Refuse Hideaway Landfill Site Specific Sustainable Remediation System Evaluation

Prepared for:
Wisconsin Department of Natural Resources
Remediation and Redevelopment Program
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LIST OF ABBREVIATIONS

BTU/kWh	British thermal unit per kilowatt hour
BTU/scf	British thermal unit per standard cubic foot
CO_2e	carbon dioxide equivalents
DOE	Department of Energy
HDPE	high density polyethylene
hp	horse power
kg	kilograms
kW	kilowatt
kWh	kilowatt hours
kWh/yr	kilowatt hour per year
LBG	Leggette, Brashears & Graham, Inc.
LFG	landfill gas
LP	liquid propane
m	meter
m^2	square meters
m^3	cubic meters
m^3/yr	cubic meters per year
MMSD	Madison Municipal Sewage District
O&M	operation and maintenance
psig	pounds per square inch gauge
PV	photovoltaic
PVC	polyvinyl chloride
RHD	Refuse Hideaway Landfill
RPO	Remedial Process Optimization
scfm	standard cubic feet per minute
USEPA	United States Environmental Protection Agency
UST	underground storage tank
VOCs	volatile organic compounds
W/m^2	watt per square meter
WDNR	Wisconsin Department of Natural Resources

1.0 INTRODUCTION

The purpose of this document is to provide a Site Specific Sustainable Remediation System Evaluation for the Refuse Hideaway Landfill (RHL) site located at 7562 U.S. Highway 14 in Middleton, Wisconsin (Figure 1). To evaluate current site conditions and the effects of any potential changes, a sustainability baseline was created that quantifies the current system's sustainability and provides the starting point from which the effect of any changes to the system/remedy can be measured. The sustainability baseline includes current carbon footprint, energy usage, current operational costs, and contaminant mass removal. Once the baseline was completed, a limited Remedial Process Optimization (RPO) study was conducted to identify major items that could be addressed to improve the sustainability and efficiency of the existing remedial system, and to reduce operation and maintenance (O&M) costs. An alternative energy evaluation was also conducted to determine if alternative energy could be used to offset current energy usage at the site.

Potential sustainable activities/alternatives were identified during the RPO and alternative energy evaluations that increase the sustainability of the remediation system by increasing the efficiency of the existing system, decreasing operation costs or decreasing the overall environmental footprint of the remediation. These activities/alternatives were vetted for potential application at the site. Three best sustainable alternatives were selected and a sustainability matrix was generated, outlining each activity's costs and benefits in terms of various sustainability metrics, such as the increase or decrease in carbon footprint, energy usage, resource usage, waste generation, and cost. The sustainability matrix will provide and quantify effects of the potential changes in relation to the sustainability metrics.

This document used information supplied by the Wisconsin Department Natural of Resources (WDNR), including utility and operation and maintenance costs, monitoring reports and as-builts, where available; a site walkthrough, and interviews with the WDNR site project manager. Due to the site's age, information was sometimes limited.

2.0 Site Description

The RHL site is a former municipal landfill that operated for 14 years, from approximately 1974 to 1988. The landfill accepted a variety of municipal, commercial, and industrial wastes, including barrels of glue and paint, barrels of ink and ink washes, spray paint booth by-products and paint stripper sludge, and spill residues containing volatile organic compounds (VOCs). The current landfill property is approximately 40 acres in size. Of the 40 acres, an estimated 23 acres was waste fill area containing an estimated 1.2 million cubic yard landfill. The topography of the landfill parcel varies extensively. Bluffs are present along the north and west sides and along a portion of the east side of the landfill. Ground elevation at the site drops as much as approximately 200 feet toward the south and east sides of the parcel. Surface drainage generally flows to the south and east. The landfill is generally bordered by agricultural land with a wetland area located southeast of the site. A site location map is shown on Figure 1.

The landfill was constructed with no liner, leaving the existing sandy soils and sandstone bedrock beneath the site exposed to contaminants leaching from the landfill. A 2-foot clay cap with a 2- to 3-foot soil cover was completed over the landfill in 1990. The landfill cover is well vegetated with grass and is generally open space. The remedial system is shown on Figure 2. The landfill flare is shown on Figure 3.

The remedial system includes a landfill gas (LFG) and leachate collection system. The LFG flare station and small equipment buildings are located along the property's east central area. The leachate loading area is located along the access road and includes a concrete pad with a drain piped back to a leachate underground storage tank (UST). The flare station is surrounded by chain link fence with a locked access gate. The locked equipment/storage buildings are located adjacent to the flare station.

A review of the United States Environmental Protection Agency (USEPA) National Priorities List Site Narrative for Refuse Hideaway Landfill identifies the site owner as "John W. Debeck (deceased) – No Owner." Site remediation efforts are 100 percent state funded.

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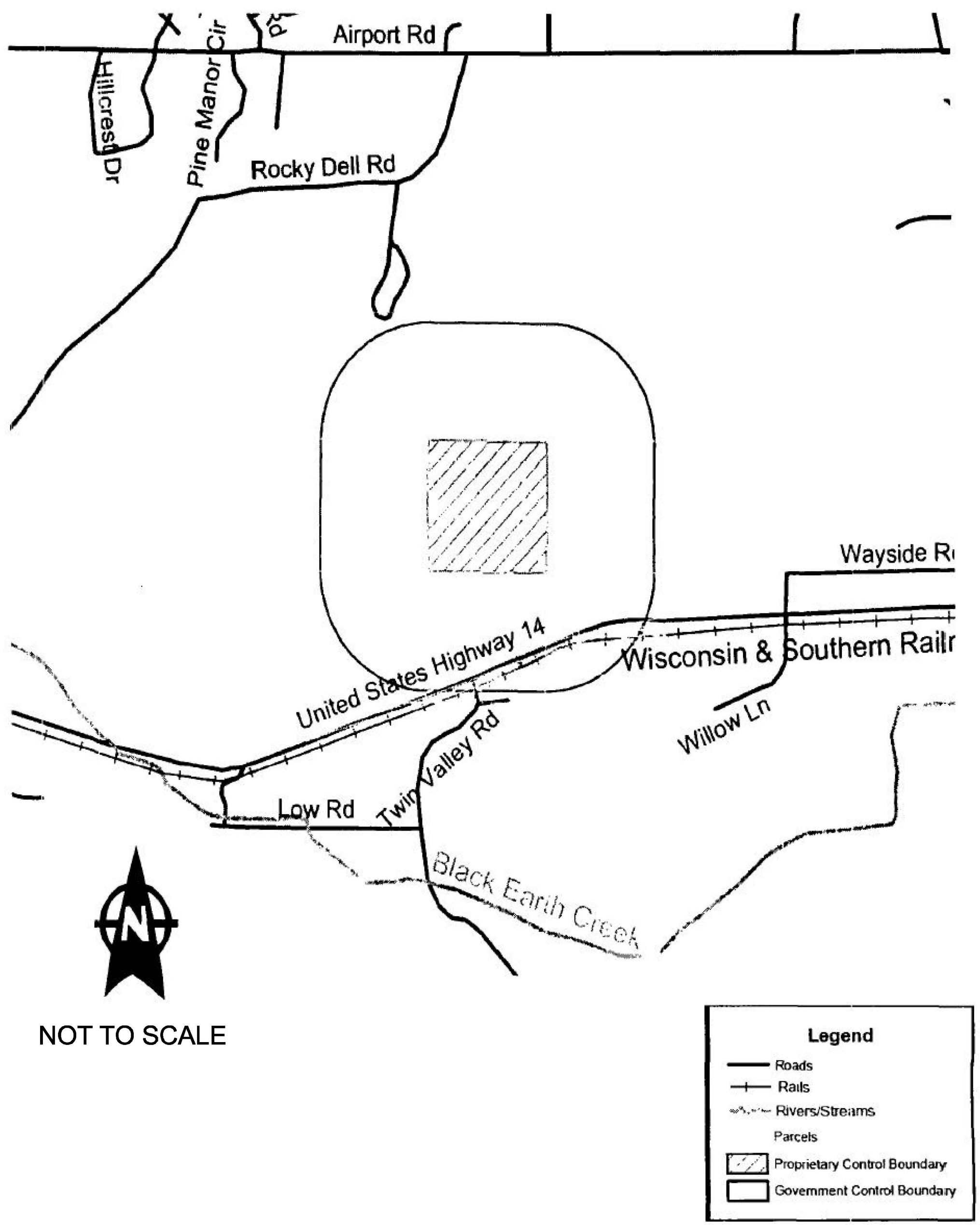

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FIGURE 1

SITE LOCATION MAP

SITE SPECIFIC

REMEDIATION SYSTEM EVALUATION

WDNR, REMEDIATION AND REDEVELOPMENT DIVISION

REFUSE HIDEAWAY LANDFILL

FILE NAME:	DRN	PROJECT NO.	DATE	FIGURE NO.
Figure 1.dgn	ALB	107343	MAY 2011	1

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FIGURE 2

VIEW OF REMEDIATION SYSTEM
SITE SPECIFIC
REMEDIATION SYSTEM EVALUATION

WDNR, REMEDIATION AND REDEVELOPMENT DIVISION
REFUSE HIDEAWAY LANDFILL

FILE NAME:	DRN	PROJECT NO.	DATE	FIGURE NO.
Figure 2.dgn	ALB	107343	MAY 2011	2

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FIGURE 3

VIEW OF LANDFILL FLARE

SITE SPECIFIC

REMEDIATION SYSTEM EVALUATION

WDNR, REMEDIATION AND REDEVELOPMENT DIVISION

REFUSE HIDEAWAY LANDFILL

FILE NAME:	DRN	PROJECT NO.	DATE	FIGURE NO.
Figure 3.dgn	ALB	107343	MAY 2011	3

3.0 CURRENT CONDITIONS

The current remedial approach at the RHL site consists of landfill gas and leachate capture with an LFG extraction and leachate collection system, and long-term groundwater monitoring for natural attenuation of contaminants in groundwater. Off-site remedial actions include providing point of entry treatment systems for two private wells.

Current site information, presented below, is a summary of data provided by the WDNR project manager during the site walkthrough and responses to questions. The USEPA "Five Year Review Report[1], dated September 2007, was also used as a source of information for this report.

The landfill gas monitoring system consists of 22 gas probes (labeled GP-1 through GP-24, with probes GP-14 and GP-15 not noted on the site maps) located along the perimeter of the landfill. The Five Year report notes that:

- Monthly monitoring for landfill gas in soil is conducted at 13 gas monitoring wells and ambient air monitoring locations around and outside of the landfill.
- Gas monitoring occurs at 11 locations on-site.
- Methane is generally not detected in the gas probes surrounding the landfill, with the exception of seasonal low-concentration detections in one or several probes located at the southwest corner of the landfill.

The Five Year report summarizes that landfill gas is migrating a short distance in one area and only seasonally from the landfill.

The LFG collection system consists of 13 vertical LFG extraction wells connected to a three-branched common header pipe system. The LFG extraction wells extend to the base of the landfill, approximately 36 to 81 feet below ground surface.

The three-branched header pipe system covers the northern, central, and southern areas of the landfill. LFG is drawn from the extraction wells to the flare station via below grade high density polyethylene (HDPE) piping by vacuum created from a 10 horse power (hp) New York blower. Where the HDPE pipe extends above the ground surface, it transitions to polyvinyl chloride (PVC) piping. Four drip legs, associated with the header piping system, remove condensate from the LFG and gravity drains it to the leachate collection system.

A Linklater Corporation fully enclosed ground flare burns the LFG. An automated control valve and flame arrestor are located between the blower and flare. A thermocouple control at the flare controls the LFG blower in the event the flame at the flare goes out. A telemetry system is activated when an alarm condition exists in the system. Flow is approximately 650 standard cubic feet per minute (scfm).

[1] Five Year Review Report, Refuse hideaway Landfill Superfund Site, Middleton Wisconsin. Wisconsin Department of Natural Resources. Dated September 18, 2007.

A single 150-gallon (estimated size) liquid propane (LP) tank supplies propane gas to the flare to ignite the flare, when necessary. The WDNR project manager reported that this tank has only been filled twice in the last 11 years. The Five Year Report notes that influent methane gas levels measured from July 2003 through June 2006 at the flare station ranged from approximately 23 to 38 percent, with a collection efficiency of 80 to 88 percent.

The most recent data was collected and documented by Leggette Brashears & Graham, Inc. (LBG) in their Operation and Maintenance Annual Report – July 2009 Through June 2010[2], and indicates the average methane gas level at the ground flare was 31.5 percent during the period of November 2009 through January 2010. Review of the historical seasonal fluctuations and data ranges reported by LBG suggests this is an accurate representation of methane gas levels at the ground flare for the year 2010.

Leachate is collected from nine of the 13 gas extraction wells. These nine wells are dual purpose gas extraction and leachate recovery wells. Pneumatic leachate pumps remove the leachate from the wells and convey it through HDPE piping to a 25,000-gallon, double walled UST. The UST is located adjacent to a concrete loading pad.

Leachate is picked up in 5,000-gallon loads several times a month. The UST is reported to be emptied by vacuum truck before it becomes half-full, which means it is pumped out an average of one to two times per week. The Five Year report indicates that between 75,000 and 232,000 gallons of leachate are removed per year, depending on seasonal weather conditions and precipitation. Leachate is transported to the Madison Metropolitan Sewerage District (MMSD) treatment plant, located approximately 15 miles to the southeast of the site. According to LBG, 469,239 gallons of leachate were removed from the site in 2010.

