SIERRA CLUB REPORT ON LANDFILL-GAS-TO-ENERGY

Prepared by the Sierra Club LFGTE Task Force
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Executive Summary

The Landfill Gas to Energy (LFGTE) Task Force was asked to evaluate whether LFGTE facilities decrease or increase net greenhouse gas (GHG) emissions. We have unanimously concluded that reliance on landfill gas to generate electricity results in increased net GHG emissions. This is clearly the case when considering the fate of new wastes that could be diverted to waste management facilities more appropriate than landfills, and is almost certainly true for wastes already buried in landfills that collect landfill gas and flare it.

Our conclusions reinforce existing Sierra Club policy that supports diversion of the organic fraction of our discards from landfills so that uncontrolled methane is not generated in the first instance. They also suggest that, in existing landfills with or without LFGTE facilities, regulations should be significantly strengthened to reduce methane emissions as much as possible.

Modern solid waste landfills generate and release significant amounts of methane, a potent contributor to global warming. When decomposable organic trash (e.g., food scraps, yard waste, and more) break down under the oxygen poor conditions in today's covered landfills, a complex mixture of combustible gases is produced. About half of that gas mixture is methane and, left undisturbed, much of it seeps out of the ground and is released to the environment over time.

More than a decade ago, the Environmental Protection Agency began requiring most larger solid waste landfills to install landfill gas collection and flaring systems, in part as a way to reduce methane emissions and their contribution to climate change. Collection and flaring of landfill gas, they reasoned, may result in some reduction in human contributions to climate change if they result in reduced fugitive releases of methane to the environment and in effective conversion of captured methane to carbon dioxide, a less potent greenhouse gas (GHG).

Enterprising landfill operators, encouraged by an EPA outreach program, are using the collected landfill gases to generate electricity and to produce additional revenue by selling that electricity to power companies. Conventional wisdom suggests that LFGTE facilities should also help to reduce global warming impacts by reducing the need to produce electricity from coal and other dirtier fuels.

Our analysis leads us to conclude that conventional wisdom is mistaken.

Findings

1) **For new wastes, disposal of decomposable organic wastes in landfills, including those with associated LFGTE facilities, clearly results in the release of substantially more greenhouse gases (and other environmental pollutants) than diversion of these wastes from land filling to other**

treatments.

When organic wastes are buried in today's landfills, methane is always produced and a substantial portion of that methane leaks into the environment.

2) **Management practices commonly employed in conjunction with LFGTE systems tend to increase fugitive methane emissions, to shift their timing toward the present (compared with standard landfill gas collection and flaring), and to reduce collection efficiency**. (See Background #5)

In particular, raising the moisture content of the landfill, the "wet cell" method, accelerates the decomposition of wastes, making room for more wastes and increasing the volume and concentration of methane produced. It also shifts methane generation forward in time, which is counterproductive to achieving the near-term reductions in GHG emissions that many scientists believe are necessary for successful control of climate change. (Some landfills that do not employ LFGTE also use the wet cell method to create space for more wastes.)

4) **Contrary to conventional wisdom, it appears the relatively small CO_2 reduction benefit that might be achieved by replacing fossil fuel electricity with LFGTE electricity is greatly outweighed by the increase in fugitive methane emissions resulting from altered landfill management practices.**

That makes LFGTE facilities counterproductive as part of a climate change mitigation strategy.[1] Because the very things necessary to reduce methane emissions from LFGTE facilities conflict with incentives to maximize revenue from the generation of electricity, it does not appear likely that landfill managers will improve practices sufficiently in the foreseeable future to result in a net GHG benefit from LFGTE. (See Background #7)

5) **While efforts to divert organic discards from landfills are developed and implemented, methane will continue to be generated from wastes that are already in place, and from future organic discards that those programs fail to divert.**

While the site is actively managed, several operational changes should immediately be made at landfills to (1) increase the amount of landfill gases that are captured, (2) avoid measures intended to augment the concentration of methane in landfill gas, and (3) cease using methods that shift overall gas generation from the future to the present unless a high percentage of that gas can be captured. (See APPENDIX B.). More research is needed on how to manage landfills to stabilize the site so that fugitive methane emissions do not continue after active maintenance ends (the "second wave", which greatly increase lifetime

[1] For LFGTE to result in any net GHG emission benefit, the management system would have to be improved dramatically so that virtually no methane or hazardous air and water pollutants escape and new monitoring methods would have to be employed to verify fugitive emission levels. Even then the amount of credit for LFGTE should be based on the net reduction of GHG emissions on a life-cycle analysis basis, taking account of the degree that fossil fuels are actually displaced by the energy from LFGTE.

emissions), That should not be at the price of significantly increasing fugitive methane emissions in the critical near term when we confront a tipping point. (Present proposals directed at the second wave are discussed further in Background #9)

6) **Current landfill regulation does not deal adequately with methane emissions or with other pollutants, including toxics that are generated in landfills and are either poorly regulated or not regulated at all.** Specific recommendations for improvements in Club policy and in federal and state landfill regulations require further exploration and should be aggressively pursued. (See Background #8)

7) **The contribution of methane emissions from landfills and other sources to global climate change has typically been underestimated.**

