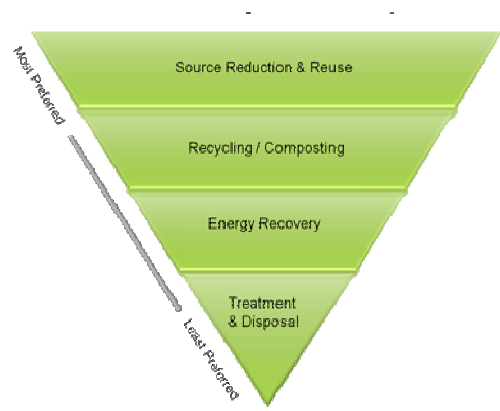
Waste Conversion Technologies

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.

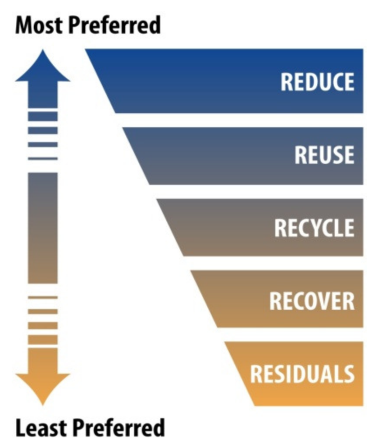
The decision of whether to implement a waste conversion facility in the Planning Area is beyond the scope of this technical paper. However, if implementation is eventually selected as an option in the Solid Waste Plan 2040, the following list of major actions has been developed to facilitate the refinement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

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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.

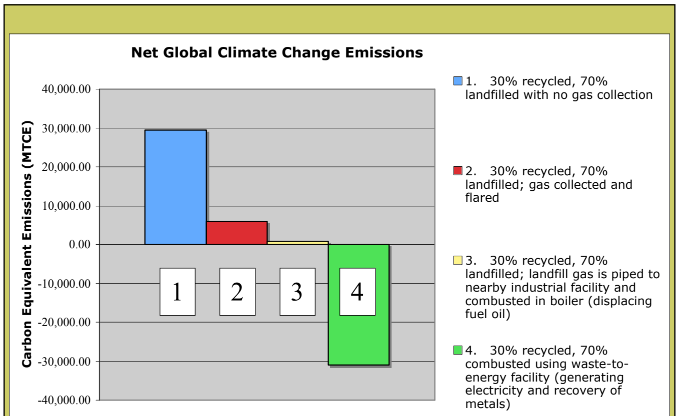
ENERGY RECOVERY COUNCIL

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.

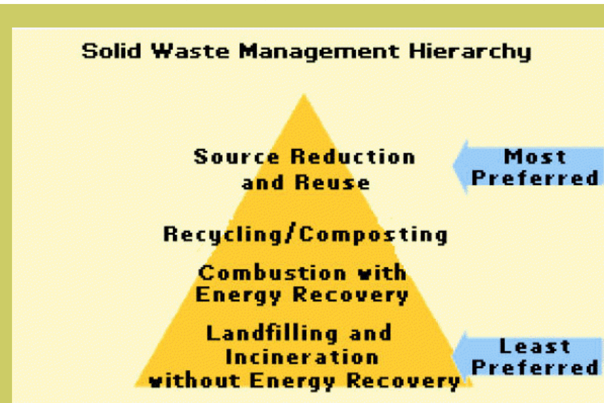
Many communities are connected to off-site recycling programs, such as curbside collection, drop off centers, MRFs, and/or yard waste management. In addition to the typical metals, glass, plastic, and paper from household and/or commercial sources, the communities reported having recycling programs for 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.

Municipal Solid Waste Disposal

Overview

Nebraska's Integrated Solid Waste Management Act (Nebr. Rev. Statutes Chapter 13, Section 13-2001 to 2043) states in 13-2020 (County, municipality, or agency; provide or contract for disposal of solid waste; joint ownership of facility; governing body; powers and duties; rates and charges) that:

> "*Effective October 1, 1993, each county and municipality shall provide or contract for facilities and systems as necessary for the safe and sanitary disposal of solid waste generated within its solid waste jurisdictional area…"*

In furtherance of this obligation the Lincoln Municipal Code (LMC) 8.32 (Solid Waste) states in 8.32.030 (Sanitary Landfill; Designated by Council) that:

> *"The City Council shall, by resolution, designate a place or places for the operation of a public sanitary landfill to be used for the disposal of solid waste, and other offensive or obnoxious substances."*

In carrying out this obligation LMC, Part 8.32.040 (Public Sanitary Landfills; Location; Type of Solid Waste Accepted for Disposal) states:

> *"Two public sanitary landfills are hereby designated for purposes of dumping and disposal of solid waste. One public sanitary landfill shall be located on 48th Street, approximately three-quarters of a mile north of Superior Street. The second public sanitary landfill shall be located at… 56th Street and Bluff Road.*

LMC 8.32.070 stipulates that the designated public sanitary landfills in the County (Bluff Road Municipal Solid Waste (MSW) Landfill and North 48th Street Construction and Demolition Waste Landfill) are authorized for the citizens of the City, residents of the County, and for the disposal of solid waste generated within the County. Additionally, two related guiding principles were identified in the Lincoln-Lancaster County 2040 Comprehensive Plan (LPlan 2040). They are as follows:

- "*No out-of-county waste is accepted for landfill disposal. This policy reserves landfill capacity for city and county residents and allow administration of programs under existing authorities.*
- *The City policy of … public ownership, operation and financing of disposal and selected integrated solid waste management services will continue during the planning period*."

In planning for solid waste management facilities, it is important to reasonably and realistically project the potential quantity of waste expected to be managed or disposed of by the various systems, facilities and programs. Underestimating quantities of waste and/or overestimating recycling and diversion can adversely affect the predicted life of the landfill and require more frequent plan adjustments.

In the State of Nebraska there are 23 permitted municipal solid waste (MSW) landfills and 28 permitted construction and demolition waste landfills. Most of the MSW landfills charge higher disposal fees than the Bluff Road MSW Landfill. However, there are two privately owned and operated MSW landfills within 60 miles of the City's facilities (one in Milford, Nebraska in Seward County and one near David City, Nebraska in Butler County), which even though they have higher posted tipping fees are known to receive waste from the Planning Area. Table 1 summarizes the posted tipping fees at MSW landfills within approximately 60 miles of the Planning Area, as well as identifies the haul distances to these MSW landfills from Lincoln.

Table 1 – Regional Landfills (2012$)

	Posted Tipping Fee ($/ ton)		Distance from Lincoln (miles)	Operation /Ownership
	In County	Out of County		
Butler County Landfill	$38.75	$38.75	50	Private/Private
Milford Landfill	$45.00	$45.00	25	Private/Private
Bluff Road Landfill	$21.00(2)	NA	-	Public/Public
York Area Landfill	$38.00	$38.00	50	Public/Public
Beatrice Landfill (1)	Avg. $39.00	Varies	40	Public/Public
Pheasant Point Landfill	$24.20	$24.20	62	Private/Private
Sarpy County Landfill (3)	$24.85	$31.52	47	Public/Public

Notes: (1) Beatrice charges vary based on cubic yard volume; average tip fee is estimated based on FY2010 revenues divided by tons.

(2) Tipping free is comprised of a $14 per ton disposal fee and a $7 per ton Occupation Tax.

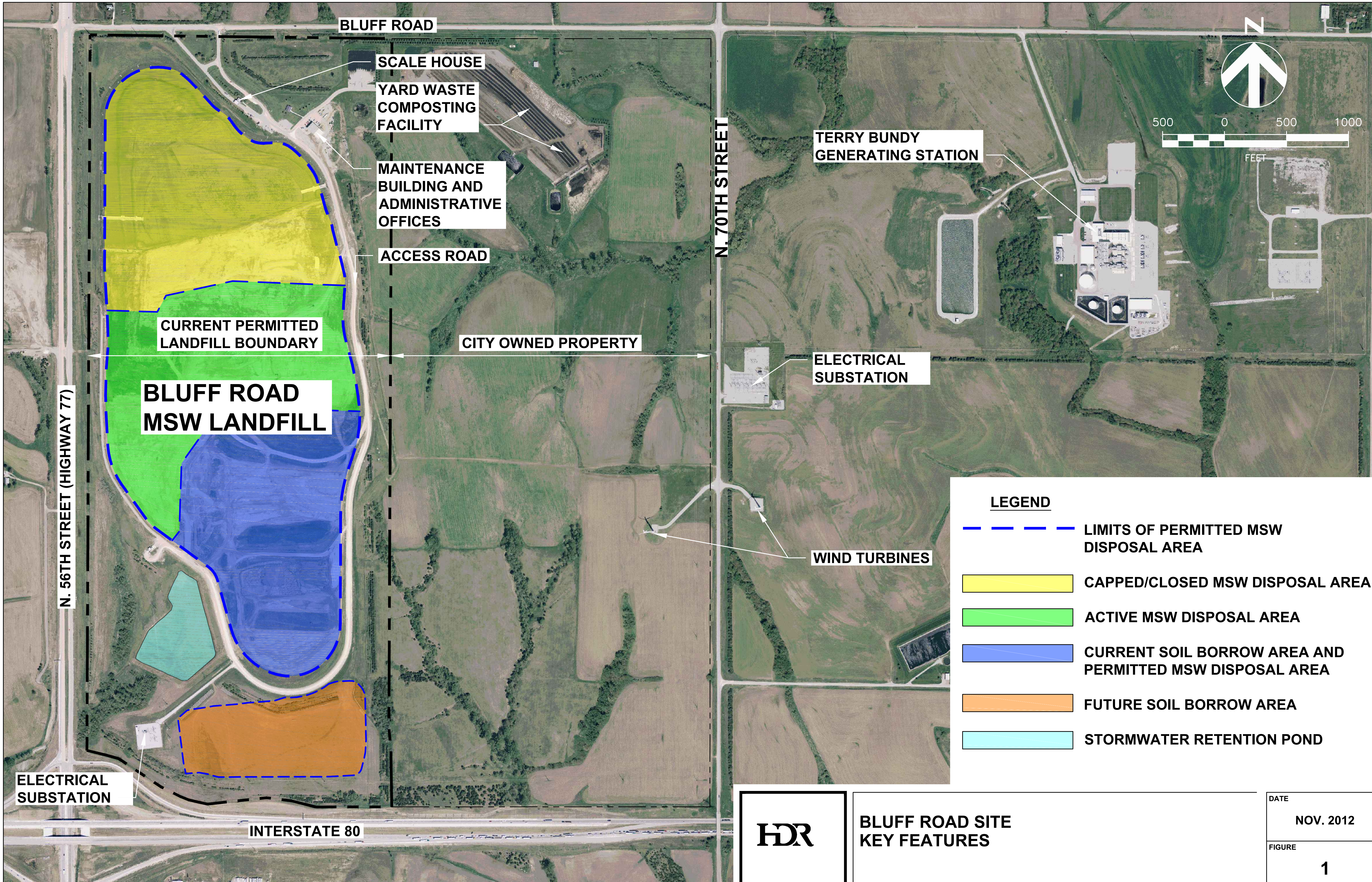
(3) Site is scheduled to close in 2013 and is being replaced with a transfer station that will ship waste to a landfill outside of Sarpy County.

NA indicates not applicable.

Current Programs

The Bluff Road MSW Landfill, 6001 Bluff Road, currently operates in the western half of this approximately 1 square-mile property. The site is permitted by NDEQ as a Municipal Solid Waste Disposal Area. The Bluff Road MSW Landfill began operations in 1988 and only accepts solid waste generated from within Lancaster County. The site contains 350 acres, of which 171 acres are permitted as a disposal area (landfill). The permitted disposal area is currently projected to reach capacity in 2032. Figure 1 shows the overall location of the Bluff Road MSW Landfill and key facility features.

The Bluff Road MSW Landfill is the only permitted MSW landfill in Lancaster County. The landfill is used by waste/refuse haulers or customers hauling materials in large trucks and trailers. Construction and demolition (C&D) waste can be delivered to and disposed of at the Bluff Road MSW Landfill or the City's North 48th Street Construction and Demolition Waste Landfill. A portion of the waste generated in the City and County is exported to other landfills in the region.



HDR

BLUFF ROAD SITE
KEY FEATURES

DATE NOV. 2012

FIGURE 1

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Facilities on the Bluff Road site include the weigh scale, scale house, the maintenance facility and administrative offices, a training building, as well as a leachate load-out facility and a landfill gas (LFG) blower and flare facility. The weigh scale located adjacent to the scale house is used to determine the weight of inbound wastes and a commercial software program calculates fees for billing to the customer.

The 171 acres of permitted disposal area has an air space capacity of over 25.2 million cubic yards (CY) (excluding the liner system and final cover). Based on projections in the permit renewal documents (the current permit expires in May 2013), the remaining air space capacity is approximately 12.5 million CY (excluding final soil cover).

Generation and Diversion

From the standpoint of the USEPA's solid waste management hierarchy landfill disposal and treatment systems are the least preferred management system. The USEPA's data suggests that nationally 54 percent of MSW is landfilled with 34 percent being recovered (via recycling and composting) and the remaining approximately 12 percent managed by combustion with energy recovery [referred to as "Waste Conversion Technologies" in a separate technical paper] (USEPA *Municipal Solid Waste in the United States: 2010 Facts and Figures*, December 2011). The data indicates municipal solid waste landfills are the most common form of waste management. Table 2 provides a summary of historical tonnages of solid waste disposed of by landfilling.

Table 2 – Historical Quantities Disposed from Planning Area (Tons)

FY	MSW Landfilled at Bluff Road MSW Landfill (1)(2)	MSW Exported	Total MSW Generated in the Planning Area that is Landfilled
88-89	278,338	-	278,338
89-90	289,604	-	289,604
90-91	296,897	-	296,897
91-92	280,449	-	280,449
92-93	258,828	-	258,828
93-94	265,414	-	265,414
94-95	257,957	-	257,957
95-96	265,196	-	265,196
96-97	284,536	-	284,536
97-98	275,512	-	275,512
98-99	286,322	-	286,322
99-00	289,542	-	289,542
00-01	278,351	15,330	293,681
01-02	265,027	32,854	297,881
02-03	275,049	27,092	302,141
03-04	282,263	29,477	311,740
04-05	280,105	29,888	309,993

05-06	285,253	36,515	321,768
06-07	288,102	31,618	319,720
07-08	288,298	22,165	310,463
08-09	261,910	16,397	278,307
09-10	272,443	15,880	288,323
10-11	287,211	17,709	304,920

Notes:

(1) Solid Waste is defined in LMC and includes garbage, refuse, commercial and industrial waste, demolition debris, building refuse, including those designated as Special Waste. MSW tons also include tonnages received from the North 48th Street Transfer Station.

