Yard Waste
Composting vs. Landfilling

A Study of Greenhouse Gas Emission Balances

City of Des Moines

May 8, 2008

Project No: 609300.00

Prepared by:
Sebesta Blomberg
Contact: **Richard Ney, Ph.D.**
1845 51st St NE, Suite 2
Cedar Rapids, IA 52402
Main: **319-294-5590**
Fax: **319-393-1905**
email: **rney@sebesta.com**

SEBESTA BLOMBERG

Table of Contents

Section		Page

1.0 Introduction

The City of Des Moines has retained Sebesta Blomberg and Associates, Inc. to perform a study of the life cycle greenhouse gas emission implications of two yard waste disposal options: composting versus landfilling. To perform this analysis we constructed similar life cycle boundaries for each process and quantify greenhouse gas emitting activities within those boundaries. For each option, the life cycle begins when the residents place yard waste at the curb, and ends with final disposition of the wastes from either the composting site or landfill.

2.0 Background

Composting has been demonstrated in some situations as being environmentally superior to landfilling of organic wastes. Composting is an aerobic (with oxygen) decay process that converts the wastes into stable carbon forms called humic substances, which form excellent soil amendment materials that can increase both soil carbon and soil nutrient contents. Being an aerobic decay process, composting results in emission of carbon dioxide (CO_2) to the atmosphere. While CO_2 is the most prevalent of the human-affected greenhouse gases, the CO_2 releases from composting of yard waste represents a cycling of the CO_2 that was taken from the atmosphere by the plant as it grew – thus the result of composting is a cycling of carbon, or a net zero increase in atmospheric greenhouse gas (GHG) concentrations, plus an added benefit of increasing carbon stored in soils when compost material is applied.

Landfilling, on the other hand, results in anaerobic (absence of oxygen) decay of the buried waste that generates methane emissions. Methane, also a GHG, is said by the Intergovernmental Panel on Climate Change (IPCC) to be 23 times more potent at producing heat in the atmosphere than carbon dioxide[1]. Thus, the landfilling process is traditionally viewed as taking the CO_2 that has been stored as carbon in plant matter and converting it into methane, a more potent GHG. Landfills are also sources of various other organic compound emissions, including some toxic species. These compounds arise from decay of a wide range of materials in the landfill, most notably non-renewable plastics. Finally, landfills also result in some permanent storage, or sequestration, of carbon deep in the soil as not all of the carbon buried in the landfill gets converted and released as methane.

2.1 Specific Situation in Des Moines

The landfill that receives solid wastes from Des Moines, the Metro Park East Landfill operated by Metro Waste Authority, is required by federal law to collect and destroy the gases that are the products of decay and that percolate up through the landfill materials to be emitted to the atmosphere. The collected gas is then required to be destroyed by combustion. The Metro Park East Landfill, together with MidAmerican Energy, has taken the gas from the landfill and combusts it in engines that generate electricity. This beneficial use of the landfill gas results in reduced emissions of GHG and other pollutants by destroying the gas and offsetting electricity that would have been generated through combustion of fossil fuels such as coal, oil or natural gas.

2.2 Analysis Constraints

The net emission or benefit calculated in our analysis represents the net emission or avoidance of GHG that occurs through the composting or landfilling processes. There is also a third scenario that could be examined; the no action alternative. If the city did not collect yard waste so that it would be left to residents' own disposal methods, some carbon sequestration may still occur as the wastes decay; however, unmanaged disposal of yard waste may also lead to development of anaerobic conditions if piles of yard waste develop. This would lead to generation of potent methane emissions. There are too many variables associated with this no action alternative for us to accurately estimate the net impact, so we have developed the results of our study independent of any assumed baseline condition of unmanaged yard waste, focusing instead on the net benefit of either composting or landfilling yard wastes.

3.0 Boundaries of the Life Cycle Analysis

We have chosen to assess the life cycle implications of the two treatment options through similar stages from collection through use of the final products of each method. Table 1 compares the life cycle activities of the two operations.