If mitigation strategies are to achieve the near-term large reductions necessary to prevent catastrophic climate change impacts, then curbing methane emissions is an important opportunity for near-term mitigation of those impacts and should be given a high priority. This opportunity is not fully recognized in Kyoto Protocol procedures and in most current mitigation programs. The latest Intergovernmental Panel on Climate Change's scientific report does explain the greater role of methane and indicates that globally the climate impact of current methane emissions over the next 20 years is almost as great as CO_2 emissions. (See Background #4)

Recommendations

While there remain a number of unresolved questions about LFGTE, the Task Force believes there is more than sufficient evidence for the Club to take action in the following areas:

***Recommendation No. 1* – The Sierra Club should resist legislative and policy initiatives that encourage LFGTE projects or that allow LFGTE facilities to receive credit in GHG emission reduction programs. Club policies and initiatives should be examined and revised as appropriate to be consistent with that objective.**

The Task Force recommends amendment of the *2006 Energy Resources Policy* (which currently does not address LFGTE) by adding a new subsection under "*VII. Resources for the Transition to a Clean Energy Future, E. Resources Opposed by the Sierra Club".*

***Recommendation No. 2* – The Sierra Club should continue to advocate the elimination of organic discards from landfills as a long-term solid waste management goal and as a component of our global climate change campaigns. The Sierra Club should explore and support solid waste management policies, laws, regulations, strategies and technologies that could help to facilitate that transition.**

This recommendation reinforces and expands upon the general principles in the Club's Zero Waste: Cradle-to-Cradle Principles for the 21st Century Policy of Feb. 2008. It also suggests the need for Club guidance and perhaps policy dealing with treatment methods for organics in the waste stream as alternatives to land disposal. The draft *Zero Waste Guidance on Landfills* does not deal with all of those issues and this Task Force has had only preliminary discussions of those options. .

<u>Recommendation No. 3</u> – Because separate collection and management of decomposable organic wastes is not fully achievable in the near term and does not help with wastes already in the ground, the Sierra Club should pursue improvement of landfill management regulation and practices aimed at reducing emissions of methane and other pollutants.

This is a recommendation for action and does not require a policy change. Specific recommendations for Club policies and guidance that address the most feasible and desirable ways to achieve reductions should be pursued on a priority basis. As a first step, Appendix B lists some changes in landfill regulations that would help to reduce fugitive emissions of methane.

<u>Recommendation No. 4</u> – The Sierra Club should seek to elevate the attention given to curbing methane generation and release from landfills and other sources as part of our global warming and energy campaigns.

This recommendation reaches beyond the scope of the Board's charge to this Task Force, but it is clear to us that methane emission reductions could and should be an integral part of any effective GHG emissions reduction strategy.

Appendix A – Background

There are eight underlying concepts that are necessary to understand these issues:

1. *Substantial volumes of methane are generated from the decomposable organic fraction of our buried discards*. Between half and two-thirds of our household and commercial discards are organic. Those wastes consist chiefly of yard trimmings, soiled paper and food scraps, with lesser quantities of pet waste, diapers, textiles and wood. When garbage and its organic fraction are buried and compacted in the ground and then covered, they decompose anaerobically (i.e. in oxygen-starved conditions), and methane (CH_4) is produced among the decomposition byproducts.

   A ton of wet organic material buried in a landfill is reflective of what one family might throw out in a year and will generate approximately 500 pounds of methane spread out over decades. Some fraction of that methane will escape from the landfill into the atmosphere, whether or not some of the methane is collected and burned. Those escaped landfill gases are commonly known as *fugitive* or *uncontrolled* emissions.

2. *Only a part of landfill gas is captured with collection systems in place.* In most large landfills, Environmental Protection Agency (EPA) regulations require the installation of gas collection systems after 5 years of first waste emplacement and continuing for a period of less than 30 years after closure. (See Figure 1) Because gas escapes from the top, sides and bottom of landfills, and because landfills often cover several hundred acres and are piled with wastes as much as several hundred feet deep, capturing all the gas is extremely challenging, even for the period when there is any gas collection. In addition, technology to measure fugitive emissions over a wide area has not been available. As a result, reliable representative measurements of the effectiveness of collection systems are not available and it has not been feasible to establish direct, enforceable methane emission limits.

   EPA estimates, without supporting data, that the best collection systems capture about 78% of the gases during the relatively small fraction of a landfill's emitting lifetime that they are installed and functional. But, the Intergovernmental Panel on Climate Change (IPCC) expressed the view that, over the long term, including the extensive times when there is little or no gas collection, the average fraction captured may be as low as 20%.

   The difference between these two values is due at least in part to the assumptions used to frame the estimates. The EPA's estimates are based on what they believe the best systems should achieve during the limited time that they operate. The IPCC's are based on average systems operating over the entire period that gas is generated.

   In particular, the major pathways for uncontrolled landfill gas emissions occur after the site is closed and set-aside funds for postclosure maintenance are gone. Based on studies that indicate moisture only reaches "23% to 34% of the waste mass”[1], and the fact that high moisture levels are necessary for effective decomposition, most gas will be generated after the cover fails, rainfall re-enters the site, and a second major wave of gas generation ensues without any controls. Consequently, landfills are a much greater source of greenhouse gases than EPA has acknowledged.

3. *None of the alternatives to land filling presents a significant methane problem*. In contrast to substantial methane generated by landfills, some fraction of which escapes, none of the commercial alternatives to the landfilling of organic wastes produces significant volumes of uncontrolled methane. These commercial alternatives include processing the organics by windrow (composting), open vessel aerobic decomposition, enclosed aerobic chambers, enclosed anaerobic chambers with methane collection, pyrolysis, and combustion/incineration.

