synfuel. Synfuel products are conveyed to the Power Module. The *Power Module* uses generic fluid bed burner/steam generation equipment to drive a steam turbine electric generator.

As of the RFI submittal date, OWR has not constructed or operated a MSW processing facility. OWR has commenced the approval process to construct and operate a commercial facility in Bozrah, CT. This facility will have a proposed maximum capacity of 250 TPD (~90,000 tpy), and contractual arrangements have been made to secure a 1,500 tons per week supply of MSW feedstock.

More information about this RFI response is presented in Appendix B.

### **3.1.2 Gasification**

Gasification involves the thermal conversion of organic carbon-based materials in the presence of internally produced heat, typically at temperatures of 1,400°F to 2,500°F, and *in a limited supply of air/oxygen* to produce a syngas composed primarily of H<sub>2</sub> and CO. Inorganic materials are converted either to bottom ash or to a solid, vitreous slag, depending on the conditions materials are processed under. Most gasification systems are closed systems and do not generate waste gases or air emission sources during the gasification phase. After cooling and cleaning in emission control systems, the syngas can be utilized in boilers, gas turbines, or internal combustion engines to generate electricity, or to make chemicals. Subsequent power generation

using syngas does have air emissions that can be filtered through a stack and air emission control system.

Gasification has reportedly been used to process MSW since the 1980s, primarily in Europe and Japan (City of LA 2005). Existing gasification systems operate at throughputs up to 1,000 tpd; gasifiers and the pre-processing, emission control, and power generation systems can be installed in parallel to increase throughput and power generation. Gasification and pyrolysis technologies are sometimes coupled, with char products resulting from pyrolysis used as feedstock for the follow-up gasification process.

Three of the RFI respondents, have developed or are developing thermal processing facilities utilizing this type of gasification technology. These respondents are BioGold Fuels Corporation, Powers Energy of America, Inc., and Taylor Biomass Energy, LLC. A brief summary of these technologies or facilities, based on information provided in each of the RFI responses, is presented below.

### **BioGold Fuels Corporation**

BioGold Fuels Corporation is a Nevada corporation based in New York City, was formed as a result of a merger with Full Circle Industries, Inc. in April 2007, and became a publicly traded company in October 2007. With the BioGold process, MSW is unloaded from trucks and conveyed to a sterilizer where it is sterilized, reduced in size, and mechanically sorted to remove recyclable metals and other inorganic material from the organic fraction of the waste. The sterilized organic and energy-containing materials are then fed into a thermo-chemical gasifier, where they are transformed at high temperature into compounds that produce a syngas composed mostly of hydrogen and carbon monoxide. Remaining solid residue can be vitrified into a glass-like solid that can be used for various construction applications.

Syngas can be used to generate electricity using commercial electricity-generating equipment, or converted to a biofuel using a standard gas-to-liquid catalytic process. BioGold would build infrastructure to generate both electricity and transportation biofuels, and would shift production according to the relative market value of these commodities.

According to its RFI response, BioGold has successfully implemented the front-end processing aspect of its technology using MSW to create a marketable recycled long-fiber product sold for

liner-board manufacture. As of March 2009, the company has not constructed or operated a MSW processing facility.

More information about this RFI response is presented in Appendix B.

**Powers Energy of America, Inc.**

Powers Energy is a national firm headquartered in Evansville, Indiana, and presents a process to produce biofuels and electricity from MSW feedstock. MSW would be delivered, handled and contained within the indoor facility. Carbon-based MSW/feedstock materials are mixed, crushed or shredded and fed into a gasification plant for bioethanol production. Feedstock materials are converted to a syngas product in the gasifiers by heating the materials in different stages to temperatures in excess of 2,000 degrees Fahrenheit. Heat recovered from the gasifier is used to generate steam and electricity. Syngas leaving the gasifier is refined, cooled and passed through the biological fermenter, where 70-90% of the gas will be converted to bioethanol through microbial activity. Off-gas from the fermenter is routed for use in steam generation. Bioethanol products go through a refining process and are marketed for use as a fuel. Ash from the gasifier is sent to a landfill for disposal.

The Lake County Indiana Solid Waste Management District approved a contract on November 20, 2008 to develop a biofuels facility with a minimum capacity of 2,000 tpd. The facility is anticipated to generate 36 million gallons of bioethanol fuel, 42,600 tons of recyclable metals and 20 MW of power on annual basis. As of March 2009, facility design plans were being prepared, but construction of this facility has not yet begun. Powers Energy is also pursuing agreements for development of a facility in northwestern Kentucky, and has begun design and permitting for this facility.

More information about this RFI response is presented in Appendix B.

**Taylor Biomass Energy, LLC**

Taylor Biomass Energy (TBE) is headquartered in Montgomery, NY where a related company has owned and operates a C&D recycling and processing facility since 1989. TBE has a project underway to couple a gasification process with the existing sorting and recycling process at the Montgomery facility. Permitting is currently underway for this action and permitting documents have been submitted to DEC for review.

As part of that project, sorted feedstock will be fed into the gasification reactor, where it will undergo a rapid thermal breakdown to produce a syngas product. The Taylor gasification process produces a medium Btu gas with a heating value of approximately half that of natural gas. This gas will have the ability to be directly substituted for natural gas or used as a fuel for engines and gas turbines, or to be used as a synthesis gas for production of biofuels or chemicals. For the Montgomery project, the syngas will be conditioned and used to generate electricity. A combustion reactor will be used to further process char products, and final ash products will be disposed of at a landfill.

More information about this RFI response is presented in Appendix B.