Table 1. Comparison of Life Cycle Activities for Composting and Landfilling Yard Wastes

Composting Life Cycle Activities	Landfill Life Cycle Activities
Curbside collection of yard waste	Curbside collection of solid waste
Transport yard waste to compost site	Transport solid waste to transfer station
-	Transfer station operation
-	Transport solid waste from transfer station to landfill
Compost facility operations	Landfill operations

Pick up and use of compost product	Use of landfill product (gas) to generate electricity

3.1 Characterizing the Current Composting Operation

3.1.1 Yard Waste Collection and Transport

The City of Des Moines operates nine different trucks specifically for collection of yard waste and transport to the Harriet Street composting facility, however only two trucks are used during winter months[2]. Actual metered fuel consumption data for calendar year 2007 indicates that just over 30,500 gallons of diesel fuel were combusted in this process[3], transporting 7,200 tons of yard waste[2]. In addition to the city-collected yard waste, citizens may periodically bring their own waste to the composting site. We will not attempt to quantify emissions from citizen transport of yard waste to the facility as there are too many unknown variables, such as the types and ages of vehicles used and distances traveled, to allow for confident estimates. However, citizens brought an additional 1,050 tons of yard waste to the Harriet Street facility, meaning that Des Moines yard waste contributions to the facility totaled 8,250 tons in 2007[2].

3.1.2 Yard Waste Composting Operation

Once the yard waste arrives at the composting facility the materials must be raked into windrows and periodically turned to ensure that oxygen is delivered throughout the materials so that anaerobic conditions, and methane generation, do not occur. This active management of the yard waste composting operation resulted in combustion of 20,786 gallons of diesel fuel, and 29,858 kilowatt hours (kWh) of electricity consumption during 2007[4].

3.1.3 Disposition of Compost Products

One of the primary benefits noted for composting operations is that the carbon-rich material makes an excellent soil amendment material. In order for this benefit to be realized, however, the material must be picked up and transported to its final destination. In 2007 the site sold 7,405 tons of compost and 475 tons of ‘overs’ (wood for erosion control)[4]. The compost materials are sold in bulk and are typically picked up in large trucks like a diesel powered dump truck.

It has proven difficult to estimate the number of trucks, their age and fuel characteristics, or distances that the trucks may travel, in order to compute a predicted GHG impact of hauling compost from the site to its final destination. We conservatively assume that the impact of hauling the compost will be a fraction of the energy required to collect the yard waste, since compost provides greater density and should be transported in fewer trucks.

We will assume that the impact of hauling finished compost product will be equal to 20 percent of hauling the wood waste to the compost facility.

3.2 Quantifying GHG Emissions from the Current Composting Operation

We utilize standard emission factors taken from the leading, internationally acclaimed Greenhouse Gas Protocol developed by the World Resources Institute (WRI) and World Business Council on Sustainable Development (WBCSD) to estimate emissions of CO_2, methane (CH_4), and nitrous oxide (N_2O) from fuel combustion. The CO_2 emissions calculations are based upon the amount of carbon contained in the fuel, and the amount of that carbon that is typically oxidized to CO_2 during combustion.

To estimate GHG emissions attributable to electricity consumption we utilize the most current emission factor for the State of Iowa as provided by the U.S. Environmental Protection Agency (EPA) in its EGRID program. EGRID provides the composite average emission factor for electricity generated and delivered within each state. The most current factors are available for the year 2004. Iowa's composite GHG emission rate is 1,943 pounds per Megawatt-hour (lbs/MWh)[5].

As we described earlier, any CO_2 generated by the composting process is treated as a zero net CO_2 contribution to the atmosphere. As the plants that make up the yard waste grow each year, they remove CO_2 from the atmosphere and fix it into plant material through photosynthesis. The generation of CO_2 emissions from composting thus simply return that CO_2 to the atmosphere resulting in no net increase of CO_2. Composting does, however, lead to increased sequestration (storage) of carbon in the compost material itself and through improvement in soil processes when compost material is added. These impacts have been quantified by the U.S. Environmental Protection Agency (EPA) and documented in a program called the Waste Reduction Model (WARM)[6]. WARM calculates the life cycle impacts of various solid waste disposal options. WARM estimates that addition of compost material to soils leads to a net storage of 0.18 metric tons of CO_2-equivalent (CO_2–eq) for each ton of yard waste composted[6]. Table 2 summarizes calculation of net GHG emissions (storage) from the current composting operation.