4. *Methane is carbon dioxide on steroids*. The difference between releases of CH_4 (from landfills alone) and CO_2 (from almost any other alternative) holds enormous consequences for climate change. Methane emissions have at least 25 times the warming potential of CO_2 emissions when climate impacts are counted over the longer term (i.e., using the 100-year "GWP").[2] In the near term, as we confront a possible tipping point, it is arguable that methane should be counted more heavily, as much as 72 times CO_2 (using the 20-year GWP). Total methane emissions from all sources are estimated to represent about 9% of CO_2-equivalent GHG emissions in the U.S. and 14% of global GHG emissions based on the longer 100-year GWP time horizon. **But the IPCC estimates that, based on a 20-year time horizon, global methane emissions in 2000 were nearly equal to CO_2 emissions in their impact on global warming.**[3] (See Figure 2 for a graphic illustration of IPCC’s analysis of the integrated impact of global emissions.) Landfills are estimated by EPA to account for about 24% of total methane emissions in the U.S. (The Task Force suspects the actual percentage may be higher.) Landfills are a much smaller percent of total methane emissions in most of the world, especially in developing nations.[4]

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[1] Debra Reinhart, *Prediction and Measurement of Leachate Head on Landfill Liners,* Florida Center for Solid and Hazardous Waste Management (Report #98-3) (1998), at p. viii. Other data from leachate recirculating landfills suggests that even in these wet cells “efficiency of the leachate recirculation system at distributing leachate throughout the waste body in the recirculation cell were [still] low.” J.W.F. Morris, et al., *Findings from long term monitoring studies at MSW landfill facilities with leachate recirculation*, WASTE MANAGEMENT 23 (2003), at p. 653.

[2] The “Global Warming Potential” or GWP was adopted in the Kyoto Protocol as a method for comparing emissions of different greenhouse gases (GHG) by weight. It is an integrated measure of impact over a specified time period and 100 years was adopted in the Kyoto Protocol (the “100-year GWP”), although some policy analysts advocate shorter time periods for counting impacts such as 20 years—the “20-year GWP”. A ton of methane emissions has 25 times the integrated impact on global warming as a ton of CO_2 using the 100-year GWP and 72 times using the 20-year GWP.

[3] Figure 2.22, p. 206, Chap. 2, Report of Working Group I: “Physical Basis of Climate Change”, Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.

[4] Stacy C. Jackson, "Parallel Pursuit of Near-Term and Long-Term Climate Mitigation," 326 Science 526 (2009); and **Error! Main Document Only.**James Hansen, "Greenhouse gas growth rates," 101 PNAS 46 (November 16, 2004), p. 161094. For more recent information about further heightening of methane's warming potential, see, Drew T. Shindell, et al., "Improved Attribution of

5. *Changes in landfill operation linked to LFGTE increase uncontrolled methane releases.* In recent years, the landfill industry has made widespread operational changes to increase revenues from energy production but with potentially significant impacts on our climate. These unfortunate practices were never contemplated in EPA's landfill rules and have never been officially vetted for their GHG implications.

For example, many landfills with associated LFGTE facilities are recirculating leachate and adopting other management practices intended to accelerate organic waste decomposition and accelerate landfill subsidence. This is called "wet cell" operation in contrast with the traditional "dry tomb" designs. The increased moisture can result in increased methane concentrations in collected landfill gas by almost half. This operational change shifts the timing of methane generation closer to the present, when it would otherwise be spread over many decades.

Many LFGTE landfills also delay installation of the cover that keeps out rainfall and reduce negative pressure in the gas collection system as additional tactics to maintain optimum conditions for methane production. The result is landfill gas with a higher methane concentration and reduced gas collection efficiency, increasing both the volume of fugitive emissions and the methane concentration in those emissions. For citations, see footnote 4. There are alternative landfill practices that theoretically might achieve better emissions control. Potential examples include a few small publicly owned and closed landfills and a small demonstration project operated to maximize gas capture at the same time energy is generated.[5] However those methods tend to make LFGTE less profitable. Without any current way to enforce proper operation, the economic incentive on an operator would be to act in ways that wind up increasing emissions in order to restore profitability. If comprehensive and practical monitoring systems were later developed and demonstrated to reliably measure all fugitive emissions, and not just those from the surface while the unit is open, then there may be grounds for reconsideration.

6. *Landfills are responsible for significant GHG emissions*. EPA GHG emission inventories estimate landfill methane emissions at about 2% of total anthropogenic (i.e. manmade) GHG emissions in the U.S in 2005. It appears that, depending upon which assumptions are adopted (i.e. high vs. low gas collection efficiency, long vs. short term time periods for measuring impacts (GWP), and wet cell vs. dry tomb management), landfills' may be responsible for a much greater impact -- up to approximately 12% of total GHG emissions. Using the latest IPCC 20-year GWP of 72 to weight methane instead of the earlier IPCC 100-year value of 21 used by EPA will, by itself, increase the estimated percentage of GHG emissions by more than three times.

Climate Forcing Emissions, 326 Science 716 (2009).

[5] Augenstein, Don, “Landfill Operation for Carbon Sequestration and Maximum Methane Emission Control: Controlled Landfilling Demonstration Cell Performance for Carbon Sequestration, Greenhouse Gas Emission Abatement and Landfill Methane Energy”, Final Report, Institute for Environmental Management (IE M), February 26, 2000.

