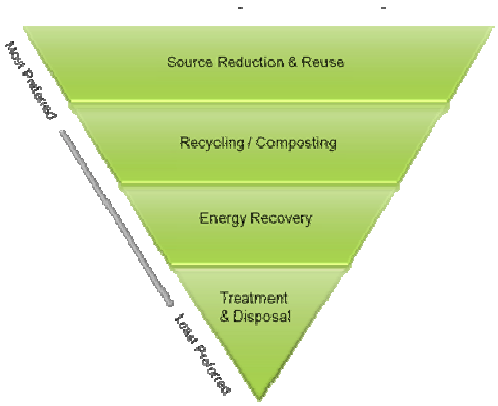
Waste Conversion Technologies

Overview

Materials destined for disposal in a landfill contain one additional major resource that can be recovered – energy. Various technologies have been demonstrated for energy recovery from waste; some of which are proven and other are considered "developing". While described by several terms in the waste management industry, including waste-to-energy (WTE), resource recovery, combustion and incineration, for the purpose of this technical paper they will all be considered a part of waste conversion technologies. The term WTE in most instances will be used interchangeably with conversion technologies that have been proven to recover energy, in the United States, on a commercial scale.



USEPA Waste Management Hierarchy

(http://www.epa.gov/wastes/nonhaz/municipal/wte/nonhaz.htm Retrieved 06/01/2012)

The USEPA recommends a hierarchical approach to municipal solid waste (MSW) management. The hierarchy includes: source reduction and reuse; recycling/composting; energy recovery; and treatment and disposal (landfilling). The hierarchy favors source reduction and reuse to reduce the volume and toxicity of waste and to increase the useful life of manufactured products. Recycling/composting, is the next preferred waste management approach to divert waste from landfills and combustors. The third tier of the hierarchy consists of energy recovery (combustion/thermal conversion). Combustion is used to reduce the volume of waste being disposed and to recover energy. EPA states that "an integrated waste management system considers fluctuating recycling markets, energy potential, and long-term landfill cost and capacity to make a waste management strategy that is sustainable…. What is economically preferable one year is not always environmentally preferable in the long run. However, by following the hierarchy of environmental preference, communities can ensure their economic decisions regarding MSW management are environmentally sound as well… community decisions are based both on environmental and economic factors." (http://www.epa.gov/wastes/nonhaz/municipal/wte/nonhaz.htm - Retrieved 10/25/2011).

In addition to energy recovery and reducing the volume of waste landfilled, there are several arguments for waste conversion technologies, including the systems reduce biologically active waste to an inert material and the processes are able to further recover other resources, such as metals. A further argument for waste conversion technologies is that once materials have reached a state when physical reuse and recovery are no longer viable (technically or economically) the remaining energy and metals resources should be recovered prior to disposal (thus this technology is also sometimes referred to as resource recovery). Additionally, approximately 60 percent of municipal solid waste (MSW) is biogenic material which is considered greenhouse gas (GHG) neutral, so the energy recovered can be credited toward an offset of fossil fuel impacts on the environment. Waste conversion facilities are classified as solid waste processing facilities and in Nebraska must be permitted under the Nebraska Department of Environmental Quality (NDEQ) Title 132 - Integrated Solid Waste Management Regulations (Title 132).

In addition, these facilities must comply with Federal, State and Local regulations governing air quality.

Current Programs

There are no facilities employing waste conversion technologies currently operating in the Planning Area, or in the state. Many municipal solid waste landfills and wastewater treatment plants recover methane, but these energy recovery efforts are not considered waste conversion technologies for purposes of this paper.

Generation and Diversion

The USEPA's data suggests that nationally 12 percent of MSW is managed by combustion with energy recovery (Source: *USEPA Municipal Solid Waste in the United States: 2010 Facts and Figures*, December 2011). The Energy Recovery Council reports that in 2010, 86 plants operate in 24 states and had a combined capacity to process more than 97,000 tons of MSW per day.

The Needs Assessment (HDR, 2012) establishes that the Bluff Road Landfill has accepted an average of 279,500 tons per year of solid waste over the last five years; based on 365 days per year, this is equivalent to 764 tons per day. The quantities of MSW available from the Planning Area for disposal through physical and/or chemical processes, such as waste conversion technologies, would depend upon numerous factors (discussed later in the paper), and continued efforts to divert material from disposal (reduce, reuse, recycle and compost). Depending upon the technology that might be selected it could be conceptually assumed that approximately 500 tons per day might be targeted for energy recovery through waste conversion technologies.

From an energy perspective raw MSW has approximately one-half the energy content of coal. So the daily disposal of 764 tons of MSW at the Bluff Road Landfill is the equivalent of burying slightly less than five railcar loads of coal in the landfill each day.

Program (Facility/System) Options

Waste conversion technologies are typically implemented as part of an integrated waste management program and as such are complimentary to other diversion programs; they can also provide a means of pre- and post-disposal recovery of certain resources. In addition to recovering an energy resource, waste conversion technologies can significantly reduce the volume of waste being landfilled.

Potential energy recovery (conversion) technologies span a wide range of developmental progress. The technologies range from those that have been successfully demonstrated for several decades and at various scales of commercial operation to those in development but yet to be successfully and/or economically demonstrated on a commercial scale. Energy recovery technologies discussed in this paper are categorization as "demonstrated" or "developing". Demonstrated technologies (at a commercial scale) include those that have been reliably operating for at least five years at a scale (size) similar to what would be utilized to manage the volume of waste for the Planning Area. Because some of these technologies are in operation only in overseas locations and may be significantly subsidized by the governments of those countries they may have limited application opportunities in the United States. The major demonstrated or developing conversion technologies are summarized in Table 1.

Table 1 – Waste Conversion Technologies

Demonstrated Technologies	Developing Technologies
Anaerobic digestion	Pyrolysis gasification
Gasification	Plasma arc gasification
Mass burn (waste to energy)	Hydrolysis
Refuse derived fuel (waste to energy)	Catalytic depolymerization

A more detailed overview of these waste conversion technologies is provided in Appendix 1.

Options Evaluation

The general issues associated with waste conversion/WTE systems and facilities are:

- Social/political acceptance
- Technology risks and commercial scale experience
- Adequate supply of waste
- Siting/location
- Permitting requirements and restrictions
- Cost of services and funding mechanism
- Energy markets
- Implementation considerations

Implementation considerations are of particular relevance because of the overall cost of these technologies and the potential for opposition.

Waste conversion technologies, as a group, have been further evaluated based on the evaluation criteria developed for use in the Solid Waste Plan 2040, as presented below.

Waste Reduction/Diversion:

While waste conversion technologies are often considered disposal technologies they serve to significantly reduce or divert the amount of waste sent to landfill disposal. Technologies such as mass-burn have been proven to reduce the tonnages of the waste combusted by 80 percent and the volume of the waste combusted by more than 90 percent. It is also sometimes argued that implementing waste conversion technologies will discourage recycling. A June 2009 study by the Governmental Advisory Associated, Inc., entitled *Recycling and Waste-to-Energy: Are They Compatible?* examined data obtained from a total of 567 municipal authorities, including 72 counties or solid waste districts and 495 cities, towns and villages covering a total population of 41.5 million people. The study found that "communities nationwide using waste-to-energy have an aggregate recycling rate at least 5 percentage points above the national average."

As noted in Appendix 1, various waste conversion technologies may target differing forms of energy outputs and materials recovered. Based on the demonstrated technologies in use in the U.S., the most prevalent form of energy sales is electricity. A key consideration in any further evaluation of waste conversion technologies will be the establishment of a viable long-term energy market. Using the 500 ton per day capacity assumption and a conversion rate of 500 kWh (kilowatt hours) per ton, an energy recovery facility could generate in the range of 9.5 to 10 MW (megawatts) of electrical power. This energy output is equivalent to meeting the energy demands of approximately 5,000 to 8,000 homes or roughly 10 percent of the total number of occupied residential housing units in single-unit to four-unit dwellings in the Planning Area.