Table 2. Summary of Net Emissions from Current Composting Operation

Current Composting Program Activity				Emission Factors*			Emissions CO_2-eq
	Material	Value	Units	CO_2	CH_4**	N_2O**	mton
Total Yard Waste to Compost Facility	Yard waste	8,250	tons	-0.18			(1,512.50)
Yard Waste Collection and Transport	Diesel	30,507	gallons	160.28	0.00489	0.00147	313.74
Fuel Used in Processing Compost	Diesel	20,786	gallons	160.28	0.00489	0.00147	213.77
Fuel Used in Processing Compost	Electricity	29,858	kWh	1,943.28			26.31

Fuel Used to Deliver Compost Product***	Diesel	6,101	gallons	160.28	0.00489	0.00147	66.35
						Net Total	**(892.33)**

* Emission factors in lbs/MMBtu except yard waste factor in mton CO_2 per ton waste and electricity factor in lbs/MWh.

** We also employ the GWP values of 23 for CH_4 and 296 for N_2O[1].

*** We have assumed that hauling compost from the facility has only 20% of the impact of hauling the yard waste to the facility.

As Table 2 summarizes, the composting process contributed to a net GHG reduction of nearly 900 metric tons CO_2-eq during 2007.

3.3 Characterizing the Current Landfill Operation

3.3.1 Solid Waste Collection and Transport

The City of Des Moines operated twenty-one trucks specifically for collection of solid waste and transport to the MWA transfer station facility[3]. Actual metered fuel consumption data for calendar year 2007 indicates that just over 103,650 gallons of diesel fuel were combusted in this process, transporting 61,000 tons of solid waste[2,3]. Although twenty-one different trucks were utilized throughout the year for solid waste pickup, a normal week saw fourteen trucks employed to collect the wastes[2].

3.3.2 Solid Waste Transfer Station Operation

Once the solid waste arrives at the transfer station the materials undergo final separation to remove unwanted materials before final transport by MWA to the landfill. Operation of equipment and the transfer station facility caused combustion of 11,071 gallons of diesel fuel and use of 133,300 kWh of electricity in 2007[4]. These energy statistics represent the total transfer station operation which handles more than just the solid waste from the City of Des Moines. In total, 169,000 tons of solid wastes were processed through the transfer station in 2007[4].

3.3.3 Transfer of Solid Waste to the Landfill

The solid waste is transferred from the transfer station to the landfill by MWA-operated trucks. These trucks combusted 57,846 gallons of diesel fuel during 2007[4].

3.3.4 Landfill Facility Operations

Once the solid waste is placed in the landfill it gets compacted and covered with a six-inch layer of soil daily. This active management of the solid waste landfill operation resulted in combustion of 226,917 gallons of diesel fuel, 545 gallons of unleaded gasoline, 7,185 gallons of E10, 12,177 gallons of propane, and 785,614 kilowatt hours (kWh) of electricity consumption during 2007[4]. This energy consumption occurred during the processing of 530,362 tons of solid waste during 2007[4].

3.3.5 Landfill Gas Collection and Combustion

Decay of the wastes in the landfill contributes to generation of landfill gases, predominantly methane and carbon dioxide. The Metro Park East Landfill employs a complex gas collection system to capture these gases and transport them through the collection system to a central location for combustion. The landfill, in partnership with MidAmerican Energy, combusts the landfill gas in engines that generate electricity. The electricity is input to the electric grid where it displaces electricity that would otherwise be generated from traditional fuels. The combustion of the landfill gas oxidizes the carbon in the fuel to CO_2, which provides for a cycling of atmospheric CO_2 from the yard waste so that there is no net increase in atmospheric CO_2 concentrations. At this point in the analysis we will not attempt to determine the GHG balances that occur from the capture and combustion of landfill gas from the Metro Park East Landfill. Collection and combustion of gas will take on importance when we analyze the potential impacts of landfilling yard wastes later in this report.

3.4 Quantifying GHG Emissions from the Current Landfill Operation

We utilize standard emission factors taken from the leading, internationally acclaimed Greenhouse Gas Protocol developed by the World Resources Institute (WRI) and World Business Council on Sustainable Development (WBCSD) to estimate emissions of CO_2, methane (CH_4), and nitrous oxide (N_2O) from fuel combustion. The CO_2 emissions calculations are based upon the amount of carbon contained in the fuel, and the amount of that carbon that is typically oxidized to CO_2 during combustion.

To estimate GHG emissions attributable to electricity consumption we utilize the most current emission factor for the State of Iowa as provided by the U.S. Environmental Protection Agency (EPA) in its EGRID program. EGRID provides the composite average emission factor for electricity generated and delivered within each state. The most current factors are available for the year 2004. Iowa's composite GHG emission rate is 1,943 pounds per Megawatt-hour (lbs/MWh)[5]. Table 3 provides a summation of GHG emissions that occur from waste transportation and processing inputs.

