Examining Increased Renewable Energy Production from Landfill Gas in Michigan

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Executive Summary

Technological advances touch every part of our lives, often without our knowledge and in places we'd least expect. Landfills may be one of these overlooked occurrences. Landfills are most commonly considered the place where our garbage goes, but increasingly over the past decade they have become sources of renewable energy that can be generated from that waste.

While energy demands are expected to increase in the future, conventional capacity to meet those needs is uncertain. Consumers and policymakers are looking at renewable energy to fill the gap. Landfill energy is one such alternative. In order to meet growing energy needs, however, landfills will need an influx of organic matter such as grass and leaves, generally called "yard waste," to fuel energy production.

Currently, yard waste is prohibited in landfills in 23 states. Banning yard waste from landfills was considered a means of promoting composting and recycling. In Michigan, yard clippings have been banned from disposal in municipal solid waste landfills since March 1995.

However, the past decade has seen increasing operational challenges at compost sites, greater interest in renewable energy production, and enhanced technology for landfill energy recovery. As a result of these developments, a review of waste disposal policy and alternatives to the yard waste ban is warranted. This discussion will focus on the latter two developments, which have given rise to a new perspective on the disposal of yard waste and its potential for energy creation.

Given the increased public support for renewable energy and the national objective of reducing dependence on fossil fuels and foreign oil, it is appropriate to explore the benefits that would result from certain and specific exemptions to the yard waste ban for the production and practical use of renewable energy generated from landfill gas.

This study set out to examine potential increased renewable energy production from landfill gas in Michigan to determine whether an exemption for landfill energy-producing facilities under the existing yard waste ban would prove fruitful. Despite the complexity of the issue, a number of clear conclusions can be drawn from the research and modeling involved in this study.

1. The most noteworthy finding, which in part drives the entire discussion, is that there has been a paradigm shift in attitudes about recycling. No longer do policymakers and the public view compost as the only recyclable product of yard waste. Recycling yard waste can now yield two options: a soil amendment through composting ***and*** an energy source, a renewable resource, through landfill gas recovery technology.

2. The economic, political, and societal changes that Michigan (and the world) has seen over the past decade have spurred increased support for renewable energy. This report cites three very recent and significant developments.

a. In January, 2007, *Michigan's 21st Century Electric Energy Plan* (MPSC 2007) demonstrated the need for additional electricity-generating resources by 2015 to meet increasing demands, preserve electric reliability, and provide affordable energy. **It is interesting that the modeling in the present study shows that if inputs are boosted, landfill energy-production facilities will be at peak capacity within 14 to 16 years—precisely when Michigan will need alternative energy sources the most.** The *21st Century Plan* recognizes landfill gas as a viable and economical form of renewable energy generation. Landfill gas is readily available and the fastest way to supplement current electricity generation.

b. As recently as February 20, 2007, in a public speech referring to her State of the State initiatives, Michigan's governor discussed her plan to make Michigan a national leader in the production and use of alternative energy by investing more than $100 million of public and private resources over the next three years in research and production of renewable energy sources (Office of the Governor 2007). In addition, she has called for 10 percent of the state's power to come from renewable sources within the next eight years. It cannot be stated more clearly: becoming a leader in alternative and renewable energy generation is one of the key strategies for improving Michigan's economy.

c. Michigan's recently revised solid waste policy[1] declares that Michigan recognizes solid waste as a resource that should be managed to promote economic vitality, ecological integrity, and improved quality of life in a way that fosters sustainability. By recognizing solid waste as a resource, Michigan can more fully realize the economic, environmental, and social benefits of utilizing waste materials that still have inherent value.

3. Composting yard waste poses operational challenges that were not fully considered when Michigan's yard waste ban was implemented in 1995. In view of these challenges, the true costs of composting have yet to be realized. Additionally, the yard waste ban has produced mixed results. In many areas of the state a market for compost simply does not exist.

4. Among sources of waste that have not already been captured, yard waste has the highest organic content and fewest operational challenges to overcome to produce more landfill gas and therefore is an excellent candidate to introduce into landfills to boost energy production.

5. Since 1985, landfill gas recovery technology has advanced into a viable renewable energy option. Forward-thinking companies have begun to harness methane to produce energy by installing collection piping as each landfill cell (portion of facility) is filled, not after it is filled. This development has demonstrated the vast potential of landfill energy-production facilities and provides the basis for the current discussion.

[1] Consensus was reached with stakeholders and the Michigan Department of Environmental Quality (MDEQ) on the updated Solid Waste Policy on May 24, 2007. The updated Solid Waste Policy is available on the MDEQ website at *http://www.michigan.gov/deq* by navigating to "Waste" and "Solid Waste."

6. A key finding, based on existing landfill energy-production facilities and modeling, is that adding yard waste to landfills can increase the creation of renewable energy. Modeling shows that we can capture even more power than we are currently producing.
7. In sum, the energy-production capacity of landfills in Michigan clearly can be improved by the reintroduction of organic yard waste material. Specifically, the results of this study[2] warrant the following conclusions: [3]
   a. Currently, 20 Michigan Type II landfills operate as landfill energy-production facilities with an equivalent of 188.8 megawatts (MW)[4] of renewable energy capacity.
   b. There are 12 more Michigan landfills with the current potential to produce an additional 36.8 MW of renewable energy capacity.
   c. By 2015 and with the addition of yard waste disposal in Michigan landfills currently operating landfill energy-production facilities, an increase in renewable energy capacity of 41 percent over current levels, or the equivalent of 265.6 MW, is projected.
   d. By 2015 and with the addition of yard waste disposal and development of all potential landfill energy-production facilities, an increase in renewable energy capacity of 67 percent over current levels, or the equivalent of 315.2 MW, is projected.
   e. Landfill gas-to-energy projects provide unparalleled reliability and availability as a renewable energy source. As long as there is solid waste, there will be landfill gas that can produce methane fuel. Additionally, landfills can provide a long-term energy source, as they produce gas for 20 to 30 years after closure.
   f. Peak years for energy production from landfills at current status fall between 2014 and 2016, precisely when Michigan is forecasted to need new energy sources.
   g. Landfill gas is a sustainable source of renewable energy, derived from landfill biomass that does not significantly limit overall landfill capacity. It is estimated that as a result of the decomposition process, yard waste loses half of its weight and 50 to 75 percent of its volume (Miller 2006; Wilson and Feucht 2004).
8. Attempts to repeal the yard waste ban in other states have met with mixed results for a variety of reasons. Recently, however, policymakers in other states have become more amenable to considering exemptions. It is time to revisit this policy in Michigan to examine whether it is producing beneficial results.

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[2] For a full review of the study including parameters and results, please see the *Landfill Energy Production Potential* section of this report.
[3] See Appendix A for comparison to similar study results.
[4] See Appendix B for a list of commonly used acronyms.

Based on analysis of current landfill energy-production capacity, landfills should be considered a source for reliable, sustainable, renewable energy. However, if landfill energy-production technology is to play a role in helping Michigan meet its future energy needs and improve its economy, we must first boost creation of landfill gas so that more renewable energy can be produced. The quality and quantity of landfill gas is directly related to the organic content of the waste input into the system. One way to increase the organic waste stream is to allow yard waste back into landfills. There are, of course, other means to this end, but none as intuitively simple because yard waste has the highest amount of organic content available in the non-landfilled waste stream.

Given the present convergence of attitude shifts, technological improvements, and the national goal of reducing dependence on fossil fuels and foreign oil, it is appropriate to explore the benefits that would result from specific exemptions to the yard waste ban for the production and utilization of renewable energy generated from landfill gas. A targeted exemption to Michigan's yard waste ban to allow more organic materials into the energy-creation process would optimize production of renewable energy from landfill gas.

Based on this report's findings and to encourage landfill gas-to-energy production, it is recommended that an exemption to the yard waste ban be explored. This exemption should establish criteria for landfill energy-production facilities (LEPFs) similar to those that other states have adopted or are currently considering. It should be noted that proposed regulations are in addition to all those that traditional landfill operators already must meet by law to safeguard public health and safety. These proposed standards would set up the collection design criteria for a facility to qualify for the yard waste ban exemption as an LEPF and require a legitimate collection system and practical end use.

There is a readily available supply of renewable power from landfill gas-to-energy technology. In the near term, this study shows that potential for a 30 percent increase in renewable energy production can be realized through two simple actions:

- Reintroduce yard waste into the municipal waste stream to be received at facilities designated as a LEPF, and
- Develop all landfill gas collection potential.

Now is the time to consider an exemption to the yard waste ban for landfill energy-producing facilities to capitalize on the benefits they can produce: job creation, a healthier environment, and renewable energy production consistent with energy policies like the *Michigan 21st Century Electric Energy Plan.*

Background

Faced with rising energy demands and uncertainty about the ability of conventional capacity to meet those needs, both consumers and policymakers are looking at renewable energy to step in and fill the gap. Renewable energy from landfill gas is one alternative. However, in order to meet growing energy needs landfills will need an influx of organic matter such as grass and leaves, commonly called "yard waste," to fuel energy production.

Currently, yard waste is prohibited in landfills in 23 states (see Exhibit 1). Banning yard waste from landfills was seen as a means of promoting composting and recycling. In Michigan, yard clippings have been banned from disposal in municipal solid waste landfills since March 1995.

EXHIBIT 1
States with a Yard Waste Ban and Landfill Gas Energy Projects and/or Candidate Sites

State	Details of ban	Landfill Gas Energy Projects	Landfill Gas Energy Candidate Landfills
Arkansas	Leaves and grass (AR Regulation 22)	2	4
Connecticut	Grass clippings only. Adopted in 1995.	2	7
Florida	Yard waste	12	20
Georgia	Yard waste	8	21
Illinois	Yard waste	34	25
Indiana	Leaves, grass, and woody vegetative matter. Adopted in 1997.	16	16
Iowa	Yard waste	4	12
Maryland	Separately collected loads of yard trimming are banned from disposal.	5	8
Massachusetts	Leaves in 1992, all other yard waste in 1993 including grass clippings, weeds, garden materials, shrub trimmings, and brush one-inch or less in diameter.	17	4
Michigan[5]	Yard waste	27	9
Minnesota	Effective in 1995.	4	8
Missouri	Solid Waste Law bans yard waste as of January 1992.	7	18
Nebraska	Effective in 1994 (banned from April 1 to November 30).	1	5
New Hampshire	Yard waste	6	N/A
New Jersey	Leaves only	14	3
North Carolina	As of January 1, 1993, banned in landfills.	13	35
Ohio	Yard waste restriction for solid waste facilities effective November 30, 1994.	17	24

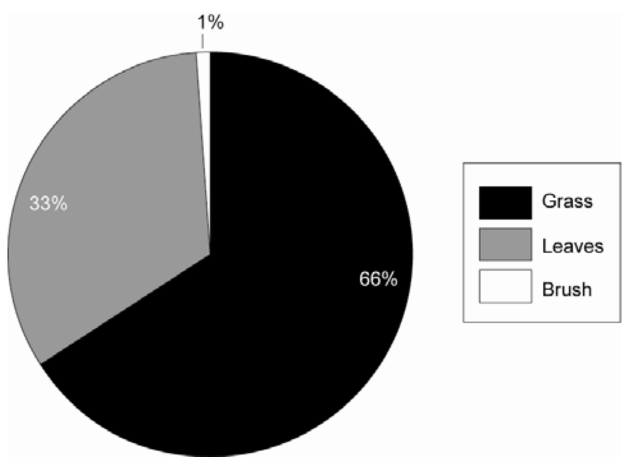
[5] Please see Appendix A for comparison to other data.

State	Details of ban	Landfill Gas Energy Projects	Landfill Gas Energy Candidate Landfills
Oregon	No details are available.	4	5
Pennsylvania	Applicable for truckloads containing more than 50% leaves.	26	17
South Carolina	Includes landscaping debris.	5	18
South Dakota	Yard waste	0	2
West Virginia	Enacted in 1997.	0	8
Wisconsin	Enacted in 1993.	2	10

SOURCE: DSM Environmental Services Inc., 2004, using data from *U.S. Recycling Laws*, 2004 edition (Raymond Communications) and *Biocycle*, State of Garbage in America, March 2004; EPA LMOP 2007.

According to U. S. Environmental Protection Agency (EPA) estimates for 2005, yard waste constitutes 13 percent of the total waste stream. See Exhibit 2 for typical composition of yard waste.

EXHIBIT 2
Yard Waste Composition



SOURCE: Coalition to Oppose Attacks on Recycling in America, January 24, 2002.

While the yard waste ban was expected to boost recycling and save landfill space, issues have developed over the course of time that suggest a review of the policy to provide alternatives to the ban is needed. These issues include but are not limited to: growing operational challenges at compost sites, increasing interest in renewable energy production, and enhanced technology for landfill energy recovery.

This study will focus on the latter two issues, which are of utmost importance and relevance in light of a contemporary shift in perspective. No longer are we viewing compost as the only recyclable product of yard waste. Recycling yard waste can now yield two options: a soil amendment through composting, ***and*** an energy source through landfill gas recovery technology. Even the recently updated draft Michigan solid waste policy expands the concept of recycling to recognize waste as a resource to be used in all its forms.