Waste conversion technologies will not minimize solid waste exportation, but would help reduce dependence on landfilling, by virtue of reducing the volume of waste material requiring disposal (only ash from the combustion process and residuals from air pollution control equipment).

Technical Requirements:

Demonstrated waste conversion technologies, and in particular modern mass burn facilities, have proven to be highly reliable if properly planned, designed and constructed, implemented, and operated and maintained. The vast majority of facilities implemented in the 1980's and 1990's are still operating 20 and 30 years later and are projected to last well into the future.

There are several technical aspects that would need to be considered in combination with social/political, economic and implementation consideration before a facility could be implemented in the Planning Area. Because of the large capital costs associated with waste conversion technologies, it would be necessary

to select a proven/demonstrated technology to minimize risks to those financing the facility and to the customers and energy markets. Appendix 1 provides additional information on waste conversion technologies that have demonstrated commercial scale experience.

To implement any significant solid waste management facility or system, it is necessary to have a site. A site to implement a waste conversion facility would need to have reasonable access to roads for vehicles delivering waste. Ideally, the site would be located near the centroid of the waste generation to minimize haul distances or near the market purchasing the energy. Water would be required for steam cycle make-up as well as for cooling. In the absence of adequate and nearby water, air-cooled technology can be employed with an increased cost and reduction in energy output. Adequate utilities would also be required for export of generated power and natural gas would likely be needed for heating and as an auxiliary fuel. To be viable the site would need to be able to obtain all required permits, including local zoning (compatibly land use determination), solid waste disposal, air emissions and others. Much like landfills, siting/permitting an energy conversion facility can be contentious and as such gaining approval may be a major factor in implementation. The City owns adequate land adjacent and to the east of the Bluff Road Landfill property, which might be considered a viable candidate site for such a facility. If a local energy (steam) market was to be established the waste conversion facility may need to be located in close proximity to the energy user.

Environmental Impacts:

The two primary areas of environmental focus associated with waste conversion technologies are air emissions and management of residuals. It may be significant to note that the United States Conference of Mayors, Adopted Resolution on Comprehensive Solid Waste Disposal Management (2005) states "Generation of energy from municipal solid waste disposed in a waste-to-energy facility not only offers significant environmental and renewable benefits, but also provides greater energy diversity and increased energy security for our nation." In a 2007 memo, the USEPA stated that all waste-to-energy facilities comply with USEPA's Maximum Achievable [air emissions] Control Technology (MACT) standards. After analyzing the inventory of waste-to-energy emissions, EPA concluded that waste-to-energy facilities produce electricity "with less environmental impact than almost any other source of electricity."

Although waste combustion facilities emit carbon dioxide (CO_2) as part of their process, by some estimates they achieve a net reduction of greenhouse gas emissions over their lifecycle. Waste combustion emits two types of CO_2: biogenic and anthropogenic. Most of the emissions (estimated 67 percent) from waste combustion facilities are biogenic. These emissions result from the combustion of biomass, which is already part of the earth's natural carbon cycle – the plants and trees that make up the paper, food, and other biogenic waste remove CO_2 from the air while they are growing, which is returned to the air when this material is combusted. The remaining CO_2 emissions are anthropogenic; they come from man-made substances in the waste that is combusted, such as unrecyclable plastics and synthetic rubbers. The USEPA stated "EPA estimates that combustion of mixed MSW at mass burn and RDF [refuse derived fuel] facilities reduce net postconsumer GHG emissions to -0.03 and -0.02 MTCE [Metric Ton Carbon Equivalent] per ton, respectively." (*Solid Waste Management and Greenhouse Gases, A Life-Cycle Assessment of Emissions and Sinks*, USEPA, September 2006). A study entitled "*Updated Analysis of Greenhouse Gas Emissions and Mitigation for Municipal Solid Waste Management Using A Carbon Balance*" (Bahor, Weitz, Szurgot) used the USEPA's Municipal Solid Waste Support Tool to undertake a life cycle assessment and comparison of MSW management options. The results of the study showed that municipal waste combustion scenarios outperformed every landfill scenario in terms of GHG emissions and estimated an equivalent emission factor of -0.30 tons of CO_2E [carbon dioxide equivalents] per ton of MSW combusted. The negative emission factor was due to the amount of avoided CO_2 from electrical generation and metals recovery being greater than the emissions factors for fossil

CO_2. The report states "The 'negative' emission factor establishes that MWC [municipal waste combustion] is a GHG mitigation process as a MSW disposal option." A similar analysis by the Energy Recovery Council entitled "*Waste Not, Want Not: The Facts Behind Waste-to-Energy*" (Michaels, April 2009) concluded that as a result of these mechanisms, waste-to-energy produces electricity at a net emission rate of negative 3,636 lbs of CO_2/MWh. In other words, on a lifecycle basis, for every ton of trash burned at a waste-to-energy plant, approximately one ton of CO_2 equivalent is reduced. The mechanisms referenced in this statement include:

> "1) by generating electrical power or steam, waste-to-energy avoids CO2 emissions from fossil fuel-based electrical generation;
> 2) the waste-to-energy combustion process eliminates the methane emissions that would have occurred if the waste was placed in a landfill; and
> 3) the recovery of metals from municipal solid waste by waste-to-energy facilities is more energy efficient than the production of metals from raw materials."

Similar reductions in fossil fuel consumption and reduction in metal mining are what USEPA has used to determine that recycling reduces GHG emissions.

A copy of the *Waste Not, Want Not: The Facts Behind Waste-to-Energy* is included as Appendix 2. It is important to note that The Energy Recovery Council (ERC) was formed to provide a forum for companies and local governments to promote waste-to-energy.

Combustion ash residue from WTE facilities often contains recoverable metals as well as aggregate type materials that can be recovered and reused. Aggregate type materials can be reused as daily and final landfill cover, road aggregate, asphalt-mixture, and in the construction of cement blocks and artificial reefs. The remaining residuals must be tested in accordance with federal regulations to ensure it is non-hazardous. Years of testing ash from every WTE facility in the country has shown that ash is safe for disposal in landfills and for reuse.

Economic Impacts:

Waste conversion technologies are typically more expensive than landfilling on the basis of tipping fees. There are many situation specific considerations that need to be considered in estimating the cost of waste conversion technologies including energy sales prices, technology, financing, operation and maintenance, and residuals disposal costs. Using tipping fee data from a wide range of facilities operating in the U.S. on commercial scale it can be conceptually estimated that a tipping fee in the range of $75 to $150 per ton would be necessary to implement a waste conversion facility employing demonstrated technology versus the $21 per ton tipping fee currently charged at the Bluff Road Landfill. Using Lincoln and Lancaster County demographics and waste generation rates, and an assumed waste conversion technology tipping fee rate of $120 per ton would roughly equate to a $13 to $14 per household per month disposal cost (excluding collection and hauling costs). After subtracting charges currently associated with disposal of wastes in Bluff Road MSW Landfill, implementation of a waste conversion facility would result in an increase of approximately $11 to $12 dollars per household per month (this assumes collection and hauling costs would not increase).

To be financially viable, a solid waste management facility in a free-market environment must generally have the lowest net costs (combined hauling and disposal) when compared to other competing alternatives (such as landfilling) in the region. A WTE facility typically does not have a lower cost than landfilling, so such a facility is not anticipated to compete favorably on a purely economic basis in a free market economy. Based on current economics some combination of rate increases, subsidies or a means of flow control would be required to make waste conversion technologies viable in the Planning Area. In addition to simply favorable economics, the financial institution or bond holders that would finance such a facility (in the range of $200 - $300 million) will want certain assurances the debt would be

repaid. If this cannot be established by the project based economics it would likely require a pledge of taxing authority and the full faith and credit of the community. The City would also need to assess how such a large financial obligation might affect the City's credit rating. If a market were to be developed for the sale of energy (with a local utility or business) the strength of this agreement would likely be considered favorably by the financing party(s); conversely a weak energy market agreement could increase the risk of debt repayment and might result in a higher interest rate (and resulting higher tipping fee) or a refusal to finance a project with weak or uncertain revenue stream. If a local utility were to be established as an energy market it may also be possible the utility would consider participating in facility financing. The backing of a large utility would provide additional confidence to the financing entity and may help reduce interest rates.