(2) Biosolids were disposed of at the Bluff Road Landfill for the first 4 years of landfill operation. After fiscal year 92-93, biosolids were diverted from landfill disposal via a land application program.

The Bluff Road MSW Landfill has accepted for disposal an average of 279,500 tons per year of solid waste over the last five years; based on 365 days per year, this is the equivalent of 764 tons per day.

Forecasts of future waste quantities sent to disposal were developed as part of the Needs Assessment using the unit waste generation rates and the LPlan 2040 projected population growth rates. These forecasts represent the waste quantities baseline expected to be generated and disposed from the Planning Area under the status quo. There are three major factors that have the potential to significantly influence the estimates of local disposal capacity needed:

- Regulatory changes related to management of biosolids and coal combustion residues (CCR)
- Changes in waste export quantities or imports
- Changes in diversion practices

Changes in recycling or diversion rates can also affect future disposal needs. The current management practices for diversion of CCR and biosolids are being evaluated by USEPA. Changes to regulations regarding biosolids have the potential to require this material to be directed to a disposal site rather than land application. If all the biosolids from the Planning Area were directed to the Bluff Road MSW Landfill starting in 2013, it would represent an increase of 11 percent in projected disposal quantities at this landfill. Disposing of biosolids in the Bluff Road MSW Landfill would theoretically decrease the overall life of the landfill by approximately 2 years.

Currently, CCR materials are largely recycled with only a small portion disposed of in a dedicated landfill (monofill). While regulatory changes may reduce the quantities that can be diverted, it is not currently projected that CCR materials will be directed to the Bluff Road MSW Landfill; as such, changes in regulation may reduce diversion rates but are not anticipated to affect the remaining MSW landfill capacity in the Planning Area.

Waste exports represent approximately 5 percent of the MSW generated in the Planning Area that might otherwise be sent to the Bluff Road MSW Landfill. If waste exports were to cease, the increase in disposal tonnage would reduce the life of the landfill by approximately 1 year.

As part of the planning process, the City may examine options to accept waste from outside Lancaster County for disposal; if this were to occur, there may be benefits to the City, but the increase in disposal quantities would reduce the overall life of the landfill(s).

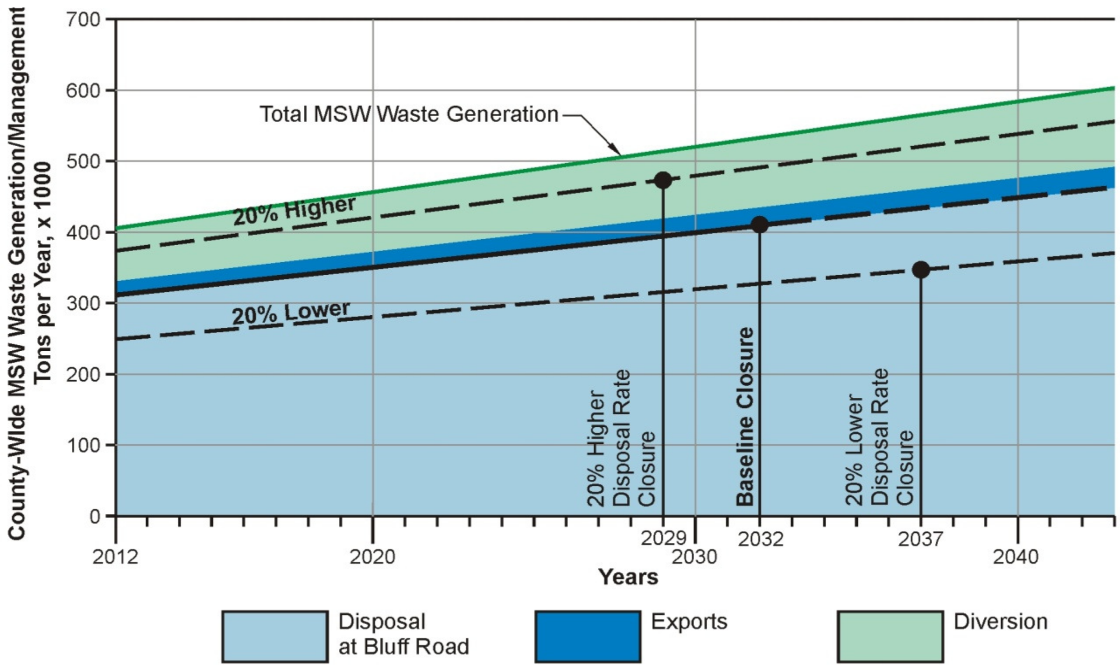
A separate technical paper discusses construction and demolition waste disposal. The North 48th Street Construction and Demolition Waste Landfill is projected to reach capacity in 2030. The quantities of C&D wastes currently delivered to the North 48th Street Construction and Demolition Waste Landfill are equivalent to approximately 20 to 30 percent of the solid waste disposed in the Bluff Road MSW Landfill. If the North 48th Street Construction and Demolition Waste Landfill were to close and the C&D waste were to be directed to the Bluff Road MSW Landfill, it would negatively affect the life of the Bluff Road MSW Landfill.

As further discussed in the Needs Assessment and technical paper on Yard Waste, approximately 3 percent of the material currently disposed of at the Bluff Road MSW Landfill was estimated to be yard waste. However, approximately 8 percent of the total MSW generation in the Planning Area is yard waste (which includes wood wastes). Of the total yard waste and wood waste collected in the Planning Area, two-thirds is currently estimated to be managed by composting and chipping (through the City's composting operation). If all of the yard waste and wood waste materials collected in the County were directed to the Bluff Road MSW Landfill starting in 2013, it would decrease the overall life of the landfill by approximately 1 year.

While it is possible to examine a wide range of factors that might affect variations in waste generation (i.e., changes in projections for population and employment growth) or improvements in waste reduction and recycling, the results of any such assumptions are still only assumed values. As such, in the Needs Assessment the baseline estimates for landfilled waste at the Bluff Road MSW Landfill have been shown with an upper and lower range of plus or minus 20 percent. The upper range may reflect one or more of the following considerations: 1) higher than projected employment, 2) higher than projected increases in population, 3) lower than projected exports, 4) imports, 5) disposal of biosolids, or 6) disposal of increased quantities of yard waste. The lower range may reflect one or more of the following considerations: 1) lower than projected employment, 2) lower than projected increases in population, 3) increased diversions, or 4) increased waste exports. If technologies such as waste combustion (e.g., waste-to-energy (WTE) or conversion technologies) are employed, they have the potential to reduce the volume of the waste requiring landfilling substantially. While not all waste would typically be managed by a WTE facility, for typical MSW, the combustion process can be expected to reduce the volume of the combusted fraction by 90 percent. The benefits of WTE and other waste conversion technologies are discussed in a separate technical paper on Waste Conversion Technologies. Depending on when such a system would be assumed to be placed in service, it could substantially increase the life of the MSW landfill or delay the siting of a new facility.

The results of these variations from the baseline are shown graphically in Figure 2. Figure 2 is intended to further illustrate the effects of uncertainties on the overall life of the City's Bluff Road MSW Landfill. The baselines and banding are also intended to be used to as a basis of evaluation for future diversion options and to illustrate how future programs may affect disposal capacity (existing or required).

Figure 2 - Waste Generation and Management Baseline



Program (Facility/System) Options

A municipal solid waste landfill is basically a facility designed to store or entomb materials discarded by society. While considered least preferred on the USEPA management hierarchy it is often the lowest cost per ton option to manage the solid waste that is not otherwise diverted from disposal by source reduction, recycling, composting or other resource recovery alternatives. Among the principal concerns with landfills is that the waste placed in these facilities is a heterogeneous mix of organic and inorganic materials that may, to varying degrees, be chemically or biologically active and as such, if not properly managed represent a risk to human health and the environment (short- and long-term). The USEPA states "Modern landfills are well-engineered facilities that are located, designed, operated, and monitored to ensure compliance with federal regulations. Solid waste landfills must be designed to protect the environment from contaminants which may be present in the solid waste stream. The landfill siting plan—which prevents the siting of landfills in environmentally-sensitive areas—as well as on-site environmental monitoring systems—which monitor for any sign of groundwater contamination and for landfill gas—provide additional safeguards. In addition, many new landfills collect potentially harmful landfill gas emissions and convert the gas into energy." (reference: http://www.epa.gov/osw/nonhaz/municipal/landfill.htm, retrieved 10/10/2012) Municipal solid waste landfills must comply with the federal regulations in 40 CFR Part 258 (Subtitle D of the Resource Conservation and Recovery Act (RCRA)), and in Nebraska must comply with the Nebraska Department of Environmental Quality (NDEQ) Title 132 – Integrated Solid Waste Management Regulations. Federal and state standards address such matters as:

- Location restrictions.
- Liners requirements.
- Leachate collection and removal systems. Leachate is the liquid that comes in contact with solid waste.
- Operating practices.
- Groundwater monitoring requirements.
- Closure and post-closure care requirements.
- Corrective action provisions.
- Financial assurance.

These standards were established in the early 1990s and have served as the basis for modern landfills and facility permitting for more than two decades.

For purposes of this technical paper landfills are addressed as a necessary facility (solid waste management option) to deal with the waste materials not otherwise diverted or recovered. As such, options are discussed in terms of providing secure long-term waste disposal capacity, via landfilling, when the existing permitted Bluff Road MSW Landfill facility reaches capacity and there remains solid waste that requires disposal.

Because of the real and perceived issues associated with MSW landfills, it is often quite costly and difficult to establish (site/permit) a new MSW landfill. Siting a new landfill often involves a mix of social, political, environmental, regulatory, technical and economic considerations and can take many years; some efforts to site new landfills (or expand existing sites) across the U.S. have been unsuccessful and contribute to a continuing trend toward fewer landfills in the U.S.

Well before the City's Bluff Road MSW Landfill reaches capacity it will be necessary to identify a suitable disposal site for landfilling waste generated in the Planning Area. The basic options for long-term capacity include the following:

- New City MSW landfill
- New Private MSW landfill
    - In the County
    - Outside the County

While the City may be able to own or participate in a regional disposal facility outside Lancaster County, this options is not evaluated in this technical paper. While it is also possible to find and secure such capacity in remote locations it is generally anticipated that such an option would result in higher costs to residents, businesses, industries, and institutions within the City and County; this assumption of higher costs is based on added transportation costs and higher disposal costs (see Table 1, which shows that landfills in proximity to Lincoln have higher disposal rates).

As noted above, one of the LPlan 2040 guiding principles related to solid waste is:

> "*The City policy of … public ownership, operation and financing of disposal … will continue during the planning period*."

LPlan 2040 also identifies that:

> "planning for expansion of the Bluff Road Landfill on City owned property just east of the existing site is anticipated…The expansion into this additional landfill area has not been permitted by the State of Nebraska Department of Environmental Quality."

One of the LPlan 2040 "Strategies for Solid Waste Management" is to:

> "Discourage future urban acreage developments in the area around the Bluff Road landfill and LES power generating operations, which are located between N. 56th and N. 84th Streets. Acreage development could impact the current and future landfill and LES operations."

Figure 1 shows the location of the land east of the current Bluff Road MSW Landfill. Unless these policies, guiding principles and strategies change a new City owned and operated MSW landfill has been determined to be the option of choice. As such, the remainder of this technical paper focuses on issues that will need to be addressed to secure the existing land east of the current Bluff Road MSW Landfill for future use.

Options Evaluation

The issues that will need to be addressed in undertaking the development of a new MSW landfill (including on land adjacent to the existing site) in the future may include:

- Siting/location restrictions
- Permitting requirements and restrictions
- Infrastructure requirements
- Cost of services and funding mechanism
- Implementation schedule

One significant challenge that exists with future landfill construction and operations is the uncertainty of public policy and the always controversial process of siting a new solid waste management facility (e.g., landfill, waste-to-energy, composting, processing) or expanding a current solid waste disposal site. To protect the City's investment in the City owned land east of the existing landfill and ensure solid waste management and disposal capacity for the Planning Area beyond 2040 (the planning period), the City will likely need to consider the following proactive measures:

- Ensure that current and future land-use plans and regulations identify landfilling and solid waste management as acceptable uses or designate the use of the land currently owned by the City for such purposes.
- Pursue including "solid waste landfilling" and "solid waste processing and management" as specifically defined and approved uses in the zoning regulations.
- Obtain all zoning and land-use approvals available or necessary to allow construction and ensure the future use of this land east of the existing Bluff Road MSW Landfill as a landfill or solid waste management site (landfill, solid waste processing, or solid waste management systems and facilities).

- Obtain the local land-use (siting) approval, if necessary, to allow for permitting of the City owned land east of the existing Bluff Road MSW Landfill as a solid waste facility (landfill or solid waste processing and management).
  - Once such land-use approval is obtained, consider incorporating the City owned land east of the existing Bluff Road MSW Landfill into the next solid waste permit renewal or as a permit modification.
- Evaluate options in land-use plans and zoning rules to prevent conflicting development near the landfill boundary. One such option may be the establishment by code or ordinance of a buffer area (setback distance) for residential and commercial development around the perimeter of the current City owned land/landfill. Such a code change or ordinance establishing setbacks would need to be structured to prevent encroachment on designated City solid waste management property by residential and commercial development for some distance (e.g., 1 mile). Effective land-use/planning designations would minimize both the likelihood of off-site nuisance issues and future pressure to increase performance standards, both of which would help control long-term costs of solid waste facilities operations.
- Acquire land adjacent to the currently permitted disposal area and City owned land, especially on the north side, to ensure that no other conflicting development can occur on these lands.

At this time, the City's operations at the Bluff Road site is not considered a significant nuisance to neighbors.

If residential and commercial development is allowed to encroach on the City's existing and future solid waste facilities, the neighbors' expectations, complaints, and opposition to expansion will likely increase, and nuisance conditions that are considered to be managed in an acceptable manner by today's standards may not be tolerated in the future (e.g., the standard performance expectation will likely increase (that is, get more stringent)). As waste quantities to be managed increase (baseline projections) and the physical size of the existing Bluff Road MSW Landfill increases, the City could be further challenged to meet these higher expectations. Several methods or options can be employed to reduce potential future nuisance concerns and meet higher expectations; however, most of these will result in higher costs of operations.

