ABSTRACT

As part of environmental engineering studies at UNITEC Auckland, a research project was undertaken to evaluate the potential of landfill gas utilisation from the Rotorua District Council landfill on State Highway 30 near Rotorua in the central North Island of New Zealand. Landfill gas is commonly utilised at New Zealand’s larger landfills especially in Auckland and Wellington.

The study reviewed operational history since 1970 and site information from previous reports held by the Rotorua District Council. This background research is an important part of the study, as comprehensive reports seldom exist, especially on older landfills. US Environmental Protection Agency computer modelling was then carried out to obtain a landfill gas generation estimate, which was then converted to a projected landfill gas recovery value. This was then followed by conceptual design drawings for a landfill gas recovery system, and a hypothetical economic evaluation for the study.

The study showed that the projected recovery of landfill gas could peak at over 1,100 cubic metres per hour by the year 2021. This rate would be reliant on factors such as demographics and changing waste streams as well as physical constraints and climate conditions. It is concluded that test wells would need to be constructed to assess the quantity and quality of the landfill gas and to minimise investment risk. A landfill gas utilisation project is commercially viable given a suitable off-site energy consumer.

1.0 INTRODUCTION

This study looks at the possible recovery, utilisation, and development of the landfill gas (LFG) generated at the Rotorua District Landfill (the Site). The Site, which is owned and operated by the Rotorua District Council (Council), is located 4 kilometres outside Rotorua, New Zealand, and contains approximately one and a half million tonnes of municipal solid waste (MSW).

The Council has operated the Site as a landfill since 1970 and has recently opened a new disposal area to increase the capacity of the landfill to allow the site to operate for approximately 20 more years. As part of this process Council obtained a Discharge to Air Consent from Environment Bay of Plenty, which included no requirement to control LFG. Previous reports showed that to reduce environmental impacts associated with the management of MSW, Council would incur costs installing and maintaining a LFG control system at the Site. This Study assesses further less expensive options that are considered more economically viable. Photo 1 shows the landfill entrance.
The study involved visiting the Site, reviewing operational history, gathering Site information, preparing a LFG recovery estimate, developing a landfill gas to energy (LFGTE) system concept, evaluating energy utilisation options, identifying regulatory approvals, and performing an economic evaluation.

2.0 SITE INFORMATION
The Site is currently owned by the Council and is set on approximately 38 hectares of land. The Site is located on moderately sloping land and is bisected by the Tureporepo Stream, which runs south-west north-east through the Site.

The Site can be divided into the following areas and activities:

- Existing and original landfill areas;
- New landfill area;
- Recycling depot;
- Dog pound.

The Site began landfill operations in 1970 and has received domestic, industrial and commercial solid wastes. The Site has also received aqueous waste in the past. Disposal of MSW at the Site can be divided into the following areas:

Area A - Original MSW disposal area;
Area B – Recently closed MSW disposal area;
Area C - Current MSW disposal area.

Area A
Area A, which is located to the south east side of the Site, was filled during the period from 1970 to 1992. After viewing old topographic information, the depth of waste through this area is estimated to be up to approximately 25 metres. It is also estimated that this part of the Site contains approximately 940,000 tonnes of MSW.

As with older landfills, this part of the Site does not have a landfill liner or a leachate control system, but perimeter cut-off drains have been constructed to control storm-water and leachate run-off. Council files show that this portion of the Site was operated as an “open landfill” and that as was the practice at the time, the waste was not regularly
covered. As a result, it can therefore be assumed that large amounts of rainfall would have penetrated the MSW, thereby increasing the rate of decomposition. Leachate levels through this part of the Site are unknown, but are not considered to be high considering the original topography and the finished contours of the landfill, which to a large extent preclude groundwater infiltration.

**Area B**

Area B adjoins Area A in the south west part of the Site. Before MSW filling started in this area, a 600 millimetres clay liner, with permeability $1 \times 10^{-8}$ metres per second was constructed. A leachate collection system was also constructed above the liner to collect leachate. A leachate pumping station was then installed to pump leachate from the Site (Worley, 1998). The recovered leachate is pumped to the Council’s wastewater treatment plant at Rotorua.

Disposal of MSW in Area B reportedly commenced in 1991. Recently completed, the maximum depth of waste from the available as-built information is approximately 30 metres and it has been calculated that this part of the Site contains over 400,000 tonnes of MSW.

This part of the Site has been operated in a manner that involves placing soil cover material over the waste at approximate two-week intervals. It is also reported that, sawdust has been used as a cover material. As a result, rainfall has been allowed to penetrate the waste mass, thus aiding the decomposition of the waste. Leachate levels within this portion of the landfill are also unknown but are expected to be low because of the use of an active leachate control system. With the area nearing completion in 1999, the new disposal Area C was developed.