On January 9, 2012 the Solid Waste Association of North America (SWANA) released a white paper titled "Waste-to-Energy Facilities Provide Significant Economic Benefits". The paper states "Waste-to-energy facilities are economically sound investments that provide multiple financial and environmental benefits to the communities that utilize them. Today, the majority of the nation's waste-to-energy facilities are owned by local governments that have invested in this critical municipal infrastructure to achieve long-term solid waste management solutions. These facilities produce clean, renewable energy while reducing waste volume by 90 percent, making them a great option for communities seeking the most advanced technology to manage their waste."

Implementation Viability:

Assuming the lack of a free market economic justification (driver) for a waste conversion facility, the driving force would need to be based on a belief in good environmental stewardship (resource conservation and recovery; long-term environmental protection (air and groundwater)). For example, a desire to limit land disposal of putrescible waste (a major driver in certain coastal communities) or a desire to recover energy from waste (rather than bury it) could be among the key drivers. Public opinion can also be a key driver. If the majority of the public supports such a facility and would agree to support the added costs, it would help drive the success of such a facility. Alternatively, climate change concerns could be a driving force. GHG emissions are lower from a WTE facility when compared to a landfill with energy recovery and a fossil fuel power plant. For a given quantity of solid waste, a landfill with energy recovery and a coal fired power plant produce approximately three times more GHG than a WTE facility when measured in $MTCO_2E$ [Metric Tonne Carbon Dioxide Equivalent].

Implementing a waste conversion facility is complex and typically involves a combination of social, political, economic, environmental, and technical matters. Often, the technical and environmental matters are easier to overcome than the social and political matters. The phrase "not in my backyard" has become synonymous with opposition to such siting/implementation efforts, and the media and public often feed on the stories of those deemed "unfortunate" because the candidate site for such a facility is in their neighborhood. Opposition to a new solid waste disposal (landfill or WTE) site is often strongest by those neighbors in the immediate vicinity of the site; there is typically less opposition from those in the service area who are most remote from the site. Some national organizations may attempt to fight siting/implementation of WTE facilities.

For elected officials, this can be a particularly troubling dilemma as such officials must often balance the needs of their local constituents (if it is in their backyard) with their obligations to provide necessary and cost-effective management of environmental needs, such as waste disposal. Unless the appropriate people in the community act as a driving force or sponsor for a site and the selected waste conversion technology, implementing a waste conversion facility may not be possible.

As noted above, to establish the economic viability of a waste conversion facility the recovered energy must be sold. The price received per unit of energy sold significantly influences the cost per ton for waste

disposal that must be charged to cover debt and operating costs. The energy market must generally enter into a long-term purchase agreement and all parties must be confident that this market will remain economically viable for the duration of the bond financing. For this reason, most WTE facilities have targeted the sale of power, in the form of electricity, to local utility companies. Not only are local utility companies considered secure long-term markets but they have a 24-hour per day, 7-day per week demand for energy and as such match up well with the typical power production from a WTE facility.

Securing an agreement to purchase energy is a first step in establishing the viability of a waste conversion or energy recovery facility. Energy purchase rates will almost certainly need to be established or estimated in order to evaluate the overall economics of a facility.

In the future, the federal government may establish carbon emission caps or require states to adopt renewable energy portfolios. Under such mandates there may be incentives for utilities to partner with local communities on a waste conversion facility. The final congressional actions on these issues may also become a driver to establishment of an economically viable waste conversion technology project. To what extent the energy generated from a waste conversion technologies will be classified as "green" or "renewable" is uncertain as of the writing of this technical paper. If refuse is classified as a renewable energy source, it would likely increase the economic viability of a facility. In addition, whether and/or how CO_2 emissions are regulated will also affect the viability and cost effectiveness of a facility. These issues are being (and have for several years been) debated by Congress.

While Congress has not recently passed regulations stipulating WTE as renewable energy, a long history of federal, state and local laws do recognize WTE as a renewable energy source. At the federal level, WTE has been recognized as an important source of renewable energy since the inception of the modern WTE industry over 30 years ago. The Federal Power Act, the Public Utility Regulatory Policy Act (PURPA), the Biomass Research and Development Act of 2000, the Pacific Northwest Power Planning and Conservation Act, the Internal Revenue Code, the Energy Policy Act of 2005, Executive Order 13123, and the Federal Energy Regulatory Commission regulations all recognize WTE as a renewable source of energy. Most recently, the Emergency Economic Stabilization Act also recognized WTE as a renewable energy source by providing a two year extension of the renewable energy production tax credit for WTE facilities and other renewable sources.

At present the City has no ordinances or agreements that obligate the delivery of waste to the City's solid waste disposal facilities. Because of the anticipated higher cost per ton to dispose of waste using a WTE facility, such a facility would be at a disadvantage to complete with current and regional landfill facilities. To secure an adequate quantity of waste to allow full utilization of a energy recovery facility (and thus generate the revenues required to pay debt and operating costs) some means of waste flow control would likely be required to direct waste to the facility. Alternately, the City would need to subsidize the cost through other funds (e.g. taxes).

The solid waste industry uses the term "flow control" to refer to a variety of mechanisms that require waste to be directed to a specific facility. Flow control may be contractual, statutory, or economic. Contractual flow control may include such techniques as a contract between a disposal site (assumed to be the City) and waste hauler or between a disposal site and a unit of government that can direct waste to the facility, such as a city, subdivision, or business. Statutory flow control may exist in ordinances and may be tied to licensing, franchises, or other agreements between a waste hauler and a governing body. Economic flow control involves pricing or price incentives, such as discounts, to make the facility attractive to the waste hauler and competitive with other disposal options.

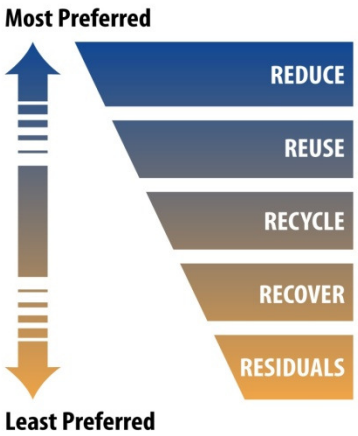
The decision of whether to implement a waste conversion facility in the Planning Area is beyond the scope of this technical paper. However, if implementation is eventually selected as an option in the Solid Waste Plan 2040, the following list of major actions has been developed to facilitate the refinement of future planning, scheduling, implementation and procurement strategies.

- Secure a commitment from a long-term viable energy market.
- Secure a long-term supply and control of waste.
- Refine or confirm the sizing analysis, technology selection and basis of design.
- Identify the siting, permitting and approval processes and timeline for critical approvals.
- Determine the site location to be utilized and confirm that it can be permitted at all levels of required approval.
- Identify site-specific environmental considerations (such as neighbor concerns) and establish reasonable mitigation strategies.
- Identify any auxiliary facilities required and any space set-asides for expansion or future management functions.
- Identify the system implementation strategy related to procurement, ownership, operation, residuals haul and disposal.
- Identify all road improvements, utility locations and fire protection requirements and refine the strategy for providing such infrastructure.
- Assess project economics to confirm that all key assumptions remain valid at all key implementation milestones.

Relationship to Guiding Principles and Goals

Waste conversion technologies are used in communities across the U.S. as a means of waste disposal and as a resource recovery technology. As it relates to the Guiding Principles and Goals of the Solid Waste Plan 2040, the possibility of implementing a waste conversion facility may be applicable, as further noted below.

- **Emphasize the waste management hierarchy**: Energy and materials recovery is a more preferred approach than landfilling (residuals disposal) in the hierarchy in that is places maximum emphasis on extracting valuable resources and reducing the toxicity of material disposed. Waste conversion technologies are also considered compatible and complimentary of other waste diversion programs when implemented as a part of a comprehensive waste management strategy.
- **Encourage public/private partnerships**: While waste conversion technology facilities may be designed, constructed and possibly operated by private entities they do not represent the same type of public/private relationship that currently exists with waste and recyclables collection and disposal. Because of cost considerations, further evaluation of public/private partnerships would be needed.