SUPPORT FOR RENEWABLE ENERGY PRODUCTION

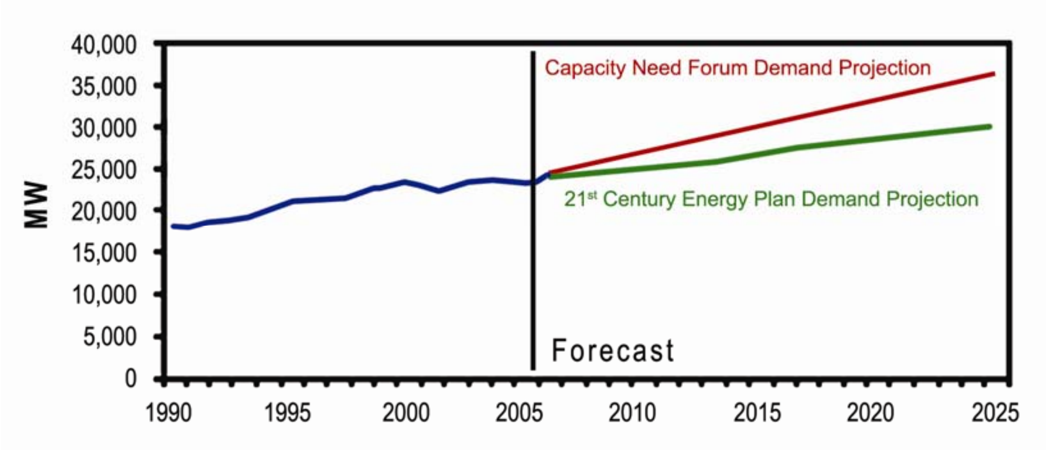
As recently as February 20, 2007, in a public speech referring to her State of the State initiatives, Michigan's governor discussed her plan to make Michigan a national leader in the production and use of alternative energy by investing more than $100 million of public and private resources over the next three years in research and production of renewable energy sources[6] (Office of the Governor 2007). In addition, she has called for 10 percent of the state's power to come from renewable sources within the next eight years.

It cannot be stated more clearly: Michigan's becoming a leader in alternative and renewable energy generation is one of the key strategies for improving Michigan's economy. In January, 2007, Governor Granholm released a policy document titled *Michigan's 21st Century Electric Energy Plan*, which outlines, among other ideas, recommendations for supplying power to meet electrical needs throughout the state into 2025 (MPSC 2007). The process of developing this plan has led to the recognition of landfill gas as a viable and economical form of renewable energy generation. Some of the noteworthy and relevant highlights include the following:

- Extensive review of Michigan's electric utility industry demonstrates the need for additional electricity generating resources to meet increasing demands, preserve electric reliability, and provide affordable energy over the next 20 years.
    - Michigan's total electricity generation requirements are expected to grow at an annual average rate of 1.3 percent from 2006 to 2025. Summer peak electricity demand is likewise expected to grow at an annual average rate of 1.2 percent over the same period. This indicates that additional generating resources will be required in the near term, and, as annual load growth of 1.2 percent continues, in the long term as well. Exhibit 3 displays these trends.

[6] Renewable energy means energy generated by solar, wind, geothermal, biomass (including waste-to-energy and landfill gas) or hydro electric sources.

EXHIBIT 3
Forecasted Energy Needs



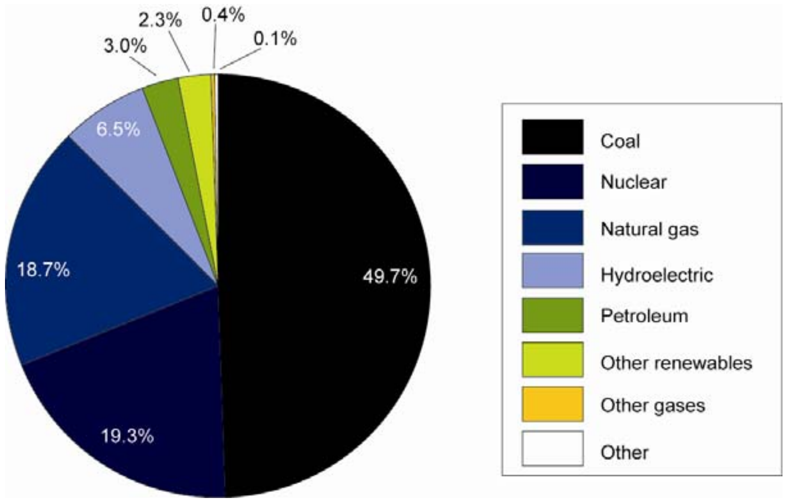
SOURCE: *Michigan's 21st Century Electric Energy Plan*, 2007 (prepared by Demand Workgroup, November 2006).

- Reliability modeling indicates that additional resources (from renewables, energy efficiency programming, or short-term generation options) will be needed to meet Michigan's electric needs by 2009, and additional baseload generation will be needed as soon as practicable but no later than 2015.

■ Reliance upon our old methods of providing electricity will not suffice for the future for a variety of reasons.

- Coal-fired plants are the major stationary source of carbon dioxide—the primary component of greenhouse gas. Michigan's coal-fired generating units emit an estimated 40 percent of the state's total emissions. While there are no known state proposals to curb carbon dioxide, discussion at the federal level has increased, and it would be prudent to consider that greenhouse gas controls could emerge in the near future. Carbon dioxide emissions regulation could raise the cost of electricity produced by conventional coal units by 1.5 to 2.0 cents per kilowatt-hour.
- Approximately 3 percent of the total electricity currently sold to Michigan utility customers is generated by renewable energy sources (see Exhibit 4). The recommended target is a minimum of 10 percent of total electricity generation from qualifying renewable resources by the end of 2015.

EXHIBIT 4
Current Electric Energy Production



SOURCE: U.S. Department of Energy, Energy Information Administration. 2005.

Other states recognize the importance and potential of landfill gas as well. Governor Edward Rendell of Pennsylvania, for example, has focused efforts on capturing landfill gas to pipe it directly to serve businesses in order to keep jobs in Pennsylvania. Under the governor's direction, the state has provided strong financial support to encourage landfill gas reuse projects with the investment of more than $3.87 million in grant funding. Landfill gas was included as a preferred energy source in Pennsylvania's Alternative Energy Portfolio Standard created by Governor Rendell and the state legislature. Pennsylvania is home to 24 operational gas-to-energy projects (State of Pennsylvania 2007).

Governor Rendell notes that "landfill gas-to-energy projects showcase a few of the many ways Pennsylvania government and industry are responding to our call to build a clean energy future using fuels made in Pennsylvania" (State of Pennsylvania, 2007).

Michigan's recently updated solid waste policy speaks clearly and positively about recycling and utilizing waste, and therefore sets the stage for examining a yard waste ban exemption. The solid waste policy statement declares that Michigan recognizes solid waste as a resource that should be managed to promote economic vitality, ecological integrity, and improved quality of life in a way that fosters sustainability. By recognizing solid waste as a resource, Michigan can more fully realize the economic, environmental, and social benefits of using waste materials that still have inherent value. These opportunities include job creation, renewable energy production, and a healthier environment (MDEQ/WHMD, May 24, 2007).

As the solid waste policy implies, our world and our perspectives on recycling have changed considerably and in a variety of ways since the 1990s, when both the yard waste ban and the most recent policy for solid waste were established. Laws and regulations, technology, and even Michigan's economy have advanced. This transformation, as well as the desire to improve the way we manage solid wastes and create and use energy, has prompted Michigan's government to revisit both its solid waste and energy policies and update them to meet the challenges Michigan faces today and in the foreseeable future.

HOW RENEWABLE ENERGY PRODUCTION FROM LANDFILL GAS WORKS

We are all familiar with how our trash gets to the landfill, but less familiar with what happens to it once it reaches its final destination. (For background information on solid waste landfills, please see Appendix C.) Once refuse is in a landfill it begins to decompose (see Exhibit 5 for varying decomposition rates). The decomposing materials within landfills create gases that can be used to create renewable energy. Landfill gas consists of about 50 percent methane (CH_4), the primary component of natural gas; about 50 percent carbon dioxide (CO_2); and a small amount of non-methane organic compounds. Methane gas occurs naturally in landfills when organic waste materials (such as food, natural fibers, grass, leaves, etc.) decompose. Municipal solid waste landfills are the largest source of human-related methane emissions in the United States, accounting for about 25 percent of these emissions in 2004 (EPA 2007).

EXHIBIT 5
Decomposition Times

Type of material	Decomposition time
Banana peel	2–10 days
Cotton rags	1–5 months
Paper	2–5 months
Rope	3–14 months
Orange peels	6 months
Yard waste	9 months–3 years
Wool socks	1–5 years
Cigarette filters	1–12 years
Milk cartons	5 years
Plastic bags	10–20 years
Leather shoes	25–40 years
Nylon fabric	30–40 years
Styrofoam cup	1–100 years
Plastic 6-pack holder rings	450 years

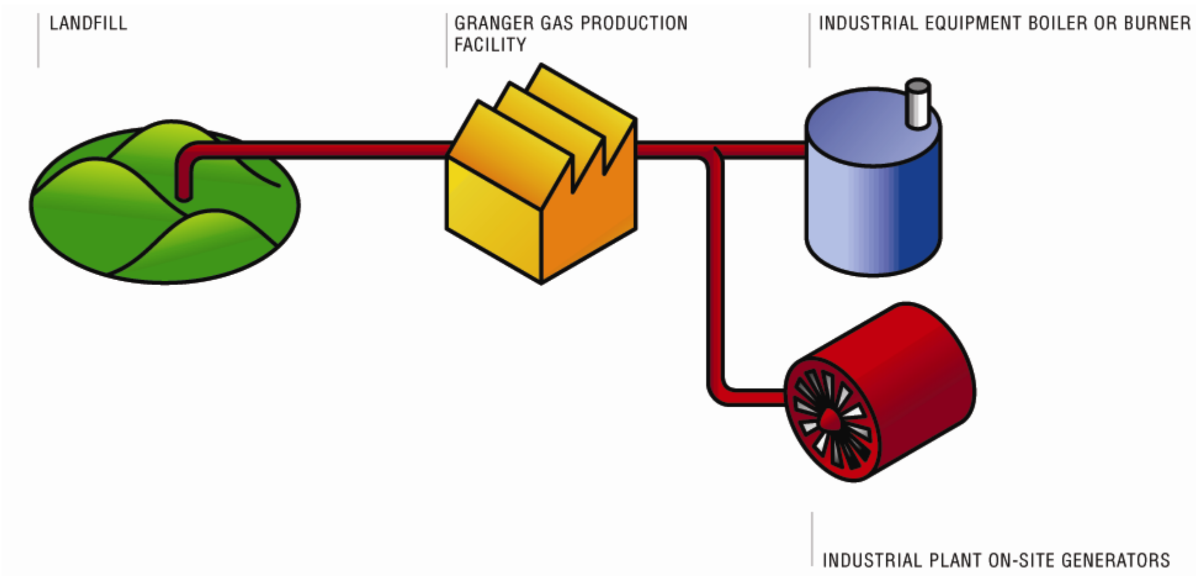
SOURCE: California Waste Management Bulletin data in Keep California Beautiful. 2007.

The failure to capture methane emissions from landfills represents a lost opportunity to use a significant energy resource. This gas can be recovered, processed, and used as an alternative to natural gas in one of two ways:

- **As a "direct-use" fuel.** Methane gas is recovered by wells placed vertically or horizontally in the landfill, transported via a network of pipes to an on-site processing facility, and then piped to nearby industrial plants. Typically, the gas is used to fuel boilers, burners, or other combustion equipment, as shown in Exhibit 6.

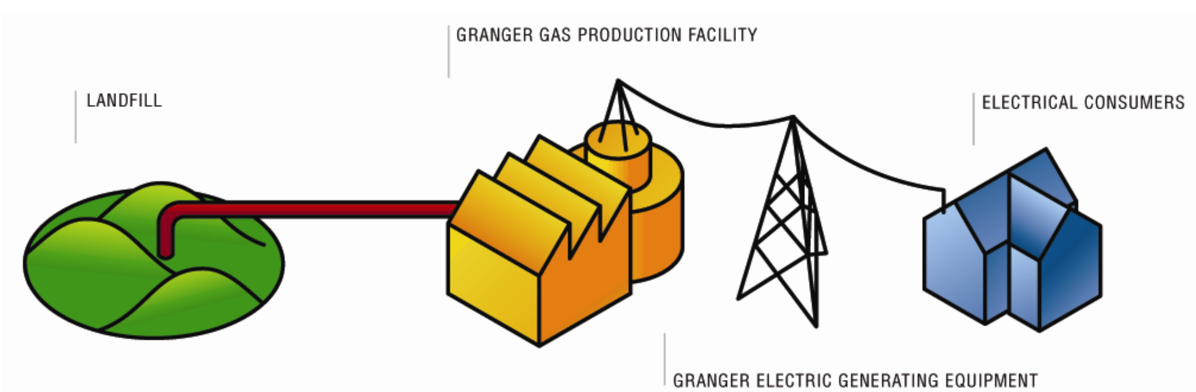
- **As a means of generating electricity.** Recovered methane gas can be used to fuel engine generators that produce electricity on-site at the landfill. This electricity is then sold to a local utility or other electrical consumers. Exhibit 7 depicts this process.