7. *Purported GW benefits of LFGTE are dubious.* The landfill industry contends that recovery of the methane from landfill gas for the generation of electricity will reduce net GHG emissions. The gain from LFGTE is alleged to occur because the electricity generated at the landfill offsets the need to generate power from dirtier combustion sources, thus avoiding the associated emissions of carbon dioxide and other harmful pollutants. That view is widely shared by politicians, EPA, and some environmental organizations. The Task Force is persuaded that this CO_2 benefit is greatly outweighed by an increase in fugitive (uncontrolled) methane emissions resulting from the altered landfill management methods apparently practiced at most LFGTE projects.

Because of the much greater potency of methane as discussed in Background #4 above, additional leakage (compared with conventional collection and flaring) of only a very small percentage of the methane generated is sufficient to overwhelm the relatively small CO_2 reduction from electricity production. When LFGTE is compared with non-landfill waste treatment options, the high leakage rates of all landfill management methods (at least 22% or more even by EPA's most optimistic estimates) makes the comparison much more unfavorable to LFGTE. An additional uncertainty is the source of electricity generation that is likely to be displaced by LFGTE, but the Task Force's conclusions do not depend on challenging the industry assumption that it would displace dirty fossil energy.

8. *Landfill gas emissions are a major source of un(der)regulated pollution.* In addition to the potent greenhouse gas, methane, landfill gases contain compounds that contribute to regional smog and hazardous pollutants harmful to human health. Because methods for measuring fugitive emissions over large non-point sources have not been available, setting emissions performance standards (which depend upon direct emissions measurements) at landfills has not been possible.

As a poor substitute for direct measurement, methane concentration levels at the surface of landfills are normally measured quarterly along a grid, at points about 100 feet apart, beginning after there is a final cover in place.[6] But, this test is effectively useless at landfills with low permeability covers because the greatest emissions are localized at a few tears in the cover and are not diffused uniformly across the surface. Conclusions based on these inadequate testing methods will fail to detect most gas leaks at landfills with composite covers.

Consequently, current regulations and emission inventories are unreliable and probably ineffective. Better empirical measurements are critical to achieving optimal improvements in regulation, although a number of feasible immediate improvements are described in Appendix B.[7]

Finally, regulations do not adequately address substantial emissions that occur after active management and regulation cease, as described below in #9.

9. *Landfills may emit substantial methane for decades after active management has ceased.* Some in industry advocate leachate recirculation

[6] 40 CFR §60.755(c).
[7] 40 CFR§ 98.343.

during active landfill operation as a way to reduce the levels of undigested waste in closed landfills, and thus reduce post-closure, “second wave” landfill gas generation and release. The result, however, is significantly increased fugitive methane emissions earlier in the life of the landfill and during the time when there is, as NASA has stated, an urgent need to reduce and not increase methane emissions.[8] Landfills that accept decomposable organic wastes should be required to begin gas collection sooner (perhaps within 2 years of the start of waste deposition, rather than the currently required five years), in order to better manage these early emissions.

In addition, lessening the effects of the second wave of landfill gas, without front-loading the system with near-term methane releases, is critical. More effective post-closure requirements and aggressive research and development efforts might be able to identify better methods for preventing second wave gas releases.

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8 James Hansen, *Greenhouse gas growth rates*, 101 PNAS 46 (November 16, 2004), p. 161094

