Oneida Herkimer
Solid Waste Management Authority

Regional Landfill

Landfill Gas Utilization Alternatives Study

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Executive Summary

Landfill gas (LFG) is a naturally occurring byproduct resulting from the decomposition of organic material contained within municipal solid waste that has been placed in a landfill. As the volume and age of organic waste in-place at the landfill increases the volume of LFG generated at the facility will continue to increase. Landfill gas contains approximately 50 percent methane and 50 percent carbon dioxide, with trace percentages of hydrogen sulfide, oxygen, nitrogen, and other compounds. The odor associated with LFG is due to the trace compounds, primarily hydrogen sulfide, within the gas. Methane in LFG is acknowledged to be a greenhouse gas that can contribute to adverse climate change impacts if left uncontrolled. As noted below, the Authority is already taking steps to ensure that it does its part to help fight global climate change.

Passive flares are being used proactively at the regional landfill to effectively manage the relatively low volume of LFG currently generated at the facility. The Authority is also proceeding with design plans for installation of a comprehensive active LFG collection system in 2010, which will be in place to effectively manage increasing amounts of LFG generated at the site as the amount and age of organic waste in-place at the landfill increases. An active system applies a vacuum to the landfill and efficiently extracts the LFG through a network of horizontal and vertical gas collection pipes. A centralized flare will be installed as part of the active LFG collection system to provide for the destruction of LFG that cannot be utilized in a renewable energy end-use and to ensure that greenhouse gas emissions from the landfill are effectively controlled.

This report evaluates three basic types of beneficial LFG utilization: (i) electricity generating options, (ii) methods for producing high BTU gas, and (iii) emerging technologies. Table E-1 provides a summary comparison of the various beneficial LFG utilization options that were evaluated.

Based on a consideration of current end-use markets and an evaluation of commercially proven technologies, the production of electricity from internal combustion engines fueled by LFG ranks as the highest valued alternative. The next steps to move forward with this beneficial LFG utilization project are outlined below.

1. In 2009, complete design of the active LFG collection system and advertise for bids from construction contractors to enable installation of the collection system to take place in 2010.

2. Revenues from operation of a LFG to energy facility will be maximized if the Authority owns the facility and either operates the facility itself or hires a contract operator. The alternative of contracting with a developer to finance, build and operate the facility would reduce revenues to the Authority by approximately 50 percent.

    - In the first half of 2009, Authority staff should continue to visit and inspect existing LFG to energy facilities that are publicly and privately owned to obtain a first hand look at project construction and operational considerations.

    - Due to the long lead times that can be involved with establishing new interconnections to the electric grid, discussions with local utility representatives should be undertaken during the second and third quarters of 2009 to determine the optimum approach to interconnect with the electric grid.

- In the third and fourth quarters of 2009, the Authority should prepare and issue a procurement document to solicit price proposals from companies that can build and/or operate the landfill gas to energy facility. Award of the construction and/or operations contract(s) should take place during the second quarter of 2010.

- Construction of the LFG to energy facility – including its interconnection to the electric grid -- should be initiated in mid-2010 with startup operations commencing in the first quarter of 2011.

- Phased expansion of the landfill gas to energy facility will take place in future years through the installation of additional engine-generator sets, as appropriate to match future volumes of LFG generated at the regional landfill. Green power production and sales will increase accordingly.

3. Relatively small portions of the LFG can be utilized in ancillary beneficial use projects to replace propane that is currently used for heating facilities at the landfill and to potentially replace diesel fuel currently used in waste transfer and leachate trucks. The implementation of these complementary LFG utilization projects can take place once the active LFG collection system is operational.

4. Since the beneficial use of LFG will reduce the emissions of greenhouse gases, the Authority may also be eligible to receive revenues for such carbon footprint reduction activities. The eligibility rules and monitoring procedures/ documentation necessary to receive revenues from the reduction of greenhouse gases should be tracked as climate change policies and initiatives continue to evolve.

Table E-1

SUMMARY OF LANDFILL GAS UTILIZATION ALTERNATIVES
ONEIDA-HERKIMER SOLID WASTE MANAGEMENT AUTHORITY
LANDFILL GAS UTILIZATION STUDY

Rank	Technology	Pros	Cons	Total Cash Flow (Over 15 Years)	Net Present Value (5% Discount Rate)	Average Net Revenue Per CFM of LFG
1	Electricity Generation Internal Combustion Engines	• Proven technology • Many options for electricity and waste heat use • Can be turned down to run at partial loads • More efficient than turbines • Waste heat easier to collect vs turbines • More tolerant of siloxanes than turbines • Newer engines can run at lower flows (400 cfm +/-)	• More intense O&M • Less tolerant of H2S • Slightly more expensive than turbines per unit • Higher Nox emissions	$22 201 000	$13 139 419	$1 120
2	Direct Gas Use (Offsite)	• More cost effective to implement - less cleaning • Do not need high gas flow	• More O&M on equipment if gas is not clean • Need large gas customer in Ava/Boonville area	$16 395 000	$9 217 701	$676
3	High BTU Gas LFG to Natural Gas Pipeline	• Efficient use of LFG • Natural gas demand is very high - good pricing	• Expensive to implement • High pressure 600 psi plus to tie into existing • May need redundant compressor to ensure delivery • Extensive treatment to remove CO2 and impurities • May need to blend some natural gas • Need higher gas flows 2000 cfm + • More extensive quality control to meet standards	$12 505 000	$6 692 968	$446
4	Electricity Generation Combustion Turbines	• Proven technology • O&M not as intensive • Many options for electricity and waste heat use • Slightly less expensive per unit than engines • More tolerant of H2S • Lower Nox emissions	• Must compress the gas additional step • Waste heat is more difficult to collect • Less tolerant of siloxanes • Less efficient than engines • Efficiency drops substantially at partial loads (i e less than 500 cfm)	$11 063 000	$6 196 245	$450
5	Electricity Generation Small Diesel Engines Bi-Fuel	• Can capture low gas flows • Modular approach can match changes in flow • Multiple units provide redundancy • Waste heat collection	• Will need multiple units • Increased O&M due to multiple units • Less tolerant of H2S • Higher Nox emissions • Need to blend diesel into the process	$7 388 653	$3 383 174	$149
6	Electricity Generation Microturbines	• Can capture low gas flows • Modular approach can match changes in flow • Multiple units provide redundancy	• Will need multiple units • Increased O&M due to multiple units • Waste heat is more difficult to collect • Operating life of equipment uncertain maybe only 5 years	$6 387 000	$2 951 895	$195
7	High BTU Gas (CLG) Vehicle Fueling	• Efficient use of LFG • Fleet fuel savings	• Expensive to implement • Need to retrofit existing vehicles • Storage tanks required for existing vehicles are large • Extensive treatment to remove CO2 and impurities • Large quantity produced at full capacity would exceed fuel requirements in the immediate vicinity	$2 849 000	$1 849 390	$509
8	Direct Gas Use (Onsite)	• Less cleaning of gas • Do not need high gas flow • Could be combined with other gas utilization option	• More O&M on equipment if gas is not clean • More gas would be produced than could be used on site	($179 000)	($137 877)	($1 705)
9	Carbon Offsets	• Applies to any landfill gas utilization option	• Process subject to regulatory changes	$4 003 000	$2 549 713	$222

1.0 Introduction

1.1 General Site Information

The Oneida-Herkimer Solid Waste Management Authority (OHSWMA) owns and operates the Oneida-Herkimer Regional Landfill located on the south side of NYS Route 294, Town of Ava, Oneida County, New York. The initial development of the OHSWMA landfill site began in 2004 and was completed in 2006. Initial development included construction of the 23.5 acres (Cell Nos. 1-3) of landfill liner system for waste disposal, access roadways, mitigation wetlands, supporting leachate collection and storage facilities, operations and maintenance buildings, storage buildings, and stormwater management facilities. The initial landfill development also included construction of a future landfill gas (LFG) handling area on the north side of the site.

Initial waste placement commenced in October 2006 in Cell No. 1. Since then, waste placement has progressed into Cell No. 2. At this time, waste placement continues in Cell Nos. 1 and 2 with a progression into Cell No. 3 anticipated in the summer of 2010.

Preliminary LFG controls have been implemented at the facility including the use of passive landfill gas flares on the cleanouts of Cell Nos. 1 and 2, installation of a horizontal collection trench in Cell No. 1 fitted with a passive flare and the installation of shallow gas vents fitted with passive flares in Cell No. 1. Equipment necessary to initiate an active gas collection system (i.e., withdrawing the landfill gas under vacuum) is expected to be installed at the site in 2010.

1.2 Purpose

The OHSWMA is currently planning the installation of an active LFG collection system to manage LFG being generated at the site. Initial operation of the active LFG collection system will include destruction of the collection gas in a flare. Although flaring LFG is effective at controlling landfill emissions and odors, landfill gas has proven to be a useful renewable energy source which can be used to generate power, as an alternative fuel, or as an alternative to propane or natural gas.

The purpose of this report is to study the possible utilization options for the LFG that will be collected at the facility.

2.0 Landfill Gas Management

2.1 LFG Composition

LFG is a naturally occurring byproduct resulting from the anaerobic decomposition of organic material contained in wastes placed in landfills. The generation of LFG is an incremental process, whereby increasing quantities of LFG will be generated with subsequent placement of solid waste. Approximately 50 to 55 percent of the LFG collected is methane. The remaining half of LFG is primarily carbon dioxide. Traces of other gases such as hydrogen sulfide are also produced. Oxygen and nitrogen are usually present in LFG because of the percentage of air contained within the landfill. Air can be introduced into the landfill either during waste placement, from atmospheric weather effects, from LFG system operations, or by diffusion of air into the landfill.

The odor associated with LFG is due to the trace compounds in the gas. Some of the most significant classes of odor causing trace constituents include esters, phenols, organic acids, and sulfur compounds (including mercaptans). Methane and carbon dioxide, the main constituents of LFG, are odorless and do not contribute to landfill odors. An effective LFG collection system is one of the most effective means of controlling landfill odors.

2.2 Landfill Gas Generation Estimates

LFG production from the facility was estimated with the use of the Landfill Gas Emissions Model (LandGEM), USEPA Version 3.02, May 2005. The program estimates landfill gas emissions for various LFG constituents based on input parameters including: the mass of waste in place at the landfill (or the annual acceptance rate), the type of waste in the landfill, the landfill design life, a methane generation constant (k), the methane generation potential (Lo), the concentration of NMOCs as hexane, the volumetric percent of LFG that is methane and the volumetric percent of LFG that is carbon dioxide. Estimates of the amount of landfill gas generated will vary substantially depending on key input parameters that are used in the model. Three different sets of input parameters have been modeled for this report, to provide a range of landfill gas generation estimates that can be considered for the regional landfill. The model was utilized to predict LFG generation based on the following three modeling scenarios:

- Default parameters indicated in the current version of the EPA's Compilation of Air Pollutant Emission Factors (AP-42), Section 2.4 (11/98).
- Clean Air Act default landfill gas constants from 40 CFR 60 Subpart WWW -- New Source Performance Standards for Municipal Solid Waste Landfills.
- A wet landfill estimate which accounts for greater landfill gas generation from leachate or liquid recirculation. Even though the Authority is currently not practicing leachate recirculation, the wet landfill estimate was analyzed to look at the potential gas quantities resulting from leachate recirculation.

Actual waste-in-place quantities or estimated waste-in-place quantities were provided by the Authority for the Regional Landfill for 2006 and 2007. To better predict the actual quantity of the LFG being generated by the landfill, only putrescible waste was accounted for in the generation estimates. An estimated maximum putrescible waste acceptance rate of 178,880 tons per year was used to project future waste placement quantities for the landfill through the year 2025.

2.2.1 AP-42 Model

The Landfill Air Emission Estimation Model was first configured to estimate the landfill emissions in accordance with criteria established in the current version of EPA's Compilation of Air Pollutant Emission Factors (AP-42). Historically, AP-42 has been found to underestimate LFG production from a landfill facility and more likely represents a drier landfill unlike the landfills located in the northeast.