EXHIBIT 6
Recovered Methane Gas Production Pathway for Industrial Plants



SOURCE: *Granger, 2001.*

EXHIBIT 7
Recovered Methane Gas Production Pathway for Electrical Consumers



SOURCE: *Granger, 2001*

In fact, many forward-thinking landfill companies harness or collect the methane produced from the landfill and use it to generate electricity. These projects are partnerships with landfills and landfill gas project developers such as DTE Energy, Waste Management, Granger III & Associates (Granger), Landfill Energy Systems, and North American Natural Resources. Landfill gas projects have been around since the late 1970s, providing renewable energy in the form of electricity and alternative fuel to residents, businesses, and industry. In 1985 Granger developed the first landfill gas-to-energy facility in Michigan, a project that provided fuel for a nearby industrial plant. Several years later, the project was converted to supply electricity generated from landfill-derived methane gas to Consumers Energy, one of the nation's largest utilities. Landfill gas serves as the "baseload renewable" for many "green power" programs, providing online availability exceeding 90 percent (EPA 2007).

BENEFITS OF LANDFILL GAS RECOVERY FOR RENEWABLE ENERGY PRODUCTION

As both Michigan's energy plan and solid waste policy indicate, using landfill gas recovery for renewable energy production can provide economic, environmental, and social benefits. The EPA also recognizes landfill gas-to-energy projects as a positive opportunity (EPA/LMOP 2007). The EPA states that landfill gas utilization projects have the following benefits:

- Involvement of citizens, nonprofit organizations, local governments, and industry in sustainable community planning and creating partnerships
- Cleaner air
- Renewable energy
- Economic development
- Improved public welfare and safety
- Reductions in greenhouse or global warming gases

The EPA proposes that linking communities with innovative ways to deal with their landfill gas will help these communities enjoy increased environmental protection, better waste management, and responsible community planning. To support these efforts, the EPA offers a voluntary assistance and partnership program dedicated to promoting the use of landfill gas as a renewable, green energy source. The Landfill Methane Outreach Program (LMOP) helps businesses, states, energy providers, and communities protect the environment and build a sustainable future by preventing emissions of methane through the development of landfill gas energy projects.

From other perspectives, too, recovering methane gas from landfills can be a compelling option (Granger 2001). Methane:

- Is a renewable source of energy. As long as there is solid waste, there will be methane. Landfills continue producing the gas for 20 to 30 years after closure.
- Doesn't deplete our natural resources like other energy-generation methods.
- Generally costs less to collect and process than natural gas.
- Burns much cleaner than conventional energy sources.

- Is a greenhouse gas, whose recovery for energy prevents it from being emitted into the atmosphere and contributing to local smog and global climate change.

Capturing landfill gas also reduces odor and other hazards associated with landfill gas emissions (EPA/LMOP 2007). In addition, a landfill designed and built for high extraction efficiency and managed for the purpose of energy recovery can have high efficiency values. Granger's facility can document achieving an 85 percent recovery rate. Landfill gas-to-energy facilities are also highly reliable, boasting upwards of 90 percent reliability for either direct or indirect uses. In comparison, each MW of wind generation requires nearly matching generation from other sources due to the 28–32 percent capacity of wind energy (MPSC 2007).

Landfill gas can be an asset when it is used as a source of energy to create electricity or heat and can often be used in place of conventional fossil fuels in certain applications. It is a reliable source of energy because it is generated 24 hours a day, 7 days a week. By using landfill gas to produce energy, landfills can significantly reduce their emissions of methane and avoid the need to generate energy from fossil fuels, thus reducing emissions of carbon dioxide, sulfur dioxide, nitrogen oxides, and other pollutants from fossil fuel combustion (EPA 2007).

The EPA has developed a *Benefits Calculator* to estimate direct, avoided, and total greenhouse gas reductions, as well as environmental and energy benefits, derived from gas-to-energy projects (EPA/LMOP 2007). In 2007, benefits for a typical 3-megawatt gas-to-energy facility are approximately equal to any one of the following:

- Removing emissions equivalent to 25,000 vehicles
- Planting 36,000 acres of forest
- Offsetting the use of 640 railcars of coal
- Averting electricity usage of 234,000 light bulbs
- Powering 1,900 homes

There are further business benefits to be derived as well:

- Existing rules require landfill owners to handle methane gas in a way that will minimize its negative impact on the environment.[7] Instead of burning it off, a practice known in the industry as flaring, the gas can be recovered, refined, and sold, thereby turning a liability into a source of revenue.
- If a landfill is located near private industry or municipalities, those entities may be able to contract with the producer to provide methane gas directly, thus ensuring a reliable and economical energy source that is dedicated to specific needs. Alternatively, renewable electricity that is generated at the landfill may be purchased.

[7] For more information concerning rules that govern landfills in Michigan please see Solid Waste Management Act Administrative Rules promulgated pursuant to Part 115 of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended, effective October 20, 2005. Applicable rules are 299.4910, 299.4911, 299.4433, and 299.4434. These rules are administered by the Michigan Department of Environmental Quality, Waste and Hazardous Materials Division.

Either scenario promotes energy practices that improve air quality.

- Converted to electricity, methane gas can supplement electrical power capacity or add "green power" to a utility's portfolio. Landfill-derived methane gas can be used to generate renewable electricity for distribution to utility customers who desire a cleaner alternative.

TECHNOLOGY FOR LANDFILL ENERGY PRODUCTION

To capitalize on landfill energy production efficiency, collection and conversion systems must be in place before the landfill starts depositing material. When Michigan's yard waste ban was enacted in 1995, few landfills in Michigan did this. Most commonly, landfill facilities installed collection systems after material was deposited rather than as it was deposited.

Twelve years later, the technology component has become an important consideration, changing the landscape of the yard waste ban policy. Recognizing the potential for fuel generation, landfill operators are increasingly coming on board to design collection systems to efficiently capture landfill gas to create energy.

According to LMOP, as of April 2007 there were approximately 424 operational landfill gas energy projects in the United States and 560 additional landfills that are good candidates for projects. According to this study, out of the 50 landfills in Michigan there are 20 with existing energy projects that could be generating the equivalent of 188.8 MW of electricity and 12 more with the potential for development. The inclusion of yard waste in these landfill energy production facilities would result in renewable energy production of 241.6 MW, or 52.8 MW more than current potential. Using the EPA's *Benefits Calculator,* this additional energy translates into powering 33,574 homes.

The balance of this report examines the relative merits of an exemption to the yard waste ban for renewable energy generated from landfill gas versus creating a soil amendment from the organic waste; explores possible exemption language; and quantifies the potential of increased renewable energy generation. This information could support changes to Michigan's waste management laws and/or a long-range plan for funding and developing the capability to generate renewable landfill gas.

Landfill Energy-Production Potential[8]

In order to consider alteration of the yard waste ban policy, it is first necessary to determine the renewable energy potential of landfill gas in Michigan. The purpose of this section is to meet that need by analyzing the current and future landfill gas energy-production capabilities in the state and to evaluate the potential increase of landfill gas and related renewable energy production at facilities appropriately designed to collect and convert landfill gas to renewable energy. To do this, the following questions were addressed:

- How is the potential energy production affected if yard waste is included in the waste stream?
- Based on analysis of current landfill energy-production capacity, can landfills be considered a source of reliable, sustainable, renewable energy production?

As a means of providing information that can be used to answer these questions, three levels of energy projections were assessed.

- Energy production from current landfill energy-producing facilities (baseline)
- Potential energy production from landfills with current energy-producing facilities with yard waste added (current projections)
- Potential energy production from landfills capable of developing landfill energy-production facilities with yard waste added (future projections)

To predict quantifiable results, common terms of analysis were needed. To compare and contrast these levels of energy production, simple electrical energy production in megawatts[9] was used. Although some site-specific applications may result in a direct gas end-user, the net result is still valid in that the analysis quantifies a certain level of energy derived from landfill energy-production facilities and does not distinguish between end uses.

Overall, a rather conservative approach was employed. When possible, precautions were taken to ensure that the capacity of landfill energy-production facilities was not overestimated. In situations where there was a range of data, the most conservative numbers were used. This approach demonstrates the best-case scenario for landfill energy capacity with conservative parameters applied.

METHODOLOGY

To analyze the impact of yard waste on landfill energy-production facilities, a model was used. Many different types of disciplines, from social sciences to physics, use modeling

[8] The material in this section was adapted from information provided by PSC's engineering and technical consultant, NTH Consultants Ltd.
[9] Electrical capacity is usually measured in watt (W), kilowatt (kW), megawatt (MW), etc. Power is energy transfer per unit of time. Capacity may be measured at any moment in time, whereas power is measured during a certain period, e.g., a second, an hour, or a year. For example, one kilowatt (kW) times 24 hours (h) equals 24 kWh.

to analyze hypothetical situations and to predict outcomes. In this case, modeling is an appropriate way to answer the question about using yard waste to increase landfill energy production. Since landfills already produce electricity, there is a sound foundation from which to build the model.

There are three primary tasks of modeling or computer simulation: model design (or building the model); model execution (or operating the model); and lastly, analysis. This section outlines how this study was conducted for each of those tasks.

A computer model was used to analyze the gas generation capacity at each landfill site. The model used in this study is LandGEM (Version 3.02), an emissions estimation tool developed and distributed by the EPA to estimate emission rates for methane, carbon dioxide, and non-methane organic compounds from landfills. The model can be run using site-specific data or default values. Even with site-specific data, it should be recognized that model results are forecasts of conditions that are influenced by parameters or inputs that can only be based on historic records. For example, weather prediction models are based upon past weather trends and data sets and are affected by a multitude of factors such as temperature, wind rates, barometric pressure, etc.

The findings of the study would be oversimplified if the aggregate statewide waste volume were used to predict energy generation. Therefore, to assess energy capacity it was necessary to evaluate gas generation at each landfill site. The individual energy capabilities of each landfill were summarized on a yearly basis. This approach provided a reasonable annual energy prediction from the current year (2007). An additional advantage of analyzing gas generation on a site-by-site basis as opposed to statewide volume is that it allowed the flexibility to filter the data set based on individual site characteristics.

The model was first built using site-specific data and gas generation parameters as inputs. The model was then operated and electrical capacity of each site was determined. As with any model, the building process includes making certain assumptions on which to run the model. In this study, statewide assumptions regarding the amount of gas recovered and the specifications of landfill energy-production generators were made. This model was run and applied to the three levels of energy projections described above.

BASELINE ASSUMPTIONS (CURRENT LANDFILL GAS PRODUCTION *EXCLUDING* YARD WASTE)

To establish a baseline, a specific value that serves as a comparison or control in a test, parameters that best calibrated to actual gas production values were obviously the favored inputs. Since Granger’s Wood Street facility has operated as a landfill energy-production facility since 1985 and has monitored data from its inception to the present, it was selected to calibrate the model parameters. This site was also selected based on the presence of significant gas recovery infrastructure, an electrical production facility, and the ability to estimate collection efficiency.

Individual Landfill Site-Specific Data and Assumptions

According to the MDEQ, there are 50 active Type II landfills operating in Michigan.[10] Sufficient data was not available for eleven landfill facilities, which were therefore excluded from the study. Since some of these excluded facilities are believed to have significant renewable energy-production capacity or potential capacity, excluding these sites renders the results of this study even more conservative. The parameters or inputs used for each landfill site include:

- Initial date of waste receipt
- Waste volumes in place
- Volumes received per year
- Permitted capacity (remaining capacity)

Sources for these data were the MDEQ Waste Volume Reports, the EPA Landfill Methane Outreach Program (LMOP), and the MDEQ Michigan Air Emissions Reporting System (MAERS) reports.

Annual waste volume acceptance after 1995 and the landfill capacity were obtained from the MDEQ Waste and Hazardous Materials Division (WHMD) Waste Data System (MDEQ/WHMD, 2005). Some waste acceptance rates and year of opening were based on the knowledge of NTH Consultants Ltd. of specific sites. When possible, actual waste acceptance rates and year of opening were used in the data set. When this information was unavailable, the annual waste volume acceptance prior to 1995 was determined by subtracting the volume of waste in each landfill in 1995 from the reported total in-place capacity. The difference was then divided by the number of years the landfill had been licensed and operating. The result was an annual waste receipt for years prior to the institution of reporting requirements (1995). For situations that involved unknown initial date of waste receipt, a standard date of 1975 was used. This date was chosen based on the likelihood that sites operating prior to this date would have been closed due to regulatory changes in the Resource Conservation Recovery Act, Subtitle D of 1976.

While it was necessary to estimate some site-specific information, the overall model results are believed to be accurate for predicting gas production at individual landfills. To allow prediction on a statewide basis, the model parameters were standardized. While the parameters used may not specifically represent individual facilities, the overall outcome does represent a reasonably accurate determination of gas production for Michigan landfills.

[10] A Type II or municipal solid waste landfill is defined (State of Michigan 1996) as a landfill that receives household waste, municipal solid waste incinerator ash, or sewage sludge and that is not a land application unit, surface impoundment, injection well, or waste pile. A municipal solid waste landfill also may receive other types of solid waste, such as construction and demolition waste, sewage sludge, commercial waste, nonhazardous sludge, conditionally exempt small quantity generator waste, and industrial waste. Such a landfill may be publicly or privately owned.

Methane Generation Rate (k = 0.05 year^{-1})

The methane generation rate, k (year^{-1}), is a constant for the rate at which methane is produced. The value is affected by moisture, pH, temperature, and other environmental factors including landfill operation (EPA 1998). It is common practice to differentiate sites receiving less than 25 inches of precipitation per year from those receiving more than 25 inches of precipitation per year. For sites that receive more than 25 inches of precipitation per year typical values range from 0.05 to 0.12 year^{-1} (Kulasingam, Othman, and Heitz, 2006) and a default k value of 0.04 year^{-1} has been recommended (EPA 1998).