Siting/location restrictions: The existing Bluff Road MSW Landfill and City owned land east of the landfill are currently zoned in a manner which allows their use for buildings or premises owned by any governmental entity, including local, county, state, federal governmental units and their subdivisions, and in some form of public use. Land to the north of these City owned parcels is generally zoned Agriculture. A review of City and County zoning regulations identifies a Waste Management and Extractive Services Use Group, which includes landfills as one potential special use (permit required).

Consistent with NDEQ Title 132 regulations, the City will need to demonstrate that any future landfill site meets certain regulatory "location restrictions". These restrictions are intended to ensure that landfills are built in suitable geological areas away from seismic faults, wetlands, flood plains, or other restricted areas. Given the proximity to the existing Bluff Road MSW Landfill it is generally anticipated that the land to the east would satisfy these requirements; however, specific investigations and analysis will ultimately be required as part of the permitting process.

Permitting: Both state and local regulations govern the siting, construction and operations of a MSW disposal site. NDEQ regulations relative to siting, design, construction and operations are quite specific and detailed. The Bluff Road MSW Landfill currently complies with these NDEQ Title 132 and related regulations; any future municipal solid waste disposal site will require subsequent NDEQ approval and involve public notice and potentially a public hearing before such approval is granted.

Infrastructure requirements: Essential infrastructure associated with a landfill is currently present at the Bluff Road MSW Landfill. Development of a new landfill to the east of the existing Bluff Road MSW Landfill will require added infrastructure including additional roadway construction, electrical power, and likely a new water source. Additional infrastructure will also be necessary for storm water management, leachate handling and management, and landfill gas management. While these all have associated costs, none of these are consider barriers and are typically part of a new landfill development.

Cost of services and funding mechanism: For purposes of this technical paper it was assumed that continued City ownership and operations of the MSW landfill will remain cost competitive with other disposal facilities in the region (currently the lowest published tipping fee). The cost of funding long-term site development is assumed to be a continued part of the City's capital improvement program and would continue to be paid for by the tipping fees assessed for use of the landfill. In the past the City has used a revenue bond to fund capital improvements at the Bluff Road MSW Landfill; it is assumed this option will remain viable in the future. Revenue bonds imply the repayment of bonds will be from revenues generated from landfill tipping fees as opposed to general obligation bonds which are generally repaid from tax levies.

Implementation Schedule: From a national perspective the timeframe associated with siting and permitting a new municipal solid waste landfill is often 5 to 10 years and not all such efforts are successful. For this reason providing long-term capacity via the City owned land adjacent to the existing Bluff Road MSW Landfill is important to securing system capacity through 2040 and beyond. Proactive measures associated with zoning, permitting and buffer areas are considered important to meeting the guiding principles associated with the LPlan 2040 and Solid Waste Plan 2040.

Options Evaluation

Consistent with the evaluation criteria developed for use in the Solid Waste Plan 2040, municipal solid waste disposal options have been evaluated based on the following considerations:

- **Waste Reduction/Diversion:** Landfilling is used to manage the municipal solid waste not otherwise diverted from disposal. As such, landfills are not a waste reduction or diversion program. While increased exportation of MSW would extend the life of the existing Bluff Road MSW Landfill it will not reduce the amount of waste generated that requires disposal in a landfill.

- **Technical Requirements:** The current baseline projections for MSW disposal indicate that the existing Bluff Road MSW Landfill will reach capacity in approximately 2032 and as such additional disposal capacity will be required before the end of the planning period. Landfills provide a high degree of flexibility in accommodating changes in waste volumes and composition. The technology utilized for modern landfills is considered reliable and has been deemed protective of the environment by the USEPA. The issues, concerns and uncertainty often discussed in association with a landfill is what risks the site may pose beyond the required 30-year monitoring and maintenance period after site closure.
- **Environmental Impacts:** Landfills are currently considered a necessity in the solid waste management system to protect human health and the environment. MSW landfills are designed and monitored to ensure protection of groundwater. As organic waste decomposes in a landfill it produces air emissions that may include criteria pollutants and greenhouse gases (principally, methane and carbon dioxide (CO_2)). Air emissions (principally particulate (dust) and CO_2) also result from facility operations and vehicles that use the landfill. An active landfill gas collection system can capture and destroy a significant portion of the methane and can also be used to generate electricity and off-set emissions from other sources. The City currently has a contract with Lincoln Electric System (LES) to use the majority of the landfill gas collected at the Bluff Road MSW Landfill to generate electricity. Also, because not all waste placed in a landfill degrades, landfills also serve to sequester carbon (help reduce a portion of the greenhouse gas generation) that might otherwise result in air emissions. Monitoring of surface water and groundwater is a routine part of landfill operations and permit compliance requirements. Such monitoring is used to demonstrate that constructed and operational controls are performing properly. As discussed under a separate technical paper on Household Hazardous & Conditionally Exempt Small Quantity Generator (Small Business) Hazardous Waste, state and federal law allows limited amounts of hazardous or toxic substances to be managed through landfill disposal. The Special Waste Permit program, household hazardous waste collection events, and conditionally exempt small quantity generator program administered by the Lincoln-Lancaster County Health Department serves to further limit and reduce the toxicity of the waste currently disposed of in the Bluff Road MSW Landfill.
- **Economic Impacts:** The initial construction, ongoing expansion and capping of completed areas of the Bluff Road MSW Landfill require significant capital expenditures. These are typically paid for from the tipping fee charged to site users. Residents and business pay landfill costs through their refuse collection fees. The City establishes landfill tipping fees based the necessity for capital and operating expenditures. The City has also used a revenue bond, repaid from tipping fees, to fund capital improvements. The tipping fee at the Bluff Road MSW Landfill is currently $21 per ton of which approximately $14 is used for landfill design, construction, operations and related expenses. The City collects $7 per ton from refuse haulers as an Occupation Tax. If the overall quantities of municipal solid waste sent to landfill disposal (in the County or exported) deceases the revenue generated by the Occupation Tax will also decrease (assuming the rate remains unchanged); significant reductions in Occupation Tax revenues will result in less funds available to subsidize/incentivize other non-disposal or waste diversion programs. Landfills are not considered a tool for economic development; however low cost disposal can be a consideration in attracting new businesses.

- **Implementation Viability:** Implementing new landfills in the Planning Area or elsewhere can be difficult and complex. Siting a new landfill often involves a mix of social, political, environmental, regulatory, technical and economic considerations and can take many years; some efforts to site new landfills across the U.S. have been unsuccessful and have contributed to a continuing trend toward fewer landfills in the U.S. Locally, proactive efforts in designating land for solid waste management and associated land-use planning and zoning can aide in siting new disposal capacity. While the City has currently adopted a policy of "public ownership, operation and financing of disposal and selected integrated solid waste management services" during the planning period, it may still require significant efforts to successfully develop and permit additional disposal capacity during this planning period. The City currently owns land that appears suitable for use as a future landfill but additional approvals will be required before it can be firmly established as a usable site. Such approval will require approval by the NDEQ as well as local approvals. From a national perspective the timeframe associated with siting and permitting a new sanitary landfill is often 5 to 10 years. As such implementation efforts will need to begin well in advance of the projected closure of the current Bluff Road MSW Landfill.

Relationship to Guiding Principles and Goals

As it relates to the Guiding Principles and Goals of the Solid Waste Plan 2040, maintaining the availability of a local MSW landfill would be applicable as further noted below:

- **Emphasize the waste management hierarchy**: while landfilling may be considered a lesser preferred option on the waste management hierarchy it nonetheless is recognized as an option where reduction, reuse, and recycle (composting) do not eliminate all municipal solid wastes from disposal. As noted in the USEPA website, "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."
- **Encourage public/private partnerships**: Currently the City's role in providing a MSW disposal site is based on fulfillment of state law and LMC as well as LPlan 2040 which states "*The City policy of privately owned and operated collection of refuse and recyclables coupled with public ownership, operation and financing of disposal … will continue during the planning period*."
- **Ensure system capacity:** Additional MSW disposal capacity is anticipated to be required before the end of the planning period. As such, a strategy to establish and ensure additional disposal capacity for municipal solid wastes will likely need to be component of the Solid Waste Plan 2040. The capacity that would be created within the City owned property east of the current Bluff Road MSW Landfill has not been estimated; however, it is reasonable to assume that under the baseline projections of waste generation and disposal needs that this site would provide disposal capacity beyond the end of the planning period.
- **Engage the community:** Public education to engage the community will be important to sustaining existing diversion programs and to implement alternatives to land disposal

of municipal solid wastes (e.g., source reduction, recycling, composting). Additionally, any effort to modify the current permit for the Bluff Road MSW Landfill or to develop a new disposal site will create additional opportunities for public comment. In terms of obtaining added landfill capacity an informed public will be important to understanding why approval of such a facility is necessary.

- **Embrace sustainable principles:** While resource recovery, reuse, waste minimization and waste diversion from landfills are often key aspects of sustainability programs, for waste that is not otherwise diverted, or does not provide a viable resource recovery option, landfills can serve to protect the environmental and minimize social impacts. Low cost disposal for waste can also have economic benefits. Recycling and energy recovery would be management alternatives of a higher priority, but may need to be balanced with economic and environmental factors.

Summary

Until such time as waste is eliminated landfills will be a necessary part of an integrated solid waste management strategy. State law and City policies and regulations make the City responsible for ownership, operation and financing of disposal facilities during the planning period.

Baseline estimates of waste generation and disposal, even under the scenario of a 20 percent decrease in disposal rates, suggests that the existing Bluff Road MSW Landfill will reach capacity prior to 2040 (the end of the planning period). Consistent with the Guiding Principle of the Solid Waste Plan 2040 to ensure system capacity it is anticipated that the Solid Waste Plan 2040 will need to include action items related to the establishment of additional MSW disposal capacity. One option indentified as anticipated in the LPlan 2040 is to plan "for expansion of the Bluff Road Landfill on City owned property just east of the existing site…The expansion into this additional landfill area has not been permitted by the State of Nebraska Department of Environmental Quality." A proactive program, including the following options may be of significant value in securing such land for future solid waste management uses:

- Ensure that current and future land-use plans and regulations identify landfilling and solid waste management as acceptable uses or designate the use of the land currently owned by the City for such purposes.
- Pursue including "solid waste landfilling" and "solid waste processing and management" as specifically defined and approved uses in the zoning regulations.
- Obtain all zoning and land-use approvals necessary to allow construction
- Evaluate options in land-use plans and zoning rules to prevent conflicting development near the landfill boundary.
- Acquire land adjacent to the currently permitted disposal area and City owned land, especially on the north side, to ensure that no other conflicting development can occur on these lands.

The capacity that would be created within the City owned property east of the current Bluff Road MSW Landfill has not been estimated; however, it is reasonable to assume that under the baseline projections of waste generation and disposal needs that this site would provide added disposal capacity beyond the end of the planning period.

Construction and Demolition Waste Disposal

Overview

Construction and demolition (C&D) waste is not clearly defined to be part of "solid waste" in Nebraska Revised Statues 81-1502. As further discussed in the technical paper on *Construction and Demolition Material Recycling*, there are many definitions and material types that are considered C&D waste. Consistent with the explanations in that technical paper, waste material resulting from new construction, remodeling or the demolition of existing structures is referred to as C&D waste. C&D wastes may be managed in wide variety of manners. C&D wastes may be landfilled at either municipal solid waste (MSW) landfills or C&D landfills; portions of the waste stream may be used as "fill" or processed (often by grinding) to create materials suitable for replacement of sands and gravels. Portions of the material from C&D projects may also be recovered for reuse, including metal, wood and certain building materials.

Nebraska Department of Environmental Quality (NDEQ) defines C&D waste as including "fill material", but "fill", which consists only of one or more of the following: sand, gravel, stone, soil, rock, brick, concrete rubble, asphalt rubble or similar material can be used for erosion control, erosion repair, channel stabilization, landscaping, roadbed preparation or other land improvement and under those conditions is exempt from NDEQ regulation. Materials which are defined as "fill" and used for the above purposes do not require regulatory reporting or disposal in a permitted facility.

NDEQ Title 132 – Integrated Solid Waste Management Regulations (Title 132), Chapter 5 establishes the "Criteria for Construction and Demolition Waste Disposal Area". C&D processing facilities in Nebraska are required to have a permit from the NDEQ, but are only required to report quantities of processed material sent to disposal (not total quantities processed or quantities diverted).

Current Programs

The North 48th Street Construction and Demolition Waste Landfill, 5101 North 48th Street, is located on City owned land. The North 48th Street site is approximately 450 acres in size; the permit renewal documents (the current permit to operate expires in July 2013) identifies 121 acres for disposal of C&D wastes. Key features of the North 48th Street site are shown on Figure 1. The City's North 48th Street Construction and Demolition Waste Landfill is located above an area where municipal solid waste (MSW) from Lincoln and Lancaster County were disposed, starting in approximately 1956; in 1990 this site discontinued taking all wastes with the exception of demolition debris and building rubbish (now referred to as construction and demolition waste). These materials were used and continue to be used to create a "dome" or "hill" above certain areas of the historic MSW landfill. The disposal of C&D waste is creating positive grades to ensure surface water drains to the ditches that convey water away from the historic MSW, rather than allowing the surface water to infiltrate (or percolate) through the historic MSW. The North 48th Street Construction and Demolition Waste Landfill has accepted an average of 76,600 tons per year of C&D waste over the last five (5) years. Lincoln's C&D Waste Landfill is more restrictive on waste types accepted than other C&D Landfill operations permitted by NDEQ. The City has limited the acceptance of large quantities of certain C&D wastes such as paper, gypsum board, rubber, plastics, shingles and asphalt. The City has also prohibited painted and treated wood. The amount of acceptable wood debris has generally been restricted to approximately 50 percent per each load. The imitations result in a portion of the construction and demolition waste being disposed of at the Bluff Road Landfill.