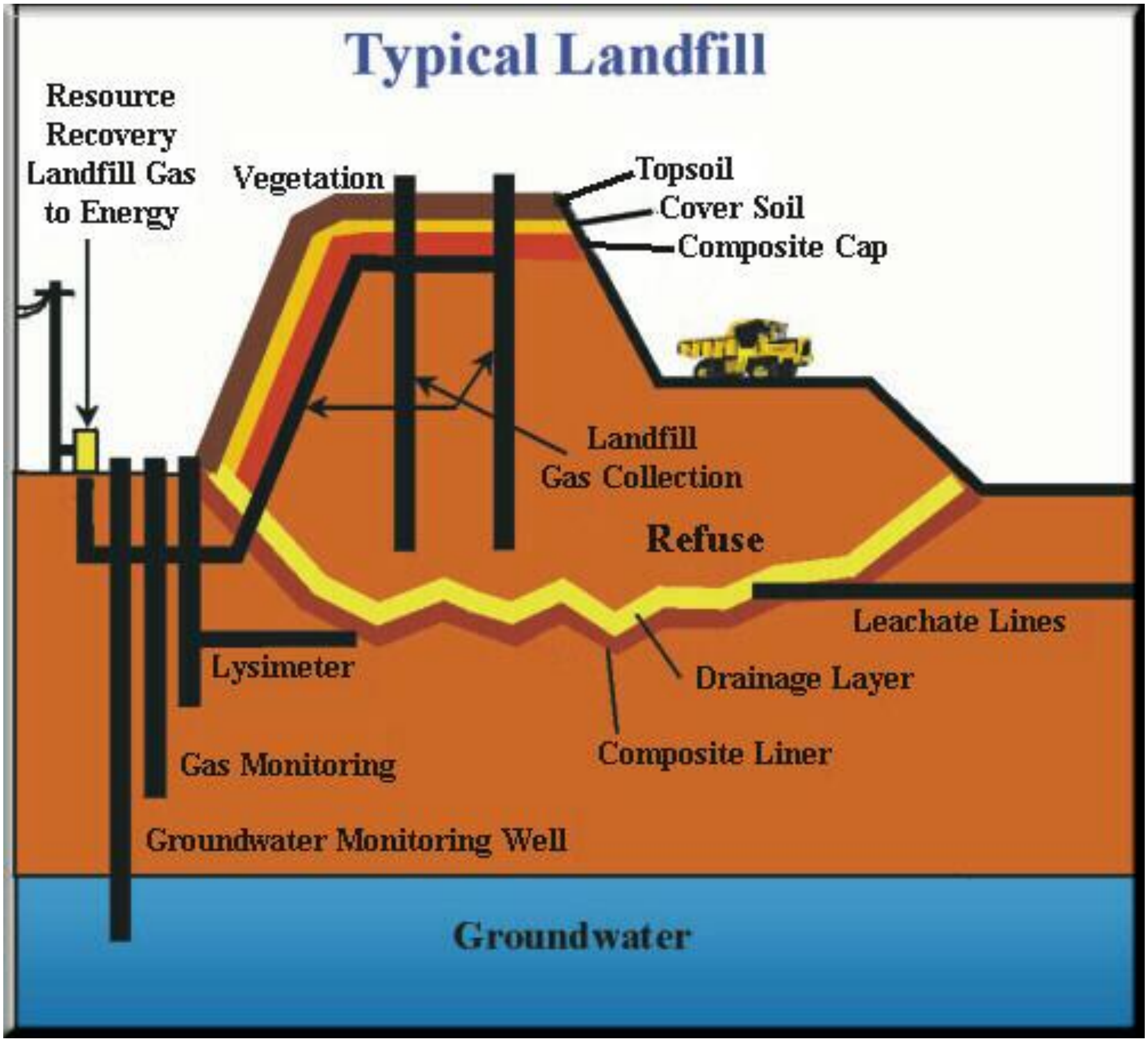

Figure 1. Profile of landfill with gas collection system. Source: **Wisconsin Department of Natural Resources.**

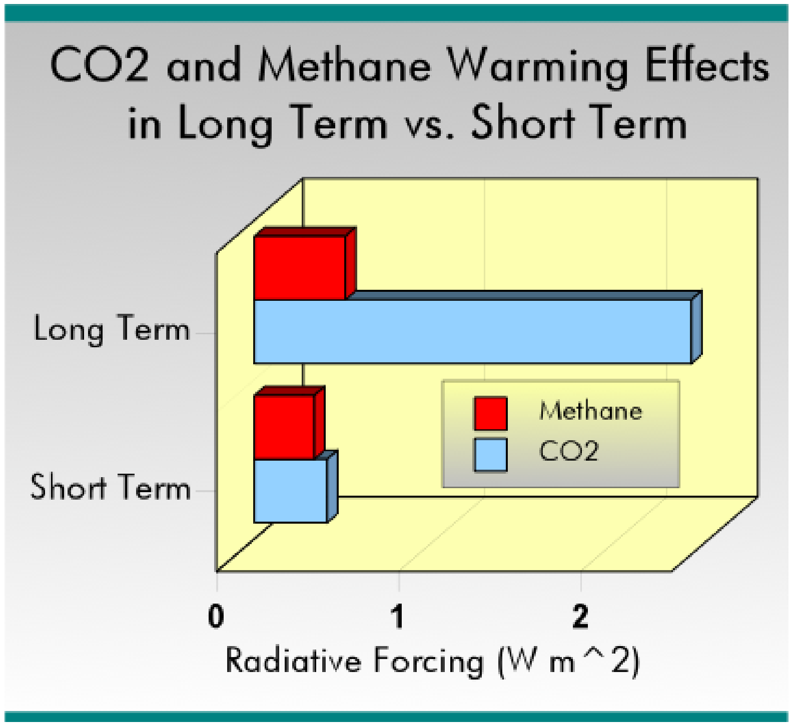

Figure 2. Integrated climate impacts of year 2000 total global emissions of $CO_2$and Methane on radiative forcing evaluated over long-term (100-year) and short-term (20-year) time horizons. "Radiative forcing" is a term used to describe the warming effect of a greenhouse gas in the atmosphere. It is the difference between the incoming radiant energy from the sun and the outgoing radiant energy in the atmosphere. Source: IPCC Fourth Assessment and Center for Competitive Waste Industry.

APPENDIX B

SOME ESSENTIAL ELEMENTS OF AN EFFECTIVE LANDFILL GAS EMISSIONS CONTROL REGULATION

Preface. The existing landfill air rule effectively leaves the detail of LF gas management design and operation to the landfill owner. Because there is no reliable system to monitor emissions, effective control of the pollutants in landfill gas requires the use of landfill management practices designed to minimize the generation and release of problem pollutants. Some of those better practices cost more to implement, and thus are often ignored.

Of course, the most effective way to avoid release of landfill gas pollutants is to divert decomposable organic wastes for responsible treatment elsewhere. As long as landfills continue to accept organic wastes, and until the organic wastes buried already are fully decomposed, landfill gas will continue to be a problem, and much better regulation of the management of landfills and landfill gas will be essential.