Using the actual and predicted waste placement through 2025, and a landfill gas composition of 50 percent Methane and 50 percent Carbon Dioxide, the model was used to estimate gas production with:

Lo = 100 cubic meters/ Mg solid waste
K = 0.04 /year
50% Methane, 50% Carbon Dioxide
NMOC hexane concentration = 595 ppmv (from AP-42, assumes no co-disposal of hazardous waste)

The model results are included in Appendix A and estimate the total LFG generation to be approximately 158 cfm in 2009. Typical landfill collection pipe networks collect between 85 percent and 95 percent of landfill gas generated during the operational phases of a landfill. This report has conservatively assumed an 85 percent collection efficiency; therefore an estimated 134 cfm would be collected for potential utilization projects.

2.2.2 Clean Air Act Model

In an effort to model a more realistic LFG production at the facility, the LAEEM was also run using the Clean Air Act New Source Performance Standards (NSPS) default constants of:

Lo = 170 cubic meters/ Mg solid waste
K = 0.05 /year
50% Methane, 50% Carbon Dioxide
NMOC hexane concentration = 595 ppmv (from NSPS)

The model results are included in Appendix A. The model results estimate total LFG generation to be 332 cfm in 2009. Typical landfill collection pipe networks collect between 85 percent and 95 percent of landfill gas generated during the operational phases of a landfill. This report has conservatively assumed an 85 percent collection efficiency; therefore, an estimated 282 cfm would be collected for potential utilization projects.

2.2.3 Wet Landfill Model

Moisture is a key component in waste degradation and resulting LFG production. Most landfill sites in the northeast have what is considered a wet waste mass due to the higher precipitation received in the region. This is demonstrated by the fact that when LFG extraction wells are drilled into the waste in many NYS landfills, it is common that leachate is encountered and the waste shows signs of advanced degradation.

Both k and Lo are moisture dependent and a wet landfill would increase these constants. Therefore, a Lo of 170 m3/Mg was chosen to represent the "wet" condition observed at many northeast landfills. This is also the published NSPS default value and is greater than the AP-42 value of 100 m3/Mg solid waste for conventional "dry" landfills. Limited data is available on "wet" landfill gas constants, however, recent research in the field of bioreactor landfills has developed experimental ranges of k in the range of approximately 0.1 to 0.25 yr-1, Lo values in the range of approximately 100 to 170 m3/Mg, with typical values of 0.15 yr-1 and 170 m3/Mg being used (USEPA Workshop, 2003). The Authority currently is not operating a bioreactor landfill or a leachate recirculation system and, therefore, a lower k value would be in order than the typical k used in the modeling of bioreactors. Based on this, the following parameters were used in order to estimate landfill gas production for the facility as outlined below:

Lo of 170 m3/Mg
K = 0.10 / yr
CH_4 of 50%, CO_2 of 50%
NMOC concentration of 595 ppmv (from AP-42 for non-co-disposal landfills)

The landfill gas production results for the wet landfill model are presented in Appendix A. The model results estimate total LFG generation to be 633 cfm in 2009. Typical landfill collection pipe networks collect between 85 percent and 95 percent of landfill gas generated during the operational phases of a landfill. This report has conservatively assumed an 85 percent collection efficiency; therefore, an estimated 538 cfm would be collected for potential utilization projects if wet landfill operation techniques were to be implemented by the Authority.

2.2.4 Summary of Generation Estimates

Figure 1 depicts the gas generation estimates for each of the model runs (AP-42, CAA and Wet landfill) in graphical format through the year 2025. For each of the model runs, LFG generation will increase over time as waste placement progresses. The highest generation estimates occur with the wet landfill model while the lowest occurs with the AP-42 model.

Based on the modeling, the OHSWMA Regional Landfill's actual landfill gas generation estimates are anticipated to be between the CAA model and the Wet landfill model estimates. Actual collected landfill gas quantities are anticipated to be between 282 and 538 cfm in 2009. In 2025, landfill gas collection quantities are anticipated to be in the range of 1,870 cfm and 2,641 cfm.

For planning purposes, LFG collection rates can be estimated to follow the CAA model since this quantity will be readily achievable if the amount of biodegradable waste disposed of at the landfill remains relatively unchanged. More refined estimates of LFG collection rates can be determined once an active landfill gas collection system is installed and in operation.

If significant changes in the waste stream occur in the future, such as the diversion of substantial quantities of organic waste away from the landfill, then landfill gas quantities could be less than what is predicted by these models.

2.4 Active Landfill Gas Collection System Implementation

2.4.1 Typical LFG Controls

The two methods typically used to collect the LFG from the waste mass are vertical extraction wells and horizontal collection trenches. The objective with either collection method is to optimize the gas extraction under vacuum from a reasonably large area of influence, minimizing air infiltration, siltation or water logging of the well or collection trench. The different LFG collection methods greatly depend on the time of installation, waste depth, waste placement operations and operational preferences. Both collection methods have advantages and disadvantages. Table 1 compares both horizontal and vertical collection methods.

Table 1
LFG Collection Methods Comparison

Item	Vertical Collection	Horizontal Collection
Installation Method	Typically rotary drilled by a contractor at final waste grade. Can be vertically extended as the waste rises. Shallow wells can be installed by facility forces.	Typically installed at the top of the waste lift by facility forces using existing site equipment.
Operations	Usually interfere with daily operations if installed in active working face. Effective operation at final grade.	Piping penetrates the sides slope away from daily operations. Can be operated effectively within an active cell.
Long Term Integrity	Usually not susceptible to settlement problems. Leachate can be pumped from the well to prevent water logging.	Susceptible to differential settlement, water logging and siltation. Can be difficult to remove accumulated leachate from the horizontal collector.
Construction Cost	Approximately \$90 to \$120 per foot including stone backfill and well casing.	Approximately \$30 to \$40 per foot depending on construction materials used.

Although vertical wells are an effective method of gas extraction, horizontal collection trenches offer some advantages. The most noticeable advantage of horizontal collectors is that they allow LFG to be actively collected during cell operation, which is one of the most effective odor control methods. This is in contrast to the typical vertical well installation practice of waiting until the waste mass is at final grade before actively collecting the gas.

2.4.2 Proposed Landfill Gas Collection System

Preliminary LFG controls have been implemented at the OHSWMA Regional Landfill including the use of passive landfill gas flares on the cleanouts of Cell Nos. 1 and 2, installation of a horizontal collection trench in Cell No. 1 fitted with a passive flare and the installation of shallow gas vents fitted with passive flares in Cell No. 1. Active gas collection (i.e., withdrawing the landfill gas under vacuum) is currently not being practiced at the site due to the relatively low volume of LFG generated.

The proposed LFG collection system for the facility will utilize both horizontal and vertical collection techniques and will build off of the existing controls which have already been implemented. Installation of an active LFG collection system will be in a progressive manner where the system is continuously expanded as the landfill's waste mass advances.

Horizontal LFG collection trenches will be installed at phased intervals during landfill operations prior to installation of the active portion of the LFG collection system in 2010, when LFG generation quantities are expected to be high enough to effectively start active collection to control odors and emissions. Header pipes will be installed to connect the wells and trenches to convey the LFG from the landfill to a landfill gas handling area on the north end of the landfill. The initial gas handling area will include a blower skid and flare. The blower skid will be used to induce the vacuum on the collection system to convey the collected gas to the flare for destruction. Condensate collected from the system will be collected in a series of traps or sumps and disposed of in the leachate collection system at the site.

Although the first phase of gas collection will include destroying the gas in a flare, adequate LFG collection quantities to begin the implementation of beneficial use options are also anticipated in 2010. A flare will always be desirable at the facility as a redundant back up under any beneficial use option described in this report, to ensure that air emissions will be adequately controlled.

3.0 Landfill Gas Utilization Alternatives

The landfill gas utilization options at the site can be divided into three general categories. These include electricity generating options, methods for producing high BTU gas, and emerging technologies. Within these categories, there are various options for the generation method as well as utilization of the finished product. Each one of the variations will be discussed and analyzed separately for comparison purposes.

3.1 Electricity Generation

Landfill gas is often used as a fuel source to generate electricity for sale to an electric utility or for on-site consumption with surplus sale to the utility. For the purposes of this analysis, it was assumed that electricity would be tied into the regional electrical grid system at an existing transformer located within the village of Boonville. Transmission and potential line upgrade costs within the local system have not been included within this report as all off-site electrical output options would require similar costs. On-site overhead electric lines would likely be constructed to transport the electricity off-site and metering and transformer protection devices will be required on-site. The costs of this on-site equipment have been included in the cost benefit analysis for each option.

For the cost benefit analysis performed for each option, it was assumed that electricity would be sold back to the grid at a rate of $0.055 per kWh, which is the current average rate that landfill gas to energy facilities in Upstate New York have been receiving It was also assumed that renewable energy credits (RECs) would be available for all electricity sales at a current net rate (after subtracting out REC marketing and transaction costs) of $0.035 per kWh, paid in

1 MW increments, which is also a typical rate currently seen in similar projects in Upstate New York. Details of the REC program are outlined in Section 4.4. While waste heat utilization is a possible secondary revenue source associated with all of the landfill gas to energy options discussed below, this was not factored into the cost benefit analysis. This is due to the fact that many varied options exist for the utilization of the waste heat and revenues would be similar across every option if the same waste heat utilization project were combined with each. Refer to section 5.2 for further discussion on waste heat utilization.

3.1.1 Combustion Engines

A very common method of converting landfill gas to electricity is through the use of internal combustion (IC) engine generator sets. With this method, an IC engine converts landfill gas into mechanical power, which turns a shaft in the engine. A generator is attached to the engine to convert rotational motion into electrical power. This is the most common method of LFG powered energy generation in New York State.

IC engines are a proven technology, and are readily available. Improvements in the technology have resulted in electrical efficiencies of up to 45 percent. The engines are capable of maintaining this efficiency at low gas flows and are more tolerant of siloxanes, a component of LFG, than other electric generation options. Waste heat produced by the engines can be collected relatively easily and used in a number of applications.

One drawback of the IC engines is the significant amount of maintenance that must be performed in order to keep the engines running efficiently. The engines are less tolerant of many LFG contaminants, including H_2S, and therefore, require cleaning and rebuilding at regular intervals (every 3-5 years) to maintain operation and efficiency. NOx emissions and noise levels also need to be addressed during facility operations.

A cost benefit analysis of this option was conducted to estimate potential net revenues to the Authority over a 15 year period of operation. This analysis was done assuming the use of Caterpillar G3520 engines, which are capable of producing approximately 1.6 MW of electricity from a LFG input of approximately 500 cfm (50% methane at 2 psi). Also added to the capital costs for the project were the installation of a high-end landfill gas pretreatment system to remove water and other contaminants and the construction of a facility to house the generation equipment and treatment systems. Analysis of the projected LFG quantities revealed that one generator would be purchased initially, with a second added in year 5, and a third added in year 9. Along with the installation of the third generator, it was also assumed that an addition to the housing facility would be required. Similar facilities have reported operations and maintenance costs in the range of approximately $0.025 per kWh of electricity produced.

Revenue sources were assumed to be from the sale of electricity to the grid, as well as revenue from RECs. Factoring in the escalation of energy costs, as well as inflation, the cost benefit analysis (see Appendix

B) of this option showed that it would result in net revenues beginning in year one, and growing over a 15 year period as the landfill gas generation rate of the landfill increases.

3.1.2 Combustion Turbines

Another very common technology for electrical generation is the combustion turbine (CT). The CT generator works by first compressing the LFG to a high pressure. This high pressure gas is then burned, creating high-pressure, high-velocity gas from which energy is extracted within the turbine. Although this is a common technology, it is not currently being used in New York State for LFG applications.

This is another proven technology, which requires less maintenance than the IC engines, due in part to the fact that they are more tolerant of the H_2S gasses present in the LFG. The CTs also produce less NOx emissions during operation than the IC engines.

While waste heat is produced by the CTs, it is more difficult to collect from them than from the IC engines, leading to less efficient total use of the LFG. The engines themselves are about 45 percent efficient, but are much more efficient at a larger scale (i.e., designed for flows of 1,000 cfm or more) than at a smaller scale. They also lose significant efficiency if gas supply drops below the design flow. The requirement of compressed gas for operation also adds an additional step to the process.