Because it falls within the recommended range and has its basis in current regulation, the Clean Air Act conventional default value of 0.05 year^{-1} was selected. Given the reported ranges for locations that receive more than 25 inches of precipitation and the fact that most Michigan counties receive more than 30 inches of precipitation per year (USDA 2002), this selection is a slightly conservative representation for Michigan landfills. Although an increase in organic material and moisture from yard waste has the potential of increasing the methane generation rate, this parameter was held constant even when modeling energy production due to the addition of yard waste to reinforce the conservative approach.

Methane Content (54 percent)

Methane content is expressed in the model as the percentage of methane by volume compared to the total amount of gases present. Many factors can affect the methane content in landfill gas, such as organic content, air infiltration, age of waste, and moisture. Field measured values range between 48 and 60 percent methane content in landfill gas. For the purposes of the study, 54 percent methane was used in the model, which represents a mid-range value.

Potential Methane Generation Capacity (100 m^3/Mg)

The potential amount of methane that can be produced by decomposition of organic matter is measured by its potential methane generation capacity, or L_0 (m^3/Mg). This value depends on the organic content of the refuse and can vary widely, from 6.2 to 670 m^3/Mg (EPA 1998). The LandGEM model default value of 100 m^3/Mg was used to establish the baseline for this study. Based on reported values and ranges, this value is a fair representation of landfills in Michigan.

PROJECTION ASSUMPTIONS (LANDFILL GAS PRODUCTION *INCLUDING* YARD WASTE)

To complete the comparison and provide an assessment of whether reintroducing yard waste into landfills can boost landfill energy capacity, the additional energy generation potential provided from yard waste disposal in active landfills is forecasted. This section describes the basis and assumptions used to modify model inputs to account for the addition of yard waste.

The same procedures for the selection of landfills and the data associated with those landfills as described earlier were used. The volumes received per year were increased to account for yard waste as described below. In keeping with the conservative approach applied throughout this evaluation, in the projection of the gas generation model (which includes yard waste) the methane generation rate (k) at 0.05 $year^{-1}$ and the total methane content at 54 percent were held the same as the baseline. The only input parameter that was revised, other than the volumetric increase due to the inclusion of yard waste, was the potential methane generation capacity.

Yard Waste Volumetric Increase

Estimates of yard waste in the total waste stream vary, with EPA estimating the lowest at 13.1 percent (2006) while other estimates range up to 19.3 percent (Tchobanoglous, Theisen, and Vigil 1993). Regardless of range, it is not expected that all yard waste would be collected and put into landfills. To account for the increased volume of yard waste, the annual future waste volume acceptance rate was increased by 10 percent. It was determined that a value of 10 percent more accurately represents the potential percentage of yard waste disposed of in Michigan landfills, recognizes that composting will still occur, and again reinforces the conservative approach of the study.

Potential Methane Generation Capacity (110 m^3/Mg)

Methane generation in municipal solid waste landfills is dependent on many factors. The value for the potential methane-generation capacity, L_0 (m^3/Mg), is affected primarily by the amount of cellular debris and moisture in the landfill. The addition of yard waste would increase both cellular and moisture content values, making it reasonable to assume that the potential methane generation capacity would also increase. It was therefore necessary to establish a rationale to determine the increase to attribute to yard waste. To do this, the chemical reaction for anaerobic decomposition of solid waste was analyzed (Tchobanoglous, Theisen, and Vigil 1993):

Organic matter (solid waste) + H_2O → biodegraded organic matter + CH_4 + CO_2 + other gases

The actual reactions occurring within a landfill are too numerous and complex to model precisely. To account for this, the substances involved were grouped into generic categories and the processes phrased in these terms. The most important metabolic pathway in refuse decomposition is believed to be the fermentation of the primary substrates (mainly paper and vegetative matter) to sugars and alcohols, followed by their conversion to organic acids, which then break down to produce methane.

Converting percentages of organic waste disposed of into molar composition by element and accounting for the biodegradable percentage of each organic component will yield the volume of gas produced per mass of solid waste. Using this methodology, it was determined that a volumetric increase from yard waste of 10 percent would result in an increase in potential methane generation capacity of 10 m^3/Mg (Tchobanoglous, Theisen, and Vigil 1993). Therefore, the value of 10 m^3/Mg was added to the baseline of 100 m^3/Mg for a resulting L_0 value of 110 m^3/Mg as applied when running the model with yard waste.

To simplify the approach, it was assumed that yard waste was added for the entire duration of the study, from initial waste receipt to present. Specifically, it was assumed that the landfills accepted yard waste from 1996 to present during the period of the yard waste ban (State of Michigan 1995). During this period, the potential methane generation capacity was held constant at 110 m^3/Mg.

CONVERSION OF LANDFILL GAS TO ELECTRICAL POWER

Having modeled to a calibration site (Granger) and applied the calibrated parameters to individual landfills, a time-based summary of energy production was needed. Outputs of the individual gas flow rates of the landfills from the LandGEM model were linked to an Excel spreadsheet to estimate total yearly electrical generation capacity. Assumptions used to convert the gas flow rate to electrical capacity are summarized below.

Collection Efficiency

Collection efficiencies have been reported to range from 60 to 85 percent with a commonly assumed average of 75 percent (EPA 1998). To date, there is not enough actual recorded field data to support any universally accepted recovery level. Thus critics offer conjecture on either side of EPA's number. Making further comparisons difficult are factors such as varying designs being used by industry, numerous installation methods and scheduling formats, and many technological advancements throughout the period since landfill gas recovery began.

The objective of this study was not to prove or disprove current collection system efficiencies, but rather, to consider what can reasonably be designed and constructed. The EPA's model takes into account average design capabilities to achieve 75 percent collection efficiency for the purpose of site gas control and suggests that in Michigan,[11] the 75 percent level is achievable under energy recovery efforts. This demonstration serves as a validation check and also provides credibility to the EPA's estimate.

This model therefore uses 75 percent to represent a fair and credible prediction of achievable collection system efficiency for energy recovery. Increased interest and emphasis on using renewable power sources that give way to technological advancements may render this percentage conservative. Economic market place drivers also have the potential to lead toward exerted efforts to recover and utilize rather than just control landfill gas. Innovation advanced by these conditions may indeed lead to collection system efficiencies of much greater than 75 percent, thus increasing energy-production capabilities and improving gas control at the same time.

Electrical Generators

Landfill gas is used as a fuel for engine generator sets to produce electricity. Each type of generator set (i.e., make and model) uses gas differently based on engine design and size. It was therefore necessary to standardize a particular engine/generator for this study. By doing so, the amount of fuel used by each generator set could then be represented as "a block" of energy and estimates of energy production could be more accurately

[11] The Granger Wood Street Facility was also used as a control example for collection system efficiency. The site has significant collection system infrastructure, where comparison of modeled results to metered flow demonstrate efficiency consistent with the EPA figure. Further, information from this site as well as comparison at Granger's Grand River Facility, demonstrates that higher efficiencies are achievable. Both sites have landfill gas recovery programs.

determined by the availability of fuel (i.e., model output). This approach takes into account standardized fuel efficiency for converting gas to energy.

The most common type of generator set used in landfill energy production is Caterpillar®. Caterpillar® manufactures two preferred sizes: the CAT-3516, using 300 standard cubic feet per minute (scfm) of landfill gas to generate 0.8 MW, and the CAT-3520, using 450 scfm to generate 1.6 MW of power. The CAT-3520 was used for this study because it is based on a more efficient landfill gas to electricity conversion.

Major Facilities

Major facilities were defined as landfills that have a potential peak gas capacity to generate 1.6 MW or more. The cut-off value of 1.6 MW was chosen based on the generator selected to standardize the study (CAT-3520).[12] If a specific landfill did not produce enough landfill gas to operate two CAT-3520s (900 scfm), it was excluded from the study. This classification was broken down further into current major facilities (landfills with existing energy-production facilities) and potential major facilities (facilities capable of generating 1.6 MW or more of energy). Exhibit 8 displays all of the facilities and their classification for this study.

[12] It has been shown at the Granger Wood Street Facility that producing less than 1.6 MW with the CAT 3520 is not economically viable.

EXHIBIT 8
Facilities and Classifications

Current Major Facilities			
1	Adrian Landfill	11	Ottawa County Farms Landfill
2	Autumn Hills Recycling and Disposal Facility	12	Peoples Landfill Inc
3	C&C Expanded Sanitary Landfill	13	Pine Tree Acres Inc
4	Carleton Farms Landfill	14	Riverview Land Preserve
5	Citizens Disposal Inc	15	Sauk Trail Hills Landfill
6	Eagle Valley Recycle & Disposal Facility	16	Venice Park Recycling & Disposal Facility
7	Forest Lawn Landfill Inc	17	Veolia ES Arbor Hills Landfill Inc
8	Granger Grand River Landfill	18	Vienna Junction Industrial Park Sanitary Landfill
9	Granger Wood Street Landfill	19	Westside Recycling & Disposal Facility
10	Oakland Heights Development Inc	20	Woodland Meadows RDF-Van Buren
Potential Major Facilities			
1	Central Sanitary Landfill	7	Northern Oaks Recycling and Disposal Facility
2	City Environmental Services Inc of Waters	8	Orchard Hills Sanitary Landfill
3	City of Midland Sanitary Landfill	9	Smiths Creek Landfill
4	Glens Sanitary Landfill	10	South Kent Landfill
5	Manistee County Landfill Inc	11	Southeast Berrien County Landfill
6	Michigan Environs Inc	12	Whitefeather Landfill
Excluded—Less Than 1.6 MW Facilities			
1	City Environmental Services of Hastings	5	Osceloa Development LLC Landfill
2	Collier Road Landfill	6	Tri-City Recycling and Disposal
3	Marquette County Landfill	7	Wexford County Landfill
4	McGill Road Landfill		
Excluded—Lack Data			
1	Brent Run	7	K and W Landfill
2	County of Muskegon Solid Waste Facility	8	Montmorency-Oscoda-Alpena SWMA
3	Cove Landfill	9	Pitsch Sanitary Landfill
4	Delta County Landfill	10	Richfield Landfill Inc
5	Dafter Sanitary Landfill	11	Wood Island Waste Management Inc
6	Elk Run Landfill		

SOURCE: NTH Consultants Ltd. 2007.

RESULTS

The results of the modeling are presented below. Exhibits 9 and 10 report the results for individual landfills and show the collective statewide potential of renewable energy generation for four endpoints: 2007, 2015, peak energy generation, and year in which peak energy generation occurs.

EXHIBIT 9
Current Major Facilities **Excluding** Yard Waste

Facility	County	2007 MW	2015 MW	Peak MW	Peak year
Adrian	Lenawee	1.6	3.2	3.2	2016
Arbor Hills	Washtenaw	16.0	20.8	22.4	2019
Autumn Hills	Ottawa	8.0	9.6	11.2	2028
C & C	Calhoun	4.8	6.4	6.4	2019
Carleton Farms	Wayne	20.8	33.6	43.2	2024
Citizens	Genesee	3.2	6.4	8.0	2023
Eagle Valley	Oakland	6.4	6.4	6.4	2014
Forest Lawn	Berrien	14.4	11.2	16.0	2009
Granger Grand River	Clinton	3.2	3.2	3.2	2005
Granger Wood Street	Clinton	4.8	6.4	9.6	2054
Oakland Heights	Oakland	9.6	6.4	9.6	2007
Ottawa County	Ottawa	11.2	12.8	12.8	2017
Peoples	Saginaw	3.2	4.8	6.4	2024
Pine Tree	Macomb	19.2	20.8	25.6	2011
Riverview	Wayne	11.2	16.0	17.6	2020
Sauk Trail	Wayne	12.8	19.2	19.2	2016
Venice Park	Shiawassee	6.4	6.4	8.0	2029
Vienna Junction	Monroe	8.0	9.6	9.6	2014
Westside Recycling	St Joseph	6.4	8.0	11.2	2073
Woodland Meadows	Wayne	17.6	19.2	20.8	2012
Average		**9.4**	**11.5**	**13.5**	**2022**
Total		**188.8**	**230.4**		

SOURCE: NTH Consultants Ltd. 2007.

EXHIBIT 10

Current and Potential Major Facilities **Including** Yard Waste

	Facility	County	2007 MW	2015 MW	Peak MW	Peak Year
CURRENT FACILITIES	Adrian	Lenawee	3.2	3.2	3.2	2016
	Arbor Hills	Washtenaw	17.6	24.0	27.2	2018
	Autumn Hills	Ottawa	8.0	11.2	14.4	2026
	C & C	Calhoun	4.8	8.0	8.0	2018
	Carleton Farms	Wayne	22.4	40.0	49.6	2023
	Citizens	Genesee	3.2	8.0	9.6	2022
	Eagle Valley	Oakland	8.0	8.0	8.0	2013
	Forest Lawn	Berrien	16.0	12.8	17.6	2009
	Grand River	Clinton	3.2	3.2	3.2	2005
	Granger Wood Street	Clinton	4.8	8.0	11.2	2049
	Oakland Heights	Oakland	9.6	6.4	9.6	2008
	Ottawa County	Ottawa	12.8	14.4	14.4	2016
	Peoples	Saginaw	3.2	6.4	6.4	2022
	Pine Tree	Macomb	20.8	24.0	28.8	2010
	Riverview	Wayne	12.8	17.6	20.8	2019
	Sauk Trail	Wayne	14.4	22.4	22.4	2015
	Venice Park	Shiawassee	6.4	8.0	9.6	2027
	Vienna Junction	Monroe	8.0	9.6	11.2	2013
	Westside Recycling	St Joseph	6.4	9.6	14.4	2073
	Woodland Meadows	Wayne	19.2	20.8	24.0	2012
	Average		**10.2**	**13.3**	**15.7**	**2021**
	Total—Current		**204.8**	**265.6**		
POTENTIAL MAJOR FACILITIES	Central Sanitary	Montcalm	3.2	4.8	6.4	2036
	City Env of Waters	Crawford	3.2	4.8	8.0	2055
	City of Midland	Midland	3.2	3.2	3.2	2009
	Glens Run	Leelanau	1.6	1.6	3.2	2055
	Manistee	Manistee	1.6	3.2	4.8	2046
	Michigan Environs	Menominee	3.2	3.2	4.8	2022
	Northern Oaks	Clare	3.2	4.8	8.0	2034
	Orchard Hill	Berrien	3.2	4.8	6.4	2022
	Smith Creek	St Clair	4.8	8.0	9.6	2023
	South Kent	Kent	3.2	4.8	4.8	2032
	Southeast Berrien	Berrien	3.2	3.2	4.8	2012
	White Feather	Bay	3.2	3.2	3.2	2017
	Average		**3.1**	**4.1**	**5.6**	**2030**
	Total—Potential		**36.8**	**49.6**		
Statewide average			**7.6**	**9.8**	**11.9**	**2024**
Total statewide			**241.6**	**315.2**		

SOURCE: NTH Consultants Ltd. 2007.
NOTE: Current major facilities are landfills with existing landfill energy-production facilities. Potential major facilities are landfills that produce enough landfill gas to generate 1.6 MW or more.