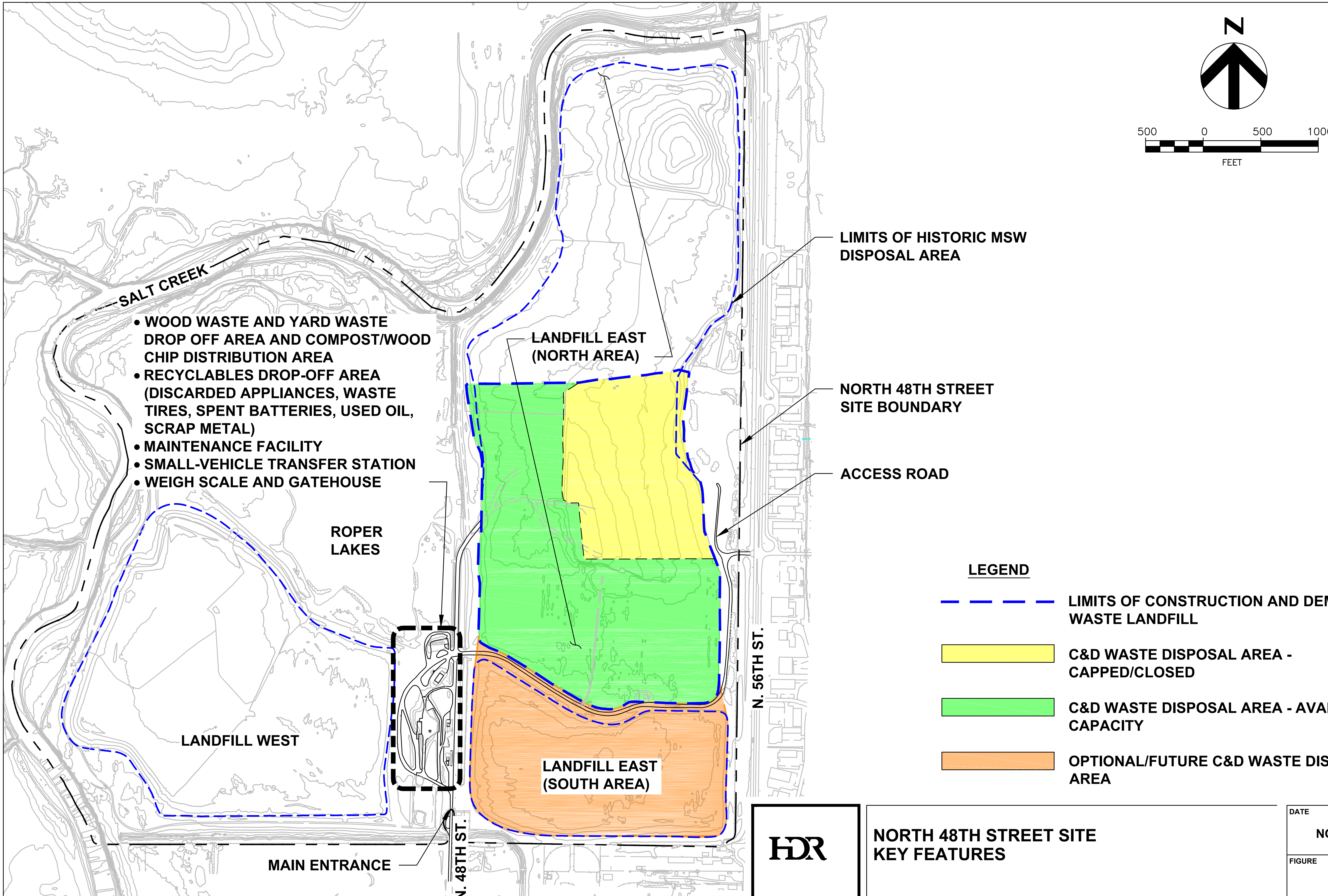
The closed MSW landfill areas at the North 48th Street site require ongoing maintenance and the City continues to monitor groundwater and for landfill gas migration associated with historic use of the site for MSW disposal.

A portion of the C&D waste stream generated in the City and County is exported to other disposal sites in the region, but the quantities exported are not required to be reported. Table 1 provides a summary of historical C&D tonnages disposed at the North 48th Street Construction and Demolition Waste Landfill. The decline in tonnage since 1994 is largely attributed to increased levels of recycling of the concrete, asphalt and metal from C&D waste streams as well as waste exports.

Table 1 –C&D Waste Landfilled at North 48th Street (Tons)

FY	Tons
88-89	138,676
89-90	121,701
90-91	147,563
91-92	202,380
92-93	269,201
93-94	356,764
94-95	167,405
95-96	112,379
96-97	92,868
97-98	88,341
98-99	101,682
99-00	86,760
00-01	61,305
01-02	88,227
02-03	78,649
03-04	98,174
04-05	76,746
05-06	86,159
06-07	75,491
07-08	89,446
08-09	53,185
09-10	59,119
10-11	76,337
11-12	105,130

Facilities on the North 48th Street site include the scale, scale house, transfer station, recyclables drop-off area, lawn waste/wood waste drop-off area, appliance de-manufacturing facility, maintenance building, and storage building. The storage building located within the C&D waste disposal area will eventually be demolished when filling progresses to this area.



LEGEND

- LIMITS OF CONSTRUCTION AND DEMOLITION WASTE LANDFILL
- C&D WASTE DISPOSAL AREA - CAPPED/CLOSED
- C&D WASTE DISPOSAL AREA - AVAILABLE CAPACITY
- OPTIONAL/FUTURE C&D WASTE DISPOSAL AREA

HDR

NORTH 48TH STREET SITE KEY FEATURES

DATE: NOV. 2012

FIGURE: 1

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The permit renewal document identifies the total C&D air space capacity as approximately 2.26 million cubic yards (CY) (excluding the final cover). Based on projections contained in Section 5 of the Needs Assessment, this landfill is expected to reach capacity in approximately 2030; the remaining air space capacity is approximately 1.2 million CY (excluding final soil cover).

Generation and Diversion

C&D waste generation has fluctuated over the years based on numerous factors, including economic activity, exports, diversion and other factors, but has been relatively stable over the past 10 years. C&D waste generation is not directly related to population growth; therefore, it is more difficult to predict C&D waste generation. For projection purposes in the Needs Assessment, the average growth rate has been assumed to be equal to the population growth rates reflected in Table 2-2 “Trend Series”.

The North 48th Street Construction and Demolition Waste Landfill has accepted for disposal an average of 76,600 tons per year over the past 5 years; based on 365 days per year, this is equivalent to 210 tons per day.

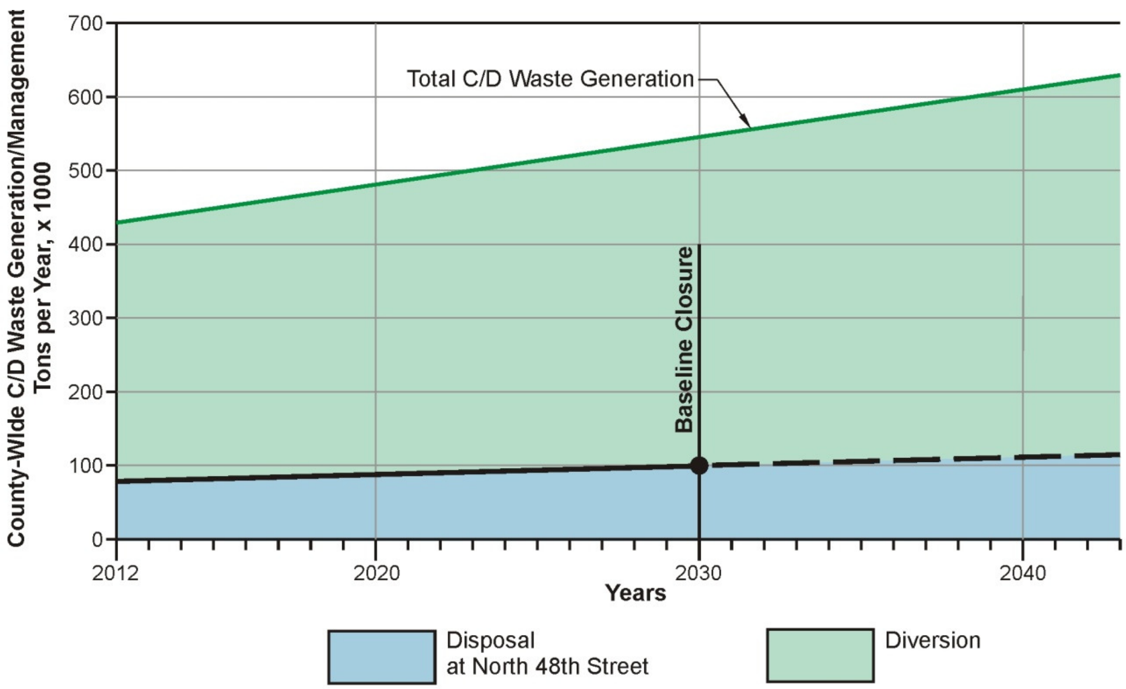
Forecast of future waste quantities sent to disposal were developed as part of the Needs Assessment using the unit waste generation rates and the LPlan 2040 projected population growth rates. These forecasts represent the waste quantities baseline expected to be generated and disposed from the Planning Area under the status quo. The major factors that have the potential to significantly influence the estimates of local disposal capacity needed are:

- Changes in waste export quantities or imports
- Changes in diversion practices (increases or decreases)

As noted in the Need Assessment, it was estimated that 75 percent of C&D waste generated in 2011 was diverted from disposal; over the past 10 years the diversion rate for C&D materials has averaged greater than 80 per percent. Changes in recycling or diversion rates can affect future disposal needs. As part of the planning process, the City may examine options to accept waste from outside Lancaster County for disposal; if this were to occur, there may be benefits to the City, but the increase in disposal quantities would reduce the overall life of the landfill(s).

While it is possible to examine a wide range of factors that might affect variations in waste generation (i.e., changes in projections for population, economic changes) or changes in waste reduction and recycling, the results of any such assumptions are still only assumed values. As such, the Needs Assessment established the baseline estimates for C&D waste generated and landfilled. Figure 2 further illustrates the projected need for C&D waste landfill capacity and the overall life of the City’s North 48th Street Construction and Demolition Waste Landfill, as currently permitted. The baseline is also intended to be used to as a basis of evaluation for future diversion options and to illustrate how future programs may affect disposal capacity (existing or required).

Figure 2 – C&D Waste Generation and Management Baseline



The North 48th Street Construction and Demolition Waste Landfill is projected to reach capacity in 2030. The quantities of C&D wastes currently delivered to the North 48th Street Construction and Demolition Waste Landfill are equivalent to approximately 20 to 30 percent of the solid waste disposed in the Bluff Road MSW Landfill. A new facility for handling C&D wastes will need to be identified during the planning period to avoid directing C&D wastes to the Bluff Road MSW Landfill. Directing C&D waste to the Bluff Road MSW Landfill would negatively affect the life of the Bluff Road MSW Landfill.

Program (Facility/System) Options

A C&D waste landfill is basically a facility designed to store or entomb materials discarded by society. While considered least preferred on the waste management hierarchy it is often the lowest cost per ton option to manage the C&D waste that is not otherwise diverted from disposal by source reduction, recycling, or other alternatives.

There are no federal regulations specific to C&D waste landfills; however, the NDEQ has specific regulations that govern the siting, design and construction, operations, closure and post-closure care of Construction and Demolition Waste Disposal Areas. Site location restrictions are similar to those for a MSW landfills; construction, operations, closure and post-closure care standards are generally less stringent due to the limitations on the types of waste that can be accepted at a C&D waste landfill.

For purposes of this technical paper a C&D waste landfill is addressed as a necessary facility (solid waste management option) to deal with materials not otherwise diverted or recovered. As such, options are discussed in terms of providing secure long-term waste disposal capacity when the existing, permitted North 48th Street Construction and Demolition Waste Landfill reaches capacity and there remains C&D waste that requires disposal.

Because of the real and perceived issues associated with landfills, it is often quite costly and difficult to establish (site/permit) a new landfill. Siting a new landfill often involves a mix of social, political, environmental, regulatory, technical and economic considerations and can take many years. Well before the City's North 48th Street Construction and Demolition Waste Landfill reaches capacity it will be necessary to identify a suitable disposal site for landfilling C&D waste generated in the Planning Area. The basic options for long-term disposal capacity include the following:

- Expansion of the existing C&D waste landfill
- New City C&D waste landfill
  - At the Bluff Road Site
  - At a new site
- New Private C&D waste landfill
  - In the County
  - Outside the County
- A new co-located C&D waste and MSW landfill

Due to transportation costs and resulting higher cost to C&D waste generators, the City's cooperation in a regional facility outside Lancaster County is not consider or evaluated further in this technical paper.

A LPlan 2040 guiding principle related to solid waste is:

> "*The City policy of … public ownership, operation and financing of disposal … will continue during the planning period*."

LPlan 2040 also identifies under the Solid Waste Disposal program, that

> *"a new facility for handling construction and demolition debris will need to be sited during the planning period, starting in 2014. While this landfill should be completed and closed, the N. 48th Street transfer station and recycling areas are scheduled to remain."*

While the remaining life may allow the starting point for siting/expansion evaluation to change, unless these policies, guiding principles and strategies change a new City owned and operated C&D waste landfill has been determined to be the option of choice. As such, the remainder of this technical paper focuses on issues that will need to be addressed in developing a new facility for future use.

The current operation on the North 48th Street site involves placing C&D waste on the area of the site know as Landfill East. As shown in Figure 1, Landfill East is divided into two areas by an access road. Both the northern and southern portions of Landfill East were used for MSW disposal between 1956 and 1990. From a conceptual perspective, if the southern portion of Landfill East were filled with C&D waste in a pattern similar to the north area this would provide approximately 1 million CY of capacity or roughly the equivalent of 13 to 15 additional years of disposal capacity. In the future the southern portion of Landfill East will require maintenance to address insufficient drainage and water ponding issues associated with historic use as an MSW disposal site, similar to what is currently being done with the filling of C&D waste on the northern portion of Landfill East. Such future maintenance can be done with clean soil, “fill”, or C&D waste material. If C&D waste material is to be used the area will require permitting, likely as a lateral expansion of the existing Construction and Demolition Waste Disposal Area.

The option of combining the C&D waste and MSW in a single landfill is considered technically viable. However, because each landfill type has separate design and construction, operations, closure and post-closure care requirements it may be more appropriate to view them as two separate facilities on the same or contiguous sites rather than a combined facility. Such a concept may have advantages as it relates to siting and operations requirements, but will also require a larger site area. Because the cost of operating a C&D waste landfill is substantially less than an MSW landfill it is not anticipated that future options will include sending C&D waste to a MSW landfill.

A soil borrow area (see Figure 3) identified at the south end of the current Bluff Road MSW Landfill property will be excavated as part of the future construction, operations and capping of that landfill. The area is suitably located, based on current NDEQ criteria, to serve as a C&D waste landfill. Based on planned excavation and conceptual filling grades, this site would provide an approximately 1 million CY of disposal capacity or roughly the equivalent of 13 to 15 additional years of disposal capacity. Significant advantages associated with this location are:

- the current site is permitted as a landfill (although the borrow area is not permitted to accept waste)
- the site is owned by the City and properly zoned
- the site would almost certainly meet the location requirements in NDEQ Title 132
- the site has most of the necessary infrastructure.