Table 3. GHG Emissions from Total Landfill Operations – Excluding Landfill Gas Impacts

Current Solid Waste Disposal Program				Emission Factors*			Emissions CO_2-eq
	Material	Value	Units	CO_2	CH_4**	N_2O**	mton

City Solid Waste to Transfer Station	Solid waste	61,000	tons				
City Solid Waste Collection and Transport	Diesel	103,657	gallons	160.28	0.00489	0.00147	1,066.03
Fuel Used at Transfer Station	Diesel	11,071	gallons	160.28	0.00489	0.00147	113.86
Electricity Used at Transfer Station	Electricity	133,300	kWh	1,943.28			117.48
Fuel Used to Transport Waste to Landfill	Diesel	57,846	gallons	160.28	0.00489	0.00147	594.90
Total Tonnage Processed at Landfill	Solid waste	530,362	tons				
Fuel Used in Processing Waste	Diesel	226,917	gallons	160.28	0.00489	0.00147	2,333.65
Fuel Used in Processing Waste	Propane	12,177	gallons	137.94	0.01291	0.00026	74.09
Fuel Used in Processing Waste	Gasoline	545	gallons	153.38	0.00489	0.00147	4.76
Fuel Used in Processing Waste	E10	7,185	gallons	147.24	0.00489	0.00147	57.79
Electricity Used at Landfill	Electricity	785,614	kWh	1,943.28			692.37
						Total	**3,162.66**

*Emission factors in lbs/MMBtu except yard waste factor in mton CO_2 per ton waste and electricity factor in lbs/MWh.

**We also employ the GWP values of 23 for CH_4 and 296 for N_2O.

The intent of our study is to determine the balance of GHG emissions between composting and landfilling yard wastes. At this point in the analysis we are not yet concerned with the landfill gas or electricity generated from that gas. These impacts will be projected specifically for the yard wastes later in this document.

4.0 Analyzing a Future Scenario Where Yard Waste is Landfilled

The main purpose of this study is to provide a comparative estimate of the life cycle GHG emissions from yard waste that is composted or landfilled. The data presented in preceding sections to quantify current emissions forms the basis from which future emissions can be projected. The inclusion of yard waste within the solid waste stream that the City of Des Moines sends to the Metro Park East Landfill will result in several changes:

- The City will no longer utilize a separate fleet of trucks for collection of yard wastes.
- The number of solid waste collection trucks has been forecast to increase by one. Although twenty one different trucks were used during 2007 for collection of solid waste, the average number or trucks in service each day was fourteen. The City estimates that on average, one additional truck will be needed each day to collect the co-mingled yard waste – an increase of seven percent.
- The City does not expect an increase in the number of trips that individual collection trucks must make to the transfer station. Normally the trucks travel two times per day to the transfer station, once at midday and once at day's end. These trucks are not currently completely full during these trips and introduction of yard waste is not expected to necessitate additional trips beyond the addition of one truck.

- Yard waste has a lower density than other solid wastes. This may lead to a decrease in the fuel efficiency of trucks traveling between the transfer station and landfill, on a fuel use per ton of waste basis. This may occur because the 'fluff' created by introducing yard waste may result in volumetric filling of the trucks before weight limits are reached. Emissions Attributable to Yard Wastes Added to Solid Waste Collection

4.1 Emissions Attributable to Yard Wastes Added to Solid Waste Collection

We use the emission rates calculated from current operations above to create factors that help us estimate the GHG emission impacts of adding yard waste to the landfilled solid waste stream. Table 4 presents the calculation of a current emission factor in terms of CO_2-eq per ton of solid waste collected. We then increase this rate by seven percent to account for the added truck that the City projects would be needed and apply this rate to the total solid waste tonnage with the added yard waste. By accounting for the added truck AND scaling based on added waste we believe we have adequately compensated for any issues related to density differences between the yard waste and solid waste. The result is a projected increase of 228.89 metric tons of CO_2-eq from City solid waste collection activities.