- **Ensure sufficient system capacity:** To be financially viable a waste conversion facility will require a firm supply of waste. The volume reduction achievable through waste conversion technologies will significantly reduce the need for landfill space and could substantially increase the life of an existing landfill or delay the construction of a new landfill facility.
- **Engage the community:** Any effort to implement an energy recovery or waste conversion technology will need to have public support. Because the process can be contentious it will be necessary and important to engage the residents and businesses in the decision process and to increase their knowledge of conservation, energy and resource recovery alternatives, and disposal options. The community must also be in general agreement with the affect such facilities would have on the current waste management program or services.

- **Embrace sustainable principles:** Maximizing recovery of energy and resources is considered a fundamental part of sustainability for those portions of the waste stream that cannot otherwise be diverted through source reduction, recycling and composting programs. Further consideration will need to be given to economics, societal and political factors as components of sustainability.

Summary

Materials destined for disposal in a landfill contain one additional major resource that can be recovered – energy. In addition to energy recovery and significant reductions in the volume of waste landfilled, most waste conversion technology facilities reduce the biologically active waste to an inert material and provide opportunities to further recover other resources such as metals. A further argument for conversion technologies is that once materials have reached a state when physical reuse and recovery are no longer viable (technically or economically) the remaining energy and metals resources should be recovered prior to disposal (thus this technology is also sometimes referred to as resource recovery). Additionally, the energy recovered can be credited toward an offset of fossil fuel impacts on the environment and from a life-cycle basis the USEPA estimates that combustion of mixed MSW at mass burn and RDF facilities reduce net postconsumer GHG emissions.

The USEPA's data suggests that nationally 12 percent of MSW is managed by combustion with energy recovery; in 2011 there were 86 plants operating in 24 states and they had a combined capacity to process more than 97,000 tons of MSW per day. Technologies such as mass-burn have been proven to reduce the tonnages of the waste combusted by 80 percent and the volume of the waste combusted by more than 90 percent. Data for communities with WTE facilities has shown that WTE is compatible with recycling and other waste reduction and resource recovery strategies.

Implementing a waste conversion facility is complex and typically involves a combination of social, political, economic, environmental, and technical matters. Waste conversion technologies are typically more expensive than landfilling on the basis of tipping fees. A WTE facility typically does not have lower cost than landfilling, so such a facility is not anticipated to compete favorably on a purely economics basis in a free market economy. Key factors in implementing an energy recovery facility include a guaranteed supply of waste and a secure long-term energy market, as well as an approved site, regulatory approvals, and public and political support. Under the current free market system (in the Planning Area) for waste collection some means of flow control would be required to direct the waste to such a facility; flow control may be contractual, statutory, or economic.

The decision of whether to implement a waste conversion facility in the Planning Area is beyond the scope of this technical paper.

THIS PAGE INTENTIONALLY LEFT BLANK

Appendix 1

Conversion Technologies Comparison

The purpose of the document is to provide information on various waste conversion technologies often promoted for the management of municipal solid waste. For purposes of this paper they are grouped as 1) Demonstrated Technologies; and, 2) Developing Technologies.

DEMONSTRATED TECHNOLOGIES

The following technologies have been or are currently being used as part of an operating solid waste disposal system. Technologies are presented in alphabetic order.

ANAEROBIC DIGESTION

Anaerobic digestion (AD) is the process of decomposing the organic portion of MSW in an oxygen-deficient environment. Anaerobic digestion is widely used on a commercial-scale basis for industrial and agricultural wastes (manure), as well as wastewater sludges. Typically, anaerobic digestion is applied to food and green waste, agricultural waste, waste water treatment plant sludge, or other similar segments of the waste stream. Bacteria produce a biogas that consists mainly of methane, water vapor, and carbon dioxide (CO_2) through a process called methanogenesis. The resulting gas can be used as a fuel for boilers or directly in an internal combustion engine or, in sufficient quantities, in a gas turbine to produce electricity. Odor is a characteristic of anaerobic digestion and requires specific control measures. Site location and odor control would be a major factor in the implementation of this technology.

AD technology has been applied on a larger scale in Europe on mixed MSW and Source Separated Organics (SSO), but there are only limited commercial-scale applications in North America. The Greater Toronto Area is home to two of the only commercial-scale plants in North America. These plants are designed specifically for processing SSO; the two plants are the Dufferin Organic Processing Facility in Toronto and the CCI Energy Facility in Newmarket. There are a number of smaller facilities in the U.S. operating on either mixed MSW, SSO, or in some cases co-digested with biosolids. Commercial scale mixed MSW facilities are operating in Varennes-Jarcy, France; Mons, Belgium; Hanovre, Germany; Bassano, Italy; Amiens, France; Barcelona, Spain; La Coruna, Spain; and Sydney, Australia. These facilities have all come on line since 2000.

GASIFICATION

Gasification converts organic material into a synthetic gas or “syngas” composed primarily of carbon monoxide and hydrogen. This syngas can be used as a fuel to generate electricity or steam. Theoretically, the syngas generated can also be used as a chemical building block in the synthesis of gasoline, diesel fuel, alcohols and other chemicals. The feedstock for most gasification technologies must be prepared into refuse derived fuel (RDF) through processing of the incoming MSW, or the technology may only process a specific subset of the waste stream such as wood waste, tires, carpet, scrap plastic or other similar waste streams. Similar to Fluidized Bed Combustion (described below), the gasification process typically requires front end processing (separation and size reduction) of the waste feedstock, and as such results in lower fuel yields (less fuel per ton of MSW input) than other technologies presented in this paper.

While there is potential for fewer complex organic compounds to be formed with the reduced oxygen environment in the gasification process, the combustion of the syngas will produce products of

combustion similar to direct combustion of the feedstock. Any mercury in the feedstock is expected to volatilize and would need to be captured from the exhaust gas. The remaining ash and char produced by the gasification process may be marketed as a construction fill material, similar to aggregate. Where markets do not exist or are not being developed, the char and ash would be disposed of in a landfill.

A number of projects have been attempted over the years in the U.S. and Europe, but the success rate has been low. Gasification plants are operating in Japan; however, these facilities are not operating on typical MSW. Either industrial waste is used as the feedstock or plastic or coke (a coal mining by-product) is added to the waste to increase the energy content of the MSW. A sampling of facilities visited by HDR had lower capacity factors (tons throughput versus rated throughput) than waste-to-energy (WTE) technologies operating in the US.

MASS BURN WASTE-TO-ENERGY

Mass burn WTE involves direct combustion of unprocessed MSW on grates in a field erected waterwall furnace and boiler. Steam is generated in the boiler and typically supplied to a turbine generator to produce electricity. Economics can be improved if a customer with a relatively continuous demand for steam can be identified. This technology has been shown to yield a more than 99 percent reduction in carbon in the fuel (e.g., less that 1 percent un-burnt carbon in the ash). Significant success has also been demonstrated in post combustion recovery of metal and aggregate from the remaining ash.

Mass burn facilities utilize an extensive set of air pollution control (APC) devices for clean-up of the flue gas. The typical APC equipment used includes: either selective catalytic reduction (SCR) or non-catalytic reduction (SNCR) for nitrous oxides (NOx) emissions reduction; spray dryer absorbers (SDA) or scrubbers for acid gas reduction; activated carbon injection (CI) for mercury and complex organic compound (e.g., dioxins) reduction; and a fabric filter (baghouse) for particulate and metals removal.

There are a large number of operating mass burn plants in the US, Europe and Japan. Most of the operating facilities in the US were constructed in the 1980s and early 1990s. Large-scale and modular mass-burn combustion technology is used in commercial operations at more than 80 facilities in the U.S., two in Canada and more than 500 in Europe, as well as a number in Asia. Mass burn is by far the most prevalent technology in use in the U.S. and across the world.

Recently in North America, new units have been added on to existing plants in Fort Meyers, Florida; Rochester, Minnesota; Hillsborough County, Florida; Honolulu, Hawaii; and a new green-field site broke ground in September, 2011 in Durham, Ontario.