Exhibit 11 presents the statewide renewable energy capacity in terms of both total and average capacity.

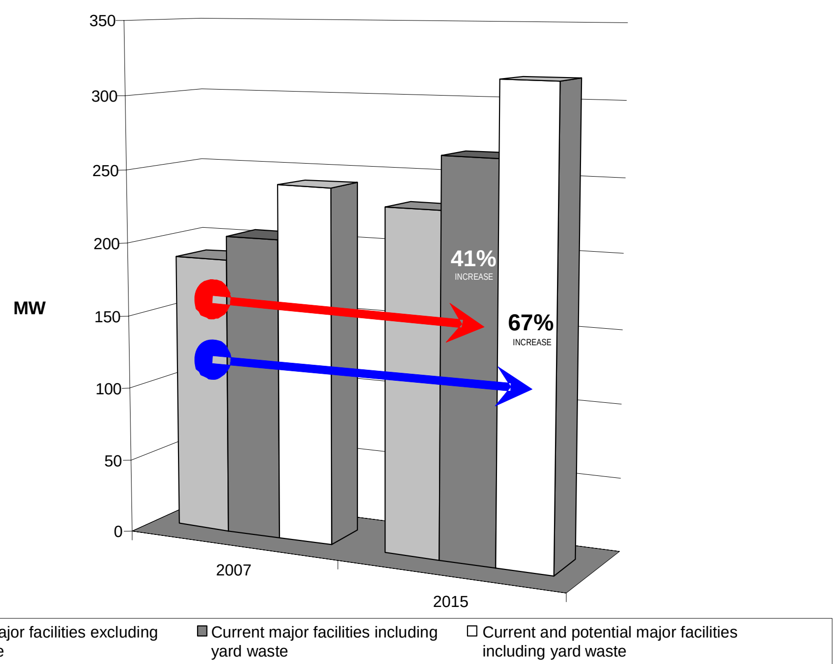
EXHIBIT 11
Statewide Landfill Energy-Production Capacity

Facility type	Yard waste	2007 (MW) Total	2007 (MW) Average	2015 (MW) Total	2015 (MW) Average	Peak year total	Peak year average	Peak (MW) total	Peak (MW) average
Current major	Excluded	188.8	9.4	230.4	11.5	2014	2022	232.0	13.5
	Included	204.8	10.2	265.6	13.3	2015	2021	265.6	15.7
Current major plus potential major	**Included**	241.6	3.1	315.2	4.1	2016	2030	316.8	11.9

SOURCE: NTH Consultants Ltd. 2007.
NOTE: Current major facilities are landfills with existing landfill energy-production facilities. Potential major facilities are landfills that produce enough landfill gas to generate 1.6 MW or more.

Exhibit 12 shows the potential energy generation capacity including and excluding yard waste for current and potential facilities statewide.

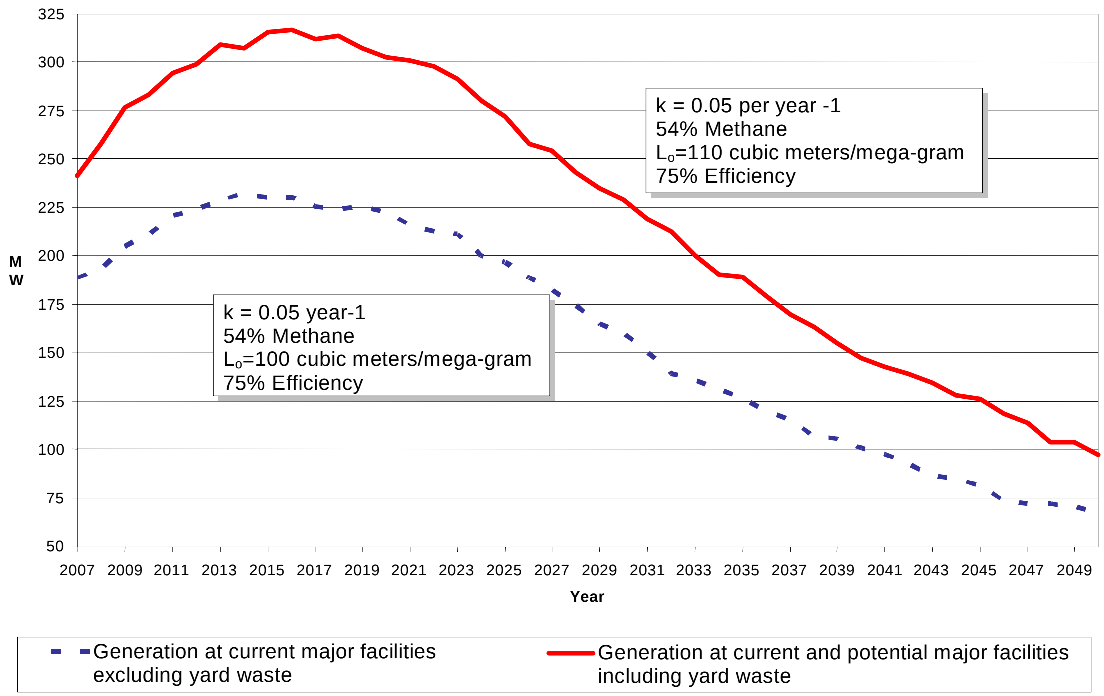
EXHIBIT 12
Statewide Energy Production



SOURCE: NTH Consultants Ltd. 2007.

Exhibit 13 shows the statewide potential renewable energy generation from the present to 2050.

EXHIBIT 13
Energy-production Capacity, Including and Excluding Yard Waste



SOURCE: NTH Consultants Ltd. 2007.

While this is an independent study incorporating defined modeling and parameters, the findings are validated from the demonstrated consensus found in similar studies, such as the Michigan Capacity Needs Forum (CNF) Report and EPA/LMOP reports. It should be noted that the CNF report was conducted under the direction of the Michigan Public Service Commission and serves as the foundation for *Michigan's 21st Century Electric Energy Plan* (MPSC 2007).

As a means of verifying electrical generation capabilities predicted by this study, reference can be made to the two above studies which also attempted to project energy capabilities of landfill gas-to-energy projects. Both CNF and EPA/LMOP sources estimate current capacity at roughly 78 MW, while this current examination estimates 188.8 MW. First reaction to these figures may suggest that these studies do not remotely agree. This study examined maximum potential capacity while the other studies reviewed existing in place generation and use. However upon closer inspection the numbers have been found to be in greater agreement than they may seem. For a detailed explanation please see Appendix A.

In sum, the energy-production capacity of landfills in Michigan clearly can be increased by the reintroduction of organic yard waste material. In addition, energy benefits from current landfill energy-production facilities can be significantly enhanced with advances in collection efficiency, as well as development at potential facilities. Specifically, based on the results of the study, the following conclusions are apparent.[13]

- Currently, 20 Michigan Type II landfills operate as landfill energy-production facilities with an equivalent of 188.8 MW of renewable energy capacity.
- There are 12 more Michigan landfills with the current potential to produce an additional 36.8 MW of renewable energy capacity.
- By 2015 with the addition of yard waste disposal to Michigan landfills currently operating landfill energy-production facilities, an increase in renewable energy capacity of 41 percent over current levels, or the equivalent of 265.6 MW, is projected.
- By 2015 and with the addition of yard waste disposal and development of all potential landfill energy-production facilities, an increase in renewable energy capacity of 67 percent over current levels, or the equivalent of 315.2 MW, is projected.
- Peak years for energy production from landfills at current status fall between 2014 and 2016, precisely when Michigan is forecasted to need new energy sources.
- Landfill gas is a sustainable source of renewable energy, derived from landfill biomass that does not significantly limit overall landfill capacity. It is estimated that as a result of the decomposition process, yard waste loses half of its weight and 50 to 75 percent of its volume (Miller 2006) and (Wilson and Feucht 2004).

[13] Please see Appendix B for comparison to similar study results.

Examination of Methods for Handling Yard Waste

As with any potential policy shift, it is important to consider the implications of both an exemption to the yard waste ban for renewable energy generated from landfill gas and the creation of a soil amendment from organic waste. Unfortunately, there are no common metrics for definitive comparisons of these two options but the following factors may be considerations in such as assessment:

- Value of landfill space saved
- Value of property permanently set aside for landfill purposes
- Value of compost
- Value of Michigan-made fuel
- Capacity for landfill facilities to generate electricity from landfill gas
- Amount of yard waste that would be deposited
- Amount of electricity generated by cubic yard of yard waste

For the purposes of this report we will focus discussion on policy and practical implications. As previously stated, Michigan is in the midst of a paradigm shift from viewing yard waste recycling with only one outcome to two: a soil amendment through composting, ***and*** an energy source through landfill gas recovery technology. While the prior sections of this report investigate the potential of landfill gas recovery technology, this section will focus on the issues associated with composting yard waste.

HOW COMPOSTING WORKS

The process of decomposition—the breakdown of raw organic materials to a finished compost—is a gradual, complex progression, one in which both chemical and biological interactions must occur in order for organic matter to become compost. By law, Michigan defines yard clippings or yard waste as leaves, grass clippings, vegetable or other garden debris, and shrubbery, or brush or tree trimmings, less than four feet in length and two inches in diameter. In the first stages of compost production, microbial organisms feed on decaying organic materials, while in the later stage of decomposition insects further break down and enrich the composting materials. The goal in composting is to create the most favorable environment possible for the desired organisms. It is estimated that as a result of the decomposition process, yard waste loses half of its weight and 50 to 75 percent of its volume (Miller 2006; Wilson and Feucht 2004).

Generally speaking, there are two types of composting. *Aerobic decomposition* occurs when organic materials decompose in the presence of oxygen. The aerobic process is most common in nature. An example is a leaf that falls on the ground and is left to decompose. There is typically no accompanying odor when adequate oxygen is present. If odors are noticeable, either the process is not entirely aerobic or there are some special conditions or materials present that are creating an odor. Aerobic decomposition or composting can be accomplished in pits, bins, stacks, or piles, if adequate oxygen is provided. Turning the material at intervals or employing other techniques for adding oxygen is useful in maintaining aerobic conditions. Decomposition of organic material in the compost pile depends on maintaining microbial activity. Any factor that slows or halts microbial growth impedes the composting process. Efficient decomposition occurs if the right conditions of aeration, moisture, particle size, and a sufficient source of carbon and nitrogen are met.

Anaerobic decomposition, which is sometimes called fermentation, takes place in nature anywhere oxygen does not have access. Intensive decomposing in this manner is usually accompanied by disagreeable odors of hydrogen sulfide and other organic compounds that contain sulfur (Texas A&M 2007).

Composting varies as much in its complexity as in the range of organic materials recovered. The four most standard composting methods (EPA 1999) are:

- **Static pile composting**: This occurs when organic waste is piled and mixed together. Composting under these conditions is slow and suited for small operations. This method requires 12 to 18 inches of loosely piled bulking agents such that air can circulate from the bottom to the top of the pile.
- **Aerated windrow/pile composting:** This method is more complex. Organic waste is formed into rows of long piles (windrows) and aerated either by embedding pipes in the pile or by turning the pile periodically. This method can accommodate large volumes of waste, including animal products or grease, but only with frequent turning and careful monitoring during the thermophilic stage (when the pile reaches 130 to 150 degrees Fahrenheit).
- **In-vessel composting:** For this process, organic materials are stored in enclosed equipment with controlled temperature, moisture, and aeration. This type of system can process large quantities of waste with fewer odor problems in a small area and can accommodate animal products.
- **Vermicomposting:** This occurs when worms break down organic materials into compost called castings. Vermicomposting bins can function indoors or outdoors, but cannot process animal products or grease.

OPERATIONAL CHALLENGES AT COMPOSTING SITES

As with any other process, there are benefits to recycling yard waste by composting, and there are disadvantages. As stated previously, one of the reasons for considering an alternative to composting yard waste through an exemption to the yard waste ban is the operational challenges of composting that were not fully recognized when the yard waste ban was implemented in 1995.