The Five Year report notes that the leachate collection system is successful in capturing leachate and its contaminants, making them unavailable for migration from the landfill.

There are two remedial equipment sheds onsite. One houses the LFG extraction blower and the other houses the leachate extraction equipment.

The LFG extraction blower shed is approximately 10 x 10 feet in size and wood construction without insulation. There are three louver vents and one turbine roof vent on the building. It houses a 10 hp New York LFG extraction blower with associated piping.

The leachate extraction equipment is housed in an approximately 10 x 10-foot prefabricated insulated metal frame shed. There are two louver vents and one turbine roof vent on the building. It houses a Curtis Toledo two-stage, 15 hp, air compressor with a 120-gallon tank to supply air to the pneumatic leachate pumps and a Hankenson dessicant air dryer to condition the air going to the pumps.

The Five Year review notes that the site's average annual costs are approximately $100,000, but fluctuate depending on the degree of operation and maintenance that occurs during a year.

[2] Operation and Maintenance Annual Report – July 2009 Through June 2010, Refuse Hideaway Landfill, 7562 U.S. Highway 14, Middleton, Wisconsin 53562. Leggette, Brashears & Graham, Inc. September 2010.

4.0 BASELINE EVALUATION

A baseline analysis was conducted for the Refuse Hideaway Landfill site. The baseline is a quantification of current site conditions using various sustainability metrics. This allows costs and benefits of potential changes to the system to be measured, using the same set of sustainability metrics.

4.1 CARBON FOOTPRINT

The primary contaminants of concern at RHL are methane gas, leachate, and VOCs. The site is currently in a long-term O&M mode. An analysis of site operations has identified applicable items associated with Scope 1 (direct discharge), Scope 2 (electricity), and Scope 3 (other indirect) at the site.

Scope 1 items identified at the site are propane usage for the flare station and methane in the LFG combusted by the flare station. Based on data from the USEPA's Landfill Gas Emissions Model (LandGEM), the landfill produced approximately 2,716,000 cubic meters (m^3) of LFG in 2010. According to LBG, influent methane concentrations averaged approximately 31.5 percent at the flare station from November 2009 to January 2010. This equates to approximately 856,000 cubic meters per year (m^3/yr) of methane discharged, with the balance comprised of carbon dioxide, oxygen, and other organic compounds. Based on the Five Year Review, 80 to 88 percent of methane is captured by the LFG system. The flare was only running 53 percent of the time that the blower was running, resulting in slightly more than half of the methane captured by the LFG system being destroyed. Approximately 23 pounds of propane are used to supplement the flare station annually.

Scope 2 items consist of electricity consumed by the leachate collection system and flare station. This information was provided by the WDNR.

Scope 3 items consist of fugitive methane escaping from the landfill; methane released while the blower is running, but the flare is not; diesel fuel consumed by trucks used to haul leachate; and unleaded gas used by O&M personnel at the site. Based on data from the Five Year Review, 80 to 88 percent of the methane produced is captured by the landfill gas system. For Scope 3, it was assumed that 20 percent of the LFG escaped due to imperfections in the landfill cap. During 2010, LBG reported the flare was running only 53 percent of the time the blower was running. This resulted in LFG escaping through the landfill gas system without being destroyed 47 percent of the time the blower was running. It was also assumed that, during 2010, 119 site visits were required for site sampling and O&M activities at 16 miles per visit (roundtrip), four site visits were required for WDNR inspections at 22 miles per visit (roundtrip), and leachate was hauled off-site 94 times (when tank is approximately 5,000 gallons full) at 30 miles per round trip.

To calculate fugitive methane emissions, the volume of methane being generated by the landfill, the LandGEM was used. Because limited historical information is available for the landfill site, several assumptions were made to use LandGEM. The assumptions for the RHL site and the LandGEM output are included in Appendix A.

The total annual carbon footprint generated by the RHL site is estimated to be 10,549 tons carbon dioxide equivalents (CO_2e). The carbon footprint analysis is included in Appendix B.

4.2 ENERGY

Electric service at the site is provided by Madison Gas and Electric Company, and is required to operate the remedial system components and provide lighting, heating, cooling, and ventilation to the buildings.

According to the WDNR, 43,039 kilowatt hours (kWh) of electricity were used at the site during 2010 for a total cost of $5,742 or approximately $480 per month. This corresponds to approximately $0.133 per kWh.

4.3 OPERATIONAL COSTS

In additional to the electrical services discussed above, other operation costs associated with the LFG and leachate system operation and monitoring include leachate transport and disposal, subcontractor costs, plowing, supply and equipment costs, telephone service, WDNR management costs, and LP gas. The Five Year review noted the annual average total costs for the site was approximately $100,000.

The WDNR currently has a contract with the MMSD to dispose leachate collected from the landfill at a cost of $7.31 per 1,000 gallons. Leachate is transported by Madison-Odana. The total costs for the 94 trips to dispose 469,000 gallons of leachate during the 12-month period between July 2009 and June 2010 was $3,428. Year round access is required to maintain the site, as leachate is removed two to six times per month. Plowing is required during winter months, with costs highly variable, depending on snowfall amounts. Telephone charges from TDS Utilities are $27 per month. The liquid propane tank has been filled twice in the past 11 years at a minimal cost.

Site sampling and O&M activities are performed by LBG. Private sampling activities are performed by BT2, Inc. Sampling costs were not provided for this report.

4.4 CONTAMINANT MASS REMOVAL

The contaminants of concern at RHL are methane gas produced by the landfill waste and leachate. Based on data from the LandGEM model, the landfill produced approximately 2,716,000 m^3 of LFG during 2010. Influent methane concentrations averaged approximately 31.5 percent at Sample Port A of the flare station from November 2009 to January 2010. Based on these values, approximately 856,000 m^3/yr of methane gas are discharged, with the balance comprised of carbon dioxide, oxygen, and other organic compounds.

During 2010, 469,000 gallons of leachate were removed from the site and transported to the MMSD treatment plant approximately 15 miles southeast of the site.

5.0 LIMITED REMEDIAL PROCESS OPTIMIZATION STUDY

RPO is a specific process that examines overall system effectiveness, including incremental changes or system replacement to include considerations of new technologies and alternative regulatory approaches. Optimization must be implemented within the confines of the existing decision document for the site.

The purpose of the limited RPO study is to identify possible changes to the site or remedial system that would significantly improve the system with regards to overall remedial sustainability. This includes decreasing the costs of operating the system and/or increasing the efficiency of contaminant mass removal. The limited RPO study is based on the current conditions previously noted in this document.

The following RPO recommendations were based on the assumption that the current technology will continue to be employed as the remedy at the site for 25 years. This is an arbitrary value selected for the purpose of comparing remedial options.

5.1 LFG SYSTEM BALANCING

Many older LFG collection systems, such as the one at Refuse Hideaway, were designed for a condition that existed at the time that the system was installed. The LFG generation rate declines as the landfill ages. If operating the LFG collection system is not balanced to account for the declining methane production, the LFG collection system may pull too hard and draw air into the LFG system through the cover or through defects in the LFG system, such as deteriorated well seals, broken pipe, cracked hose, or leaky pipe joints. This ultimately causes a decrease in the volume of landfill gas being removed from the landfill. It is recommended that the system be rebalanced to improve efficiency of the LFG collection system and raise the concentration of methane collected by the system. It is estimated that it would take approximately 20 visits to the site over a 4- to 6-week period to rebalance the system to current conditions. It is estimated that this would cost approximately $15,000 to $25,000 to complete the rebalancing. Some modifications to the site vacuum blower may be required to complete the rebalancing. This could also increase the LFG quality (methane content). Balancing the system may also help prevent some of the frequent flare issues/outages at the site. An increase in LFG quantity and quality would be required to make the methane to energy alternatives viable at the site.

5.2 LFG SYSTEM PERFORMANCE

LBG's Annual Report indicated that the blower was working 67 percent of the time and the flare was working 33 percent of the time. While the blower was working without being combusted by the flare, an estimated 230,000 kilograms (kg) of methane gas was directly released to the atmosphere. This is equivalent to 6.33 tons of CO_2 emitted to the atmosphere and approximately 60 percent of the total emissions for the site. It is recommended that the LFG system be repaired to maximize system performance. It is estimated that repairing the system would cost $10,000 to $15,000.

5.3 EVALUATE FLARE

The flare currently operating at RHL was designed for the conditions that existed at the site when the flare was installed. The LFG generation rate declines as the landfill ages. At this time, it would be relevant to evaluate other alternatives to the flare, including whether a candlestick flare or other technologies that use the methane gas for energy generation may be more appropriate remedial options, based on current site conditions.

Another option is to evaluate the current flare to determine if running it on a schedule would provide a more acceptable level of performance and more efficient combustion. This could be achieved by using a timer with the flare station. The estimated cost to purchase and install a timer is approximately $1,000 to $5,000.

5.4 EVALUATE CONDITION AND OPERATION OF PNEUMATIC PUMPS

The Five Year Review indicated that seven leachate pumps and one new pneumatic leachate pump were installed in 2005 and 2006. The seven leachate pumps were cleaned due to significant scale that accumulated during more than 10 years of use. When the pumps were reinstalled, they were still not functional. The pumps were then replaced. In addition, a pneumatic pump at Extraction Well GW-10 was installed to accommodate the greater than expected leachate build-up.

The O&M Annual Report, prepared by LBG, indicated that numerous repairs and troubleshooting activities were performed during the 2009-2010 operating year. Eight groundwater pumps required maintenance during the year and, according to the report, the pump at Extraction Well GW-13 was still malfunctioning. The manufacturer was contacted for additional support. The pump at Extraction Well GW-7 is lodged in the well and removal is not possible.

It is unclear whether additional pump repair or replacement would further optimize the LFG extraction system.

5.5 LEACHATE EVAPORATION OR WATERING

LFG can be used to evaporate leachate, reducing or eliminating the cost of off-site leachate disposal. Specially designed leachate evaporators can be purchased; however, enclosed LFG flares have also been successfully modified to accomplish leachate evaporation. Based on the volume and quality of LFG being collected from the site, an on-site leachate evaporation system may be able to handle approximately 1,500 gallons of leachate per day. The O&M Annual Report indicated that 469,239 gallons of leachate were collected for the year. This equals an average of 1,285 gallons of leachate per day or approximately 86 percent capacity of the leachate evaporation system.

Due to the cost of installing a leachate evaporator or a specially modified enclosed flare, it is not economical to install leachate evaporation equipment. It is estimated that a leachate evaporation system would cost approximately $1,000,000 to $1,200,000.

A modified enclosed flare could be installed to accomplish leachate reduction also. A study is needed to determine how much leachate could be reduced using this method. The estimated cost for the modified flare is between $125,000 and $200,000.

An alternative to evaporation is using the leachate to water the vegetation on the landfill during the May through October period, providing analytical results indicated that the leachate contains no contaminants of concern. Setting up a watering system would cost approximately $5,000.00 to $10,000.

6.0 ALTERNATIVE ENERGY ANALYSIS

An alternative energy analysis was conducted at the RHL site. The analysis includes evaluating various methane-to-energy alternatives, solar power, and wind power.

6.1 METHANE GAS TO ENERGY

The most significant concern for any use of the collected LFG, including flaring, is the methane content of the LFG, previously stated to average 31.5 percent methane by volume. To ensure complete combustion, and ensuring that emissions to the air are minimized, federal regulations (40 CFR 60.18 (c)(3)(ii)) require that flare fuel gas must have a minimum heat value of 200 British thermal unit per standard cubic foot (BTU/scf) or approximately 20 percent methane by volume.

Methane concentrations at the site exceed the threshold needed to convert methane to energy; however, concentrations in the LFG are likely elevated due to the intermittent operation of the LFG extraction system. Typically, as a landfill ages, the operation of the LFG collection system must be modified, if possible, to accommodate the declining LFG generation rate. If this is not accomplished, the LFG collection system will pull in air through the landfill cover or from the edges of the landfill and waste mass or through defects in the LFG collection system, such as failed well seals, broken pipe, cracked hose, or leaky joints. Initially, this air intrusion simply dilutes the LFG. However, prolonged periods of air intrusion can inhibit the anaerobic decomposition of the waste in the landfill, and slow or stop LFG generation. Air intrusion also presents the risk of subsurface oxidation in the landfill.

If the methane content of the LFG is sufficient (generally greater than 35 to 40 percent methane by volume), the LFG can be used for one or more beneficial purposes. Potential end uses of LFG include:

- Flaring to destroy hazardous air pollutants
- Generating electric power for internal (on landfill) use
- Generating electric power for export to the utility grid
- Direct use as a low to medium BTU fuel gas (e.g., as a boiler fuel to reduce the use of natural gas)
- Produce pipeline quality gas
- Compressed or liquefied gas vehicle fuel

Generally, any of these uses require a minimum methane content of approximately 35 to 45 percent by volume. Unless the methane content of the LFG can be improved (increased to at least 40 percent by volume), the only viable LFG utilization alternative for this site will be flaring. If the quality of the collected LFG can be improved sufficiently by reducing air intrusion, then beneficial use of the LFG can be considered. Each of the various LFG beneficial use scenarios is described briefly in the following paragraphs.

