COMMENTS to the CALIFORNIA AIR RESOURCES BOARD on LANDFILLS' RESPONSIBILITY for ANTHROPOGENIC GREENHOUSE GASES and the APPROPRIATE RESPONSE TO THOSE FACTS

by
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INTRODUCTION

This is to provide comment to the Air Resources Board and its staff in order to correct significant misunderstandings concerning the relationship of methane gas generated in landfills to climate change. What follows summarizes our upcoming 150-page report on the subject of landfills' responsibility for anthropogenic greenhouse gas emissions, with particular reference to California.

EXECUTIVE SUMMARY

Conventional wisdom, based upon statements by the Environmental Protection Agency (EPA), assumes landfill operators capture 75% or more of the methane gas (CH_4) that is generated at their facilities. Because of that assumption of high collection efficiency, landfills have been thought to be responsible for only 2% - 3% of anthropogenic, or manmade, greenhouse gases (GHG). This comment explains why the EPA assumption is demonstrably wrong, why the best available evidence does not support a value greater than 20%, and why the appropriate remedies that follow from this correction involve more diversion rather than better landfilling. Specifically–

- There are no field measurements of the efficiency of landfill gas collection systems.
- EPA's assumed 75% gas collection efficiency has no factual basis, is based upon fundamentally incorrect definitions, and uses biased selection from unsupported, and self-serving, guesses as the basis for its assumption.
- The best evidence of typical lifetime capture rates based upon correct definitions does not support a value greater than 20%, as further attested to by the International Panel on Climate Change.
- Correcting the capture rate from 75% to 20% increases landfills' responsibility for anthropogenic greenhouse gas emissions from approximately 2%-3% to 8%-9% or more.
- Because gas collection is actually very poor, the case for diverting decomposable discards from the landfill becomes clear.

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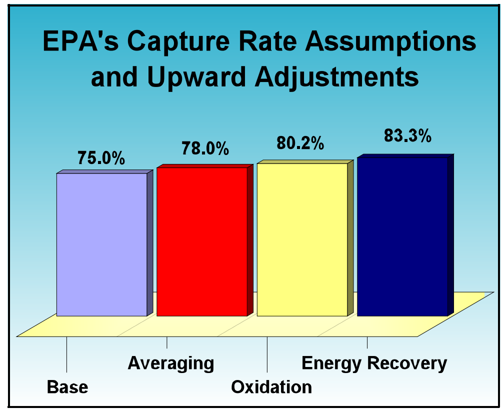
No Field Data

EPA states that landfills capture 75% of the gases generated, and then it makes several adjustments that improperly increase the value that the agency uses in calculating landfills' responsibility for GHGs to as much as 83%[1] (see CHART).



The predicate for entering this evaluation of that assumption is to understand that there is virtually no field data on the amount of fugitive gas emissions from landfills. For that reason, EPA's claims that landfills achieve high gas collection efficiencies must be recognized as essentially an arbitrary assumption without any factual basis.

On the other hand, fault does not lie with the agency for the inherent difficulty in developing any factual data on collection efficiency, for there is no smokestack or outfall in which to install devices to measure emissions. Today's mega-sized landfills occupy a space greater than 100 football stadiums, extending over hundreds of acres. Most of a modern landfill, other than a base that is set in approximately 50-foot below grade, will be in the configuration of a four-sided pyramid hundreds of feet high, dwarfing 40 Great Pyramids at Giza.

Gas that is generated inside the waste mass is not stored, and instead seeks the path of least resistance to release the resultant build