A cost benefit analysis of this option was conducted to determine potential net revenues to the Authority over a 15 year period of operation. This analysis was done assuming the use of Kawasaki GPB15X gas turbines, which are capable of producing approximately 1.4 MW of electricity from an input of approximately 22.4 MMbtu/hr, which is equivalent to about 750 cfm of LFG (50% methane at 2 psi). Also added to the capital costs for the project were the installation of a high-end landfill gas pretreatment system to remove water and other contaminants, a gas compressor to provide LFG at a minimum pressure of 206 psig and the construction of a facility to house the generation equipment and treatment systems. Analysis of the projected LFG quantities revealed that one turbine would be purchased initially, with a second added in year 7, and a third added in year 15. Along with the installation of the third generator, it was also assumed that an addition to the housing facility would be required. Similar facilities have reported operations and maintenance costs of approximately $0.025 per kWh of electricity produced.

Revenue sources were assumed to be from the sale of electricity to the grid, as well as revenue from RECs. Factoring in the escalation of energy costs, as well as inflation, the cost benefit analysis of this option (see Appendix B) showed that it would result in a net loss in year one, with net revenues starting in year 3 and growing over a 14 year period as the landfill gas generation rate of the landfill increases.

3.1.3 Microturbines

Microturbines are a smaller version of the traditional combustion turbines with the one difference being that they turn at much higher speeds. Many microturbines are equipped with a recuperator, which uses the waste heat from the exhaust gas to preheat the combustion air for greater efficiency.

One benefit of the microturbine over the CT is that they can capture much smaller gas flows. This low gas flow requirement means that typically, a group of smaller units are used together, rather than one large unit. This allows the system to respond to changes in flows much easier by the addition or subtraction of units. This unit-based system also allows for the installation of units in line with available incremental funding. In addition, the installation of multiple units provides uninterrupted operation when a unit is taken off-line for maintenance. The microturbine units also emit relatively low levels of NOx emissions in their exhaust.

The microturbines provide a relatively low efficiency in the range of 20-30 percent for units equipped with a recuperator, and also present the same waste heat recovery difficulties as the CTs. They also present increased operation and maintenance costs due to the use of multiple unit systems and their sensitivity to siloxane present in LFG. The LFG generally requires more pretreatment to remove these contaminants and to adequately pressurize the gas The pressurization is also an issue due to the low availability of low-flow high pressure compressors. Microturbines are not widely used in the LFG to energy field, and therefore, their long-term reliability still remains to be proven. Pilot projects have indicated that the expected operating time between major overhauls is approximately 11,000 hours, or 1.25 years, with a total service life of approximately 45,000 hours, or 5 years.

A cost benefit analysis of this option was conducted to determine potential net revenues to the Authority over a 15 year period of operation. This analysis was done assuming the use of Capstone C200 microturbines, which are capable of producing approximately 200 kwh of electricity from an input of approximately 2.3 MMbtu/hr or approximately 69 cfm of LFG at 50 percent methane. Also added to the capital costs for the project were the installation of a high-end landfill gas pretreatment system to remove water and other contaminants, a gas compressor to provide LFG at a minimum pressure of 75 psig and the construction of a facility to house the generation equipment and treatment systems. Analysis of the projected LFG quantities revealed that six microturbines would be purchased initially, with approximately two added every year. Along with the installation of the additional microturbines, it was also assumed that an addition to the housing facility would be required every five years. Similar facilities have reported operations and maintenance costs of approximately $0.0275 per kWh of electricity produced.

Revenue sources were assumed to be from the sale of electricity to the grid, as well as revenue from RECs. Factoring in the escalation of energy costs, as well as inflation, the cost benefit analysis of this option (see Appendix B) showed that it would result in a net revenue beginning in Year 4 and increasing each year over a 15 year period.

3.1.4 Small Diesel Engines

Small diesel engines are similar to microturbines in that they are simply a smaller version of a larger technology used to scale down required gas capacity for operation. This system would include the use of several over-the-road sized diesel engines, which have been modified to run on LFG, to turn a generator shaft. Typically these units are dual-fuel units, which can run on various combinations of LFG and No. 2 diesel fuel, with a peak LFG usage in the range of 70-92 percent of the total fuel use.

These small units provide many of the same benefits of the microturbines including lower gas flow requirements, incremental gas flow usage, smaller per unit costs, and redundancy. They also provide many of the same benefits as the IC engines in that they are more tolerant of siloxanes and have relatively high efficiencies. An additional benefit is that the electrical generation capability of the facility as a whole can be oversized slightly in comparison to the required LFG supply. In other words, instead of the LFG requirement of the facility typically remaining below the LFG supply, less investment is required to be slightly over the supply level, and No. 2 diesel fuel can be used to make up the difference.

Similarly, these units present many of the same drawbacks of microturbines including the need for multiple units, which increases operations and maintenance costs. They share the same drawbacks as IC engines in that they have a low H_2S tolerance, have relatively high NOx emissions, and are noisier than the turbines. The dual fuel system also serves as a drawback due to the need for No. 2 diesel fuel storage at the facility and the economics of the facility depending on the cost of No. 2 diesel fuel, which can be volatile.

A cost benefit analysis of this option was conducted to determine potential net revenues to the Authority after a 15 year period of operation. This analysis was done assuming the use of Ingenco dual fuel engine generators, which are capable of producing approximately 350 kwh of electricity from an input of approximately 4.1 MMbtu/hr or approximately 130 cfm of LFG at 50 percent methane and 3 gallons of No. 2 diesel fuel.

Aside from the generator equipment, also added to the capital costs for the project were the installation of a high-end landfill gas pretreatment system to remove water and other contaminants and the construction of a facility to house the generation equipment and treatment systems. Analysis of the projected LFG quantities revealed that four engine generators would be purchased initially, with an additional unit added almost every year. Along with the installation of the additional units, it was also assumed that an addition to the housing facility would be required after 9 years of operation to accommodate the additional units. An operational cost that was also factored in was the cost of No. 2 diesel fuel required to operate the units. This includes the 3 gallons per unit per hour for units operating at full LFG capacity, as well as additional diesel fuel quantities required to operate any units that will not have sufficient LFG supply to operate at full capacity. Similar facilities have reported operations and maintenance costs of approximately $0.0275 per kWh of electricity produced.

Revenue sources were assumed to be from the sale of electricity to the grid, as well as revenue from RECs. Factoring in the escalation of energy costs, as well as inflation, the cost benefit analysis of this option (see Appendix B) showed that it would result in a net loss each year for the first four years of operation, with net revenues each year thereafter.

3.2 High BTU Gas

High BTU gas, or compressed landfill gas (CLG) is essentially the same as normal pipeline natural gas (96-98% methane) but at a much higher pressure of 3,000 to 3,600 psig. The compressed gas can be used as vehicle fuel, transported off site as a single fuel source or blended as an economizing fuel.

Compression of the landfill gas to high pressures is necessary to provide the maximum usable reservoir of gas within a storage vessel. The higher the storage pressure, the more usable quantity of gas there is compressed within the storage vessel. Since significant work is require to compress the landfill gas to this high pressure, it is essential to remove the non-combustible constituents in the gas and compress only the usable methane. The process to produce this grade of compressed gas is intensive when starting with landfill gas. Landfill gas typically contains only 45-55 percent methane and is very moisture laden. As such, the gas must be filtered, dried and purified prior to high-pressure compression. The equipment necessary for this system includes a water knock-out tank, several stages of compressors, carbon filtration to eliminate hydrogen sulfide, a heating unit, membrane filters for purification, desiccant type dryers, storage tanks and dispensing equipment. To reduce operating costs, the compressors and heating units can be fitted with engine drives that utilize landfill gas as the fuel source.

Electric starter motors or propane start-up are typically utilized to initiate the operation of the system until the flow of required landfill gas can be maintained to operate the drive engines.

Moisture contamination is one of the most significant problems when utilizing high pressure CLG. The presence of moisture in the compressed gas can cause ice formation during the transfer and consumption of the high-pressure gas. This can plug the numerous small orifices and pipelines and render the system inoperable. Consequently, the gas must be dried to the maximum extent possible with the use of desiccant type dryers. These types of dryers can remove nearly all of the moisture to a compressed gas dew point of -75°F and prevent ice blockage of the system components.

3.2.1 LFG to Natural Gas Pipeline

This method of CLG utilization involves the creation of CLG as described above and sending it directly to a natural gas pipeline for off site use. This is a very efficient use of LFG due to the fact that 100 percent of the methane content of the LFG that is compressed is utilized as an alternative fuel source. Since natural gas is in such high demand, any CLG sent to the pipeline would be expected to bring in relatively high revenues.

Aside from the extensive implementation and treatment requirements described above, other drawbacks exist. These include the relatively high gas flow (2,000 cfm +) required, as well as the strict standards required by the utility that operates the natural gas lines being tied into. These may include the need to have redundant compressor equipment in order to guarantee delivery, as well as extensive quality control monitoring to ensure a quality product.

A cost benefit analysis of this option was conducted to determine potential net revenues to the Authority over a 15 year period of operation. The analysis of this option was done based on the assumption that the ideal location for a tie-in to the nearby natural gas pipeline would be at the natural gas compressor station located approximately 8 miles from the site in Boonville. Costs associated with pre-compression (required to transport the gas the 8 miles to the compressor station), transmission, final compression, and tie-in to the high pressure natural gas pipeline were estimated from similar projects. As outlined above, these costs were estimated to be quite high. Each compressor has an approximate 1,000 cfm capacity, but it was assumed that initially, two compressors would be purchased in order to provide the redundancy that would be required by the natural gas supplier. It was also assumed that an additional compressor will be purchased in year 12, once projected gas flows exceed 2,000 cfm. Operations and maintenance costs were estimated based on a similar pipeline project.

Revenues for the project were estimated based on the total MMBtu's provided to the pipeline from the site. The payment per MMBtu to the Authority from the natural gas pipeline utility were based on the NYMEX Natural Gas Futures value ($5.516/MMBtu as of 1/12/09).

The final cost benefit analysis (see Appendix B) concludes that this project would result in a net loss to the Authority for the first four years, totaling almost $1.5 million. Years 5 through 15 would yield moderate net revenues to the Authority.

3.2.2 Vehicle Fueling

Another use for CLG is for vehicle fueling and is most beneficial when a fleet of vehicles can utilize the landfill gas as the primary fuel source. CLG can also be blended with diesel fuel as an economizer, but this extends the payback period on the invested costs.

Vehicles using the compressed gas must be either retrofitted to operate on compressed natural gas or be purchased new to operate on compressed natural gas. As a part of retrofitting an existing vehicle, storage tanks must also be installed on the vehicle. Since CLG occupies approximately twice the volume of an equivalent gallon of diesel fuel, the necessary storage capacity can become an issue with new vehicles, but many vehicle manufacturers are able to incorporate the necessary storage tanks into the new vehicle design.

Heavy equipment such as bulldozers, compactors and backhoes can be retrofitted to operate on compressed gas, but present a significant problem with the installation of adequate CLG storage tank capacity for their higher consumption of fuel. Normally, the available space for storage tanks is limited and restricts the total volume of fuel storage that can be installed. The result is shortened operating time and an impractical frequency (8 or more times/day) for refueling the heavy equipment. In most cases, this reduction in the available operating time of the equipment is not desirable for the invested cost and is therefore not implemented.

Based on an initial average flow rate of 423 scfm of 50 percent methane from the landfill, a CLG system could produce approximately 1,950 equivalent gallons of diesel per day. Per discussions with the Authority's landfill management, this far exceeds the current daily diesel fuel demand at the landfill facility itself. Therefore, the cost benefit analysis for this option was performed based on the assumption that the tractor trailers that transport waste from the Authority owned transfer stations to the landfill as well as the leachate transfer trailers would also utilize this fuel. These vehicles are currently operated through a contract with a private hauler, but if this option were chosen, the Authority could either take over these services or require their contract hauler to utilize the CLG fuel at a cost savings to the Authority.