There are several different types of equipment used to generate electric power with LFG. These include reciprocating engines, microturbines, Stirling engines, and turbines. The primary difference between these systems is the amount of LFG they consume and the amount of electric power they produce. For example:

- LFG fueled microturbines generally provide approximately 20 to 250 kilowatt (kW) of generating capacity, consume approximately 6,750 to14,500 British thermal units per kilowatt hour (BTU/kWh), require a minimum fuel heat value of approximately 350 BTU/scf, require LFG drying and siloxane removal, and may require LFG compression to about 85 pounds per square inch gauge (psig) and sulfur removal. LFG, at 20 percent methane, has a heat value of approximately 200 BTU/scf. Heat recovery systems can significantly increase the thermal efficiency of microturbine based systems.

  The site has an average electric demand of approximately 4.9 kW. To account for peak demand, an output of 10 to 15 kW may be required. Therefore, one microturbine should be able to generate sufficient power to operate the on-site LFG and leachate collection systems. Any power generated that was not used on-site would be exported to the utility grid and would generate income for the state. However, unless it can be demonstrated that the methane content of the LFG can be increased to at least 35 percent by volume, generating electric power using microturbines will not be considered further.

- Stirling engines generally provide 30 to 50 kW of generating capacity, consume about 9,600 BTU/kWh, require a minimum fuel heat value of approximately 350 BTU/scf, require only low pressure (less than 2 psig) compression, and do not require LFG drying, sulfur removal, and siloxane removal. Heat recovery systems can significantly increase the thermal efficiency of Stirling engine based systems.

  The site has an average electric demand of approximately 4.9 kW. To account for peak demand, an output of 10 to 15 kW may be required. Therefore, one Stirling engine should be able to generate sufficient power to operate the LFG and leachate collection systems. Any power generated that was not used on-site would be exported to the utility grid and would generate income for the state. However, unless it can be demonstrated that the methane content of the LFG can be increased to at least 35 percent by volume, generating electric power using Stirling engines will not be considered further.

- Reciprocating engines provide approximately 250 to 1,600 kW of generating capacity. The engines generally require a minimum fuel heat value about 400 BTU/scf, require only low pressure (less than 2 psig compression), and may not require LFG drying, sulfur removal, and siloxane removal. Heat recovery systems can significantly increase the thermal efficiency of reciprocating engine based systems.

  The site does not collect enough LFG to economically operate a reciprocating engine. Unless it can be demonstrated that the methane content of the LFG can be increased to at least 40 percent by volume, generating electric power using a reciprocating engine will not be considered further.

- Turbines generally provide 700 to 21,000 kW of generating capacity, consume 8,700 to 14,100 BTU/kWh, require a minimum fuel heat value of approximately 400 BTU/scf and high pressure (greater than 200 psig) compression, and may not require LFG drying, and siloxane removal. Heat recovery systems can significantly increase the thermal efficiency of turbine based systems.

The site does not collect enough LFG to operate a turbine. Unless it can be demonstrated that the methane content of the LFG can be increased to at least 40 percent by volume, generating electric power using turbines will not be considered further.

Most landfills generate more LFG than can be used on-site, except when a flare or leachate evaporation system is installed. Therefore, off-site sale of the LFG or the power generated using the LFG is often considered. When there is an end user of gas within approximately 6 to 12 miles of the site, it is often most economical to sell the LFG for fuel to reduce the end users' consumption of natural gas or propane. This is due to the fact that there is generally less capital equipment and ongoing O&M expense associated with direct use than with other alternatives.

Although there are several commercial establishments located north and east of the site, their primary load would be seasonal heating. During the summer, they would likely not have need for the LFG, so the site would have to maintain and operate the existing LFG flare as a back-up system.

Manufacturing pipeline quality gas from LFG typically requires the raw LFG to have less than 0.2 percent oxygen and less than 3 percent nitrogen. This is very high quality LFG. The existing LFG system is estimated to be collecting gas that is approximately 2 to11 percent oxygen and 50 to 80 percent nitrogen. Even if the performance of the site LFG collection system can be improved to minimize air intrusion, it is unlikely that the improved LFG could qualify as pipeline quality gas; therefore, this alternative will not be considered further.

Manufacturing compressed or liquefied vehicle fuels, or chemical feed stocks, requires the same equipment needed to produce pipeline quality gas. This equipment is expensive to purchase, and to operate and maintain. This alternative generally requires a large landfill producing high quality LFG to develop a cost-effective project. In addition, the vehicle fuel alternatives require a fleet that has been converted to operate on compressed gas or non-petroleum liquid fuels. This site is relatively isolated from a state-owned vehicle pool, and it may be difficult to convince others, who are not involved with this project, to convert their vehicles. Therefore, vehicle fuels will not be considered further for this project.

6.2 SOLAR ENERGY

A 10 kW photovoltaic (PV) solar array was installed to the east of the blower station in the fall of 2009. The site was chosen for a pilot project because it is a south facing site with high public visibility. The PV array consists of 44 PV solar panels. Electricity produced is directly connected to the grid with no battery backup. The project is a partnership between the WDNR and the United States Department of Energy (DOE) to research the use of renewable energy to power the cleanup of contaminated sites. The total project cost was approximately $100,000, paid for by a combination of a grant from Wisconsin Focus on Energy, federal research funding, and the Wisconsin Environmental Fund. It is estimated that the electricity produced will save the State 25 percent of the approximately $6,000 in electricity costs the site uses every year to power the decontamination process.

Security on the unsecured site is a major concern, but has not been an issue at the time of this report.

6.3 WIND ENERGY

The Wisconsin Focus on Energy Wind Resource Map indicates that, in the vicinity of the site, the wind power density at an altitude of 40 meters (m) is 100 to 200 watts per square meter (W/m^2). The average electric power consumption on-site is approximately 43,039 kilowatt hours per year (kWh/yr) or approximately 4.9 kW. A wind turbine with a constant output of approximately 6 kW could meet the site's average demand. To account for peak demand and to generate power to be stored for periods when the wind turbine cannot meet the average demand, two to three times that much output, or approximately 15 to 20 kW, would be required. From the wind resource map, a wind turbine with a swept area of approximately 150 to 200 square meter (m^2), or a blade diameter of about 14 to 16 m, would meet the average demand. Any power generated that was not used or stored on-site would be exported to the utility grid and would generate income for the State.

The site is in a valley surrounded by bluffs and trees. This would greatly diminish the actual wind density at the site. Therefore, wind energy as an alternative will not be considered further.

7.0 POTENTIAL SUSTAINABLE ACTIVITIES

Implementing the recommended RPOs will result in a more effective and efficient remedial system and achieve quicker results at a lower cost (i.e., sustainable). In addition to the items mentioned in the RPO section of this document, some additional sustainable activities that may be considered are discussed below.

7.1 IMPROVEMENTS TO FLARE SYSTEM

As mentioned in the limited RPO study, 60 percent of the greenhouse gas emissions at the site are a result of inefficiencies in the flare system. The flare system should be improved so the flare is running whenever the blower operates. This could be done by scheduling the flare system using a timer so the flare/blower systems are only running for a portion of the day or redesigning the flare to run using with a lower methane flow.

7.2 INCREASE SOLAR ENERGY GENERATION

As discussed earlier, the WDNR has partnered with the DOE to conduct a pilot PV solar study. The current PV array does not produce enough electricity to support all of the site's electricity needs. Feasibility studies of the pilot project have already been conducted. Expanding the pilot project would require minimal additional assessment.

7.3 LEACHATE EVAPORATION OR WATERING

The leachate at RHL contains trace amounts of metals and VOCs. After reviewing the leachate sampling results from 2010, it has been determined that the leachate is of high enough quality to be used onsite instead of hauled to the MMSD. This would save diesel fuel burning and reduce greenhouse gas emissions. Possible activities include using the leachate to water the landfill cap or releasing the leachate for evaporation.

8.0 SUSTAINABILITY MATRIX

A sustainability matrix was created that compared sustainability metrics for the current operational baseline to three potential modifications that could be made to the system. The selected options were improving the methane flare, increasing solar energy generation, and evaporating the leachate or using the leachate for watering. Alternative energy (methane to energy) alternatives were not included in the matrix because these technologies are not viable, given the current LFG quality. This could change if some of the RPO recommendations are implemented. The sustainability matrix for the Refuse Hideaway site is presented in Table 1.

The best or most applicable sustainable alternative at the site may be a combination of the proposed options.

Table 1
Sustainability Matrix - Refuse Hideaway Landfill

	Baseline[3]		Option 1 Flare System Improvements		Option 2 Increase Solar Energy Generation		Option 3 Leachate Evaporation or Watering	
Sustainability Metrics[1,2]	**Annual**	**Life Cycle**	**Annual**	**Life Cycle**	**Annual**	**Life Cycle**	**Annual**	**Life Cycle**
Stewardship								
System Optimization (Qualitative)	Landfill gas system is removing 50 percent of landfill gas being generated.		Improved flare system would remove 100% of landfill gas in LFG extraction system (80% of total.)		Increased solar energy would provide 100% of landfill electricity needs.		Leachate will be evaporated or used for watering instead of being hauled to MMSD.	
Restoration Timeframe (yrs)	NA	25	NA	25	NA	25	NA	25
Emissions								
Tons CO_2e	10,549	263,730	4,884	122,105	10,549	263,725	10,545	263,631
Tons CO_2e from Combusted Methane	788	19,692	1,488	37,196	788	19,692	788	19,692
Tons CO_2e from LFG System Fugitive Methane	6,365	159,129	0	0	6,365	159,129	6,365	159,129
Energy Usage								
Electricity (kWh)	43,039	1,075,975	43,039	1,075,975	0	0	43,039	1,075,975
Propane (Pounds)	23	575	23	575	23	575	23	575
Cost								
O&M Cost (dollars)	$100,000	$2,500,000	$100,000	$2,500,000	$100,000	$2,500,000	$96,572	$2,414,300
Cost of Modification (dollars)	NA	NA	$1,000-5,000	$1,000-5,000	$200,000-300,000	$200,000-300,000	NA	NA
Cost per Ton CO_2e Reduced (dollars)[4]	NA	NA	$0.88	$0.04	$1,582,906.14	$63,316.25	NA	NA
Land & Ecosystems								
Community Benefits (qualitative)	NA		Reduction in fugitive methane emitted		Reduction in Scope 2 emissions - Purchased electricity		Reduction in leachate discharged to MMSD	
Materials & Waste Generation								
Leachate Generation (gallons)	469,239	11,730,975	469,239	11,730,975	469,239	11,730,975	469,239	11,730,975

[1] Metrics may be either qualitative not applicable (NA) or quantitative based on available information and scope of project.
[2] Metrics may be added or deleted based on site specific conditions.
[3] Baseline: As the system is currently being operated.
[4]Costs per Ton CO2e are based on higher Cost of Modification number listed.
* Assume upper limit costs are used for cost per ton CO_2e reduced.
MMSD: Madison Municipal Sewage District

APPENDIX A

LANDGEM ASSUMPTIONS AND ANALYSIS

Summary Report

Landfill Name or Identifier:

Date: Monday, February 28, 2011

Description/Comments:

About LandGEM:

First-Order Decomposition Rate Equation:

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} k L_o \left(\frac{M_i}{10} \right) e^{-k t_{ij}}$$

Where,

Q_{CH_4} = annual methane generation in the year of the calculation *(m^3/year)*
i = 1-year time increment
n = (year of the calculation) - (initial year of waste acceptance)
j = 0.1-year time increment
k = methane generation rate *($year^{-1}$)*
L_o = potential methane generation capacity *(m^3/Mg)*

M_i = mass of waste accepted in the i^{th} year *(Mg)*
t_{ij} = age of the j^{th} section of waste mass M_i accepted in the i^{th} year *(decimal years*, e.g., 3.2 years)

LandGEM is based on a first-order decomposition rate equation for quantifying emissions from the decomposition of landfilled waste in municipal solid waste (MSW) landfills. The software provides a relatively simple approach to estimating landfill gas emissions. Model defaults are based on empirical data from U.S. landfills. Field test data can also be used in place of model defaults when available. Further guidance on EPA test methods, Clean Air Act (CAA) regulations, and other guidance regarding landfill gas emissions and control technology requirements can be found at http://www.epa.gov/ttnatw01/landfill/landflpg.html.

LandGEM is considered a screening tool — the better the input data, the better the estimates. Often, there are limitations with the available data regarding waste quantity and composition, variation in design and operating practices over time, and changes occurring over time that impact the emissions potential. Changes to landfill operation, such as operating under wet conditions through leachate recirculation or other liquid additions, will result in generating more gas at a faster rate. Defaults for estimating emissions for this type of operation are being developed to include in LandGEM along with defaults for convential landfills (no leachate or liquid additions) for developing emission inventories and determining CAA applicability. Refer to the Web site identified above for future updates.