REFUSE DERIVED FUEL WASTE-TO-ENERGY

Refuse derived fuel WTE involves processing the MSW through screening, shredding and recovery of metals prior to the RDF fuel being combusted in a furnace or boiler. The original goal of this technology was to derive a better, more homogenous, fuel (uniform in size and composition) that could be used in a more conventional solid-fuel boiler as compared to a mass-burn combustion waterwall boiler. There are several operating RDF plants in the US. The last of these facilities opened in the early 1990s. Operating experience showed that the RDF was a corrosive fuel and extensive lining system (Inconel) was required in the RDF furnaces. The added cost for these liner systems limited the expected savings through the use of conventional solid fuel boilers.

RDF facilities are typically either very large (often 1,800 tons per day (tpd) or larger) or are constructed near a coal-fired unit that can be converted to co-fired coal and RDF. Large scale facilities allow the capital cost of the processing facility to be offset to a certain extent by the smaller boiler required. For a facility the size that would be required in Lincoln (less than 750 tpd), an RDF facility would be less economical than a mass burn facility unless an existing power plant can be readily converted to accept RDF.

RDF technology is an established technology that is used at a number of plants in the U.S., Europe and Asia. There are also a number of commercial-ready technologies that convert the waste stream into a stabilized RDF pellet that can be fired in an existing coal-boiler or cement kiln. The French Island facility located in La Crosse, Wisconsin is an example of such a RDF technology. Direct fired RDF systems required APC equipment similar to mass burn plants.

It should be noted that the only two RDF facilities in the US that are adding capacity (West Palm Beach, Florida and Honolulu) have opted to add mass burn units rather than additional RDF combustion capacity.

Fluidized Bed Combustion

This technology uses a bubbling or circulating fluidized bed of liquefied sand to combust MSW. The technology requires the use of a front-end processing system to produce a consistently sized feedstock similar to the system described above for the RDF technology.

Combustion performance and stable operation has been reported to be a challenge at some facilities. A downstream waste heat boiler is used for energy recovery.

One advantage of the fluidized bed technology is that lime can be added directly to the combustion chamber, which helps better control acid gases (e.g. sulfur dioxide (SO_2)). Generally, NOx emissions are lower in fluidized bed units than for mass-burn facilities. However, the APC equipment required would still be similar to mass burn and RDF combustion units.

This technology is in limited commercial use in the U.S. for waste applications with only one commercial-scale operating facility located in La Crosse, Wisconsin. A facility in Tacoma, Washington operated for many years but has since been shut down. Fluidized bed combustion is more commonly used for certain biomass materials and for coal combustion. It is more often considered for more uniform waste streams, such as wood wastes, tires and sludge. There are three sludge fueled fluidized bed units at the Saint Paul, Minnesota Metropolitan Wastewater Treatment Plant.

DEVELOPING TECHNOLOGIES

The following technologies are currently being developed for commercial scale use. There are no identified examples of these technologies in use, on a day-to-day basis, as part of an MSW disposal system other than one pyrolysis facility in Europe that fires MSW and three Plasma Arc facilities in Japan that process a feedstock of MSW, industrial waste and 4 percent coke.

Development of these and other technologies continues. The summary below does not include evaluations of all the technologies being offered or promoted by specific companies, vendors or developers. The combination of the limited experience and evolution of these technologies results in a potentially promising but uncertain future. For some of the developing technologies, vendors of various technologies may sometimes cease operations or merge with others and new vendors of similar technologies may appear.

PYROLYSIS GASIFICATION

Pyrolysis is one subset of gasification and is generally defined as the process of heating MSW in an oxygen-deficient environment to produce a combustible gaseous or liquid product and a carbon-rich solid residue (char). The gas or liquid derived from the process can conceivably be used in an internal combustion engine or gas turbine or as a feedstock for chemical production. Generally, pyrolysis occurs at a lower temperature and with less oxygen than gasification, although the processes are similar.

Pyrolysis systems have had some success with wood waste feedstocks. Several attempts to commercialize large-scale MSW processing systems in the U.S. in the 1980's failed, but there are several pilot projects at various stages of development. There have been some commercial-scale pyrolysis facilities in operation in Europe (e.g., Germany) on select waste streams. Vendors claim that the activated carbon byproduct from the pyrolysis is marketable, but this has not been demonstrated.

Historically, at least two large-scale facilities were built in the U.S. and had mechanical and other problems when processing mixed waste. Of particular note were large-scale pyrolysis plants built near Baltimore, Maryland and San Diego, California. They were scaled up from pilot projects and were never able to function at a commercial level. In Germany, at least one pyrolysis facility is operating. It was built in the mid-1980s and appears to still be operating today. It is a small-capacity facility and has not been replicated on a larger scale. At least one other large-scale project was attempted in the mid-1990s in Germany using another technology, but operational problems forced its closure after a short time.

PLASMA ARC GASIFICATION

Plasma arc technology uses carbon electrodes to produce a very-high-temperature arc that convert the incoming waste to vapors. The organic materials in the waste are broken down into basic compounds, while the inorganic material forms a liquid slag. The vaporized waste can be collected to produce a fuel that theoretically can be used in a boiler, engine or gas turbine, which might then allow steam or electrical energy to be produced for sale. This technology has a high electrical energy consumption but there is an overall expectation that in the future more electrical power can be produced than what is consumed in the process.

This technology claims to achieve lower levels of regulated emissions than more demonstrated technologies, like mass burn and RDF processes. However, APC equipment similar to other technologies would still be required for the clean-up of the syngas or other off-gases.

Facilities operate in Japan, most notably three developed by Hitachi Metals, in Yoshii, Utashinai, and Mihama-Mikata. These facilities are referred to as plasma direct melting reactors. This is significant owing to the desire in Japan to vitrify ash from mass burn waste to energy facilities. Many gasification

facilities in Japan accept ash from conventional WTE facilities for vitrification. The facilities in Japan are in many cases intended as ash vitrification facilities rather than energy recovery facilities. The benefit of the vitrified ash is to bind potentially hazardous elements thereby further rendering the ash inert. The following paragraphs are based on information believed to be reliable but not independently verified.

According to an October 2002 presentation by the Westinghouse Plasma Corporation to the Electric Power Generating Association, the Yoshii facility accepts 24 tpd of unprocessed MSW together with 4 percent coke and produces 100 kWh of electricity per ton of MSW. The facility also produces steam for a hotel/resort use. This facility started operation in 2000.

According to the same presentation, the Utashinai facility processes 170 tpd of MSW and automobile shredder residue (ASR) together with 4 percent coke and produces 260 kWh/ton. This is less than half the energy production that would be expected of a demonstrated WTE technology.

According to AlterNRG's web site and a presentation by Louis J. Circeo, Ph.D director of the plasma applications research program at the Georgia Tech Research Institute, the Mihama-Mikata processes 20 tpd of MSW and 4 tpd of waste water sludge and produces syngas that is combusted and the resulting heat is used to dry sewage sludge prior to gasification and to produce steam.

The economics of these plasma arc gasification facilities are difficult to quantify due in part to the lack of information provided by the various operator/vendors of these facilities. Facilities in North America have not yet operated successfully at a commercial scale.

When the syngas is combusted, air pollution control systems similar to those of demonstrated WTE facilities would be required. Emissions would not be expected to be appreciably different.

Plasma technology has received considerable attention recently, and there are several large-scale projects being planned in North America and Europe (e.g., Atlantic County, New Jersey). In addition, there are a number of demonstration facilities in North America, including the Plasco Energy Facility in Ottawa, Ontario and the Alter NRG demonstration facility in Madison, Pennsylvania in the U.S. PyroGenesis Canada, Inc., based out of Montreal, Quebec, also has a demonstration unit (approximately 10 tpd) located on Hurlburt Air Force Base in Florida that has been in various stages of start-up since 2010.