Although the addition of these transfer vehicles increases the fuel consumption at the site, a surplus of CLG fuel would still be produced at full capacity. In the second year almost 1,000,000 equivalent gallons of diesel could be generated. Due to the large volume occupied by CLG fuel relative to diesel fuel and other transportation restrictions, transport of CLG fuel to remote fueling stations is not economical. Therefore, a local user would need to be identified to utilize the surplus CLG fuel, who is in close enough proximity to fuel their vehicles at the production point (at the OHSWMA Landfill facility). Since 1,000,000 gallons per year far exceeds the fuel demands of most rural municipalities and school districts, identifying enough users to utilize all of the fuel produced is not feasible at this time. This option, however, could be combined with another option so that only the quantity of fuel needed would be produced, and the remaining LFG would be utilized in another manner.

A cost benefit analysis of this option was conducted to determine potential net revenues to the Authority over a 15 year period of operation. As described above, the analysis was done based on the assumption that fourteen waste transfer vehicles and 2 leachate transfer vehicles would utilize the fueling station. Annual fuel consumption numbers for these vehicles were obtained from the Authority for use in the analysis. Revenues were based on the avoided cost of diesel fuel purchases to operate these vehicles.

Costs associated with this project include the construction of a high-end pretreatment system, compression system, storage facility, and dispensing facility. These estimated costs were derived from a similar system currently in use at a landfill in California. Operations and maintenance costs were also derived from this project. Another cost associated with the project is the conversion to CLG powered vehicles. Since the cost to upgrade an existing vehicle is approximately the same as the additional cost of purchasing a new vehicle equipped with a CLG powered engine, this incremental cost was used. There is no cost savings associated with retrofitting older vehicles versus purchasing equipped vehicles, however, the Authority would have to determine whether the remaining operating life of existing vehicles warrants retrofitting.

The final cost benefit analysis (see Appendix B) concludes that this project would result in comparatively small net revenues to the Authority over the 15 year analysis period. However, at the Authority's current diesel fuel utilization rate, only 5-20 percent of the available landfill gas would be utilized.

3.3 Direct Landfill Gas Utilization

Landfill gas can be used directly, with minimal cleaning, to provide fuel for heating, drying processes, greenhouse operations, and a variety of other specialized industries. The gas could either be used at the landfill facility, or marketed to an outside user.

One benefit of the direct gas utilization is the minimal cleaning required, which results in minimal capital investment in filtering equipment. The other is that large quantities of gas are not required in order for a system to operate efficiently. However, the system receiving the gas supply must be designed for the gas flow available. This type of utilization works best if the gas user's consumption is relatively constant. Otherwise, excess gas may have to be flared if excess gas is present or natural gas may have to be purchased to supplement the landfill gas supply. Equipment operated with the landfill gas would most likely require more maintenance than if it were run on traditional natural gas due to the impurities in the LFG stream.

3.3.1 On-Site Use

This landfill gas could be utilized on-site to heat various facilities including the office building, maintenance shop, leachate pump station, and leachate loadout pump station. The gas would need to be dried using a desiccant dryer prior to use in the heating system, and compressed slightly for ease of transmission. The existing heating systems on-site consist of propane fired boilers which could run on the dry landfill gas without requiring retrofit. If the landfill gas is not cleaned, this may lead to higher maintenance costs on the heating equipment due to contaminant build up.

A cost benefit analysis of this option was conducted to determine potential net revenues to the Authority over a 15 year period of operation. Costs associated with the project include the construction of a simple pretreatment and compression system to remove moisture from the gas and construction of a landfill gas pipeline from the landfill gas collection and processing location to the facilities requiring heating. This was estimated to be a total of 4,100 feet of pipe. Operations and maintenance costs associated with the facility were estimated based on the requirements of the pretreatment system, as well as general upkeep of the heating equipment.

The final cost benefit analysis (see Appendix B) concludes that this project would result in minor net losses to the Authority over the 15 year analysis period. The analysis was done using the 2-year average cost to OHSWMA for propane in 2007 and 2008 of $1.61/gal. Due to the volatile nature of propane prices, an analysis was done to determine the "break even price" at which using landfill gas for heating would be economical versus using propane. The "break even price" was determined to be $2.09 per gallon. At the current utilization rate, only 5 percent of the available landfill gas would be utilized. If this project were combined with another option, the relatively low costs associated with transmission and O&M would make this an attractive secondary utilization option. As an example, a cost benefit analysis was conducted for the option of electricity generation with an internal combustion engine generator utilizing the excess gas from the on-site heating. With the gas required for on-site heating removed, the electricity generation option still resulted in large net revenues to the Authority. This analysis is also included in Appendix B.

3.3.2 Off-Site Gas Sales

Another direct use of the landfill gas would be to sell it to a local buyer for commercial use. A large gas customer in the Ava or Boonville area would need to be identified as a potential customer for the gas. Since the gas would not be of high enough quality to run through the utility-owned natural gas lines, a dedicated gas line would need to be constructed to supply gas to the facility. The gas supply and the gas customer would need to be large enough to warrant the construction of the gas line.

A cost benefit analysis of this option was conducted to determine potential net revenues to the Authority over a 15 year period of operation. Costs associated with the project include the construction of a simple pretreatment system to remove moisture from the gas, a compression system, and construction of a landfill gas pipeline from the landfill gas collection and processing location to the location of final use. Since no specific end users were identified, a distance of eight miles was assumed for the transmission distance. Pre-compression of the gas would be required in order to provide the gas at a usable flow rate to the end user.

Operations and maintenance costs associated with the facility were estimated based on the requirements of the pretreatment and compression systems. The revenue from the project is based on the price per MMBTU that the end user would pay for use of the gas. The price per MMBTU was estimated based on the New York Mercantile Exchange gas futures rate, with a discount applied based on the lower quality gas that the LFG represents.

The final cost benefit analysis concludes (see Appendix B) that this project would result in a net loss to the Authority over the first three years, and net revenues over the 15 year analysis period.

3.4 Emerging Technologies

There are various emerging technologies which propose to use landfill gas for beneficial use, but have not yet been proven on a large scale. Two of these technologies are fuel cells and liquefied natural gas (LNG) production.

3.4.1 Fuel Cells

Fuel cells create energy by combining hydrogen (obtained from the landfill gas) and oxygen (supplied from the air) in an electrochemical reaction. Electricity is produced continuously, as long as there is a supply of fuel and air, at high efficiencies on a scale of more than 50 percent. Preliminary research is being performed with fuel cells, but little to no information is available.

3.4.2 Liquefied Landfill Gas

Liquefied Landfill Gas (LLG) is somewhat similar to CLG. As with CLG, the LLG process refines the landfill gas to produce a higher purity form of methane. With LLG however, the gas is cooled by cryogenic (low temperature) refrigeration to a liquid state at -260°F. In the liquid state, the methane volume is greatly reduced to approximately 1/600th of its original volume and the storage volume necessary for a practical reservoir of fuel becomes much more feasible and manageable. To provide long-term storage of the LLG, storage vessels must be insulated and cryogenically refrigerated. When distributed to storage vessels that are only insulated, the LLG has a storage life of 6-7 days before it begins to warm and must vent to atmosphere to relieve the resulting build-up of pressure.

The LLG process is similar to the CLG process and involves several stages to purify the gas. The equipment systems include particulate filters, separators, dryers, and a cryogenic purifier. This process can typically produce a consistent stream of 90 percent – 97 percent methane. In addition to methane, the cryogenic purifier also produces a steady stream of industrial grade carbon dioxide. While the methane has obvious uses as a fuel source, the carbon dioxide can provide additional economic benefit if a demand can be identified in the region of the landfill. Carbon dioxide typically can be sold for $10 to $500 per ton, depending on the local demand and transportation and storage factors.

3.4.2.1 Vehicle Fueling

Similar to CLG, vehicle fueling is a possible use for LLG. However, unlike CLG, the difficulties associated with providing adequate storage capacity are not as significant with LLG vehicle fueling. As a comparison, approximately 10 gallons of LLG are equivalent to 6 gallons of diesel fuel. Although this does represent a 67 percent increase in LLG storage volume, it is far less than the increased storage capacity required for CLG. The LLG storage tanks must also be high pressure rated and insulated to maintain the cryogenic liquid state of the LLG. In this arrangement, the tanks allow the LLG to slowly warm and return to a gaseous state as the vehicle consumes the fuel.

Like CLG, the use of LLG as a fuel source is more economically viable with the fueling of a vehicle fleet. In addition, the reduced storage volumes associated with LLG would allow for a wider range of vehicles that could be converted to utilize LLG fuel. As with CLG, LLG could also be blended with diesel fuel, but this would again extend the payback period on the invested costs.

3.4.2.2 Off-Site LLG Uses

Possible off-site uses for LLG are similar to off-site uses for CLG, but become more feasible with the reduced need for storage capacity. Remote LLG consumption could be used wherever natural gas or propane is used. With the proper modifications to the burners, LLG can be substituted for these fuels. Unlike propane though, LLG would require cooled and insulated tanks to maintain the liquefied state of the methane. The off-site use of LLG would, however, also be somewhat analogous to a propane service business. Monitoring of consumption, delivery of fuel, and billing would all become part of the overall system operation.

4.0 Public-Private Partnership

Another option for landfill gas utilization at the site is to form a public-private partnership for the development of one of the options discussed above. This would consist of issuing an RFP for development companies who wish to utilize the landfill gas. The agreement between the landfill and the chosen company typically involves the developer leasing property at the landfill site. The developer would then invest their own money for the construction of the infrastructure for whichever utilization option they choose. The company would then have full rights to all of the gas collected by the landfill, with the landfill receiving a portion of the revenue from the utilization project. This payment amount and other terms of the agreement will vary and is determined through contract negotiations. In general, however, based on a review of other contracts with LFG project developers, it is reasonable to expect that the annual revenues to the Authority that are shown in this report would be reduced by approximately 50 percent if the Authority were to contract with a developer for such a LFG utilization project.

5.0 Secondary Benefits

Along with many of the options above come secondary beneficial use options, or benefits that are inherent to landfill gas utilization projects in general. Some of the secondary benefits are outlined below.

5.1 Carbon Dioxide Removal

Carbon dioxide is a byproduct of the landfill gas cleaning processes required for many of the utilization options described above. An intensive cleaning process can be undertaken to produce CO_2 that could be marketable for use in commercial, industrial and laboratory settings. While technically feasible, the ability to market large quantities of carbon dioxide derived from landfill gas is not well proven, in large measure due to market-place perceptions about potential landfill related impurities that may remain in the end product.

5.2 Waste Heat

The utilization options for waste heat produced by electricity generation are numerous and should be evaluated once the specific components of the generation system are known. There are options for on-site waste heat utilization such as greenhouses and fish hatcheries, as well as off-site options such as drying processes. The woodworking industries in the vicinity are one industry that may be able to use the waste heat in their wood drying processes. The waste heat can also be used to heat water for heat and hot water supply for a local user or on-site, if sufficient demand exists.

Use of waste heat from IC engines has been successfully implemented at landfill facilities. In New York State, a large greenhouse operation has been in service for over 3 years adjacent to the Modern Corporation Landfill located in the Town of Lewiston, Niagara County. The waste heat from the IC engines' jackets and manifolds is used to supply a hot water loop from the landfill gas to energy plant to the greenhouse. There is enough heat supply to operate the seven acre greenhouse to allow vegetable production (primarily tomatoes) year round. An expansion of the landfill gas to energy facility and greenhouse facility is currently being planned.

Another option for use of waste heat from electricity generation is the operation of an algae greenhouse. The heat in the exhaust from the engines is first used to heat the greenhouse facility. Once it has cooled, the exhaust can be bubbled through the algae, which use the carbon and nitrogen contained in the exhaust for photosynthesis. This process could clean the exhaust to the point that the only byproducts would be oxygen and algae. This algae could then be used to produce biofuel and heating pellets which could replace fossil fuel based transportation and heating fuels. While this process is still in the development stages, it is a promising option for future use of waste heat generated at the site.

5.3 Carbon Offsets

As previously outlined, landfill gas is composed of approximately 50 percent methane. Methane is considered a greenhouse gas, which has about 23 times the greenhouse potential of carbon dioxide, the most targeted greenhouse gas. If a LFG utilization project's reduction in greenhouse gasses can be adequately verified and quantified, this reduction can be converted to carbon offsets that can be sold to companies or individuals that want to reduce their carbon footprint. There are a number of eligibility, monitoring, and verification requirements that must be satisfied in order to sell such carbon offsets. The specific requirements will vary, depending on where such offsets are to be sold. One example of a market mechanism that is in place to facilitate the sale of such carbon offsets is the Chicago Climate Exchange.