Input Review

LANDFILL CHARACTERISTICS

Landfill Open Year	**1974**	
Landfill Closure Year (with 80-year limit)	**1989**	
Actual Closure Year (without limit)	***1989***	
Have Model Calculate Closure Year?	**No**	
Waste Design Capacity	**706,678**	*short tons*

MODEL PARAMETERS

Methane Generation Rate, k	**0.050**	*$year^{-1}$*
Potential Methane Generation Capacity, L_o	**170**	*m^3/Mg*
NMOC Concentration	**817**	*ppmv as hexane*
Methane Content	**50**	*% by volume*

GASES / POLLUTANTS SELECTED

Gas / Pollutant #1:	**Total landfill gas**
Gas / Pollutant #2:	**Methane**
Gas / Pollutant #3:	**Carbon dioxide**
Gas / Pollutant #4:	**NMOC**

WASTE ACCEPTANCE RATES

Year	Waste Accepted		Waste-In-Place	
	(Mg/year)	*(short tons/year)*	*(Mg)*	*(short tons)*
1974	39,995	43,994	0	0
1975	40,904	44,994	39,995	43,994
1976	41,111	45,222	80,898	88,988
1977	41,772	45,949	122,009	134,210
1978	42,347	46,582	163,781	180,159
1979	40,999	45,099	206,128	226,741
1980	42,353	46,588	247,127	271,840
1981	42,646	46,911	289,480	318,428
1982	43,321	47,653	332,126	365,339
1983	43,715	48,087	375,447	412,992
1984	43,985	48,383	419,163	461,079
1985	44,402	48,842	463,147	509,462
1986	44,673	49,140	507,549	558,304
1987	44,844	49,328	552,222	607,444
1988	45,370	49,907	597,065	656,772
1989	0	0	642,435	706,679
1990	0	0	642,435	706,679
1991	0	0	642,435	706,679
1992	0	0	642,435	706,679
1993	0	0	642,435	706,679
1994	0	0	642,435	706,679
1995	0	0	642,435	706,679
1996	0	0	642,435	706,679
1997	0	0	642,435	706,679
1998	0	0	642,435	706,679
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2003	0	0	642,435	706,679
2004	0	0	642,435	706,679
2005	0	0	642,435	706,679
2006	0	0	642,435	706,679
2007	0	0	642,435	706,679
2008	0	0	642,435	706,679
2009	0	0	642,435	706,679
2010	0	0	642,435	706,679
2011	0	0	642,435	706,679
2012	0	0	642,435	706,679
2013	0	0	642,435	706,679

WASTE ACCEPTANCE RATES (Continued)

Year	Waste Accepted		Waste-In-Place	
	(Mg/year)	(short tons/year)	(Mg)	(short tons)
2014	0	0	642,435	706,679
2015	0	0	642,435	706,679
2016	0	0	642,435	706,679
2017	0	0	642,435	706,679
2018	0	0	642,435	706,679
2019	0	0	642,435	706,679
2020	0	0	642,435	706,679
2021	0	0	642,435	706,679
2022	0	0	642,435	706,679
2023	0	0	642,435	706,679
2024	0	0	642,435	706,679
2025	0	0	642,435	706,679
2026	0	0	642,435	706,679
2027	0	0	642,435	706,679
2028	0	0	642,435	706,679
2029	0	0	642,435	706,679
2030	0	0	642,435	706,679
2031	0	0	642,435	706,679
2032	0	0	642,435	706,679
2033	0	0	642,435	706,679
2034	0	0	642,435	706,679
2035	0	0	642,435	706,679
2036	0	0	642,435	706,679
2037	0	0	642,435	706,679
2038	0	0	642,435	706,679
2039	0	0	642,435	706,679
2040	0	0	642,435	706,679
2041	0	0	642,435	706,679
2042	0	0	642,435	706,679
2043	0	0	642,435	706,679
2044	0	0	642,435	706,679
2045	0	0	642,435	706,679
2046	0	0	642,435	706,679
2047	0	0	642,435	706,679
2048	0	0	642,435	706,679
2049	0	0	642,435	706,679
2050	0	0	642,435	706,679
2051	0	0	642,435	706,679
2052	0	0	642,435	706,679
2053	0	0	642,435	706,679

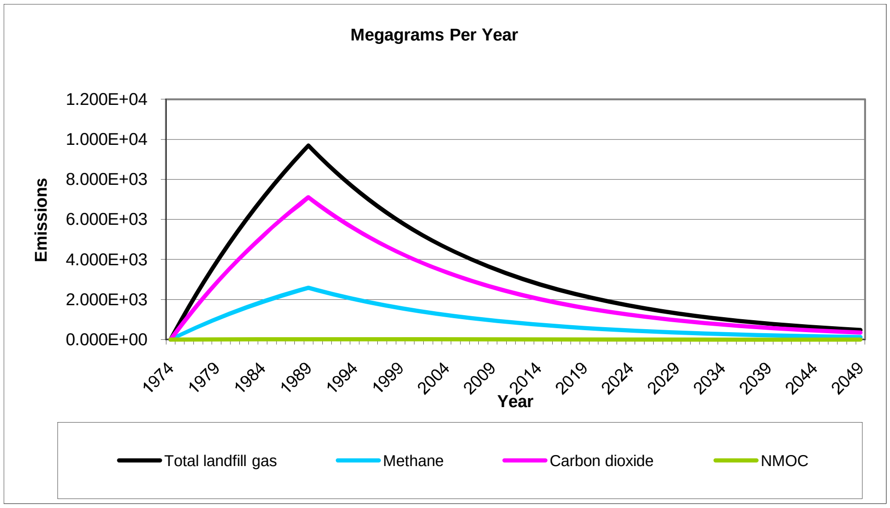
Pollutant Parameters

		Gas / Pollutant Default Parameters:		User-specified Pollutant Parameters:	
	Compound	Concentration (*ppmv*)	Molecular Weight	Concentration (*ppmv*)	Molecular Weight
Gases	Total landfill gas		0.00		
	Methane		16.04		
	Carbon dioxide		44.01		
	NMOC	4,000	86.18		
Pollutants	1,1,1-Trichloroethane (methyl chloroform) - HAP	0.48	133.41		
	1,1,2,2-Tetrachloroethane - HAP/VOC	1.1	167.85		
	1,1-Dichloroethane (ethylidene dichloride) - HAP/VOC	2.4	98.97		
	1,1-Dichloroethene (vinylidene chloride) - HAP/VOC	0.20	96.94		
	1,2-Dichloroethane (ethylene dichloride) - HAP/VOC	0.41	98.96		
	1,2-Dichloropropane (propylene dichloride) - HAP/VOC	0.18	112.99		
	2-Propanol (isopropyl alcohol) - VOC	50	60.11		
	Acetone	7.0	58.08		
	Acrylonitrile - HAP/VOC	6.3	53.06		
	Benzene - No or Unknown Co-disposal - HAP/VOC	1.9	78.11		
	Benzene - Co-disposal - HAP/VOC	11	78.11		
	Bromodichloromethane - VOC	3.1	163.83		
	Butane - VOC	5.0	58.12		
	Carbon disulfide - HAP/VOC	0.58	76.13		
	Carbon monoxide	140	28.01		
	Carbon tetrachloride - HAP/VOC	4.0E-03	153.84		
	Carbonyl sulfide - HAP/VOC	0.49	60.07		
	Chlorobenzene - HAP/VOC	0.25	112.56		
	Chlorodifluoromethane	1.3	86.47		
	Chloroethane (ethyl chloride) - HAP/VOC	1.3	64.52		
	Chloroform - HAP/VOC	0.03	119.39		
	Chloromethane - VOC	1.2	50.49		
	Dichlorobenzene - (HAP for para isomer/VOC)	0.21	147		
	Dichlorodifluoromethane	16	120.91		
	Dichlorofluoromethane - VOC	2.6	102.92		
	Dichloromethane (methylene chloride) - HAP	14	84.94		
	Dimethyl sulfide (methyl sulfide) - VOC	7.8	62.13		
	Ethane	890	30.07		
	Ethanol - VOC	27	46.08		

Pollutant Parameters (Continued)

	Gas / Pollutant Default Parameters:			User-specified Pollutant Parameters:	
	Compound	Concentration (*ppmv*)	Molecular Weight	Concentration (*ppmv*)	Molecular Weight
Pollutants	Ethyl mercaptan (ethanethiol) - VOC	2.3	62.13		
	Ethylbenzene - HAP/VOC	4.6	106.16		
	Ethylene dibromide - HAP/VOC	1.0E-03	187.88		
	Fluorotrichloromethane - VOC	0.76	137.38		
	Hexane - HAP/VOC	6.6	86.18		
	Hydrogen sulfide	36	34.08		
	Mercury (total) - HAP	2.9E-04	200.61		
	Methyl ethyl ketone - HAP/VOC	7.1	72.11		
	Methyl isobutyl ketone - HAP/VOC	1.9	100.16		
	Methyl mercaptan - VOC	2.5	48.11		
	Pentane - VOC	3.3	72.15		
	Perchloroethylene (tetrachloroethylene) - HAP	3.7	165.83		
	Propane - VOC	11	44.09		
	t-1,2-Dichloroethene - VOC	2.8	96.94		
	Toluene - No or Unknown Co-disposal - HAP/VOC	39	92.13		
	Toluene - Co-disposal - HAP/VOC	170	92.13		
	Trichloroethylene (trichloroethene) - HAP/VOC	2.8	131.40		
	Vinyl chloride - HAP/VOC	7.3	62.50		
	Xylenes - HAP/VOC	12	106.16		

Graphs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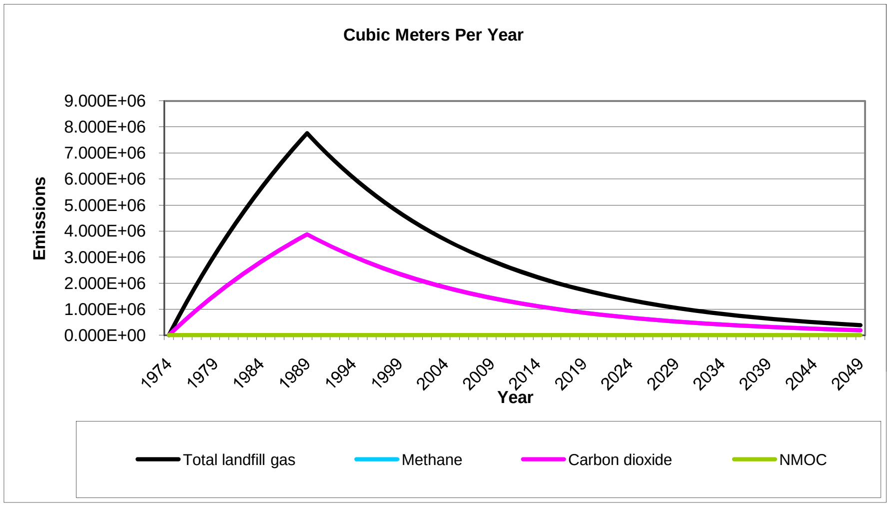
1.000E+04
8.000E+03
6.000E+03
4.000E+03
2.000E+03
0.000E+00
Emissions
1974
1979
1984
1989
1994
1999
2004
2009
2014
2019
2024
2029
2034
2039
2044
2049
Year
Total landfill gas
Methane
Carbon dioxide
NMOC


Cubic Meters Per Year
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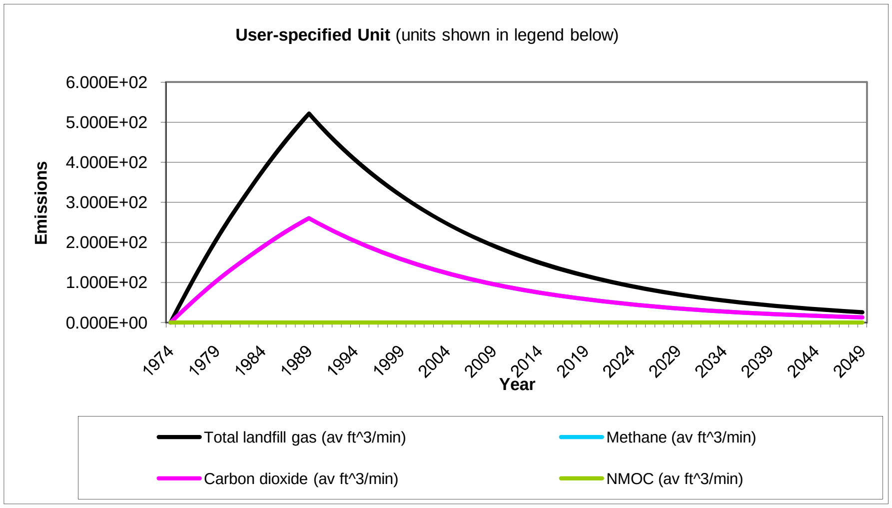
8.000E+06
7.000E+06
6.000E+06
5.000E+06
4.000E+06
3.000E+06
2.000E+06
1.000E+06
0.000E+00
Emissions
1974
1979
1984
1989
1994
1999
2004
2009
2014
2019
2024
2029
2034
2039
2044
2049
Year
Total landfill gas
Methane
Carbon dioxide
NMOC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6.000E+02
5.000E+02
4.000E+02
3.000E+02
2.000E+02
1.000E+02
0.000E+00
Emissions
1974
1979
1984
1989
1994
1999
2004
2009
2014
2019
2024
2029
2034
2039
2044
2049
Year
Total landfill gas (av ft^3/min)
Methane (av ft^3/min)
Carbon dioxide (av ft^3/min)
NMOC (av ft^3/min)