Composting advocates claim that “to simply eliminate grass collection entirely is considered the ‘best practice’ in contemporary waste management systems” (Coalition 2002). They cite the ease of leaving the grass on the lawn (grasscycling), and note that few greenhouse gases are created from the resulting composting process. Indeed, grass is a portion of the waste stream that can be responsibly self-managed by those who generate it.

The cost of composting, as in the case of many resource-based products, does not reflect the total costs involved to produce it. True costs consider not only the operational costs to retrieve and produce a good, but also environmental impacts that occur as a result of that production.

One such cost is the transportation system required when the waste stream is separated. The indirect costs of the dual transportation system are not factored into the consumer's price for the compost product. If it were, the consumer would have to make a greater contribution toward road maintenance; vehicle maintenance, operation, and fuel; and societal and environmental impacts from emissions and noise, among other factors.

Compost sites pose other operational challenges; several of the potential and real challenges faced by composting operators are discussed briefly below.[14] Some of these problems can be controlled to a degree through proper management, although this may contribute to higher operational costs, while other issues are entirely out of the hands of the composting operator.

Odor

Odors are generated at composting sites when materials are not exposed to enough air and enter an anaerobic stage of decomposition, a situation that can be commonplace. While there is always the potential for odor problems at compost sites, regular aeration of the compost greatly reduces this problem. In addition, management options to control this problem include the use of buffer zones, biofilters, or in-container (closed-system) composting. One facility in Detroit has purportedly emitted "noxious odors," which neighbors describe as a "weird gag-inducing cross between horse manure and Copenhagen snuff." Another facility in Macomb County has been ordered to shut down by December 2007, in part because of odor problems (Guyette 2007). Odor problems also fluctuate with weather: they are worse in hot weather and better with colder temperatures.

Leachate

Composting, like landfilling, can produce liquid byproducts, called leachate, that can potentially contaminate ground and surface water. Unlike landfills, which are required to follow strict regulations to protect water sources from the leachate they produce, compost sites are not regulated and monitored in the same manner. The Michigan Composting Council offers a composting operator certification program, but it is not mandatory. Current avenues for enforcing any types of standards on composting facilities are typically triggered by sight and/or odor nuisance complaints from their neighbors. While water runoff/storm water management systems, in addition to other compliance systems, are needed, they would prove prohibitively expensive.

Product Consistency/Quality

Different inputs yield compost with varying consistency and nutrient levels. Some inputs are seasonal, which can lead to these variations. Uniform nutritive content in a product is

[14] The source for much of this section is Katharine Holden, January/February 2001, *Planning for a Successful Compost Operation.*

important to customers. Because the compost operator only receives what is brought in, it can be difficult to manage the consistency of the product. Contamination of the compost with bits of plastic bag and other small municipal solid waste is inevitable and detracts from the quality and marketability of the end product.

A far more challenging problem lies in residual pesticides and herbicides that persist in some grass clippings. No grass clippings should be composted from golf courses, where high levels of persistent herbicides are used. Facilities across the country are struggling with how to handle this problem and there does not seem to be an easy answer. Facility managers, regulators, public agencies, researchers, and herbicide manufacturers continue to seek solutions to the problem, ranging from on-site treatment to regional product bans (Bezdicek et al. 2001).

Microorganisms require a certain temperature range for optimal activity. Certain temperatures promote rapid composting and destroy pathogens and weed seeds. Microbial activity can raise the temperature of the pile's core to at least 140 °F. (EPA 2006). Although the goal of successful compost operation is to reach required temperatures there is no way to ensure that this occurs uniformly throughout the pile. Therefore, seed transportation in finished product is possible. As a result, the potential to spread invasive terrestrial species should be recognized.

Viable Market Development

Time requirements for developing a viable market for compost products are variable. Landscapers provide a steady market in some areas, while agricultural demand may exist in others. The demand for compost is as varied as the community, and depends on consumer education to develop a market. In one municipality, a compost operator drastically reduced its price to facilitate distribution (Southeastern Oakland County Resource Recovery Authority 2007). The process and/or finished product pose challenges to the traditional economic theory of supply and demand.

Lack of Space for Traditional Windrow Operations

Traditional windrow composting requires that the material be spread in long piles, usually less than ten feet high, and turned regularly for aeration. Buffer zones may be needed to prevent neighbor complaints about odor and machine noise. In urbanized areas where space is limited, these operations must be located farther away from the source of the yard waste. This increases the cost of transportation for both the yard waste inputs and the compost products.

Exemption Language Review

Since March 1995, yard clippings (defined in Michigan as leaves, grass clippings, vegetable or other garden debris, and shrubbery, or brush or tree trimmings, less than four feet in length and two inches in diameter) have been banned from disposal in Michigan municipal solid waste landfills by Section 324.11514(2)(d) of Part 115, Solid Waste Management, of the Michigan Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (Act 451). The Michigan Department of Environmental Quality's Waste Management Division (MDEQ–WHMD) administers the state's solid waste program under Part 115.

The purpose of this statute is to encourage solid waste disposal methods that protect the environment and to enhance resource conservation. Several factors, including difficulty with composting operations, enhanced landfill gas recovery technology, and increased support for renewable fuels, make it at least prudent to consider an exemption to the ban.

PURPOSE

Under Michigan's new Solid Waste Policy (MDEQ/WHMD, May 24, 2007), the state's preference is first to avoid waste generation; then, to *utilize* generated waste for *beneficial purposes;* and, finally, to properly dispose of what remains. Recent state interest in reducing dependence on fossil fuels and becoming a leader in alternative or renewable fuel sources requires an examination of the current yard waste provision that reduces the amount of organic material disposed of in sanitary landfills. To encourage more waste utilization, the plan specifically recommends that Michigan should:

- Identify and remedy regulatory barriers to waste utilization
- Collaborate in regional and national efforts to encourage manufacturing and distribution systems to facilitate waste utilization
- Have a state government that leads by example
- Support the development of markets for recycled materials

Maximizing the use of available landfill gas will further the tenets of this policy, which specifically promotes economic vitality and ecological integrity. In addition, the state's *21st Century Electric Energy Plan* promotes the identification and removal of unnecessary barriers to renewable, alternative, and distributed energy applications (MPSC 2007).

All energy sources, however, necessarily involve environmental tradeoffs. The beneficial purpose of yard waste may be defined in either of two ways: as a valuable resource used to create a soil amendment, or as a valuable input to a process that can reduce Michigan's foreign fuel dependency.

PREVIOUS ATTEMPTED REPEALS OF YARD WASTE BANS

Before embarking on a review of Michigan's ban and exploring an exemption, it is instructive to survey previous attempts to repeal or modify yard waste bans elsewhere. Not only can lessons be learned, but it is also essential to consider valid concerns previously expressed in similar ventures. Some of these attempts will be discussed in chronological order.

Indiana

Indiana banned disposal of yard waste in landfills in 1996. However, Indiana allowed an exception for yard waste to be disposed of in landfills that were methane production facilities until 1999, when the Indiana General Assembly passed a provision that removed this exemption and established a compost facility development fund (Indiana HB 1908, 1999). While there is little information to be found about this exemption repeal within legislative literature, Indiana was included in order to give the most inclusive analysis possible.

Illinois

In 2001, Waste Management Inc. (WMI) proposed to repeal the local yard waste ban in Peoria, Illinois. The repeal was specific to one landfill co-owned by the city and county and operated by WMI. The stated goal of the repeal was to increase the volume of organic materials going into landfill to promote methane production.

The city of Peoria was in favor of the repeal because of associated cost savings and advocated passage of the proposal to the county. WMI and Peoria wanted to use the repeal to conduct a five-year study of landfilling yard waste along with municipal solid waste (MSW) to see if this would increase methane availability for electricity generation.

Peoria County rejected WMI's plan in January 2002, on the grounds that the proposal was contrary to the EPA's waste hierarchy, which ranks landfilling as the disposal of last resort. The county feared that increased acidic leachate would pose a potential threat to water resources. The county also concluded that any burden resulting from an unsuccessful test would rest on the community.

The WMI proposal was openly opposed by eleven leading national, state, and local recycling and environmental organizations. Local public concerns centered on the likelihood that the proposed "test" was actually an attempt to undercut composting and recycling efforts. Members of the public commented to the County Board that not enough information was available about the costs and benefits to the community of allowing this project to go ahead.

Since 2001, when this repeal of a ban was attempted in Illinois, the landscape of the municipal solid waste industry has changed extensively. It is important to note the differences between this attempt and the current exploration of a ban exemption in Michigan.

- Unlike the Illinois proposal, Michigan's ban exemption is not an attempt to reduce state/municipal budget expenditures on waste collection. Rather, it is motivated purely by enhanced landfill gas-to-energy technology and increased interest in renewable fuels.
- The technology for capturing methane as a cell (portion of a landfill facility) is being filled has been proven to capture more landfill gas for energy generation than simply collecting it after a cell is filled. There is no need for "testing" this technology.

- Lastly, the proposed exemption will benefit not just one facility, but aims to capitalize on the energy generation capacity of all landfills in Michigan that have the potential to utilize this technology. This goal is recognized by the state as an effort to boost economic development.

Iowa

In 2003, the Iowa Senate passed a bill allowing disposal of yard waste only at landfills with active methane recovery systems.[15] This repeal was spearheaded by the city of Des Moines in an effort to alleviate budgetary concerns. City officials argued that they could reduce operation costs by removing duplicate routes to pick up municipal solid waste and yard waste. This bill had previously passed the Iowa House of Representatives and was forwarded to Governor Tom Vilsak.

Governor Vilsak used the line-item veto to strike the repeal provision, citing increased demand for landfill space and protection of Iowa's water quality as factors against the bill. In addition, the bill was opposed by eight leading national and state recycling and environmental organizations.

The differences between this previous yard waste ban repeal attempt and Michigan's current considerations are not numerous but they are noteworthy.

- The municipal waste manager was seeking monetary relief from handling yard waste. The proposed exemption in Michigan reflects the enhanced landfill gas-to-energy technology and increased interest in renewable fuels. It is not merely an attempt to reduce state/municipal budget expenditures on waste collection.
- The Iowa decision to reject the repeal cited landfill capacity as a scarcity. Michigan, on the other hand, has been largely successful in creating adequate landfill capacity,[16] has a process in place for expansion of landfill space as needed, will continue to conserve valuable landfill space through increased waste utilization and recycling efforts, and already imposes strict regulatory standards and monitoring on landfills to protect water quality.

Nebraska

Nebraska recently allowed yard waste to be disposed of in landfills that have an active methane recovery system in place, but landfill operators must amend their operating permit with the state to landfill yard waste. Nebraska revised statute, chapter 13, section 13-2039, includes the state's yard waste ban with an exemption for yard waste used in methane production:

> b) A landfill may accept yard waste year-round if such yard waste:

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[15] Actual language: Iowa Senate File 458 Sec. 133, 2003: Sec. 133. Section 455D.9, Code 2003, is amended by adding the following new subsection: 1A. Yard waste may be accepted by a sanitary landfill for land disposal if the sanitary landfill operates an active methane collection system that produces electricity.

[16] Based on capacity used during 2006, the MDEQ estimates that Michigan landfills have approximately 18 years of remaining disposal capacity remaining (MDEQ/WHMD, January 31 2007).

> (i) Will be used for the production and recovery of methane gas for use as fuel (A) with the approval of the department and (B) at a landfill operating as a solid waste management facility with a permit issued pursuant to the department's rules and regulations

The Nebraska Department of Environmental Quality (NDEQ) provided guidance for yard waste acceptance at landfills in April 2007 (NDEQ 2007). The exception to the restriction on yard waste disposal in landfills is allowed when the yard waste is placed in a permitted landfill and used as part of a system to produce methane as a fuel source. The system must include an active landfill gas collection system and a legitimate user of the methane fuel. Obtaining NDEQ approval to operate a methane fuel recovery system using yard waste involves a major modification of the landfill's operating permit.

Since this guidance is so recent, no facility has yet obtained an approved permit to landfill yard waste. According to the EPA, Nebraska currently has one operating landfill gas-to-energy project and five candidate sites (EPA/LMOP 2007). Nebraska's experience in both process and language can be very instructive to Michigan as the reasons for seeking an exemption are very similar in both states even though Michigan is more advanced in its application of landfill gas-to-energy technology.

Missouri

The Missouri legislature is currently considering a provision to allow disposal of yard waste in bioreactor landfills approved by the Missouri Department of Natural Resources. (For information on bioreactor landfills, please see Appendix A.) The measure was approved by the Missouri Senate in March 2007 and is now before the Missouri House of Representatives. The summary language of the Missouri Senate provision is as follows:

> *SCS/SB 328 - This act allows yard waste to be disposed of in a municipal solid waste disposal area when the Department of Natural Resources approves the operation of the disposal area as a bioreactor and when the landfill gas produced will be used for electricity generation.*[17]

The Senate bill's sponsor, Senator Kevin Engler (R-Farmington), proposed that approval of the measure would be a "win-win" situation because it will lower collection costs, create energy, and increase available landfill space because bioreactors decompose material faster. The representative from the district in which the project will be located, Columbia, Missouri, claims the bill will enable Columbia to fulfill its goals of getting 2 percent of its electricity needs met through renewable resources (Off 2007).

Missouri currently operates seven landfill gas energy projects and has 18 candidate locations, of which the Columbia bioreactor is one (EPA/LMOP 2007).