Currently, the Chicago Climate Exchange acts as a voluntary offset trading program, where these credits can be traded for profit. Other facilities that may operate under a greenhouse gas emissions "cap" either voluntarily or through regulation can purchase these carbon offsets to "offset" any carbon emissions above that cap. Offsets can provide a cheaper alternative to capital improvements at facilities and provide additional flexibility to meet compliance obligations or goals at the lowest cost. Other methods of carbon offset sales are also available through registries or direct marketing. In all cases, there are fees associated with the marketing of the offsets in the form of third party verification and brokerage fees.

While the market for these carbon offset credits can be somewhat volatile, the number of carbon credits received varies minimally among the landfill gas utilization options. Since each option will destroy a large percentage of the methane collected, the carbon offset credits will be relatively equal among the options. The carbon offset credit revenue has been included as a separate option in the economic analysis, although it can be combined with any of the options discussed above. The potential net revenues associated with this complementary option are shown in Appendix B. One caveat to this is that these carbon offset credits are only available while landfill gas collection and destruction at the landfill is voluntary. If State or Federal regulations, policies or permits make landfill gas destruction a mandatory requirement, then these carbon offset credits would no longer be available under the current rules for such carbon offset trading programs.

5.4 Renewable Energy Certificates

Renewable Energy Certificates (RECs) are a method by which energy producers are reimbursed for producing electricity using "green" methods such as landfill gas to energy. For every 1,000 kilowatt-hours of electricity they send to the grid, the "green" energy producer is given a REC. These certificates can then be purchased for either voluntary or mandatory reasons by individuals or utilities. Mandatory markets exist because of policy decisions, such as state Renewable Portfolio Standards (RPS). Such standards require electric service providers to have a minimum amount of renewable energy in their electricity supply. Often, these policy decisions specify eligible energy resources or technologies and describe how electricity service providers must comply. Typically, the value of these RECs is built directly into the cost per kilowatt-hour agreed upon between the energy producer and the utility that is purchasing the energy from them.

5.5 Partnership with Local Municipalities

Many of the utilization options described above allow for positive partnerships with local municipalities. The presence of a local municipal energy supplier presents the opportunity for providing green power to the community at a reduced rate. Other opportunities include a regional fueling station utilizing the CLG produced from the landfill gas, which could be used for fleet fueling for local municipalities or school districts.

5.6 Greenhouse Gas Emissions

Another factor that must be taken into consideration when selecting a landfill gas utilization option is the net greenhouse gas emissions from the project. Since a primary goal of landfill gas collection and destruction is the reduction of greenhouse gas emissions, it makes sense that the utilization option chosen should not result in a net increase in greenhouse gas emissions. Each option discussed above would be used in combination with a landfill gas flare, resulting in virtually 100 percent destruction of the methane collected from the landfill. This equates to a maximum of over 160,000 tons per year and a total of almost 1.6 million tons of carbon reduction by the Authority through the utilization of landfill gas within the next fifteen years. Most of the options also result in additional greenhouse gas reductions due to the use of LFG instead of fossil fuels, although these reductions represent a relatively small percentage of the total greenhouse gas reductions resulting from methane utilization. For this reason, all of the projects discussed above are considered to have approximately equal carbon footprint reductions.

6.0 Summary

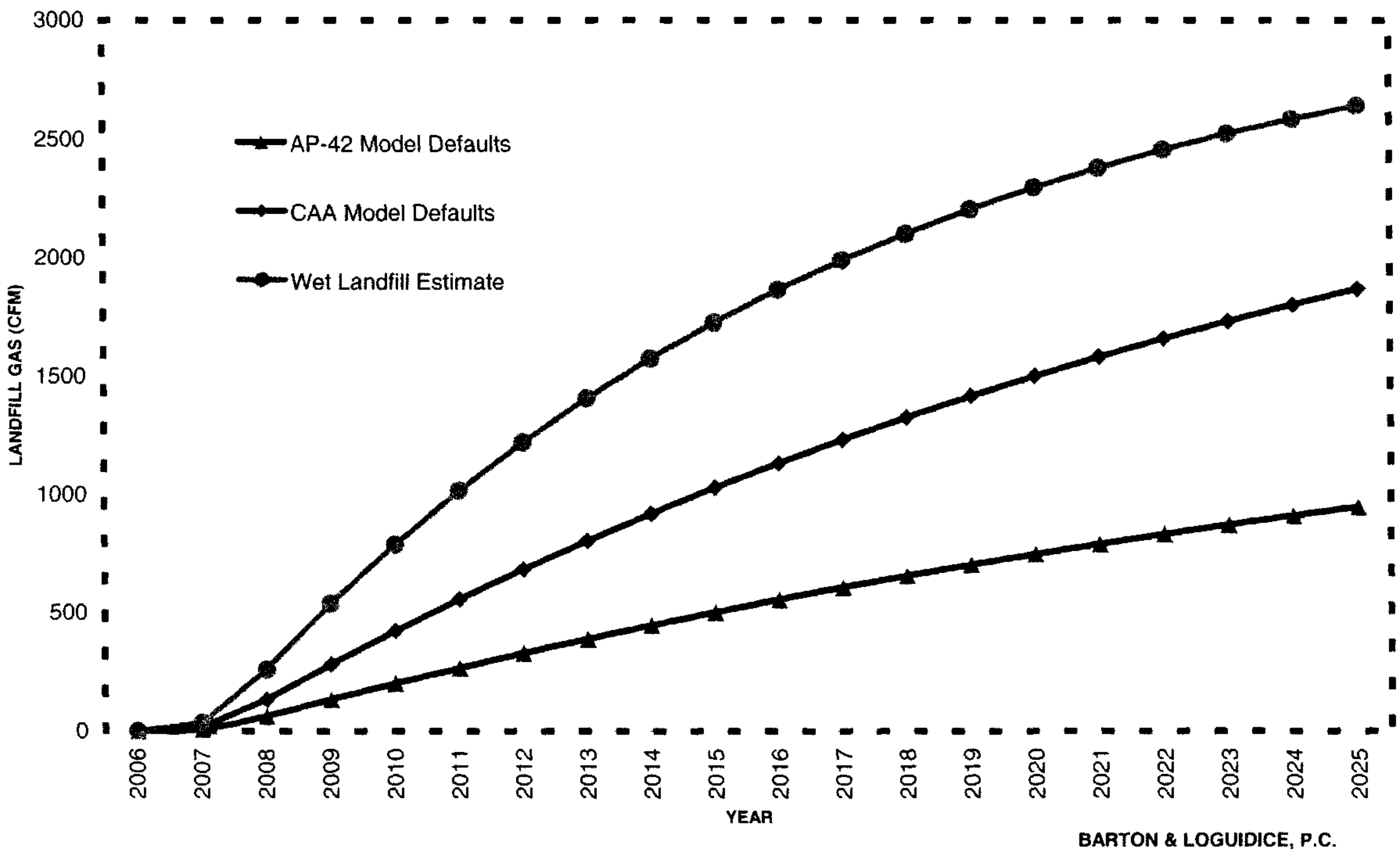
A summary of all of the options, the advantages and disadvantages of each, as well as the net cash flow and net present value of each is provided in Table E-1 of this report's Executive Summary. While a majority of the options discussed above result in positive total cash flow at the end of a 15 year study period, some present obvious advantages. All of the electricity production options present positive total cash flows, with the internal combustion engines providing the largest. The internal combustion engines also have the advantage of being a well tested technology, with success records at many facilities throughout the state. Waste heat utilization is a secondary benefit of the internal combustion engines, which also has many proven use options.

While the direct use off-site option provides large positive total cash flow at the end of the study period, and it is a relatively well tested option, a viable customer in the vicinity has not been identified. This option is not feasible unless an existing customer can be found within a reasonable vicinity of the landfill, or a new customer can be drawn to the area.

Figure 1

Estimated Landfill Gas Collection Curves

FIGURE 1
ESTIMATED LANDFILL GAS COLLECTION CURVES
(85% Collection Efficiency)



Appendix A

Landfill Gas Generation & Collection Estimates

A.1 – CAA Model
A.2 – AP-42 Model
A.3 – Wet Landfill Model (K=0.10)
A.4 – Average Collection Estimate

A.1 – CAA Model

Oneida-Herkimer Solid Waste Management Authority
Regional Landfill
Landfill Gas Generation & Collection Efficiency Estimates

CAA Model

CAA Defaults k=0.05, Lo=170, CH_4=50%
Overall Collection Network Efficiency =85%

Year	Annual Tonnage of Degradable Waste (TONS)	CAA Model Defaults LFG (CFM)	85% Collection Efficiency CAA Defaults (CFM)
2006	21,087	0	0
2007	135,659	21	18
2008	178,880	158	134
2009	178,880	332	282
2010	178,880	497	423
2011	178,880	655	557
2012	178,880	805	684
2013	178,880	947	805
2014	178,880	1,082	920
2015	178,880	1,211	1,030
2016	178,880	1,334	1,134
2017	178,880	1,450	1,233
2018	178,880	1,561	1,327
2019	178,880	1,667	1,417
2020	178,880	1,767	1,502
2021	178,880	1,863	1,583
2022	178,880	1,953	1,660
2023	178,880	2,040	1,734
2024	178,880	2,122	1,804
2025	178,880	2,200	1,870

NOTE:
1. 2006, 2007 Actual degradable waste tonnage records; 2008 to 2025 Current maximum permitted degradable waste acceptance of 178,880 TPY

A.2 – AP-42 Model

Oneida-Herkimer Solid Waste Management Authority
Regional Landfill
Landfill Gas Generation & Collection Efficiency Estimates

AP-42 Model

AP-42 Defaults k=0.04, Lo=100, CH_4=50%
Overall Collection Network Efficiency =85%

Year	Annual Tonnage of Degradable Waste (TONS)	AP-42 Model Defaults LFG (CFM)	85% Collection Efficiency AP-42 Defaults (CFM)
2006	**21,087**	**0**	**0**
2007	**135,659**	**10**	**9**
2008	178,880	75	64
2009	178,880	158	134
2010	178,880	237	202
2011	178,880	314	267
2012	178,880	388	329
2013	178,880	458	389
2014	178,880	526	447
2015	178,880	591	503
2016	178,880	654	556
2017	178,880	714	607
2018	178,880	772	656
2019	178,880	828	703
2020	178,880	881	749
2021	178,880	932	792
2022	178,880	982	834
2023	178,880	1,029	875
2024	178,880	1,075	913
2025	178,880	1,118	951

NOTE:
1. 2006, 2007 Actual degradable waste tonnage records; 2008 to 2025 Current maximum permitted degradable waste acceptance of 178,880 TPY

A.3 – Wet Landfill Model (K=0.10)

Oneida-Herkimer Solid Waste Management Authority
Regional Landfill
Landfill Gas Generation & Collection Efficiency Estimates

Wet Landfill Model (K=0.10)

Wet Estimated K=0.10, Lo=170, CH_4=50%
Overall Collection Network Efficiency =85%

Year	Annual Tonnage of Degradable Waste (TONS)	Wet Landfill K=0.10 LFG (CFM)	85% Collection Efficiency Wet Landfill (CFM)
2006	21,087	0	0
2007	135,659	42	36
2008	178,880	307	261
2009	178,880	633	538
2010	178,880	928	789
2011	178,880	1,195	1,016
2012	178,880	1,437	1,221
2013	178,880	1,655	1,407
2014	178,880	1,853	1,575
2015	178,880	2,032	1,727
2016	178,880	2,194	1,865
2017	178,880	2,341	1,989
2018	178,880	2,473	2,102
2019	178,880	2,593	2,204
2020	178,880	2,702	2,296
2021	178,880	2,800	2,380
2022	178,880	2,889	2,455
2023	178,880	2,969	2,524
2024	178,880	3,042	2,586
2025	178,880	3,108	2,641