Results

Year	Total landfill gas			Methane		
	(Mg/year)	*(m^3/year)*	*(av ft^3/min)*	*(Mg/year)*	*(m^3/year)*	*(av ft^3/min)*
1974	0	0	0	0	0	0
1975	8.303E+02	6.648E+05	4.467E+01	2.218E+02	3.324E+05	2.234E+01
1976	1.639E+03	1.312E+06	8.818E+01	4.378E+02	6.562E+05	4.409E+01
1977	2.412E+03	1.932E+06	1.298E+02	6.444E+02	9.659E+05	6.490E+01
1978	3.162E+03	2.532E+06	1.701E+02	8.446E+02	1.266E+06	8.506E+01
1979	3.887E+03	3.112E+06	2.091E+02	1.038E+03	1.556E+06	1.046E+02
1980	4.548E+03	3.642E+06	2.447E+02	1.215E+03	1.821E+06	1.224E+02
1981	5.206E+03	4.169E+06	2.801E+02	1.391E+03	2.084E+06	1.400E+02
1982	5.837E+03	4.674E+06	3.141E+02	1.559E+03	2.337E+06	1.570E+02
1983	6.452E+03	5.166E+06	3.471E+02	1.723E+03	2.583E+06	1.736E+02
1984	7.045E+03	5.641E+06	3.790E+02	1.882E+03	2.821E+06	1.895E+02
1985	7.614E+03	6.097E+06	4.097E+02	2.034E+03	3.049E+06	2.048E+02
1986	8.165E+03	6.538E+06	4.393E+02	2.181E+03	3.269E+06	2.196E+02
1987	8.694E+03	6.962E+06	4.678E+02	2.322E+03	3.481E+06	2.339E+02
1988	9.201E+03	7.368E+06	4.950E+02	2.458E+03	3.684E+06	2.475E+02
1989	9.694E+03	7.763E+06	5.216E+02	2.589E+03	3.881E+06	2.608E+02
1990	9.221E+03	7.384E+06	4.961E+02	2.463E+03	3.692E+06	2.481E+02
1991	8.772E+03	7.024E+06	4.719E+02	2.343E+03	3.512E+06	2.360E+02
1992	8.344E+03	6.681E+06	4.489E+02	2.229E+03	3.341E+06	2.245E+02
1993	7.937E+03	6.355E+06	4.270E+02	2.120E+03	3.178E+06	2.135E+02
1994	7.550E+03	6.045E+06	4.062E+02	2.017E+03	3.023E+06	2.031E+02
1995	7.182E+03	5.751E+06	3.864E+02	1.918E+03	2.875E+06	1.932E+02
1996	6.831E+03	5.470E+06	3.675E+02	1.825E+03	2.735E+06	1.838E+02
1997	6.498E+03	5.203E+06	3.496E+02	1.736E+03	2.602E+06	1.748E+02
1998	6.181E+03	4.950E+06	3.326E+02	1.651E+03	2.475E+06	1.663E+02
1999	5.880E+03	4.708E+06	3.163E+02	1.571E+03	2.354E+06	1.582E+02
2000	5.593E+03	4.479E+06	3.009E+02	1.494E+03	2.239E+06	1.505E+02
2001	5.320E+03	4.260E+06	2.862E+02	1.421E+03	2.130E+06	1.431E+02
2002	5.061E+03	4.052E+06	2.723E+02	1.352E+03	2.026E+06	1.361E+02
2003	4.814E+03	3.855E+06	2.590E+02	1.286E+03	1.927E+06	1.295E+02
2004	4.579E+03	3.667E+06	2.464E+02	1.223E+03	1.833E+06	1.232E+02
2005	4.356E+03	3.488E+06	2.344E+02	1.163E+03	1.744E+06	1.172E+02
2006	4.143E+03	3.318E+06	2.229E+02	1.107E+03	1.659E+06	1.115E+02
2007	3.941E+03	3.156E+06	2.121E+02	1.053E+03	1.578E+06	1.060E+02
2008	3.749E+03	3.002E+06	2.017E+02	1.001E+03	1.501E+06	1.009E+02
2009	3.566E+03	2.856E+06	1.919E+02	9.526E+02	1.428E+06	9.594E+01
2010	3.392E+03	2.716E+06	1.825E+02	9.061E+02	1.358E+06	9.126E+01
2011	3.227E+03	2.584E+06	1.736E+02	8.619E+02	1.292E+06	8.681E+01
2012	3.069E+03	2.458E+06	1.651E+02	8.199E+02	1.229E+06	8.257E+01
2013	2.920E+03	2.338E+06	1.571E+02	7.799E+02	1.169E+06	7.855E+01
2014	2.777E+03	2.224E+06	1.494E+02	7.419E+02	1.112E+06	7.472E+01
2015	2.642E+03	2.116E+06	1.421E+02	7.057E+02	1.058E+06	7.107E+01
2016	2.513E+03	2.012E+06	1.352E+02	6.713E+02	1.006E+06	6.761E+01
2017	2.391E+03	1.914E+06	1.286E+02	6.385E+02	9.571E+05	6.431E+01
2018	2.274E+03	1.821E+06	1.223E+02	6.074E+02	9.104E+05	6.117E+01
2019	2.163E+03	1.732E+06	1.164E+02	5.778E+02	8.660E+05	5.819E+01
2020	2.058E+03	1.648E+06	1.107E+02	5.496E+02	8.238E+05	5.535E+01
2021	1.957E+03	1.567E+06	1.053E+02	5.228E+02	7.836E+05	5.265E+01
2022	1.862E+03	1.491E+06	1.002E+02	4.973E+02	7.454E+05	5.008E+01
2023	1.771E+03	1.418E+06	9.528E+01	4.730E+02	7.090E+05	4.764E+01

Results (Continued)

Year	Total landfill gas			Methane		
	(Mg/year)	*(m^3/year)*	*(av ft^3/min)*	*(Mg/year)*	*(m^3/year)*	*(av ft^3/min)*
2024	1.685E+03	1.349E+06	9.063E+01	4.500E+02	6.745E+05	4.532E+01
2025	1.602E+03	1.283E+06	8.621E+01	4.280E+02	6.416E+05	4.311E+01
2026	1.524E+03	1.221E+06	8.201E+01	4.071E+02	6.103E+05	4.100E+01
2027	1.450E+03	1.161E+06	7.801E+01	3.873E+02	5.805E+05	3.900E+01
2028	1.379E+03	1.104E+06	7.420E+01	3.684E+02	5.522E+05	3.710E+01
2029	1.312E+03	1.051E+06	7.059E+01	3.504E+02	5.253E+05	3.529E+01
2030	1.248E+03	9.993E+05	6.714E+01	3.333E+02	4.997E+05	3.357E+01
2031	1.187E+03	9.506E+05	6.387E+01	3.171E+02	4.753E+05	3.193E+01
2032	1.129E+03	9.042E+05	6.075E+01	3.016E+02	4.521E+05	3.038E+01
2033	1.074E+03	8.601E+05	5.779E+01	2.869E+02	4.301E+05	2.890E+01
2034	1.022E+03	8.182E+05	5.497E+01	2.729E+02	4.091E+05	2.749E+01
2035	9.719E+02	7.783E+05	5.229E+01	2.596E+02	3.891E+05	2.615E+01
2036	9.245E+02	7.403E+05	4.974E+01	2.469E+02	3.702E+05	2.487E+01
2037	8.794E+02	7.042E+05	4.732E+01	2.349E+02	3.521E+05	2.366E+01
2038	8.365E+02	6.699E+05	4.501E+01	2.234E+02	3.349E+05	2.250E+01
2039	7.957E+02	6.372E+05	4.281E+01	2.125E+02	3.186E+05	2.141E+01
2040	7.569E+02	6.061E+05	4.072E+01	2.022E+02	3.031E+05	2.036E+01
2041	7.200E+02	5.766E+05	3.874E+01	1.923E+02	2.883E+05	1.937E+01
2042	6.849E+02	5.484E+05	3.685E+01	1.829E+02	2.742E+05	1.842E+01
2043	6.515E+02	5.217E+05	3.505E+01	1.740E+02	2.608E+05	1.753E+01
2044	6.197E+02	4.962E+05	3.334E+01	1.655E+02	2.481E+05	1.667E+01
2045	5.895E+02	4.720E+05	3.172E+01	1.575E+02	2.360E+05	1.586E+01
2046	5.607E+02	4.490E+05	3.017E+01	1.498E+02	2.245E+05	1.508E+01
2047	5.334E+02	4.271E+05	2.870E+01	1.425E+02	2.136E+05	1.435E+01
2048	5.074E+02	4.063E+05	2.730E+01	1.355E+02	2.031E+05	1.365E+01
2049	4.826E+02	3.865E+05	2.597E+01	1.289E+02	1.932E+05	1.298E+01
2050	4.591E+02	3.676E+05	2.470E+01	1.226E+02	1.838E+05	1.235E+01
2051	4.367E+02	3.497E+05	2.350E+01	1.166E+02	1.748E+05	1.175E+01
2052	4.154E+02	3.326E+05	2.235E+01	1.110E+02	1.663E+05	1.118E+01
2053	3.951E+02	3.164E+05	2.126E+01	1.055E+02	1.582E+05	1.063E+01
2054	3.759E+02	3.010E+05	2.022E+01	1.004E+02	1.505E+05	1.011E+01
2055	3.575E+02	2.863E+05	1.924E+01	9.550E+01	1.432E+05	9.618E+00
2056	3.401E+02	2.723E+05	1.830E+01	9.085E+01	1.362E+05	9.149E+00
2057	3.235E+02	2.591E+05	1.741E+01	8.642E+01	1.295E+05	8.703E+00
2058	3.077E+02	2.464E+05	1.656E+01	8.220E+01	1.232E+05	8.279E+00
2059	2.927E+02	2.344E+05	1.575E+01	7.819E+01	1.172E+05	7.875E+00
2060	2.785E+02	2.230E+05	1.498E+01	7.438E+01	1.115E+05	7.491E+00
2061	2.649E+02	2.121E+05	1.425E+01	7.075E+01	1.061E+05	7.126E+00
2062	2.520E+02	2.018E+05	1.356E+01	6.730E+01	1.009E+05	6.778E+00
2063	2.397E+02	1.919E+05	1.289E+01	6.402E+01	9.596E+04	6.447E+00
2064	2.280E+02	1.826E+05	1.227E+01	6.090E+01	9.128E+04	6.133E+00
2065	2.169E+02	1.737E+05	1.167E+01	5.793E+01	8.683E+04	5.834E+00
2066	2.063E+02	1.652E+05	1.110E+01	5.510E+01	8.259E+04	5.549E+00
2067	1.962E+02	1.571E+05	1.056E+01	5.241E+01	7.856E+04	5.279E+00
2068	1.867E+02	1.495E+05	1.004E+01	4.986E+01	7.473E+04	5.021E+00
2069	1.776E+02	1.422E+05	9.553E+00	4.743E+01	7.109E+04	4.776E+00
2070	1.689E+02	1.352E+05	9.087E+00	4.511E+01	6.762E+04	4.543E+00
2071	1.607E+02	1.286E+05	8.644E+00	4.291E+01	6.432E+04	4.322E+00
2072	1.528E+02	1.224E+05	8.222E+00	4.082E+01	6.119E+04	4.111E+00
2073	1.454E+02	1.164E+05	7.821E+00	3.883E+01	5.820E+04	3.911E+00
2074	1.383E+02	1.107E+05	7.440E+00	3.694E+01	5.536E+04	3.720E+00

Results (Continued)