The Sierra Club's Landfill Gas to Energy Task Force has reviewed the technical literature, most of which is produced by the industry itself and by its consultants. The Task Force has identified those industry-recommended practices its members believe can help to improve gas collection and reduce gas emissions. They are presented here as examples of the kinds of improved practices that are supported by some in the industry and that could be viewed as a useful starting point for the development improved landfill gas regulations.

The new requirements should apply to all landfills large enough to capture gas effectively, unless a case specific showing is made that a specific requirement is not technically feasible at a particular site (independent of cost considerations), or at a separable part of that site. Before any such determination is made, adequate notice and a meaningful opportunity for public comment must be provided.

These examples are offered to assist activists and staff who are attempting to address relevant issues. They are examples based on the industry literature that highlight important regulatory and management issues, but they are not necessarily considered to be sufficient by the Sierra Club. The Sierra Club has not yet developed policy recommendations in this area, but may choose to do so in the future.

These examples are generally directed at two strategies for reducing fugitive methane emissions. The first is direct capture of more of the gases generated, and the other is reduced methane generation, especially in the near term.

INCREASED GAS CAPTURE

1. **Early Horizontal collectors.** Landfill operators should be required to install horizontal gas collectors in active waste-receiving areas with each elevation change (usually daily) prior to installation of vertical gas wells, but delay operation of the collectors unti l there is sufficient depth and cover to apply vacuum. [SCS, A-1 and A-3 (p. 4).] Horizontal collectors should be spaced to overlap each pipe's zone of influence when negative pressures are applied under conditions without a low permeability cover. Co-utilizing horizontal collectors for gas collection and liquid recirculation should be prohibited.

> <u>Background</u>. *Gas is traditionally collected with rigid vertical pipes, which are perforated, and drilled into the waste mass for most of its depth. The pipes are connected with headers and lines to a fan that pulls gas from the surrounding waste mass. However, substantial gas is released before these vertical pipes can be made functional, and flexible horizontal pipes are a means to collect some of this early gas to reduce fugitive emissions.*

2. **Vertical well density.** Landfill operators should be required to reduce the spacing of vertical wells from the current 300' to 350' apart common today to not more than 150'. [SCS, A-2 (p. 4).]

> <u>Background</u>. *The effectiveness of gas collection systems is in significant part a function of how close the gas wells are spaced: in general, the closer they are to each other, the more gas will be collected. When gas collection began in the mid 1990s, wells were commonly about 150 feet apart. In more recent years, common spacing for gas wells has spread to 300-350 feet apart. The result has been less effective gas collection.*

3. **Multiple wells in same bore holes.** Landfill operators should be required to install multiple vertical wells for different depths in the same bore hole in order to allow for distinct and optimal negative pressures at each level. [SCS, A-5, at p. 4.]

> <u>Background.</u> *Landfills can often be 300 feet deep. With increasing depths, the density of the surrounding wastes increase as well, and that means more vacuum forces are needed to pull gas from the same distance from the collection pipe. However, if the same force needed to draw gas at the lower depths were used in higher depths, air would also be drawn from the surface. When more than 5% oxygen mixes with methane in landfill gas, dangerous conditions are created, which necessitates turning down the system to avoid fires and explosions, but reducing collection effectiveness as well.*

4. **Leachate collection system to gas collection system connection.** Landfill operators should be required to connect the gas collection system to the leachate collection system at the high side on bottom of landfill. .[SCS, A-4 (p. 4).]

> <u>Background.</u> *Landfill gas follows the path of least resistance, which can be at the bottom of the landfill through the pathways created by the leachate lines and their gravel packs intended to remove leachate. Good practice is to collect gas from the leachate take outs to prevent it being released into the*

atmosphere.

5. **Multiple seals around bore holes.** Landfill operators should be required to utilize at least three sets of seals, including bentonite, clay and well bore seal, where collection wells penetrate the final composite cover in order to minimize air infiltration and maximize vacuum forces. [SCS A-6, at p. 5.] Methane leak rates around the seals at each well head should be checked at least monthly during typical atmospheric conditions and, if methane levels are significantly above background, the seals should be repaired. [40 CFR §60.755(c)]

<u>Background.</u> *Ironically, much of the gas that escapes does so through the seals around the gas collection wells. Continuing subsidence at the surface cracks the original seals, and they need continuing maintenance to prevent leakage.*

6. **Enhanced monitoring.** The procedures intended to detect leaks provided under 40 CFR 60.755(c) should be replaced with optical remote scanning (ORS) over all surface areas of the landfill, including but not limited to areas around gas collection wells and side slopes. EPA needs to develop standards for the method.

<u>Background.</u> *The existing method for assessing performance of the gas collection system is based upon checking quarterly for methane concentration levels at the surface at 100 foot intervals on a grid. This method is often called the "sniff test." Because gas escapes from landfills with a final cover primarily through tears and cracks in the plastic sheet, most leaks are probably missed. This deficiency is exacerbated when the area near well seals, where there most often are leaks, is avoided. New scanning systems are more effective at assessing methane levels across the flat, horizontal surface. It is important to improve the capability of optical systems for assessing leaks on the side slopes where more leaks occur than through the top face.*

REDUCED METHANE GENERATION

7. **Installation of vertical collectors, maximum slopes and final cover.** Each landfill cell should be designed to reach final grade in not more than two years from first waste emplacement. The active vertical collectors should be installed at that time and connected with headers to a vacuum system. Not more than one year after reaching final grade, a final low permeability cover (less than 1 H 10^{-5} cm/sec.) should be installed. If a geomembrane is used to provide a low permeability barrier, exterior side slopes should not be steeper than 4:1 to facilitate stabilization of the clay and dirt layers in a final cover over the underlying geomembrane. [Oonk, at p. 11; SCS C-1 and D-6, at p 6-7; 56 Federal Register 104, at p. 2447.]