**Area C**

The Council’s newly developed modern disposal area in the northern portion of the Site has been provided for the future disposal of MSW. This new area will be developed in several stages. Area C is separated from Areas A and B by the Tureporepo Stream but is accessed using the current Site entrance and newly constructed roadway and bridge. Area C is approximately 25 hectares, and includes a lined disposal cell that incorporates a leachate collection system. It is also manages stormwater through channels and a large settling pond. It is estimated that Area C will provide approximately 20 years of operational life and that the estimated depth of waste will be up to 60 metres.

**Meteorological Information**

Rotorua meteorological statistics for 1999, as held by the National Institute of Water and Atmospheric Research Ltd Wellington, are as follows:

- Annual mean rainfall 1,444 millimetres;
- Highest monthly rainfall 360 millimetres;
- Lowest monthly rainfall 4 millimetres;
- Minimum temperature -6°C (July).

These figures are important to determine the effect of climate on the waste, and the likely decomposition and gas generation rates.
3.0 RECOVERY ESTIMATE METHODOLOGY

An assessment was performed to estimate the quantity of LFG that could be recovered during the operational life of the Site. The US Environmental Protection Agency’s Landfill Air Emission Estimation Model (Version 2.01) was used to calculate the LFG generated. An estimate of the LFG recovered was then carried out using pertinent information gained previously in this Study. The relevant input factors, assumptions, and calculation outputs are provided in this Section.

Rotorua District Council records from 1999 show that the Site currently receives approximately 88,000 cubic metres of waste material per year sourced mainly from domestic, industrial and construction/demolition sources. It is estimated that approximately 88,000 tonnes of waste are received annually, based on an average in-place density of waste at 1.0 tonnes per cubic metre.

Based on Council figures that approximately 40 percent of the waste stream consists of inert materials, it is estimated that approximately 53,000 tonnes of MSW are received at the Site on an annual basis. It is also estimated that the Site contains approximately 1,300,000 tonnes of MSW (December 1998) and that the Site will ultimately contain approximately 2,500,000 tonnes of MSW in the year 2020.

For the purposes of this Study, it is assumed that current annual waste quantities would remain unchanged throughout the operational life of the Site and that waste reduction initiatives would not be considered.

Recent application of the Waste Analysis Protocol (WAP) to the solid waste stream indicates that organic matter constitutes 49 percent of the total tonnage (18.4 percent of which is soil), followed by construction and demolition wastes totalling 19 percent with paper amounting to 13 percent (Worley, 1998). Council figures as at January 1996 are provided in Table 1.

<table>
<thead>
<tr>
<th>Composition of Waste Stream</th>
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<tbody>
<tr>
<td>Garden Green Waste</td>
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<td>Construction and Demolition</td>
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<td>Potentially Hazardous Waste</td>
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<td>Glass</td>
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Table 1. Composition of Waste Stream

The quantity of organic material is the primary factor in determining the total volume of LFG that can be generated at the Site. The rate at which LFG is generated is a function of the type of waste, and other factors such as moisture, particle size, compaction, and temperature.

Factors used in the modelling are based on site conditions, geography and the waste assessment discussed. The inputs to the model are:
- Methane Generation Potential (Lo);
- Methane Generation Rate Constant (k).

A Lo of 170 cubic metres methane per tonne of waste and a k of 0.05 per year were used based on the assessed conditions at the Site. The projected LFG generation rate has been based on LFG comprising 50 percent methane and 50 percent carbon dioxide.

The recovery rate estimate calculates the recovered LFG, which could be up to approximately 90 percent of total LFG emitted (USEPA, 1995). It is normally realistic for a LFG collection system to cover 75 percent of the waste mass, and to have a collection efficiency of approximately 80 percent. This gives an overall LFG recovery rate of 60 percent.

From the output worksheet the quantity of recovered LFG is estimated to be approximately 1,130 cubic metres per hour by 2020. The LFG recovery rate is projected to decline after the Site closes and is estimated to be approximately 437 cubic metres per hour in 2040. A graph of the projected LFG recovery rate is provided in Figure 1.

![Projected LFG Recovery Rate](image)

*Figure 1: Projected Landfill Gas Recovery Rate*

Typically, a LFGTE system would include the following components:

- Vertical Extraction Wells;
- Additional LFG Collection Points;
- Header System;
- Condensate System;
- Blower/Flare Station;
- Gas Utilisation Equipment;
- Monitoring System.

The integrated use of these components must be carefully considered to ensure efficiencies. A preliminary LFG control system design plan to be installed in Areas A and B, is provided in Figure 2.
4.0 RESULTS

After overlaying a circular grid pattern of proposed wells in Figure 2, it is estimated that approximately 22 wells could initially be installed in the more recently completed portion of Area A, and the finished disposal area, Area B. For economic reasons, wells should ideally be constructed where the waste depth exceeds approximately 15 metres. Topographic plans have been used to determine this depth and it should also be verified on-site during construction. Once Area C reaches significant depth, further wells could be progressively installed in areas where the waste depth is in excess of approximately 10 metres.

