Anaerobic Composting in Bioreactor Landfills

D. Augenstein* J. Benemann* and R Yazdani**

* Institute for Environmental Management, Inc (IEM) Palo Alto, CA
** Yolo County Public Works, Woodland CA

ABSTRACT

An advanced solid waste landfill bioreactor approach termed "controlled landfilling" has been operating at progressively larger scales at a California site since startup in 1994. Important accomplishments have included (a) rapid generation and capture of renewable methane energy to full potential (b) reduction of landfill methane greenhouse emissions by 50-80% compared to conventional gas collection technology. (c) substantial early waste volume reduction, with associated potentials for high-value landfill life extension and more capacity for given landfills.

INTRODUCTION

The Institute for Environmental Management, Inc. (IEM, Inc.) in collaboration with the Yolo County, California, Department of Public Works has operated an advanced landfill management strategy ("controlled landfilling") at its Central Landfill site outside Davis since 1994. Support has come from multiple sources including the California Energy Commission, the US Department of Energy's (DOE), National Energy Technology Laboratory (NETL) the California Integrated Waste Management Board, (CIWMB), Institute for Environmental Management, Inc., (IEM) and Yolo County itself. This paper presents a summary — necessarily abbreviated --of encouraging results that have been obtained since project inception.

Organic solid waste, placed in municipal landfills, decomposes over long terms. Among the consequences of decomposition are the generation of landfill gas (LFG), a mixture of methane and CO2. An example reaction of cellulosic material is

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Recovery of methane is desirable for many reasons. For both the US and world, energy potential of the methane in LFG is considerable. For the US landfill gas could provide additional methane at about a billion cubic feet per day. From environmental standpoints, landfill methane fugitive to the atmosphere is also a very substantial contributor to the "greenhouse effect" adding 3 to 8 percent to the annual increase in radiative forcing i.e. "greenhouse effect" due to buildup of all greenhouse gases in earth's atmosphere. Energy and climate are both important drivers for improving LFG recovery

Landfill gas has been recovered at large scales around the world for over three decades. Despite the importance of LFG recovery and long experience, problems remain with "conventional" practice. These include the decades-long time course of LFG generation, incomplete conversion of waste organics in many cases, and inefficiency of conventional well systems. Still other problems exist, but space is not sufficient for their discussion here.

Beginning in 1993, the IEM/Yolo County, California program has been addressing existing problems of landfill gas recovery as well as landfill management with the "Controlled Bioreactor Landfill". Methane generation and waste stabilization are accelerated via managed additions of supplemental liquids (ie gray waters, leachate, etc). Methane capture has been maximized, with methane greenhouse emissions minimized, via landfill design where porous gas recovery layers underlie surface barrier layers. (US Patent 7,198,433). Gas recovery layers maintained at slight vacuum effectively zeroing out greenhouse methane emissions conduct gas to collection. Cells have been intensively instrumented to determine performance. Key steps in the approach are

1. Fill the landfill cell to capacity rapidly. Use only permeable daily cover (no soil). Note that landfill cells were filled with "as is" waste directly off packer trucks - no size reduction or other preprocessing. No cost is incurred for waste preparation.

2. Near the top surface of the filled cell place a highly conductive gas collection layer of tire shreds, permeability estimated at > 10^6 Darcys, with a surface barrier layer atop the landfill

3. Introduce and meter liquid through multiple surface addition points slowly. Recirculate liquid leachate outflow back through the waste.

4. Apply slight vacuum (< 0.5 in w. g.) beneath geomembrane which enables capture of all gas

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and prevents essentially all gas emission to the atmosphere

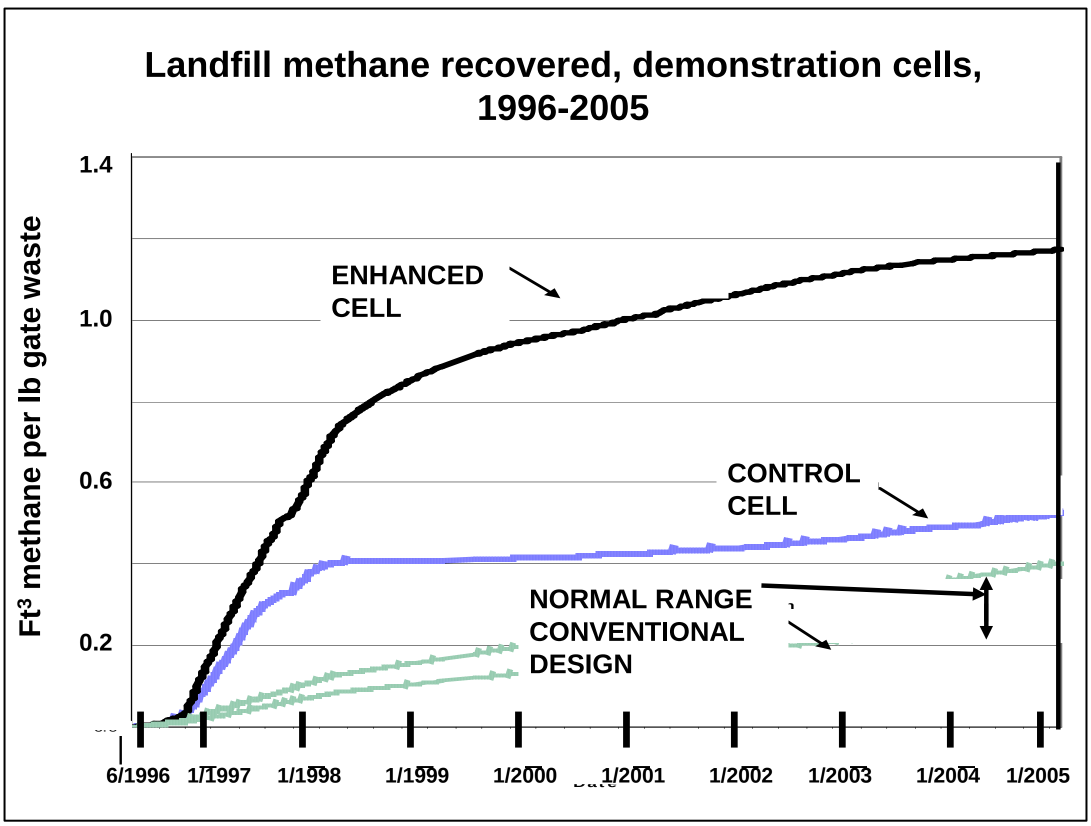
This approach has been quite successful. The following summarizes findings