NOTE:
1. 2006, 2007 Actual degradable waste tonnage records; 2008 to 2025 Current maximum permitted degradable waste acceptance of 178,880 TPY

A.4 – Average Collection Estimate

Oneida-Herkimer Solid Waste Management Authority
Regional Landfill
Landfill Gas Generation & Collection Efficiency Estimates

Average of AP-42, CAA, and Wet Landfill Models

CAA Defaults k=0 05, Lo=170, CH_4=50%
AP-42 Defaults k=0 04, Lo=100, CH_4=50%
Wet Estimated K=0 10, Lo=170, CH_4 =50%
Overall Collection Network Efficiency =85%

Year	Annual Tonnage of Degradable Waste (TONS)	85% Collection Efficiency AP-42 Defaults (CFM)	85% Collection Efficiency CAA Defaults (CFM)	85% Collection Efficiency Wet Landfill (CFM)	Average AP-42, CAA, Wet 85% Collection Efficiency (CFM)
2006	21,087	0	0	0	0
2007	135,659	9	18	36	21
2008	178,880	64	134	261	153
2009	178,880	134	282	538	318
2010	178,880	202	423	789	471
2011	178,880	267	557	1,016	613
2012	178,880	329	684	1,221	745
2013	178,880	389	805	1,407	867
2014	178,880	447	920	1,575	981
2015	178,880	503	1,030	1,727	1,086
2016	178,880	556	1,134	1,865	1,185
2017	178,880	607	1,233	1,989	1,276
2018	178,880	656	1,327	2,102	1,362
2019	178,880	703	1,417	2,204	1,441
2020	178,880	749	1,502	2,296	1,516
2021	178,880	792	1,583	2,380	1,585
2022	178,880	834	1,660	2,455	1,650
2023	178,880	875	1,734	2,524	1,711
2024	178,880	913	1,804	2,586	1,767
2025	178,880	951	1,870	2,641	1,821

NOTE
1 2006, 2007 Actual degradable waste tonnage records, 2008 to 2025 Current maximum permitted degradable waste acceptance of 178,880 TPY

Appendix B

Cost Estimates for LFG Utilization Alternatives

SUMMARY OF LANDFILL GAS UTILIZATION ALTERNATIVES
ONEIDA-HERKIMER SOLID WASTE MANAGEMENT AUTHORITY
LANDFILL GAS UTILIZATION STUDY

Rank	Technology	Pros	Cons	Total Cash Flow (Over 15 Years)	Net Present Value (5% Discount Rate)	Average Net Revenue Per CFM of LFG
1	**Electricity Generation Internal Combustion Engines**	• Proven technology • Many options for electricity and waste heat use • Can be turned down to run at partial loads • More efficient than turbines • Waste heat easier to collect vs turbines • More tolerant of siloxanes than turbines • Newer engines can run at lower flows (400 cfm +/-)	• More intense O&M • Less tolerant of H2S • Slightly more expensive than turbines per unit • Higher Nox emissions	$22 201 000	$13 139,419	$1 120
2	**Direct Gas Use (Offsite)**	• More cost effective to implement - less cleaning • Do not need high gas flow	• More O&M on equipment if gas is not clean • Need large gas customer in Ava/Boonville area	$16 395 000	$9 217,701	$676
3	**High BTU Gas LFG to Natural Gas Pipeline**	• Efficient use of LFG • Natural gas demand is very high - good pricing	• Expensive to implement • High pressure 600 psi plus to tie into existing • May need redundant compressor to ensure delivery • Extensive treatment to remove CO2 and impurities- • May need to blend some natural gas • Need higher gas flows - 2000 cfm + • More extensive quality control to meet standards	$12,505,000	$6 692 968	$446
4	**Electricity Generation Combustion Turbines**	• Proven technology • O&M not as intensive • Many options for electricity and waste heat use • Slightly less expensive per unit than engines • More tolerant of H2S • Lower Nox emissions	• Must compress the gas - additional step • Waste heat is more difficult to collect • Less tolerant of siloxanes • Less efficient than engines • Efficiency drops substantially at partial loads (i e , less than 500 cfm)	$11,063 000	$6 196,245	$450
5	**Electricity Generation Small Diesel Engines Bi-Fuel**	• Can capture low gas flows • Modular approach can match changes in flow • Multiple units provide redundancy • Waste heat collection	• Will need multiple units • Increased O&M due to multiple units • Less tolerant of H2S • Higher Nox emissions • Need to blend diesel into the process	$7 388,653	$3 383 174	$149
6	**Electricity Generation Microturbines**	• Can capture low gas flows • Modular approach can match changes in flow • Multiple units provide redundancy	• Will need multiple units • Increased O&M due to multiple units • Waste heat is more difficult to collect • Operating life of equipment uncertain - maybe only 5 years	$6,387 000	$2 951 895	$195
7	**High BTU Gas (CLG) Vehicle Fueling**	• Efficient use of LFG • Fleet fuel savings	• Expensive to implement • Need to retrofit existing vehicles • Storage tanks required for existing vehicles are large • Extensive treatment to remove CO2 and impurities- • Large quantity produced at full capacity would exceed fuel requirements in the immediate vicinity	$2 849 000	$1 849,390	$509
8	**Direct Gas Use (Onsite)**	• Less cleaning of gas • Do not need high gas flow • Could be combined with other gas utilization option	• More O&M on equipment if gas is not clean • More gas would be produced than could be used on site	($179 000)	($137,877)	($1 705)
9	**Carbon Offsets**	• Applies to any landfill gas utilization option	• Process subject to regulatory changes	$4,003 000	$2 549,713	$222

Oneida Herkimer Solid Waste Management Facility
Landfill Gas Utilization Study

Compressed Landfill Gas (CLG) Fueling Facility

Year	Estimated Gas Flow (CFM)	Equivalent Gallons of Gas per Year[1]	Current Diesel Usage/year (Gallons)[2]	Excess Gas Flow (CFM)[3]	Fuel Savings/Year *$2 88 /gal @ 3% Inflation*	Debt Service (Development Costs)[4] *Interest Rate of 5%*	O&M Costs *3% Inflation*	Total Costs	Net Revenue (Loss) to Authority	Net Revenue per CFM of LFG Utilized
1	423	675,880	182,895	234	$527,000	$352,000	$75,000	$427,000	$100,000	$530
2	557	889,589	182,895	336	$543,000	$352,000	$77,000	$429,000	$114,000	$517
3	684	1,093,311	182,895	433	$559,000	$352,000	$80,000	$432,000	$127,000	$506
4	805	1,286,168	182,895	525	$576,000	$352,000	$82,000	$434,000	$142,000	$507
5	920	1,469,519	182,895	612	$593,000	$352,000	$84,000	$436,000	$157,000	$510
6	1030	1,645,759	182,895	696	$611,000	$369,000	$87,000	$456,000	$155,000	$464
7	1134	1,811,773	182,895	775	$629,000	$369,000	$90,000	$459,000	$170,000	$473
8	1233	1,969,318	182,895	850	$648,000	$369,000	$92,000	$461,000	$187,000	$489
9	1327	2,120,073	182,895	921	$667,000	$369,000	$95,000	$464,000	$203,000	$501
10	1417	2,264,037	182,895	990	$687,000	$369,000	$98,000	$467,000	$220,000	$515
11	1502	2,399,852	182,895	1,054	$708,000	$390,000	$101,000	$491,000	$217,000	$485
12	1583	2,529,355	182,895	1,116	$729,000	$390,000	$104,000	$494,000	$235,000	$503
13	1660	2,652,468	182,895	1,175	$751,000	$390,000	$107,000	$497,000	$254,000	$523
14	1734	2,770,627	182,895	1,231	$774,000	$390,000	$110,000	$500,000	$274,000	$545
15	1804	2,881,995	182,895	1,284	$797,000	$390,000	$113,000	$503,000	$294,000	$566
								Total Cash Flow	$2,849,000	$509
								Net Present Value *5% discount*	$1,849,390	

Notes
1- Assuming 50% methane content in landfill gas, 20% of methane "lost" during scrubbing process, 125 cubic feet of methane at 5 psig per equivalent gallon of diesel, system operational 95% of the time
2- Current diesel usage based on 2009 budget from OHSWMA for fuel usage in waste and leachate transfer vehicles, and the two-year average cost to OHSWMA of $2 88 per gallon for diesel fuel used in 2007 and 2008
3- Represents landfill gas available for other uses after required volume of CLG has been generated
4- Capital costs include gas pretreatment equipment, compression equipment, and vehicle fueling station with 15 year financing period Also assumes $30,000 per vehicle for retrofit costs or additional cost of new vehicle purchase for dual fuel use Based on 14 waste transfer vehicles and 2 leachate transfer vehicles Five year useful life assumed for each vehicle

Oneida Herkimer Solid Waste Management Facility
Landfill Gas Utilization Study

Internal Combustion Engine Generator Sets - Electricity Generation

Year	Gas Flow (CFM)	IC Engine Generator Units	Electricity Generation (MW)	Excess Gas Flow (CFM)[3]	Revenue - Power to Grid per Year[1] *$0.055 /kwh @ 5% escalation*	Revenue - RECs per Year[1] *$0.035 /kwh in 1 MW blocks*	Debt Service (Development Costs)[2] *Interest Rate of 5%*	O&M Costs[4] *3% inflation*	Total Costs	Net Revenue (Loss) to the Authority	Net Revenue per CFM of LFG Utilized
1	423	1	1.3	0	$611,000	$291,000	$505,000	$342,000	$847,000	$55 000	$130
2	557	1	1.6	50	$769,000	$291,000	$505,000	$412,000	$917,000	$143,000	$282
3	684	1	1.6	177	$807,000	$291,000	$505,000	$425,000	$930,000	$168,000	$331
4	805	1	1.6	298	$848,000	$291,000	$505,000	$438,000	$943,000	$196,000	$387
5	920	2	2.9	0	$1,615,000	$583,000	$650,000	$828,000	$1,478,000	$720,000	$783
6	1030	2	3.2	0	$1,869,000	$874,000	$650,000	$928,000	$1,578,000	$1,165,000	$1,131
7	1134	2	3.2	120	$1,963,000	$874,000	$650,000	$956,000	$1,606,000	$1,231,000	$1,214
8	1233	2	3.2	219	$2,061,000	$874,000	$650,000	$985,000	$1,635,000	$1,300,000	$1,282
9	1327	3	4.2	0	$2,832,000	$1,165,000	$832,000	$1,352,000	$2,184,000	$1,813,000	$1,366
10	1417	3	4.5	0	$3,175,000	$1,165,000	$832,000	$1,473,000	$2,305,000	$2,035,000	$1,436
11	1502	3	4.7	0	$3,534,000	$1,165,000	$832,000	$1,597,000	$2,429,000	$2,270,000	$1,511
12	1583	3	4.8	62	$3,758,000	$1,165,000	$832,000	$1,663,000	$2,495,000	$2,428,000	$1,596
13	1660	3	4.8	139	$3,946,000	$1,165,000	$832,000	$1,713,000	$2,545,000	$2,566,000	$1,687
14	1734	3	4.8	213	$4,143,000	$1,165,000	$832,000	$1,764,000	$2,596,000	$2,712,000	$1,783
15	1804	4	5.7	0	$5,158,000	$1,456,000	$1,027,000	$2,188,000	$3,215,000	$3,399,000	$1,884
									Total Cash Flow	$22,201,000	$1,120
									Net Present Value *5% discount*	$13,139,419	

Notes
1- Assuming 50% methane content in landfill gas and generator operational 95% of the time
2- Annual debt service is based on a 15 year financing period for three separate projects, the construction of a LFG pretreatment system, the purchase of one engine generator set, and the construction of the associated structures in Year 1, the purchase of an additional engine generator set in Year 5, the purchase of an additional engine generator set and expansion of the structure in Year 9, and the purchase of an additional engine generator set in Year 15
3- Represents landfill gas available for other uses
4 - O&M Costs include cost of a complete overhaul of each engine every 5 years The "down time" associated with each overhaul is accounted for in the 95% operational time used in the revenue calculations

Oneida Herkimer Solid Waste Management Facility
Landfill Gas Utilization Study

Internal Combustion Engine Generator Sets - Electricity Generation
Utilizing Remaining LFG After On-Site Heat Generation