While no disadvantages have been identified, the disposal area is in close proximity to Interstate 80 and visual considerations, including screening, would need to be address during the site evaluation and permitting process. As with any other site it would also require local approval from elected officials.

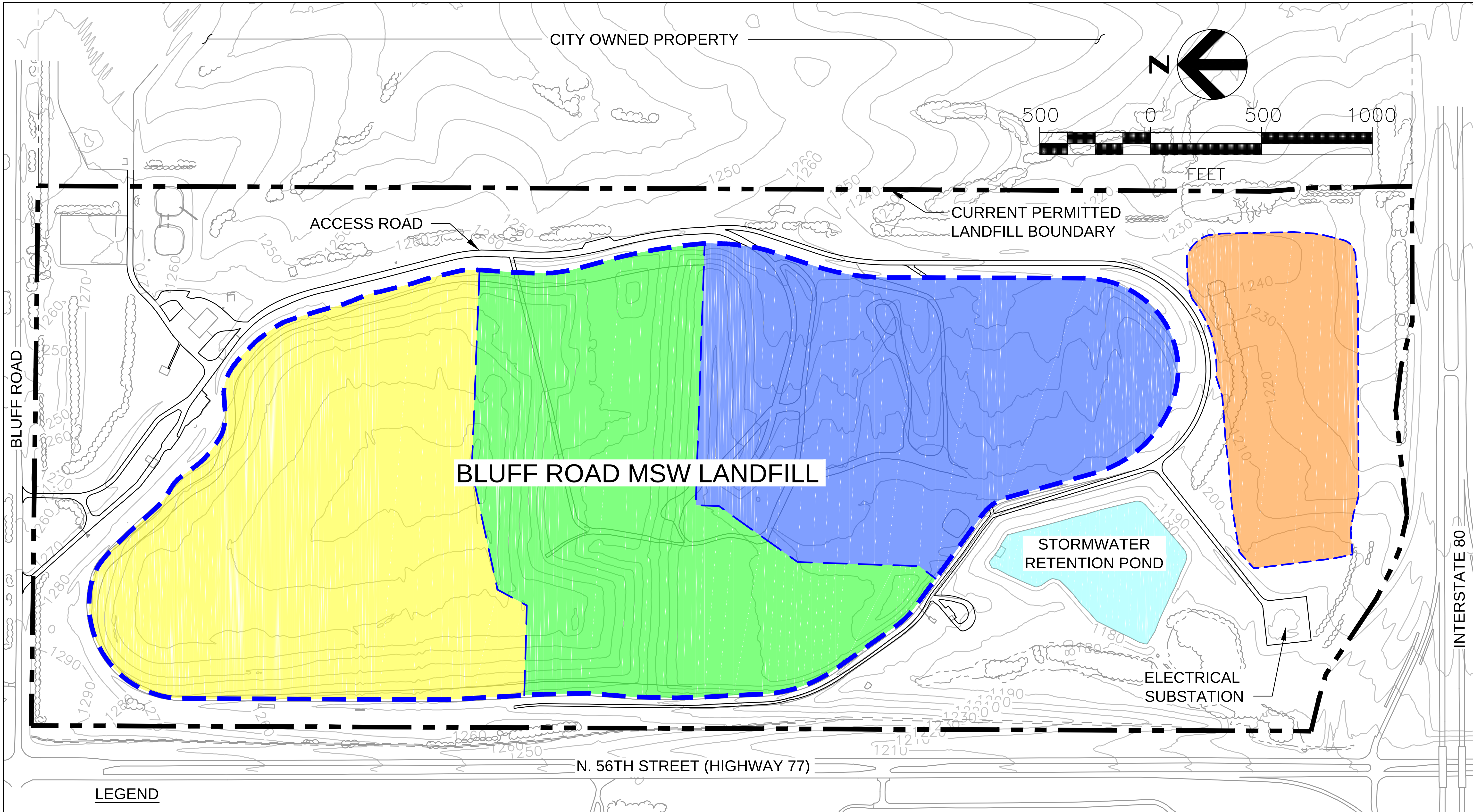
Options Evaluation

The core issues to be addressed in undertaking a lateral expansion of the existing North 48th Street Construction and Demolition Waste Landfill or using the soil borrow area on the south end of the Bluff Road site include the following:

- Permitting requirements and restrictions
- Local approval by elected officials.

One significant challenge that exists with any future landfill construction and operations is the uncertainty of public policy and the always controversial process of siting a new solid waste management facility or expanding a current solid waste disposal site.

For the purposes of this technical paper, the balance of the discussions focus on considerations associated with implementing a new C&D waste landfill on land that is not a part of the City’s currently permitted disposal sites.



LEGEND

- LIMITS OF PERMITTED MSW DISPOSAL AREA
- CAPPED/CLOSED MSW DISPOSAL AREA
- ACTIVE MSW DISPOSAL AREA
- CURRENT SOIL BORROW AREA AND PERMITTED MSW DISPOSAL AREA
- FUTURE SOIL BORROW AREA AND OPTIONAL/FUTURE C&D WASTE DISPOSAL AREA

HDR

OPTIONAL/FUTURE C&D WASTE DISPOSAL AREA
BLUFF ROAD SITE

DATE: NOV. 2012

FIGURE: 3

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In addition to the core issues listed above, establishing a new City owned C&D waste landfill will require the City to address the following:

- Identification and possibly acquisition of the required land
- Siting/location restrictions
- Permitting requirements and restrictions
- Infrastructure requirements
- Cost of services and funding mechanism
- Implementation schedule

The identification and acquisition of land for a new C&D landfill will encounter opposition and may be one of the more complex aspects of developing a new site. Assuming such an effort is successful, the City will need to consider the proactive measures, similar to the considerations addressed in the paper on Municipal Solid Waste Disposal, including the following:

- Ensure that current and future land-use plans and regulations identify landfilling and solid waste management as acceptable uses.
- Pursue including "solid waste landfilling" and "solid waste processing and management" as specifically defined and approved uses in the zoning regulations.
- Obtain the local land-use (siting) approval, if necessary, to allow for permitting of the selected parcel of land as a solid waste facility (landfill or solid waste processing and management).
- Evaluate options in land-use plans and zoning rules to prevent conflicting development near the landfill boundary. One such option may be the establishment by code or ordinance of a buffer area (setback distance) for residential and commercial development around the perimeter of a City-owned land/landfill.

At this time, the City's operations at the North 48th Street site are not considered a significant nuisance to neighbors. However, in siting a new landfill the issues that may be raised include both neighborhood nuisance considerations and property value impacts. From a logistical perspective the site chosen will, at a minimum, need to meet locational/siting criteria set forth in NDEQ Title 132; neighbors and community members may want additional siting considerations or mitigations to be considered.

Siting/location restrictions: Consistent with current practices the City owned land will likely need to be zoned Waste Management and Extractive Services Use Group. A review of City and County zoning regulations identifies a Waste Management and Extractive Services Use Group, which includes landfills as one potential special use (permit required).

Consistent with NDEQ Title 132 regulations, the City will need to demonstrate the future landfill site meets certain regulatory "location restrictions". These restrictions are intended to ensure that landfills are built in suitable geological areas away from seismic faults, wetlands, flood plains, or other restricted areas. Specific investigations and analysis will ultimately be required as part of the permitting process to demonstrate that these conditions are being satisfied or addressed.

Permitting: Both state and local regulations govern the siting, construction and operations of a C&D waste disposal site.

NDEQ regulations relative to siting, design, construction and operations are quite specific and detailed. The current North 48th Street Construction and Demolition Waste Landfill and Bluff Road Municipal Solid Waste Landfill comply with these NDEQ Title 132 and related regulations. Any new permit (or any lateral expansion of the existing site) will require public notice and potentially a public hearing before approval is granted by NDEQ.

Infrastructure requirements: Essential infrastructure will need to be provided and would generally include suitable roadways, electrical power, a water source and storm water management provisions. Site security fencing will be required and screening should be anticipated. While these all have associated costs, none are consider barriers to a new C&D waste landfill and are typically part of a new landfill development.

Cost of services and funding mechanism: For purposes of this technical paper it was assumed that continued City ownership and operation of the C&D waste landfill will remain cost competitive with other disposal facilities in the region. The cost of funding long-term site development is assumed to be a continued part of the City's capital improvement program and would continue to be paid for by the tipping fees assessed for use of the C&D waste landfill. The City has used a revenue bond to fund capital improvements at the Bluff Road Landfill; it is assumed this option would be viable in the future for a C&D waste landfill. Revenue bonds imply the repayment of bonds will be from revenues generated by tipping fees as opposed to general obligation bonds which are repaid from tax levies.

Implementation Schedule: From a national perspective the timeframe associated with siting and permitting a new municipal solid waste landfill is often 5 to 10 years and not all such efforts are successful. While the timeframe for siting and permitting a new C&D waste landfill should be somewhat shorter, there remains no certainty that such an effort would be successful. For this reason a proactive program involving land acquisition, zoning, permitting, and site designation is considered appropriate. Such proactive measures may also include establishment of site buffers and associated infrastructure.

Options Evaluation

Consistent with the evaluation criteria developed for use in the Solid Waste Plan 2040, C&D waste disposal options have been evaluated based on the following considerations:

- **Waste Reduction/Diversion**: Landfilling is used to manage the C&D waste not otherwise diverted from disposal. As such, landfills are not a waste reduction or diversion program. While exportation of C&D waste would extend the life of the existing City C&D waste landfill it will not reduce the amount of waste disposed.
- **Technical Requirements**: The current baseline projections for C&D waste disposal indicate that the existing North 48th Street Construction & Demolition Waste Landfill will reach capacity in approximately 2030 and as such additional disposal capacity will be required before the end of the planning period. The technology utilized for C&D waste landfills is considered reliable and has been deemed protective of the environment by the NDEQ. The issues, concerns and uncertainty often discussed in association with a C&D waste landfill is what risks the site may pose to neighbors.

- **Environmental Impacts**: Landfills are currently considered a necessity in the solid waste management system to protect human health and the environment. As organic waste decomposes in a C&D waste landfill it produces air emissions that may include criteria pollutants and greenhouse gases (principally, methane and carbon dioxide (CO_2)). Air emissions (principally particulate (dust) and CO_2) also result from facility operations and vehicles that use the C&D waste landfill. An active landfill gas collection system is not commonly used in C&D waste landfills, due to the limited amount of readily degradable organic waste that they accept. Also, because not all waste placed in a C&D waste landfill degrades, C&D waste landfills also serve to sequester carbon (help reduce a portion of the greenhouse gas generation) that might otherwise result in air emissions. Monitoring of surface water is a routine part of C&D waste landfill operations and a permit compliance requirement. Such monitoring is used to demonstrate that constructed and operational controls are performing properly.
- **Economic Impacts**: The initial construction and capping of completed areas of a C&D waste landfill require significant capital expenditures. These are typically paid from the tipping fee charged to site users. C&D waste generators generally pay costs associated with the C&D waste landfill through tipping fees either directly or through the firm hauling the C&D waste material to the disposal site. The City establishes landfill tipping fees based on the necessity for capital and operating expenditures. The tipping fee at the North 48th Street Construction and Demolition Waste Landfill is $4 per ton for large vehicles hauling and disposing of C&D waste material, or $4 per load for small vehicles hauling and disposing of C&D waste material. Currently C&D waste hauled to the North 48th Street Construction and Demolition Waste Landfill is exempt from the Occupation Tax. C&D waste landfills are not considered a tool for economic development; however low cost disposal can be a consideration in attracting new businesses.
- **Implementation Viability**: Implementing new landfills in the Planning Area or elsewhere can be difficult and complex. Siting a new landfill often involves a mix of social, political, environmental, regulatory, technical and economic considerations and can take many years; some efforts to site new landfills across the U.S. have been unsuccessful. Locally, proactive efforts in designating land for solid waste management and associated land-use planning and zoning can aide efforts to identify locations for new disposal capacity. While the City has currently adopted a policy of "public ownership, operation and financing of disposal and selected integrated solid waste management services" during the planning period, it may still require significant efforts to successfully develop and permit additional disposal capacity during this planning period. From a national perspective the timeframe associated with siting and permitting a new municipal solid waste landfill is often 5 to 10 years. While the timeframe for siting and permitting a new C&D waste landfill should be somewhat shorter, there remains no certainty that such an effort would be successful. For this reason a proactive program involving land acquisition, zoning, permitting, and site designation is considered appropriate.

Relationship to Guiding Principles and Goals

As it relates to the Guiding Principles and Goals of the Solid Waste Plan 2040, maintaining the availability of a local C&D waste landfill would be applicable as further noted below:

- **Emphasize the waste management hierarchy**: while landfilling may be considered a lesser preferred option on the waste management hierarchy it nonetheless is recognized as an option where reduction, reuse, and recycling do not eliminate all C&D wastes from disposal.
- **Encourage public/private partnerships**: Currently the City's role in providing a C&D waste disposal site is based on fulfillment of LMC as well as LPlan 2040 which states "The City policy of privately owned and operated collection of refuse and recyclables coupled with public ownership, operation and financing of disposal … will continue during the planning period."
- **Ensure system capacity**: Additional C&D waste disposal capacity is anticipated to be required before the end of the planning period. As such, a strategy to establish and ensure additional disposal capacity for C&D wastes will likely need to be component of the Solid Waste Plan 2040.
- **Engage the community**: Public education to engage the community will be important to implement alternatives to land disposal of C&D wastes. Additionally, any effort to purchase land and site a new landfill will create additional opportunities for public comment. In terms of obtaining added landfill capacity an informed public will be important to understanding why approval of such a facility is necessary.
- **Embrace sustainable principles**: While resource recovery, reuse, waste minimization and waste diversion from landfills are often key aspects of sustainability programs, for waste that is not otherwise diverted, or does not provide a viable alternate use or resource recovery option, landfills can serve to protect the environmental and minimize social impacts. Low cost disposal for C&D waste can also have economic benefits. Recycling and reuse would be alternatives of a higher priority, but may need to be balanced with economic and environmental factors.

Summary

Until such time as waste is eliminated landfills will be a necessary part of an integrated solid waste management strategy. City policies and regulations make the City responsible for ownership, operation and financing of disposal facilities during the planning period.