Lessons Learned

Based on this review of previous policy discussions of yard waste bans it is clear that early attempts to repeal the ban were unsuccessful. At that time however, landfill energy-

[17] Missouri State Senate home page, legislative search engine. [Online, accessed 4/23/07.] Available: *http://www.senate.mo.gov/07info/BTS_Web/Bill.aspx?SessionType=R&BillID=6282*.

production facilities were not as common as they are today. As a result of shifting perspectives on energy and landfill energy-production capabilities, recent policy considerations of the yard waste ban are much more amenable to exemptions. It is clear that any exemptions must be applied to the entire industry and not at test or specific sites. In addition, motive seems to be an important factor when legislators consider an exemption.

CONSIDERATIONS FOR EXEMPTION LANGUAGE

There is always a great deal at stake when considering changes to public policy; a possible exemption to the yard waste ban is no exception. Listed below are the factors that were considered in drafting exemption language in a responsible manner that takes into account a variety of differing perspectives.

- An active, operating gas collection system must be in place ***before*** a landfill accepts any yard waste or a state-approved site plan for a gas collection system must be required.
- This proposal should complement current reduction/recycling efforts.
- Tradeoffs must consider the relative public and private burdens borne by all parties: residents, municipalities, haulers, landfill owners, operators of gas collection systems, consumers of landfill gas.
- Policy alternatives must consider ownership of landfill sites (public/private).
- Exemptions should only apply to operations that legitimately collect landfill gas for practical use to produce energy for an end user.
- Scenarios must include effective policy options and sufficient enforcement capability to deter abuse under the guise of energy production.
- Language should create business and operational incentives for landfill operators to collect gases. Incentives should focus on increased methane production and not simply on capturing what gas is already available.
- Any exemption should create incentives for facilities that prioritize capacity on in-state waste in an attempt to discourage facilities from accepting out-of-state waste.

Proposed Exemption Language

With those considerations in mind, a draft of proposed, generalized exemption language to the yard waste ban is presented below. It should be noted that these proposed regulations are in addition to all those that landfill operators already must meet by law to safeguard public health and safety. These proposed standards set up the criteria for a facility to qualify for the yard waste ban exemption as a landfill energy-production facility (LEPF) and are not intended as a substitute for any current policies. Additionally, the proposed language is designed to encourage and even stimulate technical advances, innovation, and project development.

I. YARD WASTE as defined in Section 11506(7) may be disposed of in a solid waste facility, only after the facility has received Landfill Energy Production Facility status as a stipulation to its operating license.

II. To receive stipulation as an LEPF, a facility operator must prove that an operable gas collection system within the portion (cell) of a facility where yard waste is to be placed is planned or exists. Such systems will be designed and constructed to optimize landfill gas extraction and subject to further oversight criteria.

III. To qualify as an LEPF, an ongoing landfill-gas to energy use must be demonstrated.

IV. An LEPF must annually report energy generation and consumption to the county waste authority.

Complementary Legislation

Exploring an exemption to the yard waste ban is only one piece of a complicated puzzle of interrelated policies. This section recommends policy considerations that, while not directly related to the yard waste ban, are indirectly affected by or affect an exemption. For ease of consideration, some of the issues that have been raised throughout this report are reconsidered below.

- A responsible policy to address the issue of out-of-state waste will be important to the yard waste ban discussion. Ideally, an exemption would incorporate a credit for facilities that prioritize capacity on in-state waste (e.g., via host-community agreements) in an attempt to discourage facilities from accepting out-of-state waste. The problem with incorporating this issue into exemption language lies within the interstate commerce clause of the federal Constitution. While the clause does allow for a “resource” exception, it is doubtful that classifying a waste facility as a “resource” is sufficient to warrant an exception to the commerce clause prohibition on limiting interstate trade.
- A policy goal should be aimed at directing purchase agreements toward conditions that are consistent with the generation curve of landfill-gas renewable energy production versus traditional arrangements. Transmission access to electrical utilities can be a limiting factor for many renewable energy applications. As landfills are typically located in proximity to the waste generating population, transmission should be more readily accessible. However, it should be recognized that the transmission component of this energy transfer process would need to be addressed.
- The State of Michigan should lead by example, requiring a percentage of energy used by all state-owned/operated facilities to be generated from Michigan renewable energy sources. Qualifying Michigan renewable energy sources should include landfill energy-production facilities.

Conclusions

This study set out to examine the potential increased renewable energy production from landfill gas in Michigan to determine whether an exemption for landfill energy-producing facilities under the existing yard waste ban would prove fruitful. It is an issue that is multifaceted and encompasses considerations ranging from electricity regulation to recycling to Michigan's economic status. Despite the complexity of the issue, a number of clear conclusions can be drawn from the research and modeling involved in this study.

1. The most noteworthy finding, which in part drives this whole discussion, is that there has been a paradigm shift about recycling. No longer do policymakers and citizens view compost as the only recyclable product of yard waste. Recycling yard waste can now yield two options: a soil amendment through composting, ***and*** an energy source, a renewable resource, through landfill gas recovery technology.

2. Michigan's (and the nation's) economy and society are demanding alternative fuel options. Our world has changed considerably and in a variety of ways since the 1990s, when the yard waste ban was enacted. Michigan is no longer fearful, as it once was, of running out of landfill space. The political climate surrounding international oil and fuel markets shifts daily. All of these changes, as well as the desire to improve the way we manage solid wastes and create and use energy, prompted Michigan's government to revisit both its energy and solid waste policies and update them to meet the challenges Michigan faces today and in the foreseeable future.

3. The changes that Michigan has seen over the past decade have spurred increased support for renewable energy. This report cites three very recent and significant developments; *Michigan's 21st Century Electric Energy Plan* (MPSC 2007), the governor's plan to make Michigan a national leader in the production and use of alternative energy, and Michigan's solid waste policy, which recognized solid waste as a resource.

4. Composting yard waste poses operational challenges that were not fully known when the yard waste ban was implemented in 1995. In addition, compost sites are self-regulated. In some cases this may present environmental and health conditions that create difficulties for local control. Additionally, the yard waste ban has produced mixed results. Viable compost markets in many areas of the state simply do not exist.

5. Among sources of waste that have not already been captured, yard waste has the highest organic content and fewest operational challenges to overcome to produce more landfill gas and therefore is an excellent candidate to introduce into landfills to boost energy production.

6. Since 1985, landfill gas recovery technology has advanced into a viable renewable energy option. Forward-thinking companies have begun to capture methane to produce energy by installing collection piping as each landfill cell

(portion of a landfill facility) is filled, not after it is filled. This development has demonstrated the vast capacity and potential of landfill energy-production facilities and provides the basis for the current discussion.

7. Using existing landfill energy-production facilities and modeling capabilities, one key finding from this study is that adding yard waste to landfills can increase the creation of renewable energy. Modeling shows that we can harness even more power than we are currently producing. In sum, the energy-production capacity of landfills in Michigan clearly can be improved by the reintroduction of organic yard waste material. Specifically, based on the results of the study, the following conclusions are apparent:[18]

    a. Currently, 20 Michigan Type II landfills operate as landfill energy-production facilities with an equivalent of 188.8 MW of renewable energy capacity.
    b. There are 12 more Michigan landfills with the current potential to develop an additional 36.8 MW of renewable energy capacity.
    c. By 2015 and with the addition of yard waste disposal in Michigan landfills currently operating gas-to-energy projects, an increase in renewable energy capacity of 41 percent over current levels, or the equivalent of 265.6 MW, is projected.
    d. By 2015 and with the addition of yard waste disposal and development of all potential landfill energy-production facilities, an increase in renewable energy capacity of 67 percent over current levels, or the equivalent of 315.2 MW, is projected.
    e. Peak years for energy production from landfills fall between 2014 and 2016, precisely when Michigan is forecasted to need new, traditional energy sources.
    f. Landfill gas is a sustainable source of renewable energy, derived from landfill biomass that does not significantly limit overall landfill capacity. It is estimated that as a result of the decomposition process, yard waste loses half of its weight and 50 to 75 percent of its volume (Miller 2006; Wilson and Feucht 2004).

8. Finally, attempts to repeal the yard waste ban in other states have met with mixed results for a variety of reasons, but recently policymakers in other states have come to recognize the clear benefits of considering an exemption. It is time to revisit this policy in Michigan to ensure that it is functioning the way it was intended and producing the desired results.

Based on analysis of current landfill energy-production capacity, landfills should be considered a source for reliable, sustainable, renewable energy production. However, if landfill energy-production technology is expected to play a role in helping Michigan meet its future energy needs and improve its economy, we must first boost landfill gas production so that more renewable energy is produced. To do so, landfill gas production

[18] Please see Appendix A for comparison to similar study results.

must be fully advanced by allowing yard waste back into landfills. There are, of course, other means to this end, but none as intuitively simple because yard waste has the highest amount of organic content available in the non-landfilled waste stream.

Given the present convergence of attitude shifts, technological improvements, and the national goal of reducing dependence on fossil fuels and foreign oil, it is appropriate to explore the benefits that would result from a specific exemption to the yard waste ban for the production and utilization of renewable energy generated from landfill gas. A targeted exemption to Michigan's yard waste ban to allow more organic materials into the energy-creation process would optimize renewable energy production from landfill gas.

There is a readily-available supply of renewable power from landfill gas-to-energy technology. In the near term, this study shows that potential for a 30 percent increase in renewable energy production can be realized through two simple actions:

- Reintroduce yard waste into the municipal waste stream to be received at facilities designated as a LEPF, and
- Develop all landfill gas collection potential.

Now is the time to consider an exemption for landfill energy producing facilities under the yard waste ban to capitalize on the benefits they can produce: job creation, a healthier environment, and renewable energy production consistent with *Michigan's 21st Century Electric Energy Plan.*

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Appendix A:
Explanation of Electrical Generation Capabilities

While this is an independent study incorporating defined modeling and parameters, the findings are validated from the demonstrated consensus found in similar studies, such as the Michigan Capacity Needs Forum (CNF) Report and Environmental Protection Agency (EPA) Landfill Methane Outreach Program (LMOP) reports. It should be noted that the CNF report was conducted under the direction of the Michigan Public Service Commission and serves as the foundation for the *Michigan's 21st Century Electric Energy Plan* (MPSC 2007).

As a means of verifying electrical generation capabilities predicted by this study, reference can be made to the two above studies, which also attempted to project energy capabilities of landfill gas-to-energy projects. Both CNF and EPA LMPO sources estimate current availability at roughly 78 MW, while this current examination estimates 188.8 MW. First reaction to these figures may suggest that these studies do not remotely agree. However upon closer inspection, the numbers have been found to be closer than they may seem.

LMOP COMPARISONS

The LMOP provides a listing of electrical generation projects in Michigan based on installed generation equipment as reported by developers. These figures are based on current conditions, which would parallel this study's results for current major facilities excluding yard waste. The LMOP figures include all landfill gas-to-energy projects, including those conducted at closed sites. This study did not include closed sites since one function of the study was to consider the impact of receiving yard waste on generation capabilities, and closed sites obviously are not available to receive additional material. To make the two studies comparable, closed sites would need to be separated from active sites.

The LMOP data distinguishes between landfill gas-to-energy projects supplying end users and facilities that produce direct use alternatives. This study attempted to represent energy projections in common terms by converting *all* landfill gas to electric. The fundamental aspect of this study was to suggest *energy* potential regardless of the actual use of the energy by presenting data in a common metric: electricity. Therefore to align the figures of this study more closely to the LMOP figures, the projected electric generation from existing direct gas use projects was converted.

The LMOP figures reflect projects as constructed. This method factors in various engine selections made by developers and negotiated contracts. This current study projects maximum potential use of available gas being generated and uses a standardized engine generator set. This method represents a more optimal, but potentially achievable, number based on a common metric.

Eleven landfills were not included in this current study because landfill-specific data was not readily available. Seven landfills were not included in this study because their size was not significant for modeling future energy potential. However, the current electrical generation if it exists, was factored into the LMOP's figures.

To more accurately compare this current study and the LMOP data, these four factors were adjusted accordingly. This study estimates current electrical production at 56.6 MW, while the LMOP estimates generation at 57.1 MW. These numbers now show a much greater degree of agreement, where the remaining difference can be attributed to the fact that this current study intentionally used conservative model parameters.

CNF COMPARISONS

The Michigan Capacity Needs Forum (CNF) provides an estimate of generation potential using existing generation per LMOP data and estimating additional projects under criteria of location and general criteria for estimating projects based on waste in-place. The approach used to compare CNF figures to this current study was similar to that described above for the LMOP data.

CNF generation numbers reflect contract generation numbers rather than equipment generation capabilities (used in this study). Efforts were not made to adjust for this level of detail since the objective of this exercise was to make a general comparison, not match numbers. Results from this adjustment place the current study's estimate at 70.5 MW, compared to the CNF estimate of 71.4 MW.