The vertical extraction wells, and other collection points should be connected by a header system to a central point, where a blower draws the gas out of the landfill under vacuum. The above grade header system should be located advantageously to the extraction wells and may need to be below grade near access roads to allow vehicular access to areas of the Site. It is normal for the header system to be located above grade where possible, to minimise construction costs. The header system could easily be extended to allow future connection to the new Area C.

Condensate should be managed to ensure that it does not block pipes and render collection points inoperative. Condensate would be intercepted by condensate traps installed at set-points in the header system, which would then discharge to the leachate drainage system.
Once the system is constructed, the recovered LFG would be piped to an open flare and treated by burning. Final options for the utilisation of LFG extracted from the site would occur once the volumes and quality of LFG are known. This would help determine the sustainability of the LFGTE project.

**Gas Utilisation**

The two primary approaches to the utilisation of LFG are firstly, direct use of the gas locally, either on-site or off-site to an existing large energy user, and secondly, generation of electricity for use on-site or distribution through the power grid. For the purposes of this study, the off-site utilisation option was considered. Once LFG volumes and quality are known, further options may be assessed. Other environmental benefits will include odour, pollution and smog reduction, as well as a reduction in ozone depleting gases (USEPA, 1995).

The Natural Gas Corporation – Bay of Plenty is the supplier of natural gas in the Rotorua area and the current business tariff varies between $9.90 and $13.25 per GJ, depending on the quantity of gas used. As a result, a LFG sales cost of $9.90 per GJ has been used in this study.

**LFG Collection System Cost**

The cost associated with installation of the LFG collection system in Areas A and B has been estimated based on the following items (Rawlinsons, 1997):

- Mobilisation/Demobilisation;
- Vertical Extraction Wells;
- Header System;
- Condensate System;
- Blower/Flare Station;
- Miscellaneous Works;
- System Start-up;
- Engineering and Permitting;
- Legal and Contract;
- Contingency.

The total estimated cost to design, construct, and start-up the initial LFG control system in a portion of Area A and in Area B at the Site is estimated to be up to $1,000,000. The additional cost for future expansion into Area C could be addressed once a significant depth in filling is reached.

**LFG Supply System Cost**

The cost associated with installation of the LFG pipeline and making modifications to existing energy utilisation equipment has been based on the following items:

- Mobilisation/Demobilisation;
- LFG Pipeline;
- Modifications to Existing Equipment;
- Miscellaneous Civil Works;
- System Start-up;
- Engineering and Permitting;
• Legal and Contracts;
• Contingency.

The total estimated cost to design, build, and start-up the LFG pipeline and commission energy utilisation equipment is estimated to be over $1,000,000.

**LFG Collection System Operating Costs**
The cost associated with operation and maintenance of the LFG collection system is an important factor to consider. It is estimated to be approximately 12.5 percent of the system capital costs.

**LFG Supply System Operating Costs**
The cost associated with operation and maintenance of the LFG pipeline is estimated to be $1.00 per GJ, and an annual budget of approximately $60,000 has been allocated for these activities.

The cost associated with specialised management and co-ordination on an annual basis is estimated to be approximately $38,000.

There are a number of other costs associated with implementing a LFGTE project, one of which is finance. This cost has been calculated at 9 percent for the purposes of this study. A further cost may be the requirement for a back-up flare or biofilter, in case the system should malfunction (MfE, 2001). This cost has not been considered for this study.

Based on these assumptions, the uniform series cash flow payback period for the project is estimated to be approximately 9.5 years at 9 percent interest.

To facilitate the project process the following stages are recommended:

Stage 1 – Enter into LFGTE Development Agreement;
Stage 2 – Obtain Memorandums of Understanding with Potential Energy Customers;
Stage 3 – Prepare LFG Recovery System and Pipeline Design;
Stage 4 – Prepare Environmental Impact Submission;
Stage 5 – Install, Start-Up, and Operate the LFG Recovery System;
Stage 6 – Install and Start-Up the LFG Pipeline/Conversion of Energy Equipment;
Stage 7 – Start Commercial Operation.

**5.0 CONCLUSIONS**
The study involved evaluating regulatory requirements performing a site review, preparing a LFG recovery projection, developing a LFGTE system concept, reviewing LFG utilisation options, and performing an economic assessment. The proposed LFG system could easily be adapted to comply with any future change in resource consent conditions.

Based on the results of the LFG recovery projection, it is estimated that approximately 899 cubic metres per hour of LFG could be recovered from the Site in 2001. The LFG recovery is estimated to peak at approximately 1,130 cubic metres per hour when the Site closes in approximately 2020. After site closure, the LFG generation rate is projected to decline and is estimated to be approximately 721 cubic metres per hour in 2030.
A staged approach is required to minimise risks associated with a LFGTE project. Under the proposed project approach the LFG collection system could be installed in the year 2001 and the LFG supply system could be operational by the beginning of the year 2002. Green Energy Limited, a private company and specialist developer of renewable energy projects, are implementing this project. Green Energy has advanced the project to the stage where resource consents for a LFGTE project have been obtained and negotiations with potential energy users are underway.

Acknowledgements
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References