Year	Total landfill gas			Methane		
	(Mg/year)	*(m^3/year)*	*(av ft^3/min)*	*(Mg/year)*	*(m^3/year)*	*(av ft^3/min)*
2075	1.315E+02	1.053E+05	7.077E+00	3.513E+01	5.266E+04	3.538E+00
2076	1.251E+02	1.002E+05	6.732E+00	3.342E+01	5.009E+04	3.366E+00
2077	1.190E+02	9.530E+04	6.403E+00	3.179E+01	4.765E+04	3.202E+00
2078	1.132E+02	9.066E+04	6.091E+00	3.024E+01	4.533E+04	3.046E+00
2079	1.077E+02	8.623E+04	5.794E+00	2.877E+01	4.312E+04	2.897E+00
2080	1.024E+02	8.203E+04	5.511E+00	2.736E+01	4.101E+04	2.756E+00
2081	9.744E+01	7.803E+04	5.243E+00	2.603E+01	3.901E+04	2.621E+00
2082	9.269E+01	7.422E+04	4.987E+00	2.476E+01	3.711E+04	2.493E+00
2083	8.817E+01	7.060E+04	4.744E+00	2.355E+01	3.530E+04	2.372E+00
2084	8.387E+01	6.716E+04	4.512E+00	2.240E+01	3.358E+04	2.256E+00
2085	7.978E+01	6.388E+04	4.292E+00	2.131E+01	3.194E+04	2.146E+00
2086	7.589E+01	6.077E+04	4.083E+00	2.027E+01	3.038E+04	2.041E+00
2087	7.219E+01	5.780E+04	3.884E+00	1.928E+01	2.890E+04	1.942E+00
2088	6.867E+01	5.499E+04	3.694E+00	1.834E+01	2.749E+04	1.847E+00
2089	6.532E+01	5.230E+04	3.514E+00	1.745E+01	2.615E+04	1.757E+00
2090	6.213E+01	4.975E+04	3.343E+00	1.660E+01	2.488E+04	1.671E+00
2091	5.910E+01	4.733E+04	3.180E+00	1.579E+01	2.366E+04	1.590E+00
2092	5.622E+01	4.502E+04	3.025E+00	1.502E+01	2.251E+04	1.512E+00
2093	5.348E+01	4.282E+04	2.877E+00	1.428E+01	2.141E+04	1.439E+00
2094	5.087E+01	4.073E+04	2.737E+00	1.359E+01	2.037E+04	1.368E+00
2095	4.839E+01	3.875E+04	2.603E+00	1.293E+01	1.937E+04	1.302E+00
2096	4.603E+01	3.686E+04	2.476E+00	1.229E+01	1.843E+04	1.238E+00
2097	4.378E+01	3.506E+04	2.356E+00	1.170E+01	1.753E+04	1.178E+00
2098	4.165E+01	3.335E+04	2.241E+00	1.112E+01	1.668E+04	1.120E+00
2099	3.962E+01	3.172E+04	2.132E+00	1.058E+01	1.586E+04	1.066E+00
2100	3.769E+01	3.018E+04	2.028E+00	1.007E+01	1.509E+04	1.014E+00
2101	3.585E+01	2.870E+04	1.929E+00	9.575E+00	1.435E+04	9.643E-01
2102	3.410E+01	2.730E+04	1.835E+00	9.108E+00	1.365E+04	9.173E-01
2103	3.244E+01	2.597E+04	1.745E+00	8.664E+00	1.299E+04	8.726E-01
2104	3.085E+01	2.471E+04	1.660E+00	8.241E+00	1.235E+04	8.300E-01
2105	2.935E+01	2.350E+04	1.579E+00	7.839E+00	1.175E+04	7.895E-01
2106	2.792E+01	2.236E+04	1.502E+00	7.457E+00	1.118E+04	7.510E-01
2107	2.656E+01	2.127E+04	1.429E+00	7.093E+00	1.063E+04	7.144E-01
2108	2.526E+01	2.023E+04	1.359E+00	6.748E+00	1.011E+04	6.796E-01
2109	2.403E+01	1.924E+04	1.293E+00	6.418E+00	9.621E+03	6.464E-01
2110	2.286E+01	1.830E+04	1.230E+00	6.105E+00	9.151E+03	6.149E-01
2111	2.174E+01	1.741E+04	1.170E+00	5.808E+00	8.705E+03	5.849E-01
2112	2.068E+01	1.656E+04	1.113E+00	5.524E+00	8.281E+03	5.564E-01
2113	1.967E+01	1.575E+04	1.058E+00	5.255E+00	7.877E+03	5.292E-01
2114	1.871E+01	1.499E+04	1.007E+00	4.999E+00	7.493E+03	5.034E-01

Results (Continued)

Year	Carbon dioxide			NMOC		
	(Mg/year)	*(m^3/year)*	*(av ft^3/min)*	*(Mg/year)*	*(m^3/year)*	*(av ft^3/min)*
1974	0	0	0	0	0	0
1975	6.085E+02	3.324E+05	2.234E+01	1.947E+00	5.432E+02	3.650E-02
1976	1.201E+03	6.562E+05	4.409E+01	3.843E+00	1.072E+03	7.204E-02
1977	1.768E+03	9.659E+05	6.490E+01	5.657E+00	1.578E+03	1.060E-01
1978	2.317E+03	1.266E+06	8.506E+01	7.415E+00	2.069E+03	1.390E-01
1979	2.849E+03	1.556E+06	1.046E+02	9.115E+00	2.543E+03	1.709E-01
1980	3.334E+03	1.821E+06	1.224E+02	1.067E+01	2.976E+03	1.999E-01
1981	3.815E+03	2.084E+06	1.400E+02	1.221E+01	3.406E+03	2.288E-01
1982	4.278E+03	2.337E+06	1.570E+02	1.369E+01	3.819E+03	2.566E-01
1983	4.729E+03	2.583E+06	1.736E+02	1.513E+01	4.221E+03	2.836E-01
1984	5.163E+03	2.821E+06	1.895E+02	1.652E+01	4.609E+03	3.097E-01
1985	5.580E+03	3.049E+06	2.048E+02	1.786E+01	4.981E+03	3.347E-01
1986	5.984E+03	3.269E+06	2.196E+02	1.915E+01	5.342E+03	3.589E-01
1987	6.372E+03	3.481E+06	2.339E+02	2.039E+01	5.688E+03	3.822E-01
1988	6.743E+03	3.684E+06	2.475E+02	2.158E+01	6.019E+03	4.044E-01
1989	7.105E+03	3.881E+06	2.608E+02	2.273E+01	6.342E+03	4.261E-01
1990	6.758E+03	3.692E+06	2.481E+02	2.162E+01	6.033E+03	4.053E-01
1991	6.429E+03	3.512E+06	2.360E+02	2.057E+01	5.738E+03	3.856E-01
1992	6.115E+03	3.341E+06	2.245E+02	1.957E+01	5.459E+03	3.668E-01
1993	5.817E+03	3.178E+06	2.135E+02	1.861E+01	5.192E+03	3.489E-01
1994	5.533E+03	3.023E+06	2.031E+02	1.770E+01	4.939E+03	3.319E-01
1995	5.263E+03	2.875E+06	1.932E+02	1.684E+01	4.698E+03	3.157E-01
1996	5.007E+03	2.735E+06	1.838E+02	1.602E+01	4.469E+03	3.003E-01
1997	4.762E+03	2.602E+06	1.748E+02	1.524E+01	4.251E+03	2.856E-01
1998	4.530E+03	2.475E+06	1.663E+02	1.449E+01	4.044E+03	2.717E-01
1999	4.309E+03	2.354E+06	1.582E+02	1.379E+01	3.847E+03	2.585E-01
2000	4.099E+03	2.239E+06	1.505E+02	1.312E+01	3.659E+03	2.458E-01
2001	3.899E+03	2.130E+06	1.431E+02	1.248E+01	3.481E+03	2.339E-01
2002	3.709E+03	2.026E+06	1.361E+02	1.187E+01	3.311E+03	2.225E-01
2003	3.528E+03	1.927E+06	1.295E+02	1.129E+01	3.149E+03	2.116E-01
2004	3.356E+03	1.833E+06	1.232E+02	1.074E+01	2.996E+03	2.013E-01
2005	3.192E+03	1.744E+06	1.172E+02	1.021E+01	2.850E+03	1.915E-01
2006	3.037E+03	1.659E+06	1.115E+02	9.716E+00	2.711E+03	1.821E-01
2007	2.889E+03	1.578E+06	1.060E+02	9.242E+00	2.578E+03	1.732E-01
2008	2.748E+03	1.501E+06	1.009E+02	8.792E+00	2.453E+03	1.648E-01
2009	2.614E+03	1.428E+06	9.594E+01	8.363E+00	2.333E+03	1.568E-01
2010	2.486E+03	1.358E+06	9.126E+01	7.955E+00	2.219E+03	1.491E-01
2011	2.365E+03	1.292E+06	8.681E+01	7.567E+00	2.111E+03	1.418E-01
2012	2.250E+03	1.229E+06	8.257E+01	7.198E+00	2.008E+03	1.349E-01
2013	2.140E+03	1.169E+06	7.855E+01	6.847E+00	1.910E+03	1.283E-01
2014	2.036E+03	1.112E+06	7.472E+01	6.513E+00	1.817E+03	1.221E-01
2015	1.936E+03	1.058E+06	7.107E+01	6.195E+00	1.728E+03	1.161E-01
2016	1.842E+03	1.006E+06	6.761E+01	5.893E+00	1.644E+03	1.105E-01
2017	1.752E+03	9.571E+05	6.431E+01	5.606E+00	1.564E+03	1.051E-01
2018	1.667E+03	9.104E+05	6.117E+01	5.332E+00	1.488E+03	9.995E-02
2019	1.585E+03	8.660E+05	5.819E+01	5.072E+00	1.415E+03	9.508E-02
2020	1.508E+03	8.238E+05	5.535E+01	4.825E+00	1.346E+03	9.044E-02
2021	1.434E+03	7.836E+05	5.265E+01	4.590E+00	1.280E+03	8.603E-02
2022	1.364E+03	7.454E+05	5.008E+01	4.366E+00	1.218E+03	8.184E-02
2023	1.298E+03	7.090E+05	4.764E+01	4.153E+00	1.159E+03	7.784E-02

Results (Continued)

Year	Carbon dioxide			NMOC		
	(Mg/year)	*(m^3/year)*	*(av ft^3/min)*	*(Mg/year)*	*(m^3/year)*	*(av ft^3/min)*
2024	1.235E+03	6.745E+05	4.532E+01	3.950E+00	1.102E+03	7.405E-02
2025	1.174E+03	6.416E+05	4.311E+01	3.758E+00	1.048E+03	7.044E-02
2026	1.117E+03	6.103E+05	4.100E+01	3.574E+00	9.972E+02	6.700E-02
2027	1.063E+03	5.805E+05	3.900E+01	3.400E+00	9.486E+02	6.373E-02
2028	1.011E+03	5.522E+05	3.710E+01	3.234E+00	9.023E+02	6.063E-02
2029	9.615E+02	5.253E+05	3.529E+01	3.077E+00	8.583E+02	5.767E-02
2030	9.146E+02	4.997E+05	3.357E+01	2.926E+00	8.164E+02	5.486E-02
2031	8.700E+02	4.753E+05	3.193E+01	2.784E+00	7.766E+02	5.218E-02
2032	8.276E+02	4.521E+05	3.038E+01	2.648E+00	7.387E+02	4.964E-02
2033	7.872E+02	4.301E+05	2.890E+01	2.519E+00	7.027E+02	4.722E-02
2034	7.488E+02	4.091E+05	2.749E+01	2.396E+00	6.684E+02	4.491E-02
2035	7.123E+02	3.891E+05	2.615E+01	2.279E+00	6.358E+02	4.272E-02
2036	6.776E+02	3.702E+05	2.487E+01	2.168E+00	6.048E+02	4.064E-02
2037	6.445E+02	3.521E+05	2.366E+01	2.062E+00	5.753E+02	3.866E-02
2038	6.131E+02	3.349E+05	2.250E+01	1.962E+00	5.473E+02	3.677E-02
2039	5.832E+02	3.186E+05	2.141E+01	1.866E+00	5.206E+02	3.498E-02
2040	5.547E+02	3.031E+05	2.036E+01	1.775E+00	4.952E+02	3.327E-02
2041	5.277E+02	2.883E+05	1.937E+01	1.688E+00	4.710E+02	3.165E-02
2042	5.020E+02	2.742E+05	1.842E+01	1.606E+00	4.481E+02	3.011E-02
2043	4.775E+02	2.608E+05	1.753E+01	1.528E+00	4.262E+02	2.864E-02
2044	4.542E+02	2.481E+05	1.667E+01	1.453E+00	4.054E+02	2.724E-02
2045	4.320E+02	2.360E+05	1.586E+01	1.382E+00	3.857E+02	2.591E-02
2046	4.110E+02	2.245E+05	1.508E+01	1.315E+00	3.668E+02	2.465E-02
2047	3.909E+02	2.136E+05	1.435E+01	1.251E+00	3.490E+02	2.345E-02
2048	3.719E+02	2.031E+05	1.365E+01	1.190E+00	3.319E+02	2.230E-02
2049	3.537E+02	1.932E+05	1.298E+01	1.132E+00	3.157E+02	2.122E-02
2050	3.365E+02	1.838E+05	1.235E+01	1.077E+00	3.003E+02	2.018E-02
2051	3.201E+02	1.748E+05	1.175E+01	1.024E+00	2.857E+02	1.920E-02
2052	3.044E+02	1.663E+05	1.118E+01	9.741E-01	2.718E+02	1.826E-02
2053	2.896E+02	1.582E+05	1.063E+01	9.266E-01	2.585E+02	1.737E-02
2054	2.755E+02	1.505E+05	1.011E+01	8.814E-01	2.459E+02	1.652E-02
2055	2.620E+02	1.432E+05	9.618E+00	8.385E-01	2.339E+02	1.572E-02
2056	2.493E+02	1.362E+05	9.149E+00	7.976E-01	2.225E+02	1.495E-02
2057	2.371E+02	1.295E+05	8.703E+00	7.587E-01	2.117E+02	1.422E-02
2058	2.255E+02	1.232E+05	8.279E+00	7.217E-01	2.013E+02	1.353E-02
2059	2.145E+02	1.172E+05	7.875E+00	6.865E-01	1.915E+02	1.287E-02
2060	2.041E+02	1.115E+05	7.491E+00	6.530E-01	1.822E+02	1.224E-02
2061	1.941E+02	1.061E+05	7.126E+00	6.211E-01	1.733E+02	1.164E-02
2062	1.847E+02	1.009E+05	6.778E+00	5.908E-01	1.648E+02	1.108E-02
2063	1.757E+02	9.596E+04	6.447E+00	5.620E-01	1.568E+02	1.054E-02
2064	1.671E+02	9.128E+04	6.133E+00	5.346E-01	1.491E+02	1.002E-02
2065	1.589E+02	8.683E+04	5.834E+00	5.085E-01	1.419E+02	9.533E-03
2066	1.512E+02	8.259E+04	5.549E+00	4.837E-01	1.350E+02	9.068E-03
2067	1.438E+02	7.856E+04	5.279E+00	4.602E-01	1.284E+02	8.625E-03
2068	1.368E+02	7.473E+04	5.021E+00	4.377E-01	1.221E+02	8.205E-03
2069	1.301E+02	7.109E+04	4.776E+00	4.164E-01	1.162E+02	7.805E-03
2070	1.238E+02	6.762E+04	4.543E+00	3.961E-01	1.105E+02	7.424E-03
2071	1.177E+02	6.432E+04	4.322E+00	3.767E-01	1.051E+02	7.062E-03
2072	1.120E+02	6.119E+04	4.111E+00	3.584E-01	9.998E+01	6.717E-03
2073	1.065E+02	5.820E+04	3.911E+00	3.409E-01	9.510E+01	6.390E-03
2074	1.013E+02	5.536E+04	3.720E+00	3.243E-01	9.046E+01	6.078E-03