HYDROLYSIS

The hydrolysis process involves the reaction of the water and cellulose fractions in the MSW feedstock (e.g., paper, food waste, yard waste, etc.) with a strong acid (e.g., sulfuric acid) to produce sugars. In the next process step, these sugars are fermented to produce an alcohol. This alcohol is then distilled to produce a fuel-grade ethanol. Hydrolysis is a multi-step process that includes four major steps: Pre-treatment; Hydrolysis; Fermentation; and Distillation. Processing and separation of the MSW stream is necessary to remove the inorganic/inert materials (glass, plastic, metal, etc.) from the targeted organic materials (food waste, yard waste, paper, etc.). Similar to the RDF technology, the organic material is shredded to reduce the size and to make the feedstock more homogenous. The shredded organic material is placed into a reactor where it is introduced to the acid catalyst. The byproducts from this process are carbon dioxide (from the fermentation step), gypsum (from the hydrolysis step) and lignin (non-cellulose material from the hydrolysis step). Since the acid acts only as a catalyst, it can be extracted and recycled back into the process.

There have been some demonstration and pilot-scale hydrolysis applications completed using mixed MSW and other select waste streams. However, there has been no widespread commercial application of this technology using MSW in North America or abroad. A commercial-scale hydrolysis facility has been permitted for construction in Monroe, New York in the U.S., but this project is currently on-hold.

CATALYTIC DEPOLYMERIZATION

In a catalytic depolymerization process, the plastics, synthetic-fiber components and water in the MSW feedstock react with a catalyst under pressure at high temperatures to produce a crude oil. This crude oil can theoretically be distilled to produce a synthetic gasoline or fuel-grade diesel. There are four major steps in a catalytic depolymerization process: Pre-processing, Process Fluid Upgrading, Catalytic Reaction, and Separation and Distillation. The Pre-processing step is very similar to the RDF process where the MSW feedstock is separated into process residue, metals and RDF. This process typically requires additional processing to produce a much smaller particle size with less contamination. The RDF is mixed with water and a carrier oil (hydraulic oil) to create a RDF sludge. This RDF sludge is sent through a catalytic turbine where the reaction, under high temperature and pressure, produces a light oil. The light oil is then distilled to separate the synthetic gasoline or diesel oil.

This catalytic depolymerization process is somewhat similar to that used at an oil refinery to convert crude oil into usable products. This technology requires a processed waste stream with high plastics content and may not be suitable for a mixed MSW stream. The need for a high-plastics-content feedstock also limits the size of the facility (e.g., composition studies at Lincoln's Bluff Road Landfill suggest the MSW waste stream is less than 20 percent plastics) .

There are no large-scale commercial catalytic depolymerization facilities operating in North America that use a mixed MSW stream as a feedstock. There are some facilities in Europe that claim to utilize waste plastics, waste oils and some quantities of mixed MSW to produce a synthetic fuel. One vendor (KDV) has built a commercial-scale facility in Spain that has been in operation since the second half of 2009 that they claim uses a mixed MSW stream. However, HDR's efforts at confirming these claims through obtaining operating data or an update on the status of this facility were not successful.

APPENDIX 2

Waste Not, Want Not: The Facts Behind Waste-to-Energy

Data and facts show that waste-to-energy avoids greenhouse gas emissions, generates clean renewable energy, promotes energy independence, and provides safe reliable disposal services.

ENERGY RECOVERY COUNCIL

Waste Not, Want Not: The Facts Behind Waste-to-Energy

Report by:
Ted Michaels
President
Energy Recovery Council

April 2009

The Energy Recovery Council (ERC) was formed to provide a forum for companies and local governments to promote waste-to-energy.

In addition to providing essential trash disposal services cities and towns across the country, today's waste-to-energy plants generate clean, renewable energy. Through the combustion of everyday household trash in facilities with state-of-the-art environmental controls, ERC's members provide viable alternatives to communities that would otherwise have no alternative but to buy power from conventional power plants and dispose of their trash in landfills.

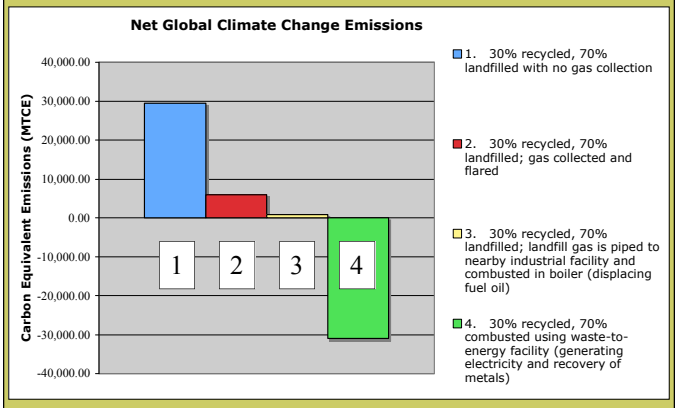
The 87 waste-to-energy plants nationwide dispose of more than 90,000 tons of trash each day while generating enough clean energy to supply electricity to approximately two million homes nationwide.

There is a national need for energy sources that promote energy independence, avoid fossil fuel use, and reduce greenhouse gas emissions. Waste-to-energy is well-positioned to deliver these qualities while also providing for safe and reliable disposal of household trash. Application of EPA's lifecycle analysis demonstrates that for every ton of waste processed at a waste-to-energy facility, a nominal one ton of carbon dioxide equivalents is prevented from entering the atmosphere. As progressive environmental policymakers in Europe have learned, waste-to-energy not only reduces a nation's carbon footprint, it is compatible with high recycling rates and helps to minimize the landfilling of trash.

The Role of Waste-to-Energy in Mitigating Climate Change

Waste-to-Energy reduces greenhouse gas emissions

Waste-to-energy achieves the reduction of greenhouse gas emission through three separate mechanisms: 1) by generating electrical power or steam, waste-to-energy avoids carbon dioxide (CO_2) emissions from fossil fuel based electrical generation, 2) the waste-to-energy combustion process effectively avoids all potential methane emissions from landfills thereby avoiding any potential release of methane in the future and 3) the recovery of ferrous and nonferrous metals from MSW by waste-to-energy is more energy efficient than production from raw materials.



Data Source: Thorneloe SA, Weitz K, Jambeck J. Application of the U.S. Decision Support Tool for Materials and Waste Management. WM Journal 2006 August.

These three mechanisms provide a true accounting of the greenhouse gas emission reduction potential of waste-to-energy. A lifecycle analysis, such as the Municipal Solid Waste Decision Support Tool, is the most accurate method for understanding and quantifying the complete accounting of any MSW management option. A life cycle approach should be used to allow decision makers to weigh all greenhouse gas impacts associated with various activities rather than targeting, limiting or reducing greenhouse gas emissions on a source-by-source basis. *(IPCC, EPA)*

The Municipal Solid Waste Decision Support Tool is a peer-reviewed tool, available through the U.S. Environmental Protection Agency and its contractor RTI International, which enables the user to directly compare the energy and environmental consequences of various management options for a specific or general situation. Independent papers authored by EPA (such as *"Moving From Solid Waste Disposal to Management in the United States," Thorneloe (EPA) and Weitz (RTI) October, 2005; and "Application of the U.S. Decision Support Tool for Materials and Waste Management," Thorneloe (EPA), Weitz (RTI), Jambeck (UNH), 2006*) report on the use of the Municipal Solid Waste Decision Support Tool to study municipal solid waste management options.

These studies used a life-cycle analysis to determine the environmental and energy impacts for various combinations of recycling, landfilling, and waste-to-energy. The comprehensive analysis examines collection and transportation, material recovery facilities, transfer stations, composting, remanufacturing, landfills, and combustion. The results of the studies show that waste-to-energy yielded the best results—maximum energy with the least environmental impact (emissions of greenhouse gas, nitrogen oxide, fine particulate precursors, and others). In brief, waste-to-energy was demonstrated to be the best waste management option for both energy and environmental parameters and specifically for greenhouse gas emissions.

When the Municipal Solid Waste Decision Support Tool is applied to the nationwide scope of waste-to-energy facilities that are processing 30 million tons of

trash—the waste-to-energy industry prevents the release of approximately 30 million tons of carbon dioxide equivalents that would have been released into the atmosphere if waste-to-energy was not employed.