<u>Background.</u> *Although the original proposed landfill gas management rule (1991) would have required installation of gas collection within two years, the final rule (1996) relaxed that requirement to five years in order to accommodate the industry's desire to build larger mega-fills that often*

required longer to reach final grade. This created a conflict between the goals of optimizing gas collection and optimizing the operator's financial scale efficiencies. Similarly, several states have found that the industry standard used for the steepness of the side slopes (3:1 or three horizontal units to 1 vertical) cannot be stabilized in part because the overlying dirt slides off the slippery plastic cover sheet. At least three states have required more gradual side slopes (4:1) to help stabilize the dirt cover.

8. **Delay any recirculation of leachate.** Leachate recirculation should be prohibited, at least until after an expendable low-permeability cover and active gas collection system have been installed. [Augenstein, at p. 4.]

Background. *In order to induce settling, which enables the landfill owner to resell space for disposal a second time, operators have been recirculating leachate. Increased moisture levels accelerate decomposition and increase compressive forces, but the result is also increased gas generation and higher methane concentration levels during the early period of landfill operation when gas collection either is not yet installed, or is not yet fully functional. In addition, if there is no low permeability cover, the gas collection system vacuum will pull air from the surface along with methane from the surrounding wastes. Too much oxygen infiltration results in a flammable mixture. To avoid fires, the vacuum pressures must be reduced to avoid pulling air from the surface. However, this also means that the negative pressures fail to reach horizontally as far, leaving more areas of the landfill uncontrolled.*

9. **De-water flooded vertical wells.** In addition to monitoring the composition of gas collected for oxygen and nitrogen intrusion landfill operators should be required to monitor gas volumes to detect gas wells that may be flooded, and to pump out flooded wells. [SCS A-8, at p. 5.]

Background. *Moisture in landfills, especially prior to installation of the final cover, can flood the gas collection piping, which compromises the ability to collect gas. Monitoring for reduced gas flows as an indicator of this condition, and then remedying the situation is important to a properly functioning gas collection system.*

SOURCES

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Washington, DC, (EPA/600/R-07/032), February 2007

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Appendix C - Annotated Bibliography
References and Contacts

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NOTE: Documents listed here were consulted by the Task Force during the course of its review. Listing does not constitute an endorsement of their contents or conclusions. Items marked with double asterisk (**) are available on the Clubhouse web site at: http://clubhouse.sierraclub.org/people/committees/lfgte/

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Intergovernmental Panel on Climate Change, Fourth Assessment Report, Report of Working Group I: "Physical Basis of Climate Change", Figure 2.22, p. 206, Chap. 2e, 2007. [*This referenced figure and page describes the original modeling that concluded that methane was almost as important as CO_2 in affecting climate change over a 20-year time horizon–-page and figure attached separately.]*** *Chapter 2 is available for downloading at: http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter2.pdf Full Working Group I Report is available at: http://www.ipcc.ch/ipccreports/ar4-wg1.htm*

Augenstein, Don, "Landfill Operation For Carbon Sequestration and Maximum Methane Emission Control: Controlled Landfilling Demonstration Cell Performance for Carbon Sequestration, Greenhouse Gas Emission Abatement and Landfill Methane Energy", Final Report, Institute for Environmental Management (IEM), February 26, 2000. [*This describes the Yolo County pilot project funded by DOE in detail after several of operation—see later update on continuing project below.*]**

"Yolo County, California Controlled Landfill Program: Results -- 12 Years' Operation", Don Augenstein, (presenter), Ramin Yazdani, Jeff Kieffer, Kathy Sananikone, John Benemann, Landfill Learning Session, World Bank, Washington, DC, May 8, 2006. [*This powerpoint presentation (in pdf format) is an update of results from the same Yolo County pilot project described above.*]**

"Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2006, April 15, 2008, U.S. Environmental Protection Agency. [*This annual report provides the basis for computing percentages of methane emissions and landfill gas in the U.S.; downloadable from EPA website at* www.epa.gov/climatechange/emissions/usinventoryreport.html]

IPCC, "Contribution of Working Group III to the Fourth Assessment Report: Technical Summary", 2007
[*This technical summary provides the overview of contributions of methane and waste management activities to global greenhouse gas emissions and discusses mitigation policies in general terms. More detailed discussion of landfill gas is in the following document.] Available for download at: http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-ts.pdf*

IPCC, Fourth Assessment Report, Chapter 10: Waste Management, Section 10.5.1 Reducing landfill CH4 emissions, 2007. [*This section discusses emission estimates and mitigation methods for landfill gas and provides the basis for the lower end of the capture ratio cited in the Task Force Report; IPCC reports can be downloaded from the IPCC web site.] Chapter 10 on Waste Management available for downloading at: http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter10.pdf*

"Evaluation of Fugitive Emissions Using Ground-Based Optical Remote Sensing Technology", EPA/600/R-07/032, February 2007. [*This EPA Report describes testing of* *two instruments that are the basis of a new fugitive gas monitoring method.]***