Baseline estimates of waste generation and disposal suggests that the existing North 48th Street Construction & Demolition Waste Landfill will reach capacity prior to 2040 (the end of the planning period). Consistent with the Guiding Principle of the Solid Waste Plan 2040 to ensure system capacity it is anticipated that the Solid Waste Plan 2040 will need to include action items related to the establishment of additional C&D waste disposal capacity. A proactive program including the following options may be of significant value in securing such land for future solid waste management uses:

- Ensure that current and future land-use plans and regulations identify landfilling and solid waste management as acceptable uses.
- Pursue including “solid waste landfilling” and “solid waste processing and management” as specifically defined and approved uses in the zoning regulations.
- Obtain the local land-use (siting) approval, if necessary, to allow for permitting of the selected parcel of land as a solid waste facility (landfill or solid waste processing and management).
- Evaluate options in land-use plans and zoning rules to prevent conflicting development near the landfill boundary. One such option may be the establishment by code or ordinance of a buffer area (setback distance) for residential and commercial development around the perimeter of a City-owned land/landfill.

Bioreactor/Bio-Stabilization Technologies

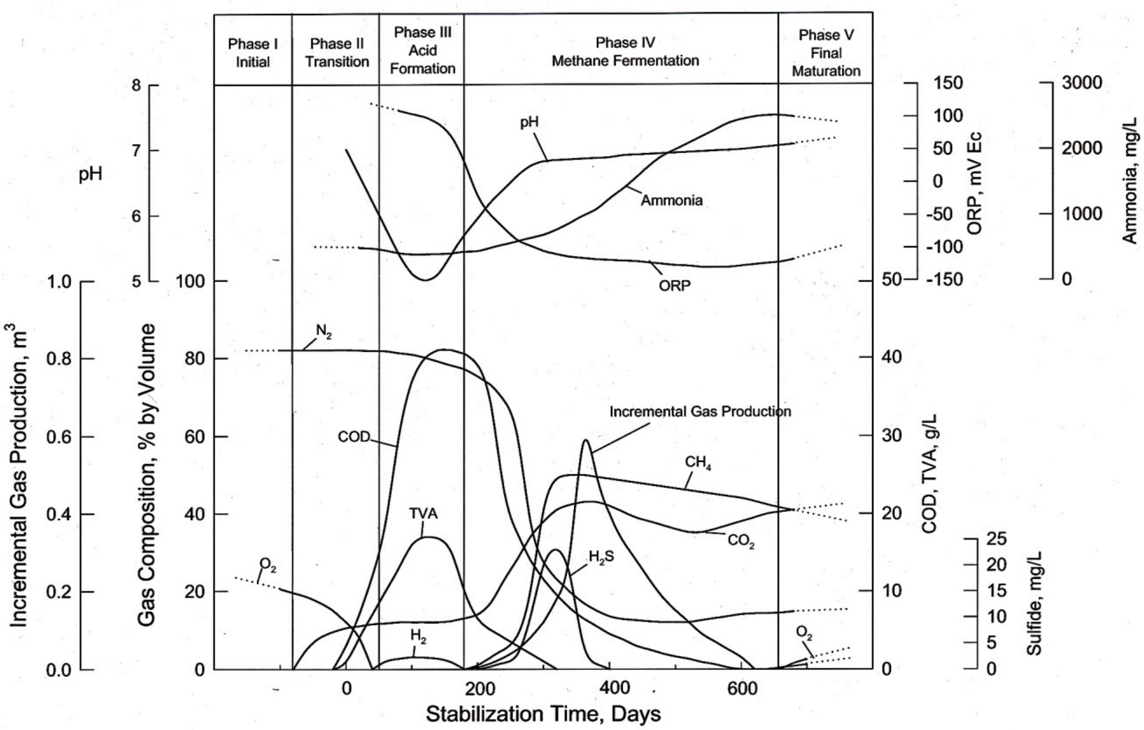
Overview

A fundamental concern often associated with conventional municipal solid waste (MSW) landfills is that they remain biologically active for many decades. Conventional landfilling practices are often referred to as a "dry tomb" approach, in which design and operation attempt to minimize liquids entering the waste mass. The waste mass in a conventional landfill is largely organic matter that degrades slowly due to the limited amount of moisture and oxygen in the landfill. Long-term biologic activity can be considered a risk to the environment as a result of landfill gas emissions and potential for release of leachate to the groundwater. Leachate is defined as the liquid that has passed through or emerged from solid waste. To address the concerns with slow rates of degradation and long-term risk to the environment, research, starting in the early 1990's, began to look at alternative to accelerate the decomposition and stabilization process. One such concept that gained significant attention became defined as a "bioreactor landfill". The purpose of this paper is to examine the concept of rapid biological stabilization using the approach sometimes referred to as a bioreactor landfill, or more generically as bio-stabilization. In essentially all instances the acceleration of the decomposition process involves adding large volumes of liquid to the waste mass, typically via leachate recirculation and the addition of liquids from other off-site sources.

The U.S. Environmental Protection Agency (USEPA) defines a bioreactor landfill as "a landfill designed and operated in a controlled manner with the express purpose of accelerating the degradation of municipal solid waste (MSW) inside a landfill containment system." The USEPA also states that "A bioreactor landfill operates to rapidly transform and degrade organic waste. The increase in waste degradation and stabilization is accomplished through the addition of liquid and air to enhance microbial processes. This bioreactor concept differs from the traditional "dry tomb" municipal landfill approach." The Solid Waste Association of North America (SWANA) has attempted to further clarify the definition of a bioreactor landfill as "any permitted Subtitle D landfill or landfill cell where liquid or air is injected in a controlled fashion into the waste mass in order to accelerate or enhance bio-stabilization of the waste." A bioreactor landfill is more than a landfill that simply recirculates leachate. USEPA generally establishes 40 percent moisture content of the waste as the trigger level for specific bioreactor landfill regulations.

Under the Resource Conservation and Recovery Act (RCRA) (40 CFR 257 and 258 (Subtitle D), published in 1991; fully effective 1993) and Nebraska Department of Environmental Quality (NDEQ) Title 132 – Integrated Solid Waste Regulations (Title 132), landfills have been designed and operated for more than a two decades to minimize liquids entering the waste mass during construction, operation, and following closure of the landfill. The philosophy behind Subtitle D regulations was to minimize leachate generation, and as a result landfill gas (LFG) production, by limiting the liquids contacting the wastes. Federal and state regulations allow for the recirculation of leachate and condensate from LFG collection systems into landfills with liners constructed as prescribed by regulation. Both federal and state regulations prohibit the disposal of bulk liquids in conventional landfills. Because of these regulatory restrictions, bioreactor landfills cannot be considered without special approval by state and federal regulators and then only as demonstration projects. The bulk liquids restriction or "dry tomb" landfill concept discourages liquid from entering the landfill and thus inhibits the decomposition and stabilization of the waste mass. Bioreactor landfills, attempt to enhance stabilization and accelerate the decomposition process through the addition of liquid. Researchers describe waste stabilization proceeding in five sequential and distinct phases (Pohland and Harper, 1986[1]). As shown in Figure 1, the first phase is waste placement. Leachate and LFG generation rates and characteristics vary with each phase and reflect the biodegradation processes taking place within the landfill. In a large-scale landfill, the waste stabilization phases overlap as waste is disposed over a long period of time. The changes in key parameters are shown graphically in Figure 1. Table 1 provides information on key leachate parameters and the ranges in concentration associated with each phase of biodegradation. "Complete stabilization is when the waste material no longer breaks down into byproducts that are released into the environment" (Walsh and O'Leary, 2002[2]). A bioreactor landfill accelerates the waste stabilization process but does not affect the sequence of the stabilization phases.

Figure 1 – Stabilization Characteristics Within a Bioreactor Landfill Unit



The point at which waste degradation is sufficiently complete to consider a landfill "stable" is not clearly defined, and due to the heterogeneous nature of the waste and imperfect biodegradation processes in a large waste mass, a conventional MSW landfill will never reach theoretical stability. Leachate quality and LFG generation are deemed the best indicators of the

[1] Pohland, F.G., and S.R. Harper. 1986. Critical Review and Summary of Leachate and Gas Production From Landfills. EPA/600/2-86/073, U.S. Environmental Protection Agency, Cincinnati

[2] Walsh, Patrick and Philip O'Leary. June 2002. "Bioreactor Landfill Design and Operation," Waste Age, pages 72 -76.

stabilization process. There is no universally accepted definition of stabilization related to landfills; some researchers and organizations have suggested that sufficient stabilization occurs when gas production reaches relatively low rates (less than 5 percent of peak value) and leachate strength remains low (COD below 1000 mg/l, BOD below 100 mg/l) (Reinhart[3]).

Table 1 –Leachate Concentration Ranges as a Function of Stabilization

Parameter	Phase II Transition	Phase III Acid Formation	Phase IV Methane Formation	Phase V Final Maturation
BOD, mg/l	100 – 10,000	1000 – 57,000	600 – 3400	4 – 120
COD, mg/l	480 – 18,000	1500 – 71,000	580 – 9760	31 – 900
TVA, mg/l as Acetic Acid	100 – 3000	3000 – 18,800	250 – 4000	0
BOD/COD	0.23 – 0.87	0.4 – 0.8	0.17 – 0.64	0.02 – 0.13
Ammonia, mg/l-N	120 – 125	2 – 1030	6 – 430	6 – 430
pH	6.7	4.7 – 7.7	6.3 – 8.8	7.1 – 8.8
Conductivity, µmhos/cm	2450 – 3310	1600 – 17,100	2900 – 7700	1400 – 4500

Source: Reinhart and Townsend, 1998[4]. Pohland and Harper, 1986

BOD = Biochemical Oxygen Demand
COD = Chemical Oxygen Demand
TVA = Total Volatile Acids
Mg/l = milligrams per liter
µmhos/cm = micomhos per centimeter (a measure of electrical conductivity)
pH is a measure of acidity
Phase I is the phase where waste is initially placed in the landfill

Current Programs

The technical paper on Municipal Solid Waste Disposal describes the City's current program for managing MSW at the Bluff Road Landfill. The City's current operations include recirculation of leachate and condensate into the landfill for disposal purposes; during periods of heavy precipitation leachate is also hauled off-site for disposal at the City's Northeast Wastewater Treatment Plant. The volume of leachate generated in any given year is a function of several factors, but is largely a function of annual precipitation. As shown in Table 2, annual quantities of leachate generated vary significantly from year to year.

Table 2 –Leachate Generation at the Bluff Road Landfill

Fiscal Year	Total Gallons	Gallons Recirculated	Gallons Treated at City's Northeast Treatment Plant
2007-08	774,241	418,000	356,241
2008-09	631,159	403,750	227,409
2009-10	2,443,207	216,750	2,226,457
2010-11	1,166,035	600,290	565,745
2011-12	1,136,653	969,296	167,357
Totals	6,151,295	2,608,086	3,543,209
Yearly Average	1,230,259	521,617	708,642

[3] Reinhart, D. Active Municipal Waste Landfill Operations: A Bioreactor, National Risk Management Research Laboratory, Office of Research and Development, USEPA.
[4] Reinhart, D., and T. Townsend. 1998. Landfill Bioreactor Design and Operation. Lewis Publishers, New York.

By permit and regulation the City's Bluff Road Landfill is not allowed to take bulk liquids. Landfill operations are designed to prevent stormwater run-on from entering the disposal area and to minimize infiltration of stormwater that falls on the landfill but does not contact the waste; storm water that comes in contact with waste percolates through the waste mass and is collected and managed as leachate.

Generation and Diversion (see Topic Outline)

Typically, liquids additions have been reported to range between 20 and 60 gallons of liquids per ton of waste to bring the moisture content in landfills up to bioreactor levels (Fickes, 2004[5]). It is estimated approximately 50 gallons of liquid per ton of waste would need to be added to obtain a moisture content of 40 percent in the waste mass at the Bluff Road Landfill.

The Bluff Road Landfill accepts an average of 278,000 tons of waste per year, based on the amount of waste accepted over the past five fiscal years. Assuming the need to add approximately 50 gallons of liquid per ton of waste, approximately 14 million gallons per year (approximately 38,000 gallons per day) would need to be added to achieve a full bioreactor condition. It would take a substantial amount of liquid from sources other than leachate generated on-site to conceivably reach bioreactor conditions; the total leachate generated represents only 8.5 percent of the total number of gallons required annually to reach the threshold to operate as a bioreactor landfill. While capturing of incident precipitation may be one source, the supply must be relatively uniform to match waste deliveries and so it would be reasonable to assume that moisture required for a bioreactor operation must come from off-site sources. Obtaining a steady supply of liquids is one reason very few bioreactor landfills are developed, especially in non-costal locations.

An alternate concept is to accept large volumes of liquid for disposal by absorption. This concept would involve less liquid than required to meet the definition of a bioreactor but still take advantage of the added moisture to help accelerate decomposition/stabilization.

Regulatory Considerations

The USEPA provided for pilot projects and a special permit program that would allow for further research and development of the bioreactor landfill technology.

Research, Development, and Demonstration Permits for Municipal Solid Waste Landfills: On March 22, 2004, the final rule of the Research, Development, and Demonstration (RD&D) Permits for Municipal Solid Waste Landfills (40 CFR 258.4, amendment to Subpart A) was published in the Federal Register. The rule became effective on April 21, 2004 and allows owners and operators of MSW landfills to obtain a RD&D permit in approved states to research, develop and demonstrate new methods of managing solid waste in landfills. NDEQ has been granted approval to administer the RD&D rules in Nebraska.

RD&D permits provide a variance from existing landfill requirements for run-on control systems, liquids restrictions, and final cover requirements. The RD&D permit rule contains the following requirements for bioreactor operations:

[5] Fickes, Michael. May 2004. "Bioreactors and Beyond" *Waste Age*.

- No increased risk to human health and the environment
- Demonstration of the following:
  - Groundwater protection
  - Maintenance of no more than 30-cm depth of leachate head on the liner
  - Methods for determining liquid seepage from the landfill
  - Landfill stability
    - Methods for determining geotechnical stability
    - Description of the methods for determining actual or potential movement of waste
- LFG collection and control pursuant to the Clean Air Act (CAA) – National Emissions Standards for Hazardous Air Pollutants (NESHAP) (40 CFR 63, Subpart AAAA)
- Monitoring results submitted at least annually

The RD&D rule allows for a 3-year permit, with permit extensions for a maximum of four 3-year permit terms (12 years total).