Recognition of Waste-to-Energy as a Contributor to Climate Change Solutions

International Acceptance

The ability of waste-to-energy to prevent greenhouse gas emissions on a lifecycle basis and mitigate climate change has been recognized in the actions taken by foreign nations trying to comply with Kyoto targets. The European Union (Council Directive 1999/31/EC dated April 26, 1999) established a legally binding requirement to reduce landfilling of biodegradable waste. Recognizing the methane release from landfills, the European Union established this directive to prevent or reduce negative effects on the environment "including the greenhouse effect" from landfilling of waste, during the whole life-cycle of the landfill.

The Intergovernmental Panel on Climate Change (IPCC) has also recognized the greenhouse gas mitigation aspect of waste-to-energy. The IPCC acknowledges that "incineration reduces the mass of waste and can offset fossil-fuel use; in addition greenhouse gas emissions are avoided, except for the small contribution from fossil carbon." This acknowledgement by the IPCC is particularly relevant due to the IPCC being an independent panel of scientific and technical experts that shared the Nobel Peace Prize with Al Gore.

The German Ministry of the Environment published a report in 2005 entitled "Waste Sector's Contribution to Climate Protection," which states that "the disposal paths of waste incineration plants and co-incineration display the greatest potential for reducing emissions of greenhouse gases." The German report concluded that the use of waste combustion with energy recovery coupled with the reduction in landfilling of biodegradable waste will assist the European Union-15 to meet its obligations under the Kyoto Protocol.

Under the Kyoto Protocol, the Clean Development Mechanism (CDM) is a method of emissions trading that allows the generation of tradable credits (Certified Emission Reductions [CERs]) for greenhouse gas emissions reductions achieved in developing countries, which are then purchased by developed countries and applied toward their reduction targets. CERs are also accepted as a compliance tool in the European Union Emissions Trading Scheme.

Waste-to-energy projects can be accorded offset status under the CDM protocol (AM0025 v7) by displacing fossil fuel-fired electricity generation and eliminating methane production from landfills. An associated CDM memorandum that set out methodology for including waste-to-energy, among others, in CDM projects. The memorandum, entitled "Avoided emissions from organic waste through alternative waste treatment processes," stated in part that CDM status could be accorded projects where "the project activity involves … incineration of fresh waste for energy generation, electricity and/or heat" where the waste "would have otherwise been disposed of in a landfill."

Domestic Recognition

The contribution of waste-to-energy to reduce greenhouse gas emissions has been embraced domestically as well. The U.S. Conference of Mayors adopted a resolution in 2004 recognizing the greenhouse gas reduction benefits of waste-to-energy. In addition, the U.S. Mayors Climate Protection Agreement supports a 7 percent reduction in greenhouse gases from 1990 levels by 2012. By signing the agreement, mayors have pledged to take actions in their own communities to meet this target, and have recognized waste-to-

> *"Generation of energy from municipal solid waste disposed in a waste-to-energy facility not only offers significant environmental and renewable benefits, but also provides greater energy diversity and increased energy security for our nation."*
>
> —The United States Conference of Mayors, Adopted Resolution on Comprehensive Solid Waste Disposal Management (2005)

How are greenhouse gases measured?

There are two types of carbon dioxide emissions: biogenic and anthropogenic. The combustion of biomass generates biogenic carbon dioxide. Although waste-to-energy facilities do emit carbon dioxide from their stacks, the biomass-derived portion is considered to be part of the Earth's natural carbon cycle. The plants and trees that make up the paper, food, and other biogenic waste remove carbon dioxide from the air while they are growing, which is returned to the air when this material is burned. Because they are part of the Earth's natural carbon cycle, greenhouse gas regulatory policies do not seek to regulate biogenic greenhouse gas emissions. *(IPCC)*

Anthropogenic carbon dioxide is emitted when man-made substances in the trash are burned, such as plastic and synthetic rubber. Testing of stack gas from waste-to-energy plants using ASTM Standards D-6866 can determine precisely the percentage of carbon dioxide emissions attributable to anthropogenic and biomass sources. Long-term measurements of biogenic CO_2 from waste-to-energy plants measure consistently at approximately sixty-seven percent. The amount of anthropogenic CO_2 is approximately 1,294 lbs/MWhr when considered as a separate factor. However, when other unit operations are also factored in on a life cycle basis—such as avoided CO_2, avoided methane, and recovered materials—the result is a negative value of 3,636 lbs/MWhr. This approach is favored by the IPCC, which has endorsed the use of life cycle assessment.

One must remember that direct emissions are only part of the equation. Because we live in a three-dimensional world, we must look at all inputs if we are truly interested in reducing how much greenhouse gas is being released to the atmosphere and how to reduce that number by the greatest amount. The use of waste-to-energy: avoids landfilling and prevents subsequent methane generation; replaces and offsets electric power generated by fossil fuels and offsets their higher greenhouse gas emissions; and recovers and recycles metals that can be used in products rather than virgin materials, which results in a large greenhouse gas savings.

It is the large amount of greenhouse gases avoided by the use of waste-to-energy compared to the limited amount of direct carbon dioxide emissions emitted through the combustion of trash that has led to the conclusion that for every ton of trash processed by a waste-to-energy plant, approximately one ton of carbon dioxide equivalents are avoided.

Air Emissions of Waste-To-Energy and Fossil Fuel Power Plants
(Pounds per Megawatt Hour)

Fuel Type	Direct CO_2[1]	Life Cycle CO_2E[2]
Coal	2,138	2,196
Residual Fuel Oil	1,496	1,501
Natural Gas	1,176	1,276
Waste-to-Energy[3]	1,294	**-3,636**

[1]Based on 2007 EPA eGRID data except WTE which is a nationwide average using 34% anthropogenic CO_2.
[2]Life Cycle CO2E for fossil fuels limited to indirect methane emissions using EPA GHG inventory and EIA power generation data. Life Cycle value would be larger if indirect CO_2 was included.
[3]Life Cycle CO_2E for WTE based on nominal nationwide avoidance ratio of 1 ton CO_2E per ton of MSW using the Municipal Solid Waste Decision Support Tool, which includes avoided methane and avoided CO_2.

energy technology as a means to achieve that goal. As of July 2, 2008, 850 mayors have signed the agreement.

Columbia University's Earth Institute convened the Global Roundtable on Climate Change (GROCC), which unveiled a joint statement on February 20, 2007 identifying waste-to-energy as a means to reduce CO_2 emissions from the electric generating sector and methane emissions from landfills. This important recognition from the GROCC, which brought together high-level, critical stakeholders from all regions of the world, lends further support that waste-to-energy plays an important role in reducing greenhouse gas emissions. The breadth of support for the GROCC position is evidenced by those that have signed the joint statement, including Dr. James Hansen of the NASA Goddard Institute for Space Studies, as well as entities as diverse as American Electric Power and Environmental Defense.

The History and Role of Waste-to-Energy as a Renewable Energy Resource

Municipal Solid Waste is a Renewable Fuel

The sustainable nature of MSW is a major component of its historic renewable status. For more than three and a half decades, despite all of the efforts of EPA and many others to reduce, reuse and recycle, the U.S. diversion rate of municipal solid waste has climbed to barely above 30%. During this same time period, the solid waste generation rate has more than *doubled* and the population has risen by more than 96 million people. Furthermore, for the past several years, the national average diversion rate has increased by less than one percentage point per year. Today, Americans dispose of 278 million tons of municipal solid waste per year of which less than 30 million tons is used as fuel in waste-to-energy facilities. It is clear to see that for the foreseeable future there will be no end to an amount of municipal solid waste available as a renewable fuel.