### **3.1.3 Plasma Arc Gasification**

Plasma technology uses an electrical discharge to heat gas, typically air, oxygen, nitrogen, hydrogen, or argon, or combinations of these gases, to temperatures above 7,000°F. The heated gas, or plasma, can then be used for welding, cutting, melting, or treating waste materials. Most past uses of plasma arc technology have been for melting incinerator ash or for thermally decomposing hazardous or medical wastes, and only recently has plasma technology integrated with gasification technologies to process MSW. This technology has potential to convert MSW to electricity more efficiently than conventional pyrolysis and gasification systems, due to its high heat flux, high temperature, almost complete conversion of carbon-based materials to syngas, and conversion of inorganic materials to a glassy, non-hazardous slag. Existing systems operate at throughputs of up to 83 tpd on MSW/auto shredder residue combination; plasma torches can be added to the reactors, and multiple reactors can be included to increase total capacity (City of LA 2005).

Plasma arc gasification typically occurs in a closed, pressurized reactor. Following pre-processing, the feedstock enters the reactor and comes into contact with the hot plasma gas. This system converts MSW and other organic carbon-based materials, including tar, oil, and char, to a syngas composed primarily of H<sub>2</sub> and CO. Inorganic materials are converted to a solid, vitreous slag. Like pyrolysis and conventional gasification, plasma arc gasification is a closed system; therefore there are no waste gases and no emission sources in the plasma gasification conversion process. After cooling and cleaning in emission control systems, the syngas produced by plasma arc gasification can either be burned immediately in a close-coupled combustion chamber or

boiler, or can be cleaned of contaminants and used in a reciprocating engine or gas turbine to generate electricity.

Two of the RFI respondents have developed, or are developing, thermal processing facilities utilizing plasma arc gasification technology. These respondents are Plasco Energy Group and Startech Environmental Corporation. A brief summary of these technologies or facilities, based on information provided in each of the RFI responses, is presented below.

### **Plasco Energy Group**

Plasco Energy Group is an Ottawa, Canada company that offers a system based on plasma arc technology. Plasco has built a 110 tpd commercial-scale demonstration facility in Ottawa that uses MSW from the city as feedstock. This facility has been in operation since January 2008. Discussions for commercial facilities are in progress in Canada, the U.S, Europe and Asia.

Plasco's waste conversion process begins with any materials with high reclamation value being removed from the waste stream and recovered for recycling. The remaining MSW is shredded and conveyed to a conversion chamber where it is converted into a crude syngas using recycled heat; this crude syngas flows to a refinement chamber and is refined using plasma torches to create a fuel called PlascoSyngas. The PlascoSyngas is cleaned and used to generate electricity. Waste heat is recovered and used to produce steam, which can be used to generate additional electricity or for industrial purposes.

Solid residue from the conversion chamber is sent to a separate high-temperature Carbon Recovery Vessel, where plasma heat is used to stabilize the solids and convert any remaining volatile compounds and fixed carbon into syngas. Remaining solids are cooled into small slag pellets. The process also yields other products including commercial salt, agricultural sulfur and water. In its response to the RFI, Plasco suggested a 440 TPD facility for the Capital region, using four of the 110 TPD units of the type currently operating at the demonstration facility in Ottawa.

More information about this RFI response is presented in Appendix B.

According to the company website (<http://www.plascoenergygroup.com/>), in June 2008 the Ottawa City Council issued a letter of intent for Plasco to build, own, and operate a 440 TPD

facility and the Central Waste Management Commission of Red Deer, Alberta has signed a contract for a 220 TPD Plasco facility.

### **Startech Environmental Corporation**

Startech is a Wilton, Connecticut based public company that offers a plasma processing technology for MSW disposal. The company was founded in 1993 and was established in 1995 as a public company. In 1996-1997, Startech built and delivered a 7 TPD system to the U.S. Army's Aberdeen Proving Ground in Maryland. In 2001, the company opened a facility in Bristol, Connecticut which houses a 5 TPD system used for customer training, marketing and demonstration purposes. In 2001 Startech delivered a 5 TPD system to Japan for the processing of PCBs and hazardous incinerator ash. The company has a 30,000 sf manufacturing facility in Bristol where its systems are built, and is in the process of developing several facilities in overseas markets.

The Plasma Converter System utilizes plasma – an electrically charged, ionized gas – to process waste materials at extremely high temperatures. Organic components of the incoming waste are used to create a plasma-converted syngas, which in turn can be used to produce electricity, recover hydrogen, and to make industrial materials. Outputs include a Plasma Converted Gas (PCG) fuel consisting of primarily hydrogen and carbon monoxide, and a glassy black obsidianite material. PCG can be reused or recycled as a fuel or as a synthesis gas to produce electricity, recover hydrogen, or to make industrial products. The Startech technology can be used to process a variety of hazardous and non-hazardous waste materials.

To date, Startech has no full-scale commercial MSW facilities in operation. The company has signed contracts for two 300 TPD MSW facilities in Europe with additional orders pending for MSW facilities in Panama (200 and 350 TPD) and Europe (100 TPD). Startech is currently manufacturing multiple systems for Puerto Rico and Poland.

More information about this RFI response is presented in Appendix B.

## **3.2 Biological and Chemical Processing**

Biological and chemical technologies operate at lower temperatures and lower reaction rates than thermal technologies. Biological technologies can convert only the biodegradable organic

content of MSW, and chemical processes can potentially convert any organic content. Neither type of technology can be used to effectively process inorganic waste materials. Some technologies involve the multiple stages of biochemical processing; byproducts vary among technologies but can include electricity, compost and chemicals.

One respondent to the RFI, ECODECO, has developed a technology that uses both biological and mechanical processes recover recyclable materials and produce a refuse derived fuel. A brief summary of this technology/facility, based on information provided in the RFI response, is presented below.

Two other specific technology groups, anaerobic digestion and ethanol production were not included in any of the RFI responses. These technologies are discussed in section 3.2.1 and 3.2.2 below.