Year	Gas Flow (CFM)	IC Engine Generator Units	Electricity Generation (MW)	Excess Gas Flow (CFM)[3]	Revenue - Power to Grid per Year[1] *$0 055 /kwh @ 5% escalation*	Revenue - RECs per Year[1] *$0 035 /kwh in 1 MW blocks*	Debt Service (Development Costs)[2] *Interest Rate of 5%*	O&M Costs[4] *3% inflation*	Total Costs	Net Revenue (Loss) to the Authority	Net Revenue per CFM of LFG Utilized
1	416	1	1 3	0	$602,000	$291,000	$505,000	$342,000	$847,000	$46,000	$110
2	550	1	1 6	43	$769,000	$291,000	$505,000	$412,000	$917,000	$143,000	$282
3	678	1	1 6	171	$807,000	$291,000	$505,000	$425,000	$930,000	$168,000	$331
4	798	1	1 6	291	$848,000	$291,000	$505,000	$438,000	$943,000	$196,000	$387
5	913	2	2 9	0	$1,603,000	$583,000	$650,000	$828,000	$1,478,000	$708,000	$775
6	1023	2	3 2	9	$1,869,000	$874,000	$650,000	$928,000	$1,578,000	$1,165,000	$1,149
7	1127	2	3 2	113	$1,963,000	$874,000	$650,000	$956,000	$1,606,000	$1,231,000	$1,214
8	1226	2	3 2	212	$2,061,000	$874,000	$650,000	$985,000	$1,635,000	$1,300,000	$1,282
9	1320	3	4 2	0	$2,818,000	$1,165,000	$832,000	$1,352,000	$2,184,000	$1,799,000	$1,363
10	1410	3	4 5	0	$3,161,000	$1,165,000	$832,000	$1,473,000	$2,305,000	$2,021,000	$1,433
11	1495	3	4 7	0	$3,519,000	$1,165,000	$832,000	$1,597,000	$2,429,000	$2,255,000	$1,508
12	1577	3	4 8	56	$3,758,000	$1,165,000	$832,000	$1,663,000	$2,495,000	$2,428,000	$1,596
13	1654	3	4 8	133	$3,946,000	$1,165,000	$832,000	$1,713,000	$2,545,000	$2,566,000	$1,687
14	1727	3	4 8	206	$4,143,000	$1,165,000	$832,000	$1,764,000	$2,596,000	$2,712,000	$1,783
15	1797	4	5 7	0	$5,140,000	$1,456,000	$1,027,000	$2,188,000	$3,215,000	$3,381,000	$1,881
									Total Cash Flow	$22,119,000	$1,119
									Net Present Value *5% discount*	$13,086,397	

Notes
1- Assuming 50% methane content in landfill gas and generator operational 95% of the time
2- Annual debt service is based on a 15 year financing period for three separate projects; the construction of a LFG pretreatment system, the purchase of one engine generator set, and the construction of the associated structures in Year 1, the purchase of an additional engine generator set in Year 5, the purchase of an additional engine generator set and expansion of the structure in Year 9, and the purchase of an additional engine generator set in Year 15
3- Represents landfill gas available after on-site electrical generation and heating
4 - O&M Costs include cost of a complete overhaul of each engine every 5 years The "down time" associated with each overhaul is accounted for in the 95% operational time used in the revenue calculations

Oneida Herkimer Solid Waste Management Facility
Landfill Gas Utilization Study

Internal Combustion Bi-Fuel Small Engine Generator Sets - Electricity Generation

Year	Gas Flow (CFM)	IC Small Engine Generator Units	Electricity Generation (MW)	Diesel Fuel Utilization (Gal/Yr)	Diesel Fuel Cost ($/Yr)[1] $2 88 /gal	Revenue - Power to Grid per Year[2] $0 055 /kwh @ 5% escalation	Revenue - RECs per Year[3] $0 035 /kwh in 1 MW blocks	Debt Service (Development Costs)[4] Interest Rate of 5%	O&M Costs[5] 3% inflation	Total Costs	Net Revenue (Loss) to the Authority	Net Revenue per CFM of LFG Utilized
1	423	4	1 4	274,071	$789,325	$641,000	$291,000	$514,468	$332,000	$1,635,793	($703,793)	($1,664)
2	557	5	1 8	290,808	$837,526	$841,000	$291,000	$644,428	$410,000	$1,891,954	($759,954)	($1,365)
3	684	6	2 1	319,102	$919,015	$1,060,000	$583,000	$648,327	$425,000	$1,992,342	($349,342)	($511)
4	805	7	2 5	359,973	$1,036,721	$1,298,000	$583,000	$652,343	$440,000	$2,129,064	($248,064)	($308)
5	920	7	2 5	147,762	$425,554	$1,363,000	$583,000	$514,468	$807,000	$1,747,022	$198,978	$216
6	1030	8	2 8	207,865	$598,651	$1,636,000	$583,000	$660,739	$917,000	$2,176,391	$42,609	$41
7	1134	9	3 2	279,804	$805,836	$1,932,000	$874,000	$665,127	$947,000	$2,417,963	$388,037	$342
8	1233	10	3 5	361,545	$1,041,249	$2,254,000	$874,000	$669,647	$979,000	$2,689,896	$438,104	$355
9	1327	11	3 9	451,145	$1,299,297	$2,604,000	$874,000	$693,158	$1,313,000	$3,305,455	$172,545	$130
10	1417	11	3 9	284,520	$819,417	$2,734,000	$874,000	$533,324	$1,441,000	$2,793,741	$814,259	$575
11	1502	12	4 2	391,411	$1,127,265	$3,131,000	$1,165,000	$702,892	$1,575,000	$3,405,157	$890,843	$593
12	1583	12	4 2	241,523	$695,586	$3,288,000	$1,165,000	$533,324	$1,642,000	$2,870,910	$1,582,090	$999
13	1660	13	4 6	363,117	$1,045,776	$3,740,000	$1,165,000	$713,219	$1,695,000	$3,453,995	$1,451,005	$874
14	1734	14	4 9	490,443	$1,412,476	$4,229,000	$1,165,000	$718,616	$1,749,000	$3,880,092	$1,513,908	$873
15	1804	14	4 9	361,545	$1,041,249	$4,441,000	$1,165,000	$533,324	$2,074,000	$3,648,572	$1,957 428	$1,085
										Total Cash Flow	$7,388,653	$149
										Net Present Value 5% discount	$3,383,174	

Notes

1- Based on 2-year average cost to OHSWMA of $2 88 per gallon for diesel fuel used in 2007 and 2008

2- Assuming 50% methane content in landfill gas and generator operational 95% of the time

3- RECs only received for portion of electricity generated using LFG The portion from diesel fuel has been subtracted

4- Annual debt service based on 15 year financing period for 2 separate projects, the installation of the LFG pretreatment system purchase of the initial 4 engine generator units, and construction of the facility in Year 1 and the construction of a building addition in Year 9
Each annual debt service payment also includes the full purchase price of additional engine generator units as required each year in Years 2-4, 6-9, 11, 13, and 14

5 - O&M Costs include cost of a complete overhaul of each engine every 5 years The "down time" associated with each overhaul is accounted for in the 95% operational time used in the revenue calculations

Oneida Herkimer Solid Waste Management Facility
Landfill Gas Utilization Study

Microturbines - Electricity Generation

Year	Gas Flow (CFM)	Units	Electricity Generation (MW)	Excess Gas Flow (CFM)[3]	Revenue - Power to Grid per Year[1] *$0 055 /kwh @ 5% escalation*	Revenue - RECs per Year[1] *$0 035 /kwh in 1 Mw blocks*	Debt Service (Development Costs)[2] *Interest Rate of 5%*	O&M Costs *3% Inflation*	Total Costs	Net Revenue (Loss) to Authority	Net Revenue per CFM of LFG Utilized
1	423	5	1 0	78	$458,000	$291,000	$772,000	$241,000	$1,013,000	($264,000)	($764)
2	557	7	1 4	73	$673,000	$291,000	$919,000	$347,000	$1,266,000	($302,000)	($624)
3	684	9	1 8	62	$908,000	$291,000	$1,071,000	$460,000	$1,531,000	($332,000)	($534)
4	805	10	2 0	114	$1,060,000	$583,000	$1,149,000	$526,000	$1,675,000	($32,000)	($46)
5	920	12	2 4	91	$1,335,000	$583,000	$1,309,000	$651,000	$1,960,000	($42,000)	($51)
6	1030	13	2 6	132	$1,519,000	$583,000	$1,547,000	$726,000	$2,273,000	($171,000)	($190)
7	1134	14	2 8	167	$1,717,000	$583,000	$1,655,000	$805,000	$2,460,000	($160,000)	($165)
8	1233	16	3 2	127	$2,061,000	$874,000	$1,855,000	$948,000	$2,803,000	$132,000	$119
9	1327	17	3 4	152	$2,299,000	$874,000	$1,958,000	$1,038,000	$2,996,000	$177,000	$151
10	1417	18	3 6	173	$2,556,000	$874,000	$2,077,000	$1,132,000	$3,209,000	$221,000	$178
11	1502	19	3 8	189	$2,833,000	$874,000	$1,779,000	$1,230,000	$3,009,000	$698,000	$532
12	1583	20	4 0	201	$3,131,000	$1,165,000	$1,720,000	$1,334,000	$3,054,000	$1,242,000	$899
13	1660	21	4 2	209	$3,452,000	$1,165,000	$1,675,000	$1,443,000	$3,118,000	$1,499,000	$1,033
14	1734	22	4 4	214	$3,798,000	$1,165,000	$1,703,000	$1,557,000	$3,260,000	$1,703,000	$1,120
15	1804	23	4 6	215	$4,169,000	$1,165,000	$1,640,000	$1,676,000	$3,316,000	$2,018,000	$1,270
									Total Cash Flow	$6,387,000	$195
									Net Present Value *5% discount*	$2,951,895	

Notes
1- Assuming 50% methane content in landfill gas and microturbines operational 95% of the time
2- Annual debt service based on 15 year financing period for 3 separate projects, the installation of the LFG pretreatment system purchase of the initial and construction of the facility in Year 1, the construction of a building addition and upgraded pretreatment in Year 6, and the construction of another building addition and upgraded pretreatment in Year 12 Additional annual debt service based on a 5 year financing period for the purchase of additional microturbines each year, as well as the purchase of replacement microturbines in years 6 through 15 to replace existing microturbines, which have a 5 year service life The "down time" required for microturbine installation and/or replacement is accounted for in the 95% operational time used in the revenue calculations
3- Represents landfill gas available after on-site electrical generation and heating

Oneida Herkimer Solid Waste Management Facility
Landfill Gas Utilization Study

Carbon Offsets

Year	Gas Flow (CFM)	Methane Destroyed (scf/yr)[1]	Methane Destroyed (Mg/yr)	Landfill Methane Offsets (Mg CO_{2e}/yr)[2]	Annual Carbon Offset Income	Annual O&M Costs	Net Revenue (Loss) to Authority	Net Revenue per CFM of LFG
					$3 /Offset	*3% inflation*		
1	423	111,164,400	2,101	38,335	$115,000	$31,000	$84,000	$199
2	557	146,313,900	2,765	50,456	$151,000	$35,000	$116,000	$208
3	684	179,820,900	3,398	62,011	$186,000	$39,000	$147,000	$215
4	805	211,540,860	3,997	72,949	$219,000	$43,000	$176,000	$219
5	920	241,697,160	4,567	83,348	$250,000	$46,000	$204,000	$222
6	1030	270,684,000	5,115	93,344	$280,000	$50,000	$230,000	$223
7	1134	297,988,920	5,631	102,760	$308,000	$53,000	$255,000	$225
8	1233	323,901,000	6,120	111,696	$335,000	$57,000	$278,000	$226
9	1327	348,696,180	6,589	120,247	$361,000	$60,000	$301,000	$227
10	1417	372,374,460	7,036	128,412	$385,000	$63,000	$322,000	$227
11	1502	394,712,460	7,458	136,115	$408,000	$66,000	$342,000	$228
12	1583	416,012,400	7,861	143,460	$430,000	$69,000	$361,000	$228
13	1660	436,261,140	8,243	150,443	$451,000	$72,000	$379,000	$228
14	1734	455,695,200	8,611	157,145	$471,000	$75,000	$396,000	$228
15	1804	474,012,360	8,957	163,462	$490,000	$78,000	$412,000	$228
						Total Cash Flow	$4,003,000	$222
						Net Present Value *5% discount*	$2,549,713	

Notes:
1- Assume LFG is 50% methane and that utilization method destroys 100% of LFG collected.
2- Assume 18.25 metric tons of CO_2 per ton of methane combusted.