Table 4. Impact of Adding Yard Waste to Solid Waste Collection Program

Solid Waste Collection Program				Emission Factors (lb/MMBtu)			Emissions CO_2-eq
	Material	Value	Units	CO_2	CH_4	N_2O	mton
City Solid Waste to Transfer Station	Solid waste	61,000	tons				
City Solid Waste Collection and Transport	Diesel	103,657	gallons	160.28	0.00489	0.00147	1,066.03
						Total	**1,066.03**
Solid Waste Metric - Emission per Ton						**lb CO_2/ton**	**38.53**
Future Solid Waste to Transfer Station	Solid waste	69,250	tons	41.23			1,294.92
Increase from Adding Yard Waste						**Increase**	**228.89**

Table 5 presents a similar analysis for transfer station operations. Total current transfer station waste processed and energy consumption are used to calculate a GHG emission factor in terms of CO_2-eq per ton of waste processed at the transfer station. We then apply this factor to the current City of Des Moines solid waste tonnage and compare that to the City of Des Moines solid waste tonnage including the yard waste. The result is a projected increase in annual GHG emissions of 40.26 metric tons of CO_2-eq.

Table 5. Impact of Adding Yard Waste to Transfer Station Operations

Transfer Station Operations				Emission Factors (lb/MMBtu)			Emissions CO_2-eq
	Material	Value	Units	CO_2	CH_4	N_2O	mton
Total Tonnage Processed	Solid waste	169,297	tons				
Fuel Used at Transfer Station	Diesel	11,071	gallons	160.28	0.00489	0.00147	113.86

Electricity Used at Transfer Station	Electricity	133,300	kWh	1,943.28			117.48
Fuel Used to Transport Waste to Landfill	Diesel	57,846	gallons	160.28	0.00489	0.00147	594.90
						Total	**826.23**
Transfer Station Metric - Emission Per Ton						**lb CO_2/ton**	**10.76**
Current City Solid Waste to Transfer Station	Solid waste	61,000	tons	10.76			297.70
Future Solid Waste to Transfer Station	Solid waste	69,250	tons	10.76			337.97
Increase from Adding Yard Waste						**Increase**	**40.26**

Table 6 presents the same analysis method for emissions from current landfill operations. Total current landfill waste processed and energy consumption are used to calculate a GHG emission factor in terms of CO_2-eq per ton of waste processed at the landfill. We then apply this factor to the current City of Des Moines solid waste tonnage and compare that to the City of Des Moines solid waste tonnage including the yard waste. The result is a projected increase in annual GHG emissions of 49.20 metric tons of CO_2-eq.

Table 6. Impact of Adding Yard Waste to Current Landfill Processing Operations

Current Landfill Operations	Material	Value	Units	Emission Factors (lb/MMBtu)			Emissions CO_2-eq mton
				CO_2	CH_4	N_2O	
Total Tonnage Processed	Solid waste	530,362	tons				
Fuel Used in Processing Waste	Diesel	226,917	gallons	160.28	0.00489	0.00147	2,333.65
Electricity Used at Landfill	Electricity	785,614	kWh	1,943.28			692.37
Fuel Used in Processing Waste	Propane	12,177	gallons	137.94	0.01291	0.00026	74.09
Fuel Used in Processing Waste	Gasoline	545	gallons	153.38	0.00489	0.00147	4.76
Fuel Used in Processing Waste	E10	7,185	gallons	147.24	0.00489	0.00147	57.79
						Total	**3,162.66**
Landfill Metric - Emission Per Ton						**lb CO_2/ton**	**13.15**
Current City Solid Waste to Transfer Station	Solid waste	61,000	tons	13.15			363.76
Future Solid Waste to Transfer Station	Solid waste	69,250	tons	13.15			412.95
Increase from Adding Yard Waste						**Increase**	**49.20**

4.1.1 Landfill Gas Emissions and Offsets

As we described earlier, from a simplified view, anaerobic decay of carbonaceous materials in a landfill generates methane gas. Decay within landfills is actually a much more complex process that includes a combination of both aerobic and anaerobic processes that leads to development of landfill gas that contains a mixture of methane, CO_2 and small amounts of other compounds. The CO_2 released from landfilled waste represents a cycling of the CO_2 that was taken from the atmosphere by the plant as it grew – thus the result of composting is a cycling of carbon, or a net zero increase in atmospheric greenhouse gas (GHG) concentrations. Emissions of methane are treated much differently, however, due to the potency of methane at producing heat in the atmosphere relative to CO_2. A unit emission of methane has the impact of 23 units of

CO_2, so any carbon atom that is stored from CO_2 into plant matter, but emitted in the form of methane, has magnified the global warming impact of that carbon atom.