## **ECODECO**

ECODECO is an international company with headquarters in Italy, and has recently established a cooperative arrangement with International Center for Commercial Affairs (ICCA) to assist in the pursuit of opportunities in the U.S. market. The company has developed the Biocubi Process, an aerobic biological treatment method, to remove moisture and improve the heating efficiency of products to be used as fuel inputs for subsequent processes. Processing takes place in the company's ITS (Intelligent Transfer Station). The putrescible fraction of MSW undergoes an aerobic treatment, and the released heat is used to dry and thermally hygienize the feedstock. Separation occurs following the bio-drying phase, and recyclable materials are removed from the feedstock. The bio-dried material is then mechanically refined to produce a solid fuel which can be used to generate electricity or as a fuel source by cement kilns.

ECODECO's technology has been successfully implemented in Europe for more than a decade. They have identified several facilities in Italy, Spain and England, and report that there are 17 ITS facilities in total throughout the world. To date, none of these facilities have been constructed in the U.S.

The response to the RFI noted a capital cost of \$56.7 million for a facility capable of serving the Capital Region Planning Unit and processing 230,000 TPY. Operational costs for a facility in the U.S. were not estimated by ECODECO, but tipping fees of €95 to €125 (euros) per ton were noted for some European facilities.

Representatives of ECODECO attended the SWMP Steering Committee meeting on July 21, 2009 and gave a presentation about their technology and facilities. At that meeting an estimated capital cost of \$64 million and an estimated operating cost of \$38 per ton were noted. ECODECO representatives were accompanied by representatives from Buzzi Unicem, a large Cement manufacturer with facilities in the U.S., who expressed a keen interest in utilizing the solid fuel from the ECODECO process to displace the use of coal in cement kilns.

More information about this RFI response is presented in Appendix B.

### 3.2.1 Anaerobic Digestion

*Anaerobic digestion* is a biological process by which microorganisms digest organic material in the absence of oxygen, producing a solid byproduct (digestate) and a gas (biogas). In the past, anaerobic digestion has been used extensively to stabilize sewage sludge, but has been adapted more recently to process the organic fraction of MSW. In anaerobic digestion, biodegradable material is converted by a series of bacterial groups into methane and CO<sub>2</sub>. In a primary step called hydrolysis, a first bacterial group breaks down large organic molecules into small units like sugars. In the acidification process, another group of bacteria converts the resulting smaller molecules into volatile fatty acids, mainly acetate, but also hydrogen (H<sub>2</sub>) and CO<sub>2</sub>. A third group of bacteria, the methane producers or methanogens, produce a medium-Btu biogas consisting of 50-70% methane, as well as CO<sub>2</sub>.

This biogas can be used to fuel boilers or reciprocating engines to generate electricity, and requires minimal pretreatment. It can also be upgraded to pipeline quality and used as compressed natural gas (CNG), a vehicular fuel. In addition to biogas, anaerobic bioconversion generates a residue consisting of inorganics, non-degradable organics, non-degraded biodegradables, and bacterial biomass. If the feedstock entering the process is sufficiently free of materials like colored plastics, this residue can have market value as a compost material. Anaerobic digestion facilities are able to process up to 800 tpd of MSW.

None of the respondents to the RFI proposed the use of anaerobic digestion technology. This technology has been employed with MSW feedstock in Europe by companies that have responded to recent solicitations by other jurisdictions, such as New York City and Los Angeles. NorthEast Biogas, a New York based company, is seeking to develop projects using anaerobic digestion, but this company did not respond to the RFI. Discussions with representatives of this

company indicated their interest in projects with organic waste feedstock, but not MSW feedstock.

### **3.2.2 Ethanol Production**

Various ethanol production processes have been developed at pilot scales, and some at demonstration scales, to generate ethanol from paper and vegetative matter in the MSW stream. In these processes, a purified lignocellulosic material – which is able to break cellulose-based plant material down to its component sugar molecules – is chopped up and introduced into a hydrolysis reactor. The effluent of this reactor is mostly a sugar solution, which is prepared for fermentation. This solution is detoxified and introduced to a fermenter, in which microorganisms convert the sugar to ethanol and CO<sub>2</sub>. Next, the solution is introduced into an energy-intensive, combined distillation and dehydration process to bring the ethanol concentration up to fuel grade (99%) ethanol. A solid residue of unfermented solids and microbial biomass is recovered through the anaerobic digestion process, and its marketability as a compost material depends on the purity of feedstock as well as its visual quality. Solid residues can be burned or gasified if alternative methods of reuse are not feasible.

A commercial scale facility had been permitted for development in Middletown NY. The \$285-million waste-to-ethanol processing plant is said to be capable of processing and converting up to 960 tpd of MSW to ethanol for commercial sale and use. The facility has been in the development stages since 1996, and received its required permits from the NYSDEC. However the facility has never been developed (news archive from the Middletown Times Herald-Record at [http://archive.recordonline.com/news/masada/masada\\_list.htm](http://archive.recordonline.com/news/masada/masada_list.htm)), and given the delays and reported legal issues, is believed to be unlikely to move forward.

## 4.0 RECENT ASSESSMENTS CONDUCTED BY OTHER JURISDICTIONS

Several municipalities, counties and solid waste authorities have conducted recent assessments of alternative technologies. Three of the more comprehensive efforts are reviewed and summarized here.

### 4.1 New York City

In 2004, the New York City Department of Sanitation (DSNY) presented the first phase of its New Solid Waste Management Plan (New SWMP). The planning process was initiated following the 2001 closure of the Fresh Kills Landfill in Staten Island, which had accepted much of the City's solid waste for years. Since the closure of this facility, New York City's solid waste management system has relied predominantly on truck-based transportation and utilizes a combination of local, land-based transfer stations and long-haul shipping to remote, out-of-state landfills.

New York City's system is considered unsustainable over the long term, due to the heavy costs associated with the transport and disposal of solid waste at remote landfills, as well as the environmental impacts of a system so reliant on long-haul trucking. Thus, the City's New SWMP cites "dramatically reducing the number of truck trips and miles associated with disposal of New York City's waste" as a primary goal.