Clean Air Act – NESHAP: A MSW landfill must meet the requirements in 40 CFR 63, Subpart AAAA, National Emission Standards for Hazardous Air Pollutants (NESHAP) for Municipal Solid Waste Landfills, and in 40 CFR 60, Subpart Cc, Emission Guidelines (EG), or Subpart WWW, New Source Performance Standards (NSPS) for Municipal Solid Waste Landfills. Besides establishing NESHAPs for MSW landfills, Subpart AAAA requires all landfills defined by Section 63.1935 to meet the Emission Guidelines/New Source Performance Standards (EG/NSPS) requirements of 40 CFR 60, Subpart Cc or Subpart WWW,

The Bluff Road MSW Landfill is currently required to meet the EG requirements of 40 CFR 60, Subpart Cc. If future operations were conducted as a bioreactor, additional landfill gas controls would be required.

Program (Facility/System) Options

There are several different bioreactor landfill technologies currently being tested and demonstrated in the U.S. and throughout the world, including the following:

- Anaerobic
- Aerobic
- Sequential anaerobic-aerobic (hybrid)
- Facultative
- Biological permeable cover
- Flushing

These technologies are further described in Appendix 1. It is beyond the scope of this technical paper to recommend one technology over another. The most commonly used bioreactor or rapid stabilization technologies have been the anaerobic (waste decomposition in the absence of oxygen), aerobic (waste decomposition in the presence of oxygen), and hybrid (aerobic conditions in the upper landfill sections and anaerobic conditions in the lower landfill sections). In addition to full scale bioreactor landfill technology there may be alternatives that do not meet the accepted definition of a bioreactor landfill but attempt to achieve many of the same outcomes; these alternatives may be considered forms of bio-stabilization efforts. Examples of bio-stabilization techniques include:

- Leachate recirculation,

- Liquids addition (below bioreactor levels),
- In-vessel anaerobic digestion (discussed in the technical paper on Waste Conversion Technologies)

Bioreactor technology is an evolving approach to managing MSW landfills. Research into bioreactors began in earnest in the late 1990s. The exact number of landfill projects in the US is unknown; a 2004 estimate identified approximately 20 full-scale bioreactor demonstration projects are under construction, in startup, or in the early stages of operation (O'Brien, 2004[6]).

The potential benefits of full-scale bioreactor (and to a less extent bio-stabilization) operations include the following:

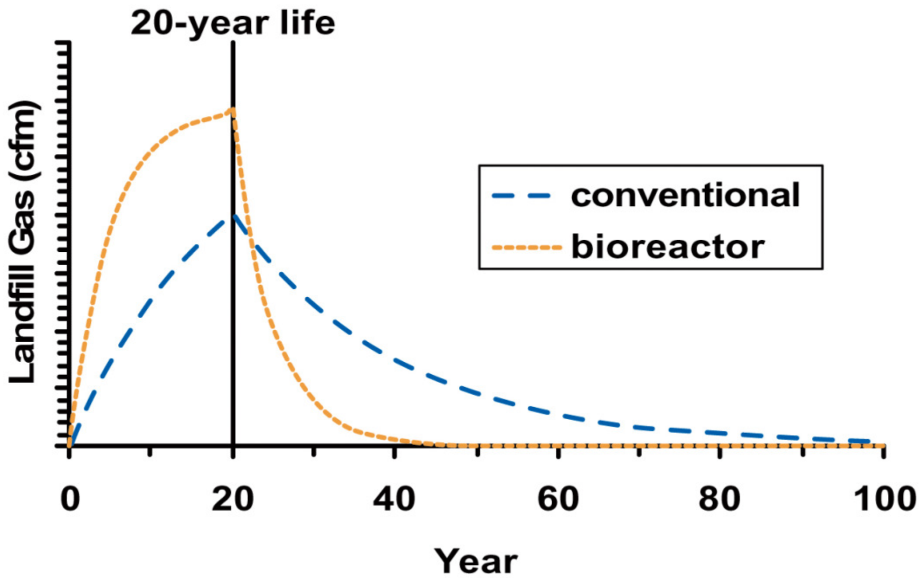
- Recovered landfill airspace, which effectively extends landfill life.
  - Retrofitted existing landfill cells are estimated to recover 15 to 30 percent of MSW landfill airspace (Hater, 2003).
  - New construction cells are estimated to recover 30 to 50 percent of MSW landfill airspace (Hater, 2003).
- Increased revenue opportunities; both for long-term waste disposal and short-term liquids disposal.
- Landfill stability in less than the 30-year post-closure care period.
- Reduced long-term pollution potential associated with leachate and LFG.
- Eliminated (or reduced) off-site leachate treatment/disposal costs.
- Improved leachate quality as the waste stabilizes.
- More landfill-gas-to-energy potential (short-term).
  - Greater LFG generation rate earlier in the life of the landfill. Research suggests that LFG generation rate is 2 to 10 times the rate associated with conventional landfills.
  - Significantly reduced LFG generation rate 10 years after closure, with potential reduction to post-closure LFG collection and monitoring costs (see Figure 3).

With leachate recirculation and limited liquids addition (less than full bioreactor operation), several of these benefits may also be realized but to a lesser degree. As noted above, later retrofitting of landfill cells may extend landfill life by 15 to 30 percent (versus 30 to 50 percent for new landfill cells). For Midwest landfills, including the Bluff Road Landfill, recirculation of leachate and limited additions of moisture from other off-site sources may be more commonly used for liquids disposal (disposal by absorption) as opposed to rapid stabilization of the landfill.

Each bioreactor technology requires moisture additions, which can include leachate, biosolids, and/or other acceptable liquids. Bioreactor landfill technology and bio-stabilization techniques accelerate the biological decomposition of organic wastes by optimizing the conditions necessary for their decomposition. In general, the optimum conditions for waste decomposition include waste moisture content of 35 to 45 percent by weight and temperatures between 120 ºF and 160 ºF.

[6] O'Brien, Jeremy K. 2004. "The Solid Waste Manager's Guide to the Bioreactor Landfill." *MSW Management, MSW Elements*

Figure 3 – Modeled Behavior of Conventional and Bioreactor Landfills



Source: Recreated from graphic in Waste Management presentation to NDEQ, 2003.

Options Evaluation

Bioreactor landfills are technically viable, with many benefits but with limits to their applicability. Site specific aspects that may limit applicability of the bioreactor technology can include:

- Insufficient quantities of liquids
- Absence of consistent sources of liquids
- Absence of an active gas collection system (note: Bluff Road Landfill has an active gas collection system, but currently only in closed areas of the landfill).
- The landfill owner's preference to avoid additional bioreactor construction costs and operational issues
- An abundance of landfill airspace and available land in the region at a low capital cost.
- Neighborhood concerns with odor

If the City of Lincoln were to consider the bioreactor landfill technology now or in future landfill construction, the issues that would need to be addressed include:

- Risk
- Regulatory compliance and permitting
- Design evaluation (calculations) and facility features (required for permit approval)
- Construction considerations (liquids storage/handling/distribution equipment and monitoring systems)
- Liquid quantities, sources and storage requirements
- Operational changes (including monitoring and record keeping)
- Optimizing site life
- Post-closure (care and duration)
- Costs implications (initial costs, increased operating costs, cost recovery, added revenues)
- Managing odors and emissions

Additionally, NDEQ has maintained that any facility permitted under the RD&D rules should have a research purpose and have suggested that purpose needs to be different than bioreactor/bio-stabilization research underway in other landfills.

Typically, bioreactor landfills will cost more to construct and operate. The investment in added capital and operating costs may be off-set by fees charged for liquids disposal, added revenue (long-term) based recovered air space which can increase the overall tonnage disposed over the life of the site, and reduced long-term (post-closure) care costs, due to reduced gas generation and weaker leachate characteristics, which may translate into lower disposal rates (assumes wastewater treatment plant charges fees based on both volume and BOD and COD characteristics).

Consistent with the evaluation criteria developed for use in the Solid Waste Plan 2040, bioreactor/bio-stabilization landfill options have been evaluated based on the following considerations:

- **Waste Reduction/Diversion:** Landfilling is used to manage the waste not otherwise diverted from disposal. As such, landfills are not a waste reduction or diversion program. While bioreactor/bio-stabilization techniques would extend the life of the existing Bluff Road Landfill it will not reduce the amount of waste disposed.
- **Technical Requirements:** The bioreactor technology would likely increase the useful life of the existing and any new landfill, especially if it contains high levels of organic matter. Landfills provide a high degree of flexibility in accommodation changes in waste volumes and composition. The technology utilized for modern landfills is considered reliable and has been deemed protective of the environment by the USEPA. The issues, concerns and uncertainty often discussed in association with a landfill is what risks the site may pose beyond the required 30-year monitoring and maintenance period after site closure. The bioreactor technology targets reducing those risks by accelerating decomposition, reducing long-term landfill gas generation and improving the characteristics of the leachate, which in turn would reduce the risk for impacts to the groundwater.
- **Environmental Impacts:** Landfills are currently considered a necessity in the solid waste management system to protect human health and the environment. The bioreactor technology increases the emissions of greenhouse gases from the landfill, most notably methane and CO2, with a goal of capturing and destroying a significant portion of the methane, which can also be used to generate electricity and off-set emissions from other sources. In contrast to conventional “dry tomb” landfill strategies, bioreactor landfill technology attempts to digest organic matter as opposed to sequester carbon that might otherwise result in air emissions. Additionally, the bioreactor landfill technology attempts to reduce the toxicity of the leachate with a goal of reducing long-term risk to ground water in the event of a release to groundwater. Monitoring of groundwater is a routine part of landfill operations and a permit compliance requirement and is required to continue for 30-years after site closure. Potential health and safety aspects of a bioreactor landfill are not considered significantly different than conventional landfill technologies, but increases in landfill gas and leachate production will require added monitoring and management (added construction and operating costs).
- **Economic Impacts:** The initial construction and ongoing operation, as well as monitoring and reporting costs, will be higher than a conventional landfill. The investment in added capital and operating costs may be off-set by fees charged for

liquids disposal, added revenue (long-term) based recovered air space, reduced long-term (post-closure) care costs, increased short term gas sales revenue (assuming available market), and reduced long-term leachate disposal costs based on weaker leachate characteristics, which may translate into lower disposal rates (assumes wastewater treatment plant charges fees based on both volume and BOD and COD characteristics). These are typically paid from the tipping fee charged to site users. Residents and businesses pay landfill costs through their refuse collection fees. Landfills are not considered a tool for economic development; however the availability of the energy recovered from the landfill gas may be a consideration in attracting new businesses.

- **Implementation Viability:** Implementing the bioreactor landfill technology may be more complex than simply permitting and constructing such landfills in the Planning Area. Issues that are likely to be raised in the siting and development may include: increased costs, odors, permitting (state and local), increased traffic (if additional liquids are delivered in tanker trucks), and environmental risks. From a technical perspective a sustainable source of liquids would need to be identified; this is not considered a technology that can be used off and on as liquids are available. Currently, the maximum period for a bioreactor landfill is 12 years; there is no certain future on continued use of the bioreactor landfill technology.

Relationship to Guiding Principles and Goals

As it relates to the Guiding Principles and Goals of the Solid Waste Plan 2040, the application of the bioreactor or bio-stabilization technologies is only relevant to the maintaining the availability of a local MSW landfill as further noted below:

- **Emphasize the waste management hierarchy**: while landfilling may be considered a lesser preferred option on the waste management hierarchy it nonetheless is recognized as an option where reduction, reuse, and recycling (composting) do not eliminate all wastes from disposal. The utilization of bioreactor and bio-stabilization technologies are not specifically a part of the hierarchy except to the extent that they extend the life a landfill.
- **Encourage public/private partnerships**: Currently the City's role in providing a MSW disposal site is based on fulfillment of state law and Lincoln Municipal Code as well as LPlan 2040. The utilization of bioreactor and bio-stabilization technologies do not specifically relate to a public/private partnership.
- **Ensure system capacity:** Additional MSW disposal capacity is anticipated to be required before the end of the planning period (reference technical paper on Municipal Solid Waste Disposal). The utilization of bioreactor and bio-stabilization technologies could play a role in a strategy to establish and ensure additional disposal capacity by extending the life of existing or future disposal sites.
- **Engage the community:** Public education to engage the community will be important in any effort to modify the current landfill permit or to undertake a lateral expansion of the disposal area. The utilization of bioreactor and bio-stabilization technologies will create additional issues in the permitting process; additional research would need to determine how the public might view these techniques in the framework of permitting a new landfill or lateral expansion of the existing site. In terms of siting and obtaining added landfill capacity, an informed public will be important to understanding why approval of such a facility is necessary.

- **Embrace sustainable principles:** While resource recovery, reuse, waste minimization and waste diversion from landfills are often key aspects of sustainability programs, for waste that is not otherwise diverted or does not provide a viable resource recovery option, landfills can serve to protect the environmental and prevent social impacts. If the increased gas generation associated with these bio-stabilization technologies can be captured and the long-term liability can be reduced, then the utilization of bioreactor and bio-stabilization technologies may have some role in future landfill management. Again, this pre-supposes all of the economic and environmental challenges can be overcome.

Summary

Bioreactor and bio-stabilization technologies accelerate decomposition and stabilization of landfilled waste and have the potential to reduce long-term risks, in comparison to conventional "dry tomb" MSW landfills. They also provide an opportunity to increase the quantity of waste placed within a given landfill space. In essentially all instances the acceleration of the decomposition process involves adding large volumes of liquid from sources other than the liquids generated from the landfill operation. Both federal and state regulations prohibit the disposal of bulk liquid wastes in conventional landfills. Because of these regulatory limitations, bioreactor landfills cannot be considered without special approval by state and federal regulators, and then only as demonstration projects.

The "dry tomb" landfill concept discourages liquid from entering the landfill and thus inhibits the decomposition and stabilization of waste. Bioreactors, on the other hand, attempt to enhance stabilization through the addition of liquid and the acceleration of the degradation process.

Using the 278,000 ton per year average for waste currently being landfilled at the Bluff Road Landfill, it would take a total liquid addition of approximately 14 million gallons per year (approximately 38,000 gallons per day) to achieve a full bioreactor condition. Based on annual leachate generation rates it would take a substantial amount of liquid from other off-site sources to conceivably reach bioreactor conditions.

RD&D permits provide a variance from existing conventional landfill requirements for run-on control systems, liquids restrictions, and final cover requirements; the RD&D permit rule also contains additional requirements related to operations and monitoring. The RD&D rule allows for a 3-year research and development permit, with permit extensions for a maximum of four 3-year permit terms (12 years total).

Issues that would need to be evaluated in further considering implementation would include: potential for increased revenues, benefits of accelerating site stabilization, odor controls, increase landfill gas production, and added costs for construction and operation.