An evaluation of the gas collection system was completed by Barker Lemar Engineering Consultants in October 2007 with measurements showing methane concentrations ranging between 53.6 to 58.8 percent by volume[7]. In 2007 the landfill reported average monthly capture of 96,349,525 cubic feet of landfill gas from all waste-in-place[7].

To estimate the impact of landfilling yard wastes we have to take into account more potential impacts on total GHG balances:

- The amount of methane that will be generated from the yard waste
- The amount of that methane that is captured versus the amount that still leaks to the atmosphere
- The CO_2 generated from combustion of the methane
- The amount of buried carbon that stays sequestered in the landfill
- The CO_2 offset as generated electricity displaces other electric generating sources

4.1.2 The Amount of Methane Generated from the Yard Waste

To estimate the amount of methane generated by landfilling the yard waste we again turn to the EPA WARM program. EPA estimates that an average of 0.968 metric tons of CO_2-eq methane is generated from each ton of yard waste landfilled[6]. Translated by using the GWP value of methane this statistic predicts 0.042 metric tons of methane per ton of yard waste placed in the landfill. This results in prediction of 347 metric tons of methane (7,996 metric tons CO_2-eq) from the 8,250 tons of Des Moines yard waste.

4.1.3 The Amount of Methane That Reaches the Atmosphere

To estimate the amount of methane generated by landfilling the yard waste that reaches the atmosphere we again turn to the EPA WARM program and incorporate the collection efficiency for the Phase 2 system at Metro Park East Landfill. The landfill gas will potentially be emitted to the atmosphere if it escapes to the atmosphere without being gathered by the collection system. Figure 1 presents the stated gas collection efficiencies taken from the April 2008 "Metro Park East Sanitary Landfill Revised 2007 Air Emission Inventory" completed by Shaw Environmental & Infrastructure, Inc[8]. The current and future disposal area which has importance for this study the Phase 2 area rated at 90 percent collection efficiency.

Figure 1. Gas Collection Efficiencies at the Metro Park East Sanitary Landfill[8]

Collection Efficiency	
Closed Area	75%
South Area	40%
North Area	40%
Wet weather Area	25%
Phase 1a Area	90%
Phase 1b Area	90%
Phase 2 Area	90%
C&D Area	0%

Applying this 90 percent capture efficiency to the WARM-predicted methane generation rate says that 34.7 metric tons of methane would not be collected by the system. However, the WARM program study also tells us that 90 percent of methane that is not collected by the system encounters oxygen as it bubbles up through the upper layers of the landfill[6]. According to the WARM documentation, 90 percent of the carbon contained in the methane becomes oxidized to CO_2, and since this CO_2 is of biogenic origin the net emission of CO_2 is zero. The calculated impact of landfill gas leakage from the system yields:

347 mton CH_4 generated from yard waste * 10% escape from collection * 10 percent not converted to CO_2 = 3.47 metric tons of CH_4 from the landfilled City of Des Moines yard waste.

With a GWP of 23, this emission equates to 3.47 * 23 = 79.81 metric tons CO_2-eq.

4.1.4 The CO_2 Generated from Combustion of Captured Methane

Combustion is an oxidation process that combines carbon with oxygen. The goal of the combustion process is to convert all carbon to CO_2. Any combustion of CH_4 will lead to formation of CO_2 and since this CO_2 is of biogenic origin from the yard waste is treated as a net zero contribution to the atmosphere.

4.1.5 The Amount of Carbon Sequestered by Landfilled Yard Waste

To estimate the amount of carbon sequestered by landfilling the yard waste we again turn to the EPA WARM program. The WARM study reports that 0.08 metric tons of carbon equivalent, or 0.293 metric tons of CO_2-eq are stored as a result of landfilling a ton of yard wastes[6]. For the City of Des Moines yard waste tonnage of 8,250 this corresponds to storage of 2,420 metric tons of CO_2-eq.

4.1.6 The CO_2 Offset from Generated Electricity

In 2007 the landfill gas collected by the Metro Park East Landfill generated 6.4 MW of electricity over 99.4 percent of available hours in 2007[9]. This means that 55,727,616 kWh of electricity were generated from 1,156.2 million cubic feet of gas. This electricity displaces grid electricity that would be generated from other sources throughout Iowa and the region. As we did previously in our analysis, we use the EGRID value of 1,943.28 lbs CO_2/MWh to estimate the impact of electricity on GHG emissions. The electricity generated by the Metro Park East Landfill gas displaced 49,113 metric tons of CO_2-eq that would have otherwise occurred had that electricity been generated at standard rates.