Results (Continued)

Year	Carbon dioxide			NMOC		
	(Mg/year)	*(m^3/year)*	*(av ft^3/min)*	*(Mg/year)*	*(m^3/year)*	*(av ft^3/min)*
2075	9.640E+01	5.266E+04	3.538E+00	3.084E-01	8.605E+01	5.782E-03
2076	9.170E+01	5.009E+04	3.366E+00	2.934E-01	8.185E+01	5.500E-03
2077	8.723E+01	4.765E+04	3.202E+00	2.791E-01	7.786E+01	5.232E-03
2078	8.297E+01	4.533E+04	3.046E+00	2.655E-01	7.407E+01	4.976E-03
2079	7.893E+01	4.312E+04	2.897E+00	2.525E-01	7.045E+01	4.734E-03
2080	7.508E+01	4.101E+04	2.756E+00	2.402E-01	6.702E+01	4.503E-03
2081	7.141E+01	3.901E+04	2.621E+00	2.285E-01	6.375E+01	4.283E-03
2082	6.793E+01	3.711E+04	2.493E+00	2.174E-01	6.064E+01	4.074E-03
2083	6.462E+01	3.530E+04	2.372E+00	2.068E-01	5.768E+01	3.876E-03
2084	6.147E+01	3.358E+04	2.256E+00	1.967E-01	5.487E+01	3.687E-03
2085	5.847E+01	3.194E+04	2.146E+00	1.871E-01	5.219E+01	3.507E-03
2086	5.562E+01	3.038E+04	2.041E+00	1.780E-01	4.965E+01	3.336E-03
2087	5.291E+01	2.890E+04	1.942E+00	1.693E-01	4.723E+01	3.173E-03
2088	5.033E+01	2.749E+04	1.847E+00	1.610E-01	4.492E+01	3.018E-03
2089	4.787E+01	2.615E+04	1.757E+00	1.532E-01	4.273E+01	2.871E-03
2090	4.554E+01	2.488E+04	1.671E+00	1.457E-01	4.065E+01	2.731E-03
2091	4.332E+01	2.366E+04	1.590E+00	1.386E-01	3.867E+01	2.598E-03
2092	4.120E+01	2.251E+04	1.512E+00	1.318E-01	3.678E+01	2.471E-03
2093	3.919E+01	2.141E+04	1.439E+00	1.254E-01	3.499E+01	2.351E-03
2094	3.728E+01	2.037E+04	1.368E+00	1.193E-01	3.328E+01	2.236E-03
2095	3.546E+01	1.937E+04	1.302E+00	1.135E-01	3.166E+01	2.127E-03
2096	3.373E+01	1.843E+04	1.238E+00	1.079E-01	3.011E+01	2.023E-03
2097	3.209E+01	1.753E+04	1.178E+00	1.027E-01	2.864E+01	1.925E-03
2098	3.052E+01	1.668E+04	1.120E+00	9.767E-02	2.725E+01	1.831E-03
2099	2.904E+01	1.586E+04	1.066E+00	9.290E-02	2.592E+01	1.741E-03
2100	2.762E+01	1.509E+04	1.014E+00	8.837E-02	2.465E+01	1.657E-03
2101	2.627E+01	1.435E+04	9.643E-01	8.406E-02	2.345E+01	1.576E-03
2102	2.499E+01	1.365E+04	9.173E-01	7.996E-02	2.231E+01	1.499E-03
2103	2.377E+01	1.299E+04	8.726E-01	7.606E-02	2.122E+01	1.426E-03
2104	2.261E+01	1.235E+04	8.300E-01	7.235E-02	2.019E+01	1.356E-03
2105	2.151E+01	1.175E+04	7.895E-01	6.882E-02	1.920E+01	1.290E-03
2106	2.046E+01	1.118E+04	7.510E-01	6.547E-02	1.826E+01	1.227E-03
2107	1.946E+01	1.063E+04	7.144E-01	6.227E-02	1.737E+01	1.167E-03
2108	1.851E+01	1.011E+04	6.796E-01	5.924E-02	1.653E+01	1.110E-03
2109	1.761E+01	9.621E+03	6.464E-01	5.635E-02	1.572E+01	1.056E-03
2110	1.675E+01	9.151E+03	6.149E-01	5.360E-02	1.495E+01	1.005E-03
2111	1.593E+01	8.705E+03	5.849E-01	5.099E-02	1.422E+01	9.557E-04
2112	1.516E+01	8.281E+03	5.564E-01	4.850E-02	1.353E+01	9.091E-04
2113	1.442E+01	7.877E+03	5.292E-01	4.613E-02	1.287E+01	8.648E-04
2114	1.372E+01	7.493E+03	5.034E-01	4.388E-02	1.224E+01	8.226E-04

APPENDIX B

CARBON FOOTPRINT ANALYSIS

AECOM

Carbon Footprint Calculations   Baseline

Refuse Hideaway Landfill
7562 US Highway 14
Middleton, WI 53562

Scope 1

			Emission Factors			Mass						CO_2e Greenhouse Gas Potentials			Total		
												1	25	298			
Gaseous Fuels Burned On-Site	**Year**	**Usage (lbs/yr)**	lbs CO_2/gal	lb CH_4/gal	lb N_2O/gal	lb CO_2	kg CO_2	lb CH_4	kg CH_4	lb N_2O	kg N_2O	kg CO_2e/kg CO_2	kg CO_2e/kg CH_4	kg CO_2e/kg N_2O	kg CO_2e	lb CO_2e	ton CO_2e
Propane for Flare	2010	23.0	12.5	0.0002	0.0009	18,827.50	8,540.15	0.30	0.14	1.36	0.61	8,540.15	3.42	183.24	8,726.81	19,242.61	9.62
Methane Gas- Destroyed	2010	--	--	--	--	--	--	--	259,802.34	--	--	--	714,456	--	714,456.42	1,575,376.41	787.69
			See Note 1	*See Note 1*	*See Note 1*				*See Note 2*				*See Note 3, 4*	*See Note 3*			

Scope 2

				Emission Factors			Mass			CO_2e Greenhouse Gas Potentials			Total		
										1	25	298			
Purchased Electricity	**Year**	**Usage (kWh)**	**Usage (GWh)**	lb CO_2/GWh	lb CH_4/GWh	lb N_2O/GWh	lb CO_2	lb CH_4	lb N_2O	lb CO_2e/lb CO_2	lb CO_2e/lb CH_4	lb CO_2e/lb N_2O	kg CO_2e	lb CO_2e	ton CO_2e
Remedial System	2010	43,039	0.043039	1.97	26.79	27.3	0.08	1.15	1.17	0.08	28.83	350.14	835.65	379.05	0.19
		See Note 5		*See Note 6*	*See Note 6*	*See Note 6*					*See Note 3*	*See Note 3*			

Scope 3

				Emission Factors			Mass			CO_2e Greenhouse Gas Potentials			Total		
										1	25	298			
Sampling/O&M Vehicle Usage	**Year**	**Usage (miles/yr)**	**Usage (gal/yr)**	kg CO_2/gallon	kg CH_4/gallon	kg N_2O/gallon	kg CO_2	kg CH_4	kg N_2O	kg CO_2e/kg CO_2	kg CO2e/kg CH_4	kg CO2e/kg N_2O	kg CO_2e	lb CO_2e	ton CO_2e
Unleaded Gasoline	2010	1,992	110.67	8.81	0.0036	0.0004	974.97	0.40	0.04	974.97	10.08	13.06	998.11	2,200.84	1.10
Diesel - Leachate Hauling	2010	2,820	353	10.15	0.000041	0.000038	3,577.88	0.01	0.01	3577.88	0.36	4.03	3,582.27	7,898.90	3.95
Methane Gas - Fugitive from LFG System	2010	--	--	--	--	--	--	230,935.41	--	--	5,773,385	--	5,773,385.22	12,730,314.42	6,365.16
Methane Gas- Fugitive Escape	2010	--	--	--	--	--	--	122,684.44	--	--	3,067,111	--	3,067,110.90	6,762,979.53	3,381.49
				See Note 7	*See Note 7*	*See Note 7*		See Note 2			*See Note 3*	*See Note 3*			

Totals		
kg CO_2e	lb CO_2e	ton CO_2e
9,569,095.38	21,098,391.76	10,549.20

Assumptions: *Unleaded gasoline used for consultant transport to conduct O&M actvities.*
Diesel fuel used for leachate transport. Leachate disposed of in Madison, Wisconsin.
119 site visits in 2010 for site sampling and O&M; 30 miles/visit (roundtrip)
4 site visits per year for WDNR inspections; 22 miles/visit (roundtrip)
94 site visits for leachate disposal (tank emptied at ~5,000 gallons); 30 miles/visit (roundtrip)
18 miles/gallon for field vehicle and 8 miles/gallon for Heavy Duty Hauling Vehicle.

Conversions/Factors: *1,000 kWh = 1.0E+6 GWh*
Density of methane = 0.717 kg/m^3 (gas)
Density of propane= 1.83 kg/m^3 (gas)

Source Notes:
1. *Leonardo Academy, Emission Factors and Energy Prices for Leonardo Academy's Cleaner and Greener Program, April 21, 2009*
2. *Derived from 2010 cubic meters per year methane value presented in the Results table, landgem-v302.xls prepared by Paul Wintheiser, P.E., AECOM Environment..*
3. *Greenhouse Gas Potential for CH4 and N2O taken from IPCC Fourth Assessment Report (2007).*
4. *For every pound of methane combusted there are 2.75 pounds of carbon produced.*
5. *Utility usage reported by Madison Gas and Electric.*
6. *EPA (Environmental Protection Agency) eGRIDweb Parent Company Owner-based Level Emissions Profile- Madison Gas & Electric Co. Emission Profile, 2005.*
7. *EPA (Environmental Protection Agency) Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobil Combustion Sources, Section 3, Table 2: CH_4 and N_2O Emission Factors for Highway Vehicles, Gasoline Light-Duty Trucks, and Section 4, Table 5: Factors for Gasoline and On-Road Diesel Fuel, May 2008.*

AECOM

Carbon Footprint Calculations Option 1 - Improvements to Flare System

Refuse Hideaway Landfill
7562 US Highway 14
Middleton, WI 53562

Scope 1

Gaseous Fuels Burned On-Site	Year	Usage (lbs/yr)	Emission Factors			Mass						CO_2e Greenhouse Gas Potentials			Total		
												1	25	298			
			lbs CO_2/gal	lb CH_4/gal	lb N_2O/gal	lb CO_2	kg CO_2	lb CH_4	kg CH_4	lb N_2O	kg N_2O	kg CO_2e/kg CO_2	kg CO_2e/kg CH_4	kg CO_2e/kg N_2O	kg CO_2e	lb CO_2e	ton CO_2e
Propane for Flare	2010	23.0	12.5	0.0002	0.0009	18,827.50	8,540.15	0.30	0.14	1.36	0.61	8,540.15	3.42	183.24	8,726.81	19,242.61	9.62
Methane Gas- Destroyed	2010	--	--	--	--	--	--	--	490,737.74	--	--	--	1,349,529	--	1,349,528.80	2,975,711.00	1,487.86
			See Note 1	*See Note 1*	*See Note 1*				*See Note 2*				*See Note 3, 4*	*See Note 3*			

Scope 2

Purchased Electricity	Year	Usage (kWh)	Usage (GWh)	Emission Factors			Mass			CO_2e Greenhouse Gas Potentials			Total		
										1	25	298			
				lb CO_2/GWh	lb CH_4/GWh	lb N_2O/GWh	lb CO_2	lb CH_4	lb N_2O	lb CO_2e/lb CO_2	lb CO_2e/lb CH_4	lb CO_2e/lb N_2O	kg CO_2e	lb CO_2e	ton CO_2e
Remedial System	2010	43,039	0.043039	1.97	26.79	27.3	0.08	1.15	1.17	0.08	28.83	350.14	835.65	379.05	0.19
		See Note 5		*See Note 6*	*See Note 6*	*See Note 6*					*See Note 3*	*See Note 3*			