Appendix1

Bioreactor Landfill Technologies

Bioreactor landfill technology accelerates the biological decomposition of organic wastes by optimizing the conditions necessary for their decomposition. Optimal conditions for decomposition include waste moisture content of 35 to 45 percent by weight and temperatures between 120 ºF and 160 ºF.

There are several different bioreactor landfill technologies including:

- Anaerobic
- Aerobic
- Sequential anaerobic-aerobic (hybrid)
- Facultative
- Biological permeable cover
- Flushing

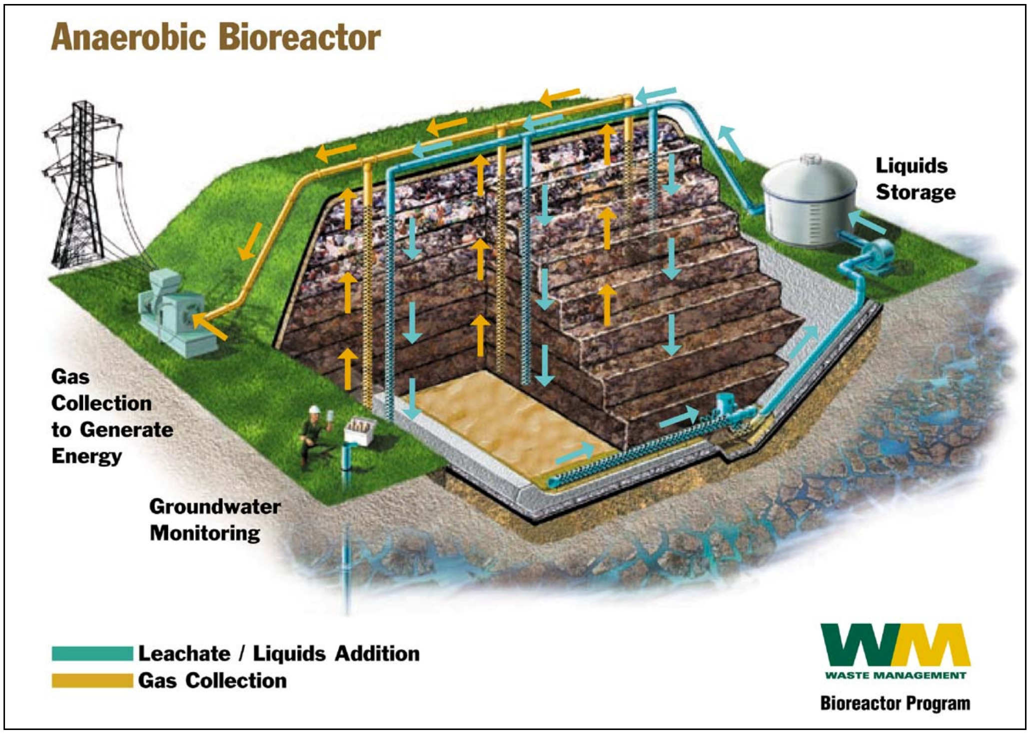
The most commonly used bioreactor or rapid stabilization technologies have been the anaerobic (waste decomposition in the absence of oxygen), aerobic (waste decomposition in the presence of oxygen), and hybrid (aerobic conditions in the upper landfill sections and anaerobic conditions in the lower landfill sections). Insufficient research exists at this time to quantitatively identify the differential percentage of airspace gained between an anaerobic, aerobic, and hybrid bioreactor. Each bioreactor technology requires liquids additions, including leachate and other acceptable liquids.

Anaerobic Bioreactor

In an anaerobic bioreactor, biodegradation of the waste occurs in the absence of oxygen and produces LFG (methane) faster than a conventional landfill, aerobic bioreactor, or hybrid bioreactor (see Figure 1). Anaerobic conditions can also produce more odors. Both LFG and odors require management.

Waste biodegradation occurs at a slower rate in the anaerobic bioreactor than the aerobic or hybrid bioreactor. Waste mass temperatures may be monitored to track the bioreactor progress toward reaching the optimum temperature range. The anaerobic bioreactor method has the most similarities to conventional landfilling, except with higher quantities of liquids addition (beyond levels achieved with leachate recirculation) and increased LFG production.

Figure 1 – Anaerobic Bioreactor



Source: Waste Management, Landfill Bioreactors: What's the Impact?, August 2003.

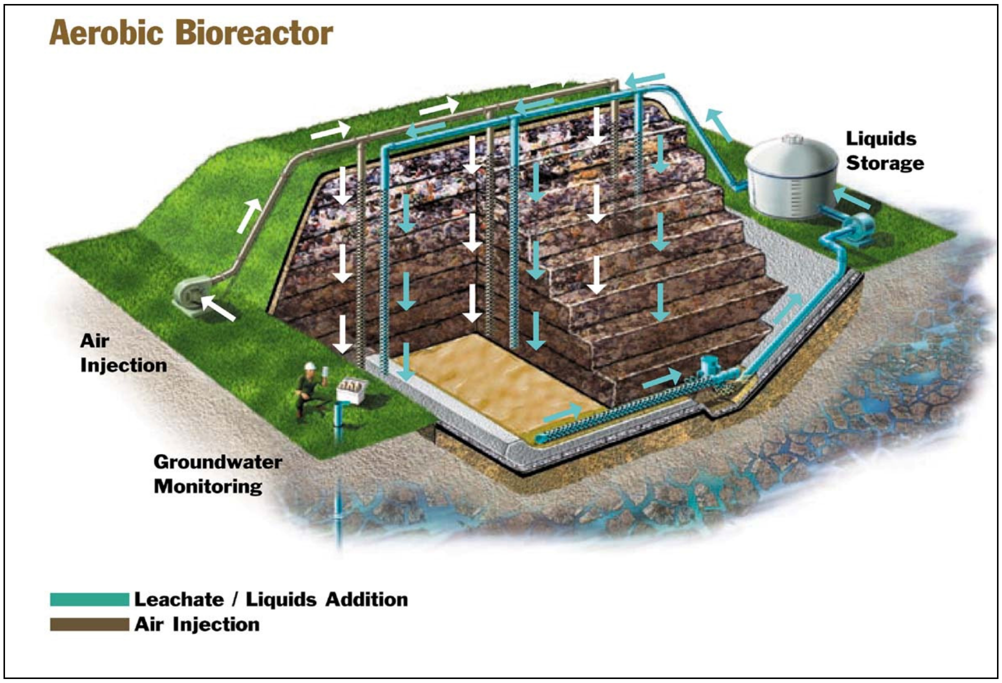
Aerobic Bioreactor

Aerobic biodegradation occurs in the presence of oxygen. In an aerobic bioreactor, air is injected into the waste mass using vertical wells and/or buried horizontal piping systems to promote the aerobic activity (see Figure 2). Similar to most well-run yard waste composting systems, aerobic reactions within a landfill provide rapid biodegradation, prolonged higher temperatures (greater than 142 ºF), reduced methane gas production, and reduced odors. The rapid waste biodegradation produces heat and, combined with the presence of oxygen injection, increases the risk for fires in the aerobic bioreactor landfill. Monitoring of waste mass temperatures is necessary to prevent fires. Aerobic conditions can be difficult to maintain uniformly in a bioreactor landfill. However, this technology provides the greatest acceleration of waste decomposition.

Sequential Anaerobic-Aerobic Bioreactor

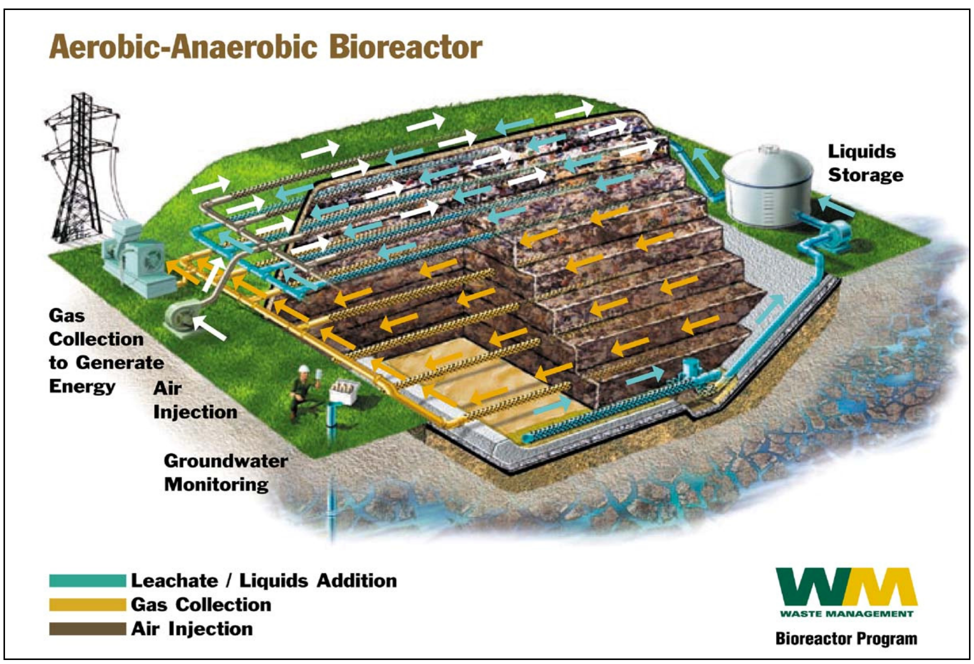
The sequential anaerobic-aerobic bioreactor, also known as the hybrid bioreactor, accelerates waste degradation by liquids addition followed by periodic air injection in the upper sections of the landfill (see Figure 3). The aerobic process is often used to accelerate the heat generation process necessary to sustain biodegradation. Once temperatures are established and degradation is progressing, air injection may be terminated and anaerobic processes are allowed to take over. Termination of air injection is also monitored and controlled to prevent spontaneous combustion and landfill fires. The hybrid bioreactor has more rapid waste biodegradation than the anaerobic bioreactor and greater LFG (methane) generation than the aerobic bioreactor. LFG will be primarily produced in the lower (anaerobic) sections of the landfill and will need to be collected.

Figure 2 – Aerobic Bioreactor



Source: Waste Management, Landfill Bioreactors: What's the Impact?, August 2003.

Figure 3 – Anaerobic-Aerobic (Hybrid) Bioreactor



Source: Waste Management, Landfill Bioreactors: What's the Impact?, August 2003.

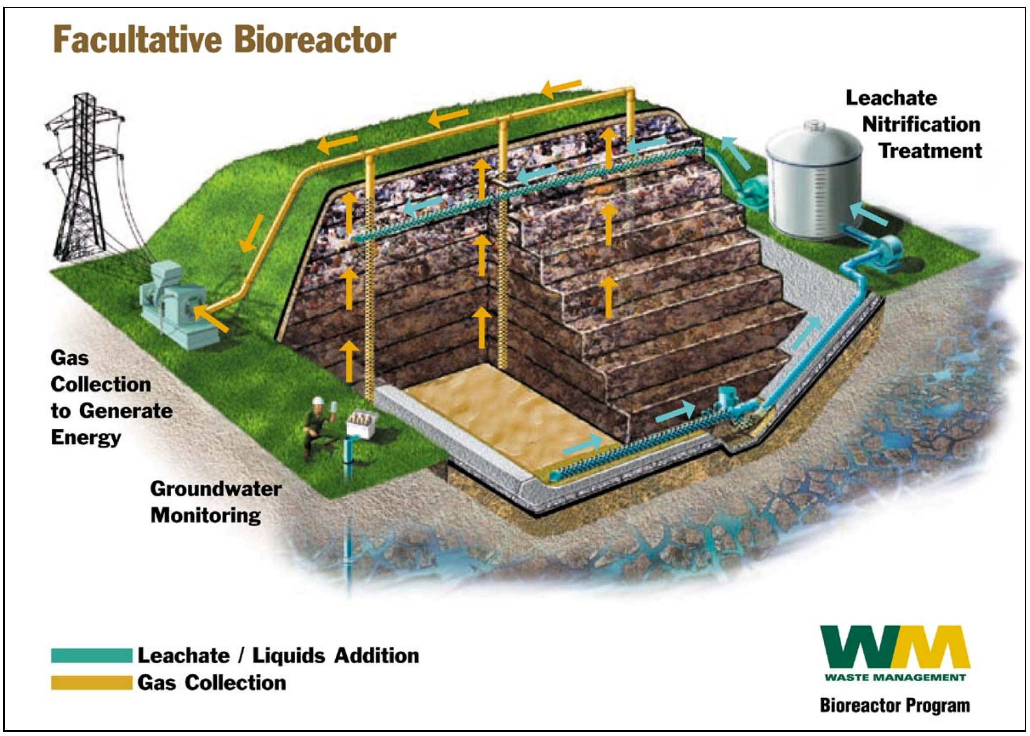
The buried piping distribution system installed in a hybrid bioreactor can serve multiple purposes. Waste biodegradation can be enhanced through cycling the buried distribution lines between liquid distribution and aeration.

Facultative Bioreactor

A "facultative" bioreactor is a landfill that is operated anaerobically and has recirculation of "nitrated" leachate (see Figure 4). Nitrated leachate is leachate that has been treated to convert ammonia to nitrate. Leachate with high ammonia levels (greater than 1,500 mg/kg) can generate odors and inhibit the biodegradation process. Nitrated leachate results when leachate is collected, aerated, and treated (nitrification) in a surface contact biological reactor to reduce ammonia concentrations for better leachate quality (conducive to active biodegradation). The facultative bioreactor has characteristics similar to both anaerobic and aerobic bioreactors.

The piping and design features for a facultative installation are the same as for a landfill operated as an anaerobic bioreactor. The facultative bioreactor may require additional site space and equipment for the leachate treatment system that is not required for the other bioreactor technologies.

Figure 4 – Facultative Bioreactor



Source: Waste Management, Landfill Bioreactors: What's the Impact?, August 2003.

Biological Permeable Cover

Biological permeable cover (BPC) is a landfill cover consisting of permeable material (such as tire chips, geonet, glass cullet, or gravel) underlying a layer of compost or soil capable of supporting vegetation. The cover allows infiltration of rainwater to keep MSW wet for continued biodegradation, while bacteria in the cover biologically digest the methane produced by the landfill. BPC may be appropriate for areas receiving intermediate cover.

Flushing Bioreactor

An additional bioreactor technology is termed the flushing bioreactor. The concept is to actively encourage degradation in a landfill to breakdown and release the organic pollution load and the waste is then flushed (with high volumes of water) to wash out any soluble degradation products (Beaven & Knox 1999). Costs for the flushing bioreactor, however, may be two to four times higher than the conventional landfill (Karnik & Perry 1997).