> *Waste-to-energy plants are a "clean, reliable, renewable source of energy" that 'produce 2,800 megawatts of electricity with less environmental impact than almost any other source of electricity." Communities "greatly benefit from the dependable, sustainable [solid waste disposal] capacity of municipal waste-to-energy plants."*
>
> —USEPA letter from Assistant Administrators Marianne Horinko, Office of Solid Waste and Emergency Response, and Jeffery Holmstead, Office of Air and Radiation to IWSA, 2/14/03

Waste-to-Energy has a Long Track Record as Renewable

Policymakers for three decades (since the inception of the commercial waste-to-energy industry) have recognized municipal solid waste as a renewable fuel. The most recent statutory recognition came in section 203 of the Energy Policy Act of 2005, which defined municipal solid waste as "renewable energy."

While the Energy Policy Act of 2005 is the most recent example, waste-to-energy is given full renewable status for the municipal solid waste it processes under a number of statutes, regulations, and Executive Orders, including:

- the Federal Power Act
- the Public Utility Regulatory Policy Act
- the Biomass Research and Development Act of 2000
- the Pacific Northwest Power Planning and Conservation Act
- Section 45 of the Internal Revenue Code
- Executive Order 13423
- Federal Energy Regulatory Commission regulations (18 CFR.Ch. I, 4/96 Edition, Sec. 292.204)
- statutes in more than two dozen states, including more than a dozen renewable portfolio standards.

The production of clean energy from garbage has been attained by a heavy investment by the waste-to-energy industry and its municipal partners. Waste-to-energy facilities achieved compliance in 2000 with Clean Air Act standards for municipal waste combustors. More than $1 billion was spent by companies and their municipal partners to upgrade facilities, leading EPA to write that the "upgrading of the emissions control

systems of large combustors to exceed the requirements of the Clean Air Act Section 129 standards is an impressive accomplishment."

Waste-to-Energy Generates Much Needed Baseload Renewable Power

It is important to consider that waste-to-energy plants supply power 365-days-a-year, 24-hours a day and can operate under severe conditions. For example, Florida's waste-to-energy facilities have continued operation during hurricanes, and in the aftermath of the storm provide clean, safe and reliable waste disposal and energy generation. Waste-to-energy facilities average greater than 90% availability of installed capacity. The facilities generally operate in or near an urban area, easing electric transmission to the customer and minimizing waste transport. Waste-to-energy power is sold as "baseload" electricity to utilities that can rely upon its supply of electricity. There is a constant need for trash disposal, and an equally constant need for reliable energy generation.

Waste-to-Energy Actively Participates in the REC Markets

Municipalities and companies that own and operate waste-to-energy facilities are already actively participating in the renewable energy trading markets. Waste-to-energy is included in many state renewable portfolio standards and has traded frequently in those markets. Facilities have also sold RECs to entities interested in acquiring RECs on a voluntary basis. Furthermore, waste-to-energy facilities have successfully won bids to sell RECs to the federal government through competitive bidding processes.

States Defining Waste-to-Energy as Renewable in State Law
(as of 6/30/08)

Alaska	Maine	New York
Arkansas	Maryland	Oregon
California	Massachusetts	Pennsylvania
Connecticut	Michigan	South Dakota
District of Columbia	Minnesota	Virginia
Florida	Montana	Washington
Hawaii	Nevada	Wisconsin
Iowa	New Hampshire	
Indiana	New Jersey	

Waste-to-Energy is Compatible with Recycling

Statistics compiled for more than a decade have proven that waste-to-energy and recycling are compatible despite many attempts by naysayers to conclude otherwise. Since research on the subject began in 1992, communities that rely upon waste-to-energy maintain, on average, a higher recycling rate than the national EPA average.

WTE Community Average Recycling Rate vs. National Average

Year	WTE Recycling Rate	National Recycling (4)
2004	34% (1)	31%
2002	33% (2)	30%
1992	21% (3)	17%

(1) Source: J. V. L. Kiser, based on feedback from 94 WTE communities.
(2) Source: J. V. L. Kiser, based on feedback from 98 WTE communities.
(3) Source: J. V. L. Kiser, based on feedback from 66 WTE communities.
(4) Source: U.S. EPA, based on most recent data available during the study year

Communities that employ integrated waste management systems usually have higher recycling rates and the use of waste-to-energy in that integrated system plays a key role. Specific examples of why waste-to-energy communities are successful recyclers include:

- communities with waste-to-energy plants tend to be more knowledgeable and forward thinking about recycling and MSW management in general;
- communities with waste-to-energy plants have more opportunities to recycle since they handle the MSW stream more;
- the municipal recycling program can be combined with on-site materials recovery at the waste-to-energy plant (e.g. metals recovered at a waste-to-energy plant post-combustion usually cannot be recycled curbside and would otherwise have been buried had that trash been landfilled); and
- waste-to-energy plant officials promote recycling during facility tours and conduct community outreach efforts that may not be occurring in other locations.

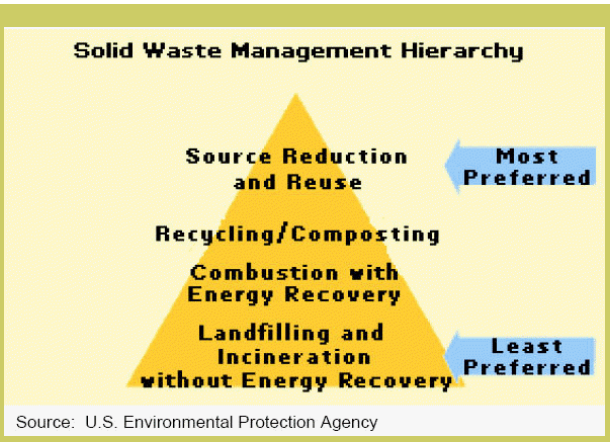
Many communities are connected to off-site recycling programs, such as curbside collection, drop off centers, MRFs, and/or yard waste management. In addition to the typical metals, glass, plastic, and paper from household and/or commercial sources, the communities reported having recycling programs for handling other materials. These ranged from batteries, used oil, and e-waste, to household hazardous waste, public and school outreach programs, and tires management, to scrap metals, food waste, and artificial reef construction projects.

The U.S. Environmental Protection Agency and the European Union Prefers Waste-to-Energy to Landfilling

Waste-to-energy has earned distinction through the U.S. Environmental Protection Agency's solid waste management hierarchy, which recognizes combustion with energy recovery (as they refer to waste-to-energy) as preferable to landfilling. EPA recommends that after efforts are made to reduce, reuse, and recycle, trash should be managed at waste-to-energy plants where the volume of trash will be reduced by 90%, the energy content of the waste will be recovered, and clean renewable electricity will be generated.

Municipal solid waste should be managed using an integrated waste management system. IWSA encourages and supports community programs to reduce, reuse, recycle and compost waste. Unfortunately, one hundred percent recycling rates are not technically, economically, or practically feasible. After waste is reduced, reused, and recycled, waste will be leftover that must be managed. That is where waste-to-energy comes in.

As noted earlier, EPA's hierarchy is consistent with actions taken by the European Union, which went further by establishing a legally binding requirement to reduce landfilling of biodegradable waste. The result has been increased recycling rates, higher waste-to-energy usage, reduced greenhouse gas emissions, and less dependence on fossil fuels.



Source: U.S. Environmental Protection Agency

EPA's Solid Waste Management Hierarchy underscores the importance of waste-to-energy as a critical component of any sustainable integrated waste management system.

Waste-to-Energy Reduces Greenhouse Gas Emissions in Three Important Ways

Avoided methane emissions from landfills. When a ton of solid waste is delivered to a waste-to-energy facility, the methane that would have been generated if it were sent to a landfill is avoided. While some of this methane could be collected and used to generate electricity, some would not be captured and would be emitted to the atmosphere. Waste-to-energy generates more electrical power per ton of municipal solid waste than any landfill gas-to-energy facility.

Avoided CO_2 emissions from fossil fuel combustion. When a megawatt of electricity is generated by a waste-to-energy facility, an increase in carbon dioxide emissions that would have been generated by a fossil-fuel fired power plant is avoided.

Avoided CO_2 emissions from metals production. Waste-to-energy plants recover more than 700,000 tons of ferrous metals for recycling annually. Recycling metals saves energy and avoids CO_2 emissions that would have been emitted if virgin materials were mined and new metals were manufactured, such as steel.