Waste containerization, and intermodal barge and rail transport of the containerized solid waste, are key components of the New SWMP's strategy to decrease reliance on truck transport and improve the overall efficiency of the City's waste management system. Additionally, the plan provides mechanisms to expand and improve the City's recycling program in an effort to promote the beneficial reuse of recyclable materials and decrease the quantity of materials requiring landfill disposal.

The New SWMP investigated several emerging technologies in order to evaluate their potential contributions to New York City's program.

As part of its solid waste management planning and ongoing effort to reduce the quantity of waste exported from the City, in 2004 the DSNY completed the *Phase 1 Evaluation of New and*

*Emerging Solid Waste Management Technologies* (NYC Economic Development Corporation and NYC Department of Sanitation, 2004). The Phase 1 Study involved three steps of analysis.

In Step 1 technologies were identified that met the City's definition of "new and emerging", and which had a sponsor who provided sufficient information to allow an evaluation of the technology. Of the 43 technologies reviewed, 33 met the Step 1 screening criteria and were subsequently evaluated in Step 2 of the process. These 33 technologies included 21 thermal (gasification) technologies, 7 anaerobic digestion technologies, 1 aerobic digestion technology, 3 hydrolysis technologies, 1 chemical and 1 mechanical processing technology.

In Step 2 a number of second-level screening criteria were developed to perform a preliminary review of the 33 technologies. These second-level screening criteria included the following:

- Readiness to be operational within a ten-year timeframe
- The facility must be able to accept and process at least 50,000 tons per year (137 tons per day), which is the minimal capacity required to provide meaningful benefit to New York City's waste management system
- Reliability, as evidenced by successful commercial or pilot facilities
- Environmental performance of the technology must meet or exceed New York State permit and regulatory requirements
- Beneficial use of waste must be demonstrated through a technology's production of a useful and marketable product
- Residual waste requiring landfill disposal must not exceed 35% by weight of incoming waste.

Of the 33 technologies subjected to the second-level screening criteria, 19 did not meet these criteria and were removed from further consideration in the evaluation process. One technology did not meet the residual waste criterion, and 18 did not meet the reliability criterion.

Following Step 2, the 14 remaining technologies are shown below in Table 2.

**Table 2**  
**Technologies Remaining after Step 2 Screening**

<i>Anaerobic Digestion</i>	<i>Thermal Processing</i>	<i>Hydrolysis</i>
Arrow Ecology & Engineering Canada Composting Orgaworld Organic Waste Systems Waste Recovery Systems	Dynecology EBARA GEM America Global Energy Solutions Interstate Waste Technologies Pan American Resources Rigel Resource Recovery Taylor Recycling Facility	Masada Oxynol

In Step 3, a final set of specific criteria were applied to the 14 technologies that had met first- and second-level screening criteria. Whereas Steps 1 and 2 sought to exclude technologies unsuited to meet the City’s needs, Step 3 offered a more detailed evaluation of each of the 14 technologies and provided general findings relative to the emerging technologies by category, without eliminating any individual technologies from consideration. The Step 3 criteria included:

- Readiness and reliability
- Facility size and design flexibility
- Utilization of the existing city solid waste collection system
- Utility needs
- Extent of beneficial use of waste
- Marketability of products
- Quantity and quality of residuals requiring landfill disposal
- Environmental impacts
- Facility siting
- Public acceptability
- Estimated cost
- Opportunities for economic growth
- Experience and resources of project sponsor
- Willingness to develop publicly or privately owned facility
- Risk profile

Following the application of these Step 3 criteria, the Phase 1 Study concluded that anaerobic digestion and thermal processing (gasification) technologies are suitable to be considered for use in the U.S., including New York City. These technologies have been successfully implemented outside of the U.S. Hydrolysis technology is also offered as a potential alternative, and the

report noted that a recently permitted hydrolysis facility in Middletown, NY could be monitored to verify its efficacy. If New York City seriously considers investing in a thermal processing, anaerobic digestion, or hydrolysis technology, the Phase 1 Study suggests that the City may wish to implement a pilot project in order to mitigate the risk of its investment.

The Phase 1 Study noted that, relative to manufacturers of conventional waste-to-energy (WTE) technologies, the overall experience of manufacturers of the emerging technologies is not as extensive. However, the thermal technologies (gasification) and anaerobic digestion offer certain advantages over conventional WTE technologies. Emissions of pollutants would potentially be lower for these emerging technologies, particularly the emissions of dioxins and heavy metals. Additionally, the volume of residuals would potentially be lower with the emerging technologies than with conventional WTE technologies. Based on the information available for review, the cost to operate innovative technologies is potentially comparable to conventional technologies. The Phase 1 Study recommended a focused, detailed review to supplement and verify information provided for the Phase 1 Study, to help determine if a demonstration facility would warrant consideration for New York City's solid waste system.

As a follow-up to the recommendations of the Phase 1 Study, DSNY prepared the *Phase 2 Focused Verification and Validation of Advanced Solid Waste Management Conversion Technologies* (2006). This Phase 2 study represents a more detailed evaluation of the 14 technologies identified through the Phase 1 Evaluation, which are believed to be among the most advanced in their respective categories.

Questionnaires were distributed to the sponsors of these 14 technologies, and preliminary interviews were conducted with sponsors to determine whether sufficient information could be made available for the City to consider a technology in the Phase 2 Study. Based on the information available for the study, 2 anaerobic digestion technologies and 4 thermal processing technologies were selected for detailed review in the full Phase 2 analysis, as shown in Table 3.