Oneida Herkimer Solid Waste Management Facility
Landfill Gas Utilization Study

Direct Use - Onsite Heating

Year	Gas Flow (CFM)	MMBtu's From LFG/Year[1]	Current Propane Usage/Year (gallons)	Current MMBtu Usage/Year[2]	Excess Gas Flow (CFM)	Propane Fuel Savings/Year[3] *$1.61 /gal @ 3% Inflation*	Debt Service (Development Costs)[4] *Interest Rate of 5%*	O&M Costs *3% Inflation*	Total Costs	Net Revenue (Loss) to Authority	Net Revenue per CFM of LFG Utilized (7 CFM)
1	423	111,164	18,719	1,713	416	$30,000	$41,000	$5,000	$46,000	($16,000)	($2,286)
2	557	146,314	18,719	1,713	550	$31,000	$41,000	$5,000	$46,000	($15,000)	($2,143)
3	684	179,821	18,719	1,713	678		$41,000	$5,000	$46,000	($46,000)	($6,571)
4	805	211,541	18,719	1,713	798	$33,000	$41,000	$5,000	$46,000	($13,000)	($1,857)
5	920	241,697	18,719	1,713	913	$34,000	$41,000	$6,000	$47,000	($13,000)	($1,857)
6	1029	270,513	18,719	1,713	1,023	$35,000	$41,000	$6,000	$47,000	($12,000)	($1,714)
7	1134	297,989	18,719	1,713	1,127	$36,000	$41,000	$6,000	$47,000	($11,000)	($1,571)
8	1233	323,901	18,719	1,713	1,226	$37,000	$41,000	$6,000	$47,000	($10,000)	($1,429)
9	1327	348,696	18,719	1,713	1,320	$38,000	$41,000	$6,000	$47,000	($9,000)	($1,286)
10	1417	372,374	18,719	1,713	1,410	$39,000	$41,000	$7,000	$48,000	($9,000)	($1,286)
11	1502	394,712	18,719	1,713	1,495	$41,000	$41,000	$7,000	$48,000	($7,000)	($1,000)
12	1584	416,157	18,719	1,713	1,577	$42,000	$41,000	$7,000	$48,000	($6,000)	($857)
13	1660	436,261	18,719	1,713	1,654	$43,000	$41,000	$7,000	$48,000	($5,000)	($714)
14	1734	455,695	18,719	1,713	1,727	$44,000	$41,000	$7,000	$48,000	($4,000)	($571)
15	1804	474,012	18,719	1,713	1,797	$46,000	$41,000	$8,000	$49,000	($3,000)	($429)
									Total Cash Flow	($179,000)	($1,705)
									Net Present Value *5% discount*	($137,877)	

1 - Assuming 50% methane content in LFG and 1,000 BTU per cubic foot of methane.
2 - Assume 91,500 BTU per gallon of propane.
3 - Based on 2-year average cost to OHSWMA for propane in 2007 and 2008 of $1.61/gal. Project would show a positive net present value when propane cost reaches $2.09/gal.
4 - Capital costs include installation of a gas pipeline to the maintenance building, leachate pump station and leachate transfer pump station. Annual debt service based on 15 year financing period.

Oneida Herkimer Solid Waste Management Facility
Landfill Gas Utilization Study

Direct Use - Offsite Buyer[1]

Year	Gas Flow (CFM)	MMBtu's From LFG/Year[2]	Revenue - Landfill Gas To Customer[3]	Debt Service (Development Costs)[4]	O&M Costs	Total Costs	Total Revenue (Loss) to Authority	Net Revenue per CFM of LFG Utilized
			$4.413 /MMBtu @ 5% escalation	*Interest Rate of 5%*	*3% Inflation*			
1	423	111,164	$491,000	$659,000	$277,000	$936,000	($445,000)	($1,052)
2	557	146,314	$678,000	$659,000	$285,000	$944,000	($266,000)	($478)
3	684	179,821	$875,000	$659,000		$659,000	$216,000	$316
4	805	211,541	$1,081,000	$659,000	$302,000	$961,000	$120,000	$149
5	920	241,697	$1,296,000	$659,000	$311,000	$970,000	$326,000	$354
6	1030	270,684	$1,525,000	$659,000	$321,000	$980,000	$545,000	$529
7	1134	297,989	$1,762,000	$659,000	$330,000	$989,000	$773,000	$682
8	1233	323,901	$2,011,000	$659,000	$340,000	$999,000	$1,012,000	$821
9	1327	348,696	$2,274,000	$659,000	$350,000	$1,009,000	$1,265,000	$953
10	1417	372,374	$2,549,000	$659,000	$361,000	$1,020,000	$1,529,000	$1,079
11	1502	394,712	$2,837,000	$659,000	$372,000	$1,031,000	$1,806,000	$1,202
12	1583	416,012	$3,140,000	$727,000	$504,000	$1,231,000	$1,909,000	$1,206
13	1660	436,261	$3,457,000	$727,000	$519,000	$1,246,000	$2,211,000	$1,332
14	1734	455,695	$3,792,000	$727,000	$535,000	$1,262,000	$2,530,000	$1,459
15	1804	474,012	$4,142,000	$727,000	$551,000	$1,278,000	$2,864,000	$1,588
						Total Cash Flow	$16,395,000	$676
						Net Present Value *5% discount*	$9,217,701	

1 - An offsite buyer of the landfill gas has not been identified in the area.
2 - Assumes 50% methane content in LFG and 1,000 BTU per cubic foot of methane.
3 - Assumes landfill gas would be purchased by customer in place of the equivalent quantity of natural gas in MMBtu at 80% of the NYMEX Natural Gas Futures value ($5.516/MMBtu as of 1/12/09)
4 - Capital costs include installation of a gas pipeline to a customer located 8 miles from the landfill site and the installation of pretreatment and compression equipment in Year 1, and the installation of a third compressor in Year 12. Annual debt service based on 15 year financing period. Assumes that customer will incur all costs associated with upgrading existing or purchasing new equipment to operate utilizing landfill gas.

Oneida Herkimer Solid Waste Management Facility
Landfill Gas Utilization Study

Combustion Turbines - Electricity Generation

Year	Gas Flow (CFM)	Turbine Units	Electricity Generation (MW)	Excess Gas Flow (CFM)[3]	Revenue - Power to Grid $0.055 /kwh @ 5% escalation	Revenue - RECs *$0.035 /kwh in 1 Mw blocks*	Debt Service (Development Costs) *Interest Rate of 5%*	O&M Costs[4] *3% Inflation*	Total Cost	Net Revenue (Loss) to Authority	Net Revenue per CFM of LFG Utilized
1	423	1	0.8	0	$373,000	$0	$580,000	$194,000	$774,000	($401,000)	($948)
2	557	1	1.1	0	$516,000	$291,000	$580,000	$258,000	$838,000	($31,000)	($56)
3	684	1	1.3	0	$666,000	$291,000	$580,000	$322,000	$902,000	$55,000	$80
4	805	1	1.6	58	$848,000	$291,000	$580,000	$399,000	$979,000	$160,000	$199
5	920	1	1.6	173	$890,000	$291,000	$580,000	$411,000	$991,000	$190,000	$207
6	1030	1	1.6	283	$935,000	$291,000	$580,000	$424,000	$1,004,000	$222,000	$216
7	1134	2	2.2	0	$1,341,000	$583,000	$819,000	$590,000	$1,409,000	$515,000	$454
8	1233	2	2.4	0	$1,530,000	$583,000	$819,000	$658,000	$1,477,000	$636,000	$516
9	1327	2	2.6	0	$1,730,000	$583,000	$819,000	$729,000	$1,548,000	$765,000	$577
10	1417	2	2.7	0	$1,940,000	$583,000	$819,000	$800,000	$1,619,000	$904,000	$638
11	1502	2	3.2	8	$2,386,000	$874,000	$819,000	$962,000	$1,781,000	$1,479,000	$985
12	1583	2	3.2	89	$2,505,000	$874,000	$819,000	$991,000	$1,810,000	$1,569,000	$991
13	1660	2	3.2	166	$2,630,000	$874,000	$819,000	$1,021,000	$1,840,000	$1,664,000	$1,002
14	1734	2	3.2	240	$2,762,000	$874,000	$819,000	$1,051,000	$1,870,000	$1,766,000	$1,018
15	1804	3	3.3	0	$2,954,000	$874,000	$1,145,000	$1,113,000	$2,258,000	$1,570,000	$870
									Total Cash Flow	$11,063,000	$450
									Net Present Value *5% discount*	$6,196,245	

1 - Assuming 50% methane content in landfill gas, 1000 btu per cubic foot of methane and turbine operational 95% of the time
2 - Annual debt service is based on a 15 year financing period for three separate projects, the construction of a LFG pretreatment system, the purchase of one combustion turbine, and the construction of the associated structures in Year 1, the purchase of an additional combustion turbine in Year 7, and the purchase of an additional combustion turbine and expansion of the structure in Year 15
3 - Represents landfill gas available after on-site electrical generation and heating

Oneida Herkimer Solid Waste Management Facility
Landfill Gas Utilization Study

Natural Gas Pipeline Tie In

Year	Gas Flow (CFM)	MMBtu/yr[1]	Revenue - Natural Gas to System[2] *$5.516 /MMBtu @ 5% escalation*	Debt Service (Development Costs)[3] *Interest Rate of 5%*	O&M Costs *3% Inflation*	Total Cost	Net Revenue (Loss) to Authority	Net Revenue per CFM of LFG Utilized
1	423	84,485	$466,000	$794,000	$277,000	$1,071,000	($605,000)	($1,430)
2	557	111,199	$644,000	$794,000	$285,000	$1,079,000	($435,000)	($781)
3	684	136,664	$831,000	$794,000		$794,000	$37,000	$54
4	805	160,771	$1,027,000	$794,000	$302,000	$1,096,000	($69,000)	($86)
5	920	183,690	$1,232,000	$794,000	$311,000	$1,105,000	$127,000	$138
6	1030	205,720	$1,448,000	$794,000	$321,000	$1,115,000	$333,000	$323
7	1134	226,472	$1,674,000	$794,000	$330,000	$1,124,000	$550,000	$485
8	1233	246,165	$1,911,000	$794,000	$340,000	$1,134,000	$777,000	$630
9	1327	265,009	$2,160,000	$794,000	$350,000	$1,144,000	$1,016,000	$766
10	1417	283,005	$2,422,000	$794,000	$361,000	$1,155,000	$1,267,000	$894
11	1502	299,981	$2,695,000	$794,000	$372,000	$1,166,000	$1,529,000	$1,018
12	1583	316,169	$2,983,000	$929,000	$504,000	$1,433,000	$1,550,000	$979
13	1660	331,558	$3,284,000	$929,000	$519,000	$1,448,000	$1,836,000	$1,106
14	1734	346,328	$3,602,000	$929,000	$535,000	$1,464,000	$2,138,000	$1,233
15	1804	360,249	$3,934,000	$929,000	$551,000	$1,480,000	$2,454,000	$1,361
						Total Cash Flow	$12,505,000	$446
						Net Present Value *5% discount*	$6,692,968	

1- Assuming 50% methane content in landfill gas, 20% of methane "lost" during scrubbing process, 1000 Btu per cubic foot of methane, system operational 95% of the time.

2 - Revenue per MMBtu based on the NYMEX Natural Gas Futures value ($5.516/MMBtu as of 1/12/09)

3 - Capital costs include installation of a gas pipeline to the Boonville pressurization station located 8 miles from the landfill site and the installation of pretreatment and compression equipment in Year 1, and the installation of a third compressor in Year 12. Annual debt service based on 15 year financing period.