Scope 3

Sampling/O&M Vehicle Usage	Year	Usage (miles/yr)	Usage (gal/yr)	Emission Factors			Mass			CO_2e Greenhouse Gas Potentials			Total		
										1	25	298			
				kg CO_2/gallon	kg CH_4/gallon	kg N_2O/gallon	kg CO_2	kg CH_4	kg N_2O	kg CO_2e/kg CO_2	kg CO2e/kg CH_4	kg CO2e/kg N_2O	kg CO_2e	lb CO_2e	ton CO_2e
Unleaded Gasoline	2010	1,992	110.67	8.81	0.0036	0.0004	974.97	0.40	0.04	974.97	10.08	13.06	998.11	2,200.84	1.10
Diesel - Leachate Hauling	2010	2,820	353	10.15	0.000041	0.000038	3,577.88	0.01	0.01	3577.88	0.36	4.03	3,582.27	7,898.90	3.95
Methane Gas - Fugitive from LFG System	2010	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Methane Gas- Fugitive Escape	2010	--	--	--	--	--	--	122,684.44	--	--	3,067,111	--	3,067,110.90	6,762,979.53	3,381.49
				See Note 7	*See Note 7*	*See Note 7*		See Note 2			*See Note 3*	*See Note 3*			

Totals		
kg CO_2e	lb CO_2e	ton CO_2e
4,430,782.53	9,768,411.93	4,884.21

Assumptions: *Unleaded gasoline used for consultant transport to conduct O&M actvities.*
Diesel fuel used for leachate transport. Leachate disposed of in Madison, Wisconsin.
119 site visits in 2010 for site sampling and O&M; 30 miles/visit (roundtrip)
4 site visits per year for WDNR inspections; 22 miles/visit (roundtrip)
94 site visits for leachate disposal (tank emptied at ~5,000 gallons); 30 miles/visit (roundtrip)
18 miles/gallon for field vehicle and 8 miles/gallon for Heavy Duty Hauling Vehicle.
Option 1 assumes that flare is burning 100% of time that blower is running resulting in no fugitive emissions from LFG System

Conversions/Factors: *1,000 kWh = 1.0E+6 GWh*
Density of methane = 0.717 kg/m^3 (gas)
Density of propane= 1.83 kg/m^3 (gas)

Source Notes:
1. *Leonardo Academy, Emission Factors and Energy Prices for Leonardo Academy's Cleaner and Greener Program, April 21, 2009.*
2. *Derived from 2008 cubic meters per year methane value presented in Table Results - 1, landgem-v302.xls prepared by Paul Wintheiser, P.E., AECOM Environment..*
3. *Greenhouse Gas Potential for CH4 and N2O taken from IPCC Fourth Assessment Report (2007).*
4. *For every pound of methane combusted there are 2.75 pounds of carbon produced.*
5. *Utility usage reported by Madison Gas and Electric.*
6. *EPA (Environmental Protection Agency) eGRIDweb Parent Company Owner-based Level Emissions Profile- Madison Gas & Electric Co. Emission Profile, 2005.*
7. *EPA (Environmental Protection Agency) Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobil Combustion Sources, Section 3, Table 2: CH_4 and N_2O Emission Factors for Highway Vehicles, Gasoline Light-Duty Trucks, and Section 4, Table 5: Factors for Gasoline and On-Road Diesel Fuel, May 2008.*

Carbon Footprint Calculations Option 2 - Increase Solar Energy Generation

Refuse Hideaway Landfill
7562 US Highway 14
Middleton, WI 53562

Scope 1

			Emission Factors			Mass						CO_2e Greenhouse Gas Potentials 1	25	298	Total		
Gaseous Fuels Burned On-Site	**Year**	**Usage (lbs/yr)**	lbs CO_2/gal	lb CH_4/gal	lb N_2O/gal	lb CO_2	kg CO_2	lb CH_4	kg CH_4	lb N_2O	kg N_2O	kg CO_2e/kg CO_2	kg CO_2e/kg CH_4	kg CO_2e/kg N_2O	kg CO_2e	lb CO_2e	ton CO_2e
Propane for Flare	2010	23.0	12.5	0.0002	0.0009	18,827.50	8,540.15	0.30	0.14	1.36	0.61	8,540.15	3.42	183.24	8,726.81	19,242.61	9.62
Methane Gas- Destroyed	2010	--	--	--	--	--	--	--	259,802.34	--	--	--	714,456	--	714,456.42	1,575,376.41	787.69
			See Note 1	*See Note 1*	*See Note 1*				*See Note 2*				*See Note 3, 4*	*See Note 3*			

Scope 2

				Emission Factors			Mass			CO_2e Greenhouse Gas Potentials 1	25	298	Total		
Purchased Electricity	**Year**	**Usage (kWh)**	**Usage (GWh)**	lb CO_2/GWh	lb CH_4/GWh	lb N_2O/GWh	lb CO_2	lb CH_4	lb N_2O	lb CO_2e/lb CO_2	lb CO_2e/lb CH_4	lb CO_2e/lb N_2O	kg CO_2e	lb CO_2e	ton CO_2e
Remedial System	2010	--	--	1.97	26.79	27.3	--	--	--	--	--	--	--	--	--
		See Note 5		*See Note 6*	*See Note 6*	*See Note 6*					*See Note 3*	*See Note 3*			

Scope 3

				Emission Factors			Mass			CO_2e Greenhouse Gas Potentials 1	25	298	Total		
Sampling/O&M Vehicle Usage	**Year**	**Usage (miles/yr)**	**Usage (gal/yr)**	kg CO_2/gallon	kg CH_4/gallon	kg N_2O/gallon	kg CO_2	kg CH_4	kg N_2O	kg CO_2e/kg CO_2	kg CO2e/kg CH_4	kg CO2e/kg N_2O	kg CO_2e	lb CO_2e	ton CO_2e
Unleaded Gasoline	2010	1,992	110.67	8.81	0.0036	0.0004	974.97	0.40	0.04	974.97	10.08	13.06	998.11	2,200.84	1.10
Diesel - Leachate Hauling	2010	2,820	353	10.15	0.000041	0.000038	3,577.88	0.01	0.01	3577.88	0.36	4.03	3,582.27	7,898.90	3.95
Methane Gas - Fugitive from LFG System	2010	--	--	--	--	--	--	230,935.41	--	--	5,773,385	--	5,773,385.22	12,730,314.42	6,365.16
Methane Gas- Fugitive Escape	2010	--	--	--	--	--	--	122,684.44	--	--	3,067,111	--	3,067,110.90	6,762,979.53	3,381.49
				See Note 7	*See Note 7*	*See Note 7*		See Note 2			*See Note 3*	*See Note 3*			

Totals		
kg CO_2e	lb CO_2e	ton CO_2e
9,568,259.73	21,098,012.71	10,549.01

Assumptions: *Unleaded gasoline used for consultant transport to conduct O&M actvities.*
Diesel fuel used for leachate transport. Leachate disposed of in Madison, Wisconsin.
119 site visits in 2010 for site sampling and O&M; 30 miles/visit (roundtrip)
4 site visits per year for WDNR inspections; 22 miles/visit (roundtrip)
94 site visits for leachate disposal (tank emptied at ~5,000 gallons); 30 miles/visit (roundtrip)
18 miles/gallon for field vehicle and 8 miles/gallon for Heavy Duty Hauling Vehicle.
**Option 2 assumes that all electricity for remedial system will be powered with solar power*

Conversions/Factors: *1,000 kWh = 1.0E+6 GWh*
Density of methane = 0.717 kg/m^3 (gas)
Density of propane= 1.83 kg/m^3 (gas)

Source Notes:
1. Leonardo Academy, Emission Factors and Energy Prices for Leonardo Academy's Cleaner and Greener Program, April 21, 2009
2. Derived from 2008 cubic meters per year methane value presented in Table Results - 1, landgem-v302.xls prepared by Paul Wintheiser, P.E., AECOM Environment..
3. Greenhouse Gas Potential for CH4 and N2O taken from IPCC Fourth Assessment Report (2007).
4. For every pound of methane combusted there are 2.75 pounds of carbon produced.
5. Utility usage reported by Madison Gas and Electric.
6. EPA (Environmental Protection Agency) eGRIDweb Parent Company Owner-based Level Emissions Profile- Madison Gas & Electric Co. Emission Profile, 2005.
7. EPA (Environmental Protection Agency) Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobil Combustion Sources, Section 3, Table 2: CH_4 and N_2O Emission Factors for Highway Vehicles, Gasoline Light-Duty Trucks, and Section 4, Table 5: Factors for Gasoline and On-Road Diesel Fuel, May 2008.

AECOM

Carbon Footprint Calculations

Option 3 - Leachate Evaporation or Watering

Refuse Hideaway Landfill
7562 US Highway 14
Middleton, WI 53562

Scope 1

			Emission Factors			Mass						CO_2e Greenhouse Gas Potentials 1	25	298	Total		
Gaseous Fuels Burned On-Site	**Year**	**Usage (lbs/yr)**	lbs CO_2/gal	lb CH_4/gal	lb N_2O/gal	lb CO_2	kg CO_2	lb CH_4	kg CH_4	lb N_2O	kg N_2O	kg CO_2e/kg CO_2	kg CO_2e/kg CH_4	kg CO_2e/kg N_2O	kg CO_2e	lb CO_2e	ton CO_2e
Propane for Flare	2010	23.0	12.5	0.0002	0.0009	18,827.50	8,540.15	0.30	0.14	1.36	0.61	8,540.15	3.42	183.24	8,726.81	19,242.61	9.62
Methane Gas- Destroyed	2010	--	--	--	--	--	--	--	259,802.34	--	--	--	714,456	--	714,456.42	1,575,376.41	787.69
			See Note 1	*See Note 1*	*See Note 1*				*See Note 2*				*See Note 3, 4*	*See Note 3*			

Scope 2

			Emission Factors			Mass			CO_2e Greenhouse Gas Potentials 1	25	298	Total		
Purchased Electricity	**Year**	**Usage (kWh)**	**Usage (GWh)**	lb CO_2/GWh	lb CH_4/GWh	lb N_2O/GWh	lb CO_2	lb CH_4	lb N_2O	lb CO_2e/lb CO_2	lb CO_2e/lb CH_4	lb CO_2e/lb N_2O	kg CO_2e	lb CO_2e	ton CO_2e
Remedial System	2010	43,039	0.043039	1.97	26.79	27.3	0.08	1.15	1.17	0.08	28.83	350.14	835.65	379.05	0.19
		See Note 5		*See Note 6*	*See Note 6*	*See Note 6*					*See Note 3*	*See Note 3*			

Scope 3

				Emission Factors			Mass			CO_2e Greenhouse Gas Potentials 1	25	298	Total		
Sampling/O&M Vehicle Usage	**Year**	**Usage (miles/yr)**	**Usage (gal/yr)**	kg CO_2/gallon	kg CH_4/gallon	kg N_2O/gallon	kg CO_2	kg CH_4	kg N_2O	kg CO_2e/kg CO_2	kg CO2e/kg CH_4	kg CO2e/kg N_2O	kg CO_2e	lb CO_2e	ton CO_2e
Unleaded Gasoline	2010	1,992	110.67	8.81	0.0036	0.0004	974.97	0.40	0.04	974.97	10.08	13.06	998.11	2,200.84	1.10
Diesel - Leachate Hauling	2010	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Methane Gas - Fugitive from LFG System	2010	--	--	--	--	--	--	230,935.41	--	--	5,773,385	--	5,773,385.22	12,730,314.42	6,365.16
Methane Gas- Fugitive Escape	2010	--	--	--	--	--	--	122,684.44	--	--	3,067,111	--	3,067,110.90	6,762,979.53	3,381.49
				See Note 7	*See Note 7*	*See Note 7*		See Note 2			*See Note 3*	*See Note 3*			

Totals		
kg CO_2e	lb CO_2e	ton CO_2e
9,565,513.11	21,090,492.86	10,545.25

Assumptions: *Unleaded gasoline used for consultant transport to conduct O&M actvities.*
Diesel fuel used for leachate transport. Leachate disposed of in Madison, Wisconsin.
119 site visits in 2010 for site sampling and O&M; 30 miles/visit (roundtrip)
4 site visits per year for WDNR inspections; 22 miles/visit (roundtrip)
94 site visits for leachate disposal (tank emptied at ~5,000 gallons); 30 miles/visit (roundtrip)
18 miles/gallon for field vehicle and 8 miles/gallon for Heavy Duty Hauling Vehicle.
**Option 3 assumes that no leachate hauling is required*

Conversions/Factors: *1,000 kWh = 1.0E+6 GWh*
Density of methane = 0.717 kg/m^3 (gas)
Density of propane= 1.83 kg/m^3 (gas)

Source Notes:
1. *Leonardo Academy, Emission Factors and Energy Prices for Leonardo Academy's Cleaner and Greener Program, April 21, 2009*
2. *Derived from 2008 cubic meters per year methane value presented in Table Results - 1, landgem-v302.xls prepared by Paul Wintheiser, P.E., AECOM Environment..*
3. *Greenhouse Gas Potential for CH4 and N2O taken from IPCC Fourth Assessment Report (2007).*
4. *For every pound of methane combusted there are 2.75 pounds of carbon produced.*
5. *Utility usage reported by Madison Gas and Electric.*
6. *EPA (Environmental Protection Agency) eGRIDweb Parent Company Owner-based Level Emissions Profile- Madison Gas & Electric Co. Emission Profile, 2005.*
7. *EPA (Environmental Protection Agency) Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Mobil Combustion Sources, Section 3, Table 2: CH_4 and N_2O Emission Factors for Highway Vehicles, Gasoline Light-Duty Trucks, and Section 4, Table 5: Factors for Gasoline and On-Road Diesel Fuel, May 2008.*