Results in terms of the first demonstration cell are shown in figure 1. The greater rate and speed of gas generation over the control for the first demonstration cell is obvious from figure 1. For initial tests, the rate constant for methanogenesis has been over 0.4 $year^{-1}$, some tenfold "normal" for a waste mass of this size. Corresponding to solids' reduction to gas, there has been rapid waste volume reduction, shown in figure 2. This is a benefit that extends landfill life. Scaleup has proven quite practical; A full scale cell is shown in fig 3 (An IEM, Inc employee is shown in the figure for scale) .The controlled landfill cells at Yolo County, CA contain approximately 300,000 tons of waste. Figure 4 shows that the gas generation of all cells ranges between three and ten-fold higher than expectations for "business as usual.

The amount of methane captured can be compared with "business as usual" by taking into account (a) increased methane generation due to optimization of biological conditions, this increase being between 10-20% This increased generation is combined with an increase in capture from a "business as usual" industry level estimated at 60-85% to 90 97%. This combination of factors, along with careful control, generally increases the overall methane energy recovery by 20 to 50% compared to conventional landfill operation. At the same time greenhouse methane emissions are reduced by 50-80%, with corresponding climate benefits.

A conservative estimate carried out for the US Department of Energy shows greenhouse benefits from application of the controlled landfill bioreactor technology to 50% of US waste that equate 50 to 100 million tons CO2eq annually.. The potential for extra US energy is considerable, equivalent to about a billion cubic feet of methane daily in the form of methane in the mixed gas.

The economics and cost/benefit ratios for energy from controlled landfilling have been estimated over a range of likely scenarios of varied landfill size and operating costs. For LFG from controlled landfill operation vs. conventional, the incremental costs were compared to the incremental landfill gas recoverable. Costs (adjusted to 2008 indices) ranged from approximately 0.75 to 7.50 per Gigajoule of methane contained in mixed gas. Other economic benefits come from greater amounts of LFG are usable at greater scale, and can be recovered with greater predictability.



Enhanced decomposition reduces volume quickly, can extend landfill life.