"Technologies and Management Options for Reducing Greenhouse Gas Emissions From Landfills", SCS Engineers , APRIL 2008 , California INTEGRATED WASTE MANAGEMENT BOARD *[This report is a guidance document for landfill operators of landfills and may be useful as we consider what improvements in operations should be recommended for consideration by EPA; however, we did not use this explicitly in reaching the conclusions in our report.]***

"Background Information Document for Updating AP42 Section 2.4 for Estimating Emissions from Municipal Solid Waste Landfills", Prepared by Eastern Research Group, Inc., for U.S. EPA, EPA/600/R-08-116, Sep. 2008. [*This indicates EPA's latest information on landfill emissions in preparation for planned updating of their AP-42 emission factor documents; we did not find it terribly useful in preparing the Report.]***

"Stop Trashing the Climate: Full Report", June 2008, Institute for Local Self-Reliance, by Brenda Platt, Institute for Local Self-Reliance, David Ciplet, Global Anti-Incinerator Alliance/Global Alliance for Incinerator Alternatives, Kate M. Bailey and Eric Lombardi, Eco-Cycle, available at www.stoptrashingtheclimate.org . [*Provides the environmental case for zero waste approach and against landfilling.*]

Center for a Competitive Waste Industry, Comments to the California Air Resources Board on Landfills' Responsibility for Climate Change and the Appropriate Response to those Facts (2007). Available at http://competitivewaste.org/documents/LNDFL-LFG-GHG-CA-ARB-5_000.pdf [This report provides an explanation of the issues underlying a full understanding of landfill gas generation, capture and energy recovery that is not reflected in waste industry or most EPA reports.]

Chad Leatherwood (ERG), Memorandum to Brian Guzzone, Meg Victor, U.S. Environmental Protection Agency, Re: Review of Available Data and Industry Contacts Regarding Landfill Gas Collection Efficiency, Dated November 18, 2002 *[When EPA is asked for the basis for its assumed 75% collection efficiency factor, it references this memorandum prepared for EPA by its contractor, ERG. The Task Force does not agree with the conclusions of this memo, but cites it to illustrate one of the problems.]***

SCS Engineers, Current MSW Industry Position and State-of-the-Practice on LFG Collection Efficiency, Methane Oxidation, and Carbon Sequestration in Landfills. 2007**.** **Available online at** http://competitivewaste.org/documents/LFGTE-CAIndustryWhitePaper.pdf [Waste Industry position on landfill gas presented to the California Air Resources Board]

Center for Competitive Waste Industry, Critique of SCS Engineers Report Prepared for California's Landfill Companies on Gas Collection Performance. 2008. Available online at http://competitivewaste.org/documents/LNDFL-LFG-CaptureRate-ReplytoSCS7.pdf. *[Critique of waste industry position.]*

U. S. Environmental Protection Agency Documents –

Methane Emissions in the United States: Estimates for 1990 (Report to Congress) (EPA 430-R-93-003)(1993)

Compilation of Air Pollutant Emission Factors (AP-42)(Fifth Edition 1998)

Development of Construction and Use Criteria for Sanitary Landfills (EPA530/SW-19D-73)(1973)

Draft Background Paper: Changes to the Methodology for the Inventory of Methane Emissions from Landfills (August 26, 2004)

Geosynthetic Clay Liners Used in Municipal Solid Waste Landfills (EPA 530-F-97-002)(Revised December 2001)

Greenhouse Gas Emissions from Management of Selected Materials in Municipal Solid Waste (EPA 530-R-98-013)(September 1998)

Landfill Methane Outreach Program, Creating Partnerships and Power from Landfill Gas (EPA-430-F-02-013)(2002)

"Measurement of Fugitive Emissions at Bioreactor Landfill", EPA-600/R-05/096 August 2005. [*This earlier EPA Report describes testing of the new monitoring methods at a bioreactor landfill.]**

U.S. Methane Emissions 1990-2020: Inventories, Projections, and Opportunities for Reductions (EPA 430-R-00-013)(September 1999)

Solid Waste Management And Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks (EPA530-R-02-006)(June 2002)

Turning a Liability into an Asset: A Landfill Gas-to-Energy Project Development Handbook (EPA 430-B-96-004(September 1996)

Office of Air Quality Planning and Standards and Office of Air and Radiation, *Emission Factor Documentation for AP-42, Section 2.4, Municipal Solid Waste Landfills* (Revised 1997)

[These are the primary EPA documents that reference landfill gas emissions.]

Persons Consulted

Susan Thorneloe, EPA Office of Research and Development, re: monitoring methods. *(mainly she just sent us references and did not answer direct questions.)*

Larry Bingham. He was on the original engineering team that designed the first landfill-gas-to-energy system at the Los Angeles County Sanitation District's Palo Verde landfill in 1974, and who operated LFGTE systems for many years.

OTHER ONLINE RESOURCES

http://www.epa.gov/landfill/ & http://www.epa.gov/methane/scientific.html
[*These sites may be useful for background information on landfill methane and also to*

understand how EPA is actively positioning LFGTE as a solution (hence the need for Club action on this issue).

http://www.ilsr.org/pubs/pubswtow.html & http://www.stoptrashingtheclimate.org/
The bibliography (end note) list in the Institute for Local Self Reliance report "Stop Trashing the Climate" includes hundreds of entries, many of which re-enforce the conclusions reached by the Task Force.