Appendix B:
Commonly Used Acronyms

CNF	Capacity Needs Forum report
EPA	U.S. Environmental Protection Agency
LEPF	Landfill Energy-Production Facility
LMOP	Landfill Methane Outreach Program
MAERS	Michigan Air Emissions Reporting System
MDEQ/WHMD	Michigan Department of Environmental Quality, Waste and Hazardous Materials Division
MPSC	Michigan Public Service Commission
MSW	Municipal Solid Waste
MSWLF	Municipal Solid Waste Landfill
MW	Megawatt

Appendix C:
Solid Waste Landfills[19]

Modern landfills are well-engineered facilities that are located, designed, operated, and monitored to ensure compliance with federal regulations. Solid waste landfills must be designed to protect the environment from contaminants which may be present in the solid waste stream. The landfill siting plan—which prevents the siting of landfills in environmentally-sensitive areas—as well as on-site environmental monitoring systems—which monitor for any sign of groundwater contamination and for landfill gas—provide additional safeguards. In addition, many new landfills collect potentially harmful landfill gas emissions and convert the gas into energy. There are several types of solid waste landfills:

- Municipal solid waste
- Bioreactors
- Construction and demolition debris
- Industrial waste

MUNICIPAL SOLID WASTE LANDFILLS

Municipal solid waste landfills (MFWLFs) receive household waste. MSWLFs can also receive non-hazardous sludge, industrial solid waste, and construction and demolition debris. All MSWLFs must comply with the federal regulations in 40 CFR Part 258 (Subtitle D of RCRA), or equivalent state regulations. Federal MSWLF standards include:

- **Location restrictions**—ensure that landfills are built in suitable geological areas away from faults, wetlands, flood plains, or other restricted areas.
- **Composite liners requirements**—include a flexible membrane (geomembrane) overlaying two feet of compacted clay soil lining the bottom and sides of the landfill, protect groundwater and the underlying soil from leachate releases.
- **Leachate collection and removal systems**—sit on top of the composite liner and remove leachate from the landfill for treatment and disposal.
- **Operating practices**—include compacting and covering waste frequently with several inches of soil to help reduce odor; control litter, insects, and rodents; and protect public health.
- **Groundwater monitoring requirements**—require testing groundwater wells to determine whether waste materials have escaped from the landfill.
- **Closure and postclosure care requirements**—include covering landfills and providing long-term care of closed landfills.

[19] The material in this appendix is excerpted from U.S. Environmental Protection Agency (EPA). March 21, 2007. *Solid Waste Landfills*. [Online, accessed 5/1/07] Available: ***http://www.epa.gov/epaoswer/non-hw/muncpl/landfill/sw_landfill.htm.***

- **Corrective action provisions—**control and clean up landfill releases and achieve groundwater protection standards.
- **Financial assurance—**provides funding for environmental protection during and after landfill closure (i.e., closure and postclosure care).

Some materials may be banned from disposal in municipal solid waste landfills including common household items such as paints, cleaners/chemicals, motor oil, batteries, and pesticides. Leftover portions of these products are called household hazardous waste. These products, if mishandled, can be dangerous to public health and the environment. Many municipal landfills have a household hazardous waste drop-off station for these materials.

MSWLFs can also receive household appliances (also known as white goods) that are no longer needed. Many of these appliances, such as refrigerators or window air conditioners, rely on ozone-depleting refrigerants and their substitutes. MSWLFs have to follow federal disposal procedures for household appliances that use refrigerants.

BIOREACTOR LANDFILLS

Bioreactors are municipal solid waste landfills that are designed to quickly transform and degrade organic waste. The increase in waste degradation and stabilization is accomplished through the addition of liquid and, in some cases, air to enhance microbial processes. Bioreactors are a new approach to landfill design and operation that differ from the traditional "dry tomb" municipal landfill approach.

CONSTRUCTION AND DEMOLITION (C&D) DEBRIS LANDFILLS

These landfills accept only C&D debris such as concrete, asphalt, brick, wood, drywall, asphalt roofing shingles, metals, and some types of plastics generated during the construction and demolition of homes, commercial buildings, and other structures. C&D landfills are subject to less stringent standards than municipal solid waste landfills due to the relatively inert nature of C&D debris materials.

INDUSTRIAL WASTE LANDFILLS

These landfills are designed for the management of non-hazardous industrial process wastes. Industrial waste consists of a wide variety of non-hazardous materials that result from the production of various goods and products. Industrial waste landfills are subject to the federal requirements in 40 CFR Part 257, Subparts A and B, as well as any state-specific regulations.

Addendum

Landfill Emissions: The relationship between landfill gas collection efficiency and emissions

January 9, 2007

BACKGROUND

In the June 6, 2007, report entitled *Examining Increased Renewable Energy Production from Landfill Gas in Michigan*, it was established that additional renewable energy can be created by adding yard waste to landfills in Michigan. Since some of the gas generated at a landfill will escape into the atmosphere as fugitive emissions, this addendum to the June 2007 report examines the relationship between landfill gas collection efficiency and landfill gas emissions.

GREENHOUSE GASES AT LANDFILLS

The majority of greenhouse gas emissions[1] in the United States occur in the form of carbon dioxide as result of energy use. However, over a 100-year period, methane is over 20 times more effective in trapping heat in the atmosphere than carbon dioxide and is emitted from a variety of natural and human-influenced sources, including landfills.[2]

In 2001, methane accounted for only 9 percent of the nation's anthropogenic (human-caused) greenhouse gas emissions by volume. Due to methane's high heat-trapping characteristics, however, monitoring and minimizing methane emissions is a key element of greenhouse gas management strategies.

According to the U.S. Environmental Protection Agency (USEPA), landfills are the largest human-related source of methane in the United States, currently accounting for 34 percent of all methane emissions. Methane is generated in landfills as waste decomposes under anaerobic (without oxygen) conditions. The amount of methane created depends on the quantity, organic composition, and moisture content of the waste and the design and management practices at the site.[3]

Landfill gas is generated by microbial decomposition of municipal solid waste (MSW) in a landfill under both aerobic (with oxygen present) and anaerobic conditions. MSW

[1] Greenhouse gases, in the order of relative abundance in the atmosphere, include water vapor, carbon dioxide, methane, nitrous oxide, and ozone. These gases allow sunlight to enter the atmosphere freely. When sunlight strikes the Earth's surface, some of it is reflected back towards space as infrared radiation (heat). Greenhouse gases absorb this infrared radiation and trap the heat in the atmosphere. (National Energy Information Administration, U.S. Department of Energy, available online at *http://www.eia.doe.gov /oiaf/1605/ggccebro/chapter1.html* [accessed 12/27/07].

[2] U.S. Environmental Protection Agency, available online at *http://www.epa.gov/methane/* [accessed 12/27/07].

[3] U.S. Environmental Protection Agency, available online at *http://www.epa.gov/methane/sources. html#anthropogenic* [accessed12/27/07].

initially decomposes under aerobic microbial activity, which produces predominately nitrogen gas and carbon dioxide. As oxygen levels decline, gas composition changes to a mixture of methane and carbon dioxide. Landfill gas consists of about 50 percent methane (the primary component of natural gas), about 50 percent carbon dioxide and trace amounts of non-methane organic compounds.

ENERGY RECOVERY AND EMISSIONS AT MICHIGAN LANDFILLS

In order to minimize emissions for regulatory compliance[4] and recover landfill gas for energy production, many landfill owners and operators have installed landfill gas recovery and utilization systems. The goal of these systems is to remove the maximum amount of gas possible from the waste for use in electrical generation, thus minimizing its migration to the atmosphere in the form of emissions. In Michigan, there are 20 operating landfill gas-to-energy facilities. There are 12 additional potential major landfill gas-to-energy facilities[5] in the state that may be developed with the right incentives to collect and utilize landfill gas.

By using landfill gas to produce energy, landfills can significantly reduce their emissions of methane and at the same time avoid the need to generate energy from fossil fuels, thus reducing emissions of carbon dioxide, sulfur dioxide, nitrogen oxides, and other pollutants that result from fossil fuel combustion.[6]

The USEPA has developed a *Benefits Calculator* to estimate direct, avoided, and total greenhouse gas reductions, as well as environmental and energy benefits, derived from gas-to-energy projects.[7] In 2007, benefits for a typical three-megawatt gas-to-energy facility are approximately equal to any one of the following:

- Removing emissions equivalent to 25,000 vehicles
- Planting 36,000 acres of forest
- Offsetting the use of 640 railcars of coal
- Averting electricity usage of 234,000 light bulbs
- Powering 1,900 homes

By 2015, with the addition of yard waste disposal to Michigan landfills currently operating landfill energy-production facilities, an increase in renewable energy capacity of 41 percent over current levels, or the equivalent of 265.6 MW, is projected. At peak

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[4] For more information concerning rules that govern landfills in Michigan please see the Solid Waste Management Act Administrative Rules promulgated pursuant to Part 115 of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended, effective October 20, 2005. Applicable rules are 299.4910, 299.4911, 299.4433, and 299.4434. These rules are administered by the Michigan Department of Environmental Quality, Waste and Hazardous Materials Division.

[5] Major facilities were defined as landfills that have a potential peak gas capacity to generate 1.6 MW or more.

[6] U.S. Environmental Protection Agency (USEPA). March 8, 2007. Landfill Methane Outreach Program (LMOP). [Online, accessed 2/19/07] Available: *http://www.epa.gov/lmop/*.

[7] Ibid.

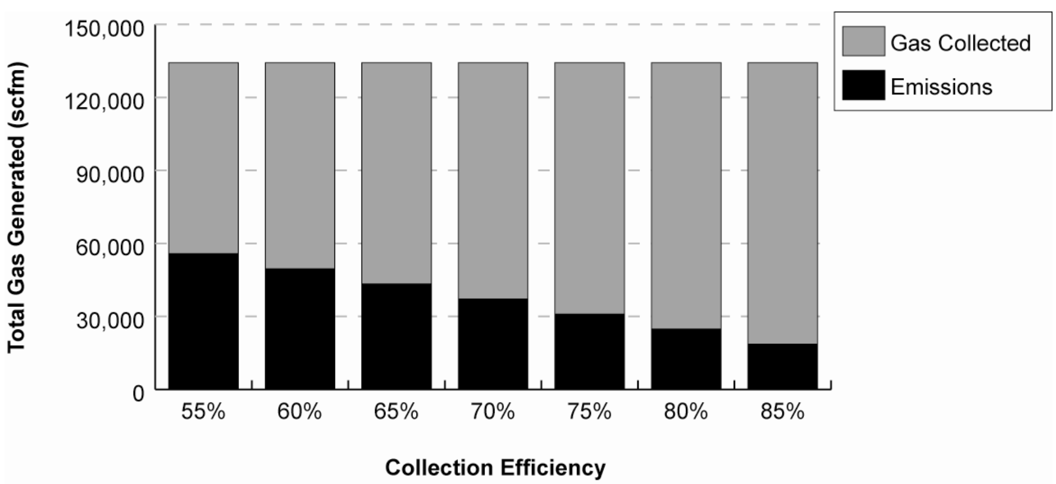
gas generation in 2015 the addition of yard waste to current and potential major facilities in Michigan would also result in landfill-specific increases in uncaptured emissions ranging from 9 to 54 percent with a median of 16 percent and a per landfill average increase of 27 percent, if collection efficiencies are not improved. The statewide percent change (statewide volumetric basis) is 23 percent.[8]

RELATIONSHIP BETWEEN EMISSIONS AND RATE OF COLLECTION

The relationship between collection efficiency and emissions is linear, meaning a one unit change in collection efficiency causes a one unit change in emissions. In this statewide example, for each 1 percent increase in collection efficiency, emissions at landfills will decrease by approximately 1,300 standard cubic feet per minute in 2015 (yard waste included).

The addition of yard waste will create the potential for increased gas production within a landfill. This does not automatically mean that emissions will increase. The collection efficiency of the gas collection system at the landfill determines the amount of emissions that escape into the atmosphere. Therefore, ensuring a statewide increase in collection efficiency as a condition for allowing the addition of yard waste will offset any increase in emissions that may potentially result from the addition of yard waste to the landfill. As Exhibit 1 shows, as the collection efficiency increases, the proportion of gas collected increases and the proportion of gas emitted decreases.

EXHIBIT 1
Proportion of Landfill Gas Emitted Statewide at Increasing Collection Efficiency, 2015, with the Addition of Yard Waste



SOURCE: NTH Consultants, 2007.

[8] NTH Consultants, Lansing, Michigan. December 20, 2007, memorandum to Public Sector Consultants Inc., *Summary of Landfill Gas Emissions Related to Yard Waste*.

In summary, these results indicate that the proper management of collection efficiency will reduce potential emissions resulting from the addition of yard waste. Specifically, a 1 percent increase in efficiency will increase the volume collected by 20 percent, with a corresponding reduction in surface emissions.

CONCLUSIONS

Increasing the amount of organic matter disposed in landfills will increase potential landfill gas production. However, increased gas production coupled with increased collection efficiencies has the potential to negate any increases in emissions associated with the addition of yard waste to the disposal stream at a landfill. Landfill gas collection systems designed to remove the maximum amount of gas possible from the waste are essential to ensure that emissions will not increase as a result of the disposal of additional organic material. The collection efficiency of the landfill gas collection system will determine whether there is an increase in emissions as a result of increased organic composition of the MSW.

An alternative view of this issue considers landfill emissions on a statewide, or aggregate, basis. Although there is a general lack of published baseline data regarding current statewide collection efficiency, the USEPA suggests a collection efficiency of 60 percent.[9] At this collection efficiency, a 7.4 percent increase in statewide collection efficiency would be required to offset the landfill gas resulting from the addition of yard waste; in other words, an average statewide collection efficiency of 67.4 percent would be required to ensure that no additional emissions result from the disposal of yard waste to Michigan landfills. Thus, on a statewide basis, requiring the current and potential major facilities to have a collection efficiency of at least 70 percent before allowing the landfill to accept yard waste would adequately protect against the potential emissions resulting from yard waste disposal at landfills.[10]

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[9] USEPA. November 1998. AP42, Fifth Addition, Volume 1 Chapter 2.4 Municipal Solid Waste Landfills.
[10] NTH Consultants, Lansing, Michigan. December 20, 2007, memorandum to Public Sector Consultants Inc., *Summary of Landfill Gas Emissions Related to Yard Waste*.