Comparing profiles--enhanced vs. control cell

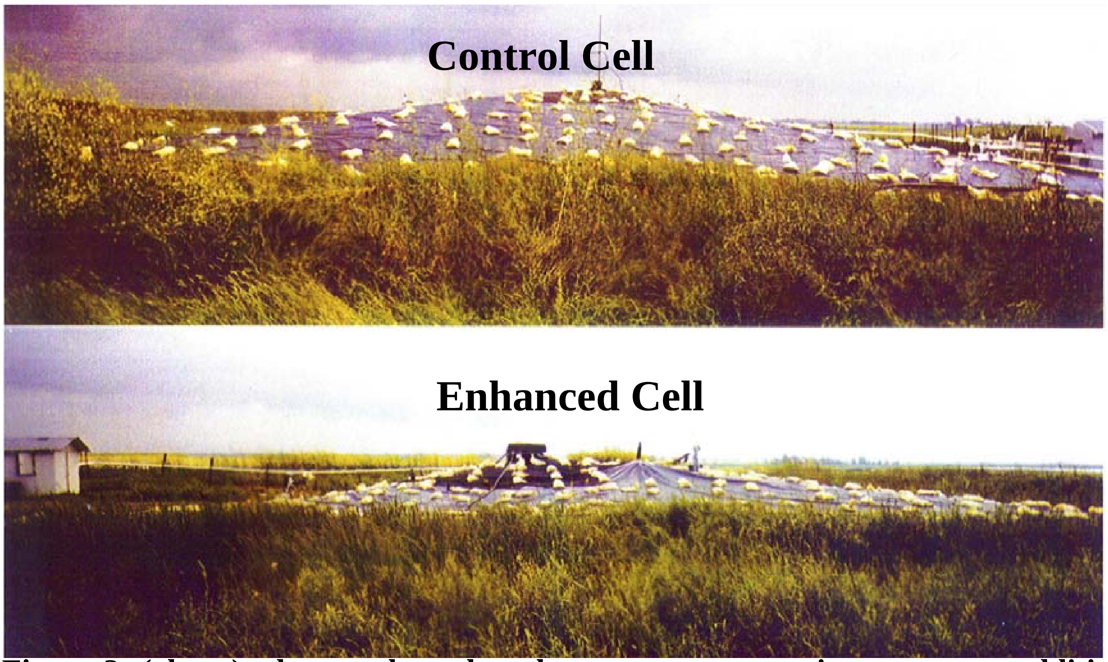


Figure 2 (above) shows volume loss due to waste conversion to gas, an additional benefit

Figure 3 (below illustrates Scaled up operations

Scaleup: Completed 3.5 Acre (Northeast) cell, 2001

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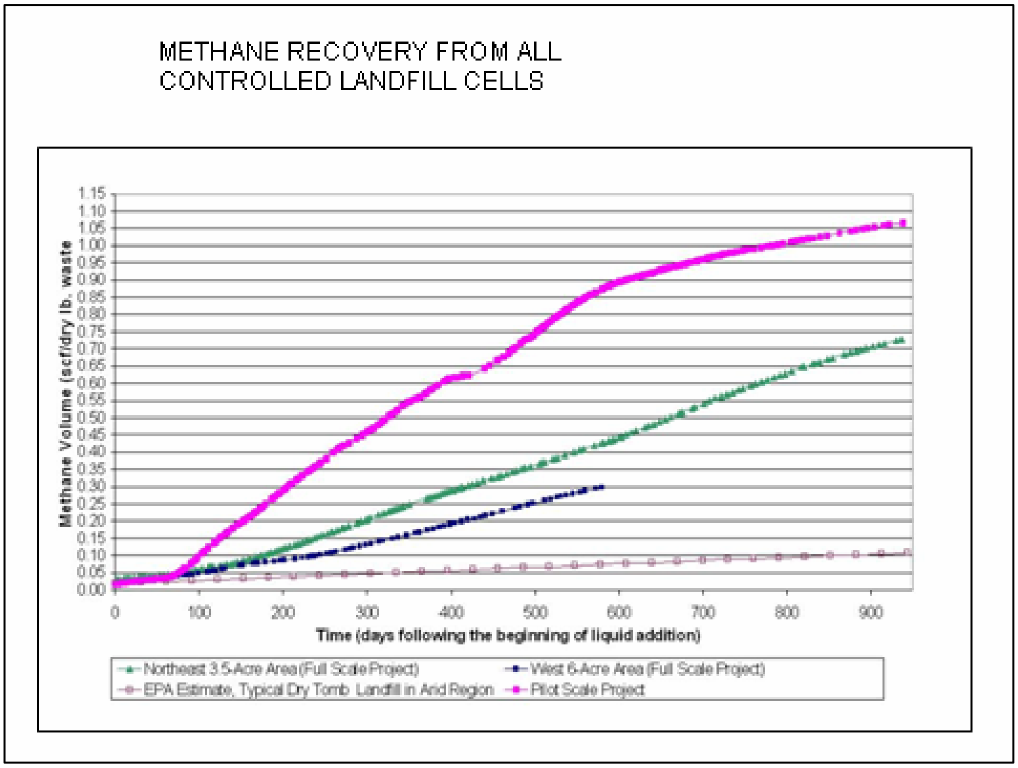

Landfill gas can be substituted with straightforward carburetor or burner adjustments, for pipeline "natural" gas in a wide variety of commercially available natural gas fueled equipment (Augenstein and Pacey, 1992) including electrical gensets. With the large amount of US landfill gas potentially marketable, and economics and benefits appearing attractive, it is not surprising that major waste companies are pursuing variants of bioreactors. And IEM, Inc., in addition to its existing and pending patents, is pursuing its own proprietary improvements.

Notwithstanding attractions of controlled landfills, one hurdle often poses an obstacle in the US. Controlled landfill permitting is difficult under typical regulation extant in the US The IEM/ Yolo Project team has benefited from over 10 years of experience permitting under California's strict regulatory standards. It has also had cooperation of State Agencies—the CA Waste Board and Energy Commission. It has had very important cooperation of the US EPA under EPA's project xL, which allows regulatory flexibility for approaches that achieve superior environmental performance. The team and sponsors consider that such superior environmental performance is being shown

Obviously, climate concerns and increasingly tight energy supplies worldwide are becoming increasingly important as drivers. The project team is pursuing applications for this controlled landfill technology both in the US and in landfills worldwide. Consistent with project objectives, a presentation link is available on the website of the World Bank, Washington, at http://siteresources.worldbank.org/INTUSWM/Resources/Angenstein_controlledlandfill.pdf

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For other information: Contact authors at the Institute for Environmental Management, Inc, email Iemdon@aol.com. Leave phone number.