To estimate the amount of electricity that would be generated from landfill gas emanating from Des Moines yard waste we use several important values and work backward:

- The electric generation rates at the landfill were 55,728 MWh per 1,156.2 million cubic feet of gas. This creates a factor of 48.20 MWh per million cubic feet.
- The yard waste is predicted to generate an average of 347 metric tons of methane annually, 90 percent of which will be captured. Methane weighs 0.0413 pounds per cubic feet, so the yard waste is predicted to generate 16,673,644 cf methane annually.
- Methane makes up 53.6 to 58.8 percent of the landfill gas by volume. If we assume the higher methane concentration we will conservatively estimate the amount of total landfill gas attributable to the yard waste:
- 16,673,644 cf methane / 58.8% = 28,356,538 cf landfill gas.
- Applying the electric generation factor for electricity per cf landfill gas yields:
- 28.357 million cf * 48.20 MWh per million cf = 1,375 MWh from the yard waste
- Finally, we apply the EGRID factor for Iowa electric generation to determine the amount of GHG offset by use of the landfill gas:
- 1,375 MWh * 1943.28 lb CO2/MWh = 1,212 metric tons CO_2

4.2 Assembling the Complete GHG Balance for Landfilling Yard Waste

Under the current composting arrangement yard waste from the City of Des Moines is estimated to generate a net GHG emission benefit of 959 metric tons of CO_2-eq annually. We have attempted to determine the change in emissions that would occur if the yard wastes were shipped to the Metro Park East Landfill along with the rest of Des Moines' solid waste. Table 7 summarizes net GHG emissions from landfilling Des Moines yard waste.

Table 7. Summary of Net GHG Emissions from Landfilling Des Moines Yard Waste

Landfilling of Yard Wastes	Emissions Increase (Decrease) metric ton CO2-eq
Emission Increase from Added Solid Waste Collection	228.89
Emission Increase from Added Transfer Station Operations	40.26
Emission Increase from Added Landfill Operations	49.20
Emission Increase from Methane Escaping to Atmosphere	79.81
Emission Increase from Combustion of Methane to CO2	**Net zero**
Emission Decrease from Carbon Sequestration	(2,420)
Emission Decrease from Electricity Displacement	(1,212)
Net GHG Emissions from Landfilling Yard Waste	**(3,234)**

If the City of Des Moines chose to landfill their yard wastes into the Metro Park East Landfill, they would create a net greenhouse gas emission decrease of 3,234 metric tons of CO_2-eq. If we compare this to the current reduction of 892 metric tons CO_2-eq provided by the composting operation, we see that the landfilling option provides more than three times the GHG benefit presented by the current composting operation.

5.0 Summary

A comparison of the life cycle greenhouse gas emissions is made for City of Des Moines Yard Waste disposal between composting and landfilling of the waste. Life cycle boundaries for the analyses were drawn similarly to provide comparison; each life cycle begins with collection of the yard waste, proceeds through processing of the waste, then to final disposition of the waste as either compost material or landfill gas combusted to generated electricity. Although composting enjoys a reputation as being more environmentally beneficial than landfilling, the collection of landfill gas and generation of electricity from those renewable gases leads to more than three times the amount of greenhouse gas emission reductions than does the composting operation.

6.0 References

1. "2007 Gas Collection System Evaluation and Gas Monitoring Report Metro Park East Landfill," October 2007, Barker Lemar Engineering.

2. Climate Change 2001: The Scientific Basis, IPCC Third Assessment

3. Emissions & Generation Resource Integrated Database (eGRID), http://www.epa.gov/cleanenergy/energy-resources/eGRID/index.html

4. "Metro Park East Sanitary Landfill Revised 2007 Air Emission Inventory," April 2008, Shaw Environmental & Infrastructure, Inc.

5. Personal Communications, Albert Aguilar, City of Des Moines, April 2008.

6. Personal Communications, Brian Bennett, City of Des Moines, April 2008.

7. Personal Communications, Jeff Dworek, Metro Waste Authority, April 2008.

8. Personal Communications, Bill Devine, Metro Methane Recovery Facility, May 2008.

9. "Solid Waste Management and Greenhouse Gases A Life-Cycle Assessment of Emissions and Sinks," 3rd Edition, September 2006, ICF