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**Table 3**  
**Phase 2 Solid Waste Conversion Technologies**

<i>Anaerobic Digestion</i>	<i>Thermal Processing</i>
Arrow Ecology & Engineering Waste Recovery Systems	EBARA GEM America Interstate Waste Technologies Rigel Resource Recovery

The detailed Phase 2 process consisted of the following:

- The *Technical Review and Evaluation* process sought to validate process schematics and major system components, confirm mass and energy balances, review site layout and arrangement, and review operating data and related information for reference facilities.
- *Environmental Review and Evaluation* consisted of independent calculations and review of environmental performance, including air pollutant emissions, water usage, wastewater discharge, residue requiring landfill disposal, and quality of products.
- An *Economic Evaluation* was performed to project the order-of-magnitude costs that could be expected from the technologies for commercial-scale projects.

**Findings and Conclusions**

The Phase 2 Study built upon information gained during the Phase 1 process, and evaluated a number of specific technologies at an advanced level of detail. Important findings of the analytical process include the following:

- *Technical Findings* confirm that anaerobic digestion and thermal processing technologies could potentially be applied successfully in New York City. Independent reviews were performed relative to mass and energy balances, energy-generating efficiency of the technologies, recovery rates of recyclable materials, quantities of residue requiring landfill disposal, and siting requirements of each technology. The evaluation verified information obtained during the Phase 1 study and provided by manufacturers.
- *Environmental Findings* show that anaerobic digestion and thermal processing technologies could potentially offer better environmental performance than conventional

waste-to-energy technologies. Environmental benefits include the decreased emission of air pollutants, increased beneficial use of waste, and reduced reliance on landfill disposal.

- *Economic Findings* for the Phase 2 Study indicate that on a commercial scale, anaerobic digestion and thermal processing technologies are less costly or comparable in cost to New York City's current exporting practices.

**The study found that – among the emerging technologies evaluated – Anaerobic Digestion and Thermal Processing technologies were best suited for commercial implementation in the New York City waste management system.**

New York City's Phase 2 Study suggests that issues related to the transfer of design and operational experience from existing overseas facilities to the U.S. may present difficulties as new technologies transition to commercial operations in the U.S. Preparation of an Implementation Plan is recommended as a next step in the implementation of a demonstration facility. The Implementation Plan would lay the groundwork necessary to provide design, construction, performance, and cost information that would be used to develop a commercial-scale facility.

Since completion of the Phase 2 Study, New York City's implementation efforts for the New SWMP have focused on establishing an improved network of marine transfer stations to export solid waste from the city. The City has not yet prepared an Implementation Plan for the introduction of emerging solid waste technologies and/or facilities, and has not initiated a development process for any such facility. DSNY representatives identify difficulty in siting such a facility locally as an obstacle in the implementation of emerging solid waste technologies (as well as conventional solid waste processing facilities).

## 4.2 City of Los Angeles

According to the 2005 *RENEW LA* report, the Los Angeles basin, which is comprised of Los Angeles, Orange and western San Bernardino and Riverside counties, disposes of approximately 70,000 TPD of MSW. Several landfills have recently closed, and the Puente Hills Landfill – which has the highest daily capacity of any landfill in the U.S. – is planned for closure by the year 2013. The Puente Hills closure could displace as much as 13,200 tons per day of MSW disposal capacity, and other disposal options will be required to serve the region's needs (Smith, 2005).

The California Integrated Waste Management Act of 1989 (AB 939) mandated a 50% diversion from landfill disposal by the year 2000 as well as the creation of various plans, programs, and facilities that cities and counties throughout California should adopt in order to achieve these goals (Smith, 2005). In 1994, the City Council of Los Angeles declared the goal of 70% diversion of MSW from landfills by the year 2010. The RENEW LA plan provides a vision to move beyond that 70% goal to a zero waste system. To do so, the City prepared a study entitled *Evaluation of Alternative Solid Waste Processing Technologies* to review alternative MSW processing technologies that process post-source separated MSW.

The highest-level objective of the evaluation is to:

Identify alternative MSW processing technologies that will increase landfill diversion in an environmentally sound manner, while emphasizing options that are energy efficient, socially acceptable, and economical. (URS, 2005)

This objective is subdivided into three lower-level objectives:

- Maximize Environmental (Siting) Feasibility (i.e., minimize impacts to the environment and citizens);
- Maximize Technical Feasibility (i.e., search for technologies that are commercially available within the development timeframe of 2005-2010 and will significantly increase diversion from landfills); and
- Maximize Economic Feasibility (i.e., provide an overall cost that is competitive with other solid waste processing methods).

Various screening criteria were applied in order to identify potential technologies that could meet the project objectives. The first set of screening criteria helped determine the initial list of technologies to be reviewed and included:

- Meet 200 tons/day capacity (throughput) requirement;
- Consider technologies at the commercial or late-emerging stage;
- Include technologies that produce marketable byproducts; and
- Include technologies that are compatible with post-source separated MSW.

Based on these criteria, sixteen technologies were identified and are broken down into three categories as outlined in Table 4 below.

**Table 4-Technologies Evaluated for Renew LA by Category**

<i>Thermal Technologies</i>	<i>Biological/Chemical Technologies</i>	<i>Physical Technologies</i>
Advanced Thermal Recycling	Anaerobic Digestion	Refuse-Derived Fuel (RDF)
Pyrolysis	Aerobic Digestion/Composting	Densification/Pelletization
Pyrolysis/Gasification	Ethanol Fermentation	
Pyrolysis/Steam Reforming	Syngas-to-Ethanol	
Conventional Gasification-Fluid	Biodiesel	
Conventional Gasification-Fixed	Thermal Depolymerization	
Plasma Arc Gasification	Catalytic Cracking	

Next, the technologies were reviewed to determine if they meet the following criteria:

- *Waste Treatability* - ability of the alternative MSW processing technology to efficiently treat the organic portion of the waste stream;
- *Conversion Performance* - ability of the conversion technology to convert the organic portion of the post-source separated MSW stream into useful products;
- *Throughput Requirement* - ability of the alternative processing technology to treat at least 200 tons/day of post-source separated MSW in 2008-2010;
- *Commercial Status* - conversion technology that can be developed on a commercial scale within the project development period (2008-2010); and
- *Technology Capability* - Can support the development of conversion technology at commercial scale and can demonstrate the conversion technology with MSW at a scale of at least 25 tons/day.

The ten technologies listed in Table 5 met these criteria.

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**Table 5 - Technologies Advancing for Further Consideration in Renew LA**

<i>Thermal Technologies</i>	<i>Biological/Chemical Technologies</i>
Advanced Thermal Recycling	Anaerobic Digestion
Pyrolysis	Aerobic Digestion/Composting
Pyrolysis/Gasification	Thermal Depolymerization
Pyrolysis/Steam Reforming	
Conventional Gasification-Fluid	

Conventional Gasification-Fixed Plasma Arc Gasification
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Next, a life cycle study was conducted using supplier data to develop a comparative analysis of the remaining ten technologies. The life cycle study focused on the issues that demonstrate the greatest differentiation between advanced thermal recycling or conversion technologies and existing traditional solid waste management processes, including: energy consumption, criteria pollutants, and carbon emissions. When compared to landfilling of post-source separated MSW, the results of the life cycle analysis showed that three of the waste processing technologies (advanced thermal recycling, gasification, and anaerobic digestion) will provide substantial savings/reductions with respect to energy consumption, air emissions of criteria pollution, and carbon emissions/climate change issues.

Suppliers were then surveyed to create a “short list” from the ten technologies. About 225 suppliers were screened, and only twenty-six met the criteria to submit their detailed qualifications to the City. Of the twenty-six suppliers requested to submit qualifications, seventeen provided responses. The seventeen suppliers and their technologies were thoroughly evaluated in order to create a short list. Table 6 below identifies the seventeen suppliers.

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**Table 6 - List of Seventeen Suppliers that Submitted Qualifications for Renew LA**

<i>Technology Group</i>	<i>Company Name</i>	<i>Technology</i>
Thermal	Ebara	Fluid Bed Gasification
Thermal	Interstate Waste Technologies	Pyrolysis/Gasification
Thermal	Omnifuel	Fluid Bed Gasification
Thermal	Primenergy	Fixed Bed Gasification
Thermal	Taylor Recycling	Circulating Fluid Bed Pyrolysis
Thermal	WasteGen	Pyrolysis
Thermal	Whitten	Fixed Bed Gasification
Thermal	Pan American Resources	Pyrolysis
Thermal	Covanta	Thermal Recycling
Thermal	Waste Recovery Seattle Inc.	Thermal Recycling
Thermal	Seghers Keppel	Thermal Recycling
Biological	Arrow Ecology	Anaerobic digestion
Biological	Canada Composting	Anaerobic digestion
Biological	Global Renewables	Anaerobic digestion
Biological	Organic Waste Systems	Anaerobic digestion
Biological	Wright Environmental	Aerobic Composting (Biodryer)

Biological

Waste Recovery Systems Inc.

Anaerobic Digestion

The supplier data were used to conduct a comparative analysis of technologies and rank suppliers for further assessment. The comparative analysis addressed a number of technical, environmental, and cost issues, including:

- Throughput (respondents provided data for different throughput rates);
- Electricity production;
- Net efficiency in kWh/ton feedstock;
- Diversion rate/solid wastes;
- Air emissions;
- Regulatory issues;
- Capital cost;
- Revenues; and
- Estimated tipping fees.

Once the comparisons were complete, each technology was ranked using the criteria below.

- *Ability to Market Byproducts* - Experience selling byproducts with strong markets is desired;
- *Visual Impact of Facility* - Facilities with higher stacks or structures will exhibit greater visual impacts;
- *Operational Experience* - The number of operating plants is an indication of overall experience;
- *Economics* - Worst Case Breakeven Tipping Fee;
- *Supplier Credibility* - Suppliers must have organizations (including partners) with sufficient technical and financial resources;
- *Landfill Diversion* - Percent by weight of inlet MSW sent to landfill (includes rejects and unmarketable materials – worst case);
- *Engineering the Complete System* - Demonstrated ability to design the complete facility; and
- *Permitability* - This is a function of expected environmental impacts, and the potential for a difficult regulatory process or pathway.

The ranking process concluded that thermal technologies (thermal conversion - and advanced thermal recycling) would best satisfy the project's highest level objective, i.e. to maximize landfill diversion. The following conclusions were made regarding the two technologies:

- An alternative MSW processing facility can be successfully developed in the City of Los Angeles.
- The technologies best suited for processing post-source separated MSW on a commercial level are the thermal technologies. These include advanced thermal recycling and thermal conversion (pyrolysis and gasification).
- The biological/chemical conversion technologies and physical technologies present significant technical challenges for treatment of the post-source separated MSW. While biological conversion technologies show the most promise in this group, they also bring significant challenges.

In summary, the advantages of the thermal technologies over biological conversion are:

- Higher landfill diversion rates, which is a primary objective of the project;
- Lower production of solid byproducts and correspondingly greater production of electricity, a higher value product with a more well-developed market;
- Less risk with regard to byproduct marketability;
- Significantly higher thermal efficiencies and, therefore, higher revenue/ton because thermal processes convert essentially all organics to energy; and
- More operational experience at higher throughputs.

The Evaluation recommended that the City should proceed with the following activities to continue development of an alternative MSW processing facility for post-source separated MSW utilizing a thermal technology:

- Initiate public outreach;
- Develop short list of suppliers;
- Conduct an initial siting study;
- Prepare RFP and Select preferred suppliers;
- Conduct Facility Permitting and Conceptual Design; and
- Perform Detailed Design and Construction.

As a result of the recommendations, the City issued an RFP in February 2007 for both commercial and emerging technology facilities to process post-source separated municipal solid waste (City of Los Angeles, 2008). Twelve proposals were received on August 22, 2007 from the companies listed in Table 7.

**Table 7 - Companies that Responded to City of LA RFP**

#	Company Name
1	Zia Metallurgical Processes, Inc.
2	Interstate Waste Technologies (IWT)
3	Covanta Energy Corp.
4	Wheelabrator Technologies Inc.
5	WRSI/DESC
6	Plasco Energy Group
7	Community Recycling
8	Carbon Sequestration
9	CA Renewable Technologies LLC
10	Urbaser & Keppel Seghers
11	CA Renewable Technologies LLC (emerging)
12	Rainbow Disposal

As of November 2009, the City of Los Angeles had identified a preferred emerging technology provider, CA Renewable Technologies LLC (CART), and the parties have commenced contract negotiations. California Renewable Technologies has proposed a 150 tpd sorting and biological processing system that utilizes dry mechanical pre-sorting and a water bath sorting system; following these sorting processes, the remaining organic materials are ground up and processed through two-stage anaerobic digestion. CART has proposed to site the facility outside of the City of Los Angeles boundaries. Contract negotiations with CART will provide an opportunity to define the costs and terms of an agreement before the potential development of a facility moves forward.

In addition to the CART emerging technology facility, the City of Los Angeles will also enter into contract negotiations to develop a commercial-scale, conventional solid waste processing facility. This facility will process approximately 1,000 tpd of MSW. As of November 2009, the City was in the final stages of selecting a preferred candidate from among a short list including two conventional waste-to-energy proposals and two “hybrid” proposals combining mechanical/biological/thermal processes. Contract negotiations for this commercial-scale project are expected to begin early in 2010.

### 4.3 Delaware Solid Waste Authority

The Solid Waste Management Technical Working Group was established by the Secretary of Delaware's Department of Natural Resources and Environmental Control (DNREC), and was commissioned to:

...perform a feasibility review of available municipal solid waste management alternatives and recommend a municipal solid waste management program or programs capable of being implemented that would best serve Delaware's long-term and short-term municipal solid waste management needs (Working Group 2005).

The State of Delaware has experienced population growth at a rate higher than the national average, concurrent with a per-capita waste generation rate that is likely increasing faster than the national average. Delaware's recycling rate stands well below the national average.

These trends in waste generation, combined with a limited capacity for solid waste disposal, present imminent capacity issues for solid waste management throughout Delaware, and particularly for Northern Delaware. The disposal of sludge from the Wilmington Waste Water Treatment Plant and the disposal of waste tires present additional solid waste management issues. The Working Group's 2005 *Solid Waste Management Alternatives for Delaware* was prepared to help address these issues.

In the Working Group's judgment, the primary challenge related to Delaware's solid waste management is to preserve the valuable, low-cost landfill capacity it currently has. The Plan offers a two-pronged approach to meet this primary objective. First, it emphasizes the need for Delaware to adopt an aggressive and effective recycling or materials recovery to divert materials from its landfills. Second, the Plan evaluates a number of new processing technologies with potential to reduce the volume of waste requiring landfill disposal and convert waste materials into useable products, and recommends a course of action to pursue their implementation in Delaware.

The Working Group considered a full range of solid waste technologies, most of which were considered new or emerging. The study included 7 thermal, biological, or mechanical processing technologies, as shown in Table 8 below.

**Table 8 - Technologies evaluated by the Delaware Working Group.**

<i>Thermal Processing</i>	<i>Biological Processing</i>	<i>Mechanical Processing</i>
Waste-to-Energy (WTE) Gasification Plasma Arc Conversion	Aerobic Composting Anaerobic Digestion Bioreactor Landfills	Autoclave with Mechanical Processing

A set of 7 technical criteria was selected to evaluate the solid waste management technologies being considered for potential implementation in the State of Delaware. These criteria are as follows:

- **Readiness and Reliability** – Addresses the question of how confident the state can be that if a full-size facility were built, it would operate effectively. The number and length of tenure of successfully operating commercial facilities were used to rate the readiness of technologies, and an assessment of reliability was based upon a technology’s susceptibility to process interruptions in commercial operations.
- **Inputs and Pre-Processing** - Focused on what inputs the system would process, and how those inputs had to be pre-processed in order for them to be converted (or disposed of) effectively by the technological process. Each technology was rated according to the types of wastes it had demonstrated the ability to process, and according to the method and degree of pre-processing required.
- **Potential Public Health and Nuisance, Environmental, and Worker Safety Risks** – Emissions of criteria and other air pollutants, the composition and safety of residual materials left over from processing, resource consumption required for operations, and worker safety were among the items considered for this criterion.
- **Energy Balance** – The percentage of total energy inputs (including the energy value of the waste stream) represented by total usable energy outputs was used as a measure of energy balance.
- **Materials Balance** - The percentage of the waste stream that is converted into useful products and, therefore, does not have to be disposed of in a landfill, was used as a measure of materials balance.
- **Economics** – Costs and revenues were projected for each technology to evaluate its economic feasibility.
- **Legal and Policy Issues** - For any technology ultimately constructed in Delaware, local, state and federal laws and regulations would impose significant restrictions. Local zoning ordinances would impact site selection and approval; state and federal laws impose a variety

of permitting obligations and restrictions. Additionally, community acceptance is key to the implementation of waste management technologies. The characteristics and requirements of each technology were considered in the context of legal compliance and community acceptance.

For each of the 7 technologies, the Working Group assigned a summary rating value to each of the 7 evaluation criteria. These ratings subjectively integrate all factors considered in the evaluation.

Table 9 summarizes the average ratings assigned to each technology for each of the 7 criteria, as well as for conventional landfills. Ratings have been rounded to the nearest whole number. Please note these ratings are not on a mathematical scale. For instance, a rating of 8, although significantly better, is not necessarily twice as good as a rating of 4. Nor can the ratings be added together to provide a summary score. However, the ratings *do* allow comparisons to be made among technologies for each criterion.

**Table 9 – Delaware Working Group Criteria Rankings**

	Readiness and Reliability	Inputs and Pre-Processing	Public Health, Environment, Worker Safety	Energy Balance	Materials Balance	Economics	Legal and Policy Issues
Waste to Energy	8	8	7	10	8	7	2
Gasification	5	8	8	8	10	5	6
Plasma Arc Conversion	5	8	7	8	10	4	6
Aerobic Composting	7	4	6	2	6	8	8
Anaerobic Digestion	8	5	8	5	8	8	8
Bioreactor	8	9	8	5	4	9	6
Autoclave with Mechanical Processing	6	4	5	NA	8	1	8
Landfill	9	9	7	3	2	10	6

Of the 7 technologies evaluated, one, the bioreactor landfill, is an approach that is already in use at 2 Delaware facilities. This process accelerates the decomposition of waste in the landfills thereby increasing their effective capacity, while generating increased amounts of methane, which is a valuable energy source. The Working Group recommends that the Delaware Solid Waste Authority continue to pursue and enhance this approach, and supports its efforts to convert the landfill gas to electricity.

Two technologies – Autoclave with Mechanical Processing and Aerobic Composting – were not rated highly because the market for their products in Delaware is very uncertain. Products from both processes could be used to enhance soil quality, but, without substantial pre-processing, they would

most likely contain too much contamination to allow other than very restricted use. The products from either could be also used as a feedstock for a combustion or conversion process that results in the generation of electricity, but the Working Group was unconvinced that this would be more economical or generate fewer risks than using the waste materials themselves for these purposes.

Two of the thermal processes – Gasification and Plasma Arc Conversion – were also rated relatively low. Both of these technologies would substantially reduce the amount of waste requiring landfill disposal (by over 90%) and would both be used to produce a synfuel product that can be used to generate electricity. However, no commercial sized facilities employing either technology have been built in the United States (and no commercial sized facilities using the plasma arc process with an MSW feedstock anywhere in the world), which led the Working Group to conclude that their readiness and reliability has not been adequately demonstrated.

Anaerobic Digestion and Waste-to-Energy were rated highest of the 7 technologies. Both significantly reduce the amount of waste requiring landfill disposal, and both produce a useful product.

Compared to a Waste-to-Energy facility, the Anaerobic Digestion process has the following advantages:

- It does not generate hazardous air emissions which subsequently have to be captured by pollution control equipment,
- Because it does not generate hazardous pollutants, it is likely to be less controversial, and the construction of a facility would not require that current Delaware statutes be amended or repealed,
- Its product has alternative uses, and
- It can also handle sewage sludge in the feed stream.

The waste-to-energy process, on the other hand, has the following advantages over the anaerobic digestion process:

- Its effectiveness in processing solid wastes and reliably generating electricity has been clearly demonstrated in the United States in facilities processing 1,000 tons per day or more,
- It has among the most positive energy balances,
- It requires comparatively little acreage to process 1,000 tons per day, and
- It can process whole tires in limited quantities.

The Working Group expressed its reservations regarding the Waste-to-Energy technology's potential to generate dioxin and furan byproducts, and suggests that its support of this technology is contingent upon the results of a National Academy of Sciences assessment of the toxicology of these compounds. With this caveat, the Working Group recommends that Delaware focus its decision making process on the Anaerobic Digestion and Waste-to-Energy technologies.

## 5.0 CONCLUSIONS

Several of the companies responding to the RFI who utilize emerging technologies have successfully developed these facilities at multiple locations in industrialized countries in Europe or in Canada. Several of these companies with gasification technologies have reportedly developed demonstration facilities in the U.S. or Canada. Only one of the demonstration facilities routinely operates with MSW feedstock at a daily volume on the same order of magnitude as is needed to service the needs of the Planning Unit. Several of the companies are in the process of developing commercial scale facilities in the U.S. or are in the advanced stages of a procurement process to develop a commercial facility on behalf of a municipality or other local or regional solid waste agency in the United States.

All of the emerging technologies have potentially negative attributes, when compared to conventional technologies for solid waste management. These include:

- Lack of well-established performance history creates risk in several categories as noted below:
  - True cost of construction and operation are not yet known. As a result these costs may be initially underestimated, and if so, the resulting financial distress of higher than expected costs may cause the project to fail.
  - Environmental performance and impacts of full scale operations may not be fully examined. This may result in extended review time to secure facility permits, delaying project implementation and increasing the cost of the project. Further, compared to conventional technologies, the risk of unexpected environmental contamination is greater.
- Marketability of recovered materials, bio-fuels, and byproducts presents a financial risk to the projects. This risk occurs as a result of uncertainty with the technical efficacy of the process (at full commercial scale) as well as because of potential fluctuations in market prices for the commodities being recovered and produced. This is especially true with respect to the anticipated use of byproducts, such as the vitreous slag produced by the plasma gasification technology, or the residues from other gasification technologies. Since widespread markets for these materials may not currently exist, stable long-term markets may need to be developed. If these efforts are not successful, and the material is not marketable, it will need to be disposed of, and this unanticipated cost will result in a negative financial impact on the project and its sponsors.

These potentially negative attributes can be overcome by a company with sufficient financial resources to assure successful completion and operation of facilities utilizing one of these emerging technologies.

In addition, most of the emerging technologies have potentially positive attributes which make them attractive for further consideration. These potentially positive attributes include:

- Significantly less residue for disposal than conventional waste-to-energy technology;
- Lower emissions and higher level of material recovery than conventional waste-to-energy technology;
- Lower capital and operating costs than conventional waste-to-energy technology;

Because these technologies are still emerging, these potentially positive attributes remain to be proven through commercial operations at a scale similar to what would be required to service the Planning Unit. This will warrant continued attention during the course of the review process for the SWMP, as it is possible that one or more of these technologies establish full scale commercial operations in the United States by the time the new SWMP is formally adopted and approved and it is time to commence procurement of new facilities.

## 6.0 REFERENCES

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## APPENDICES

Appendix A – Request for Information

Appendix B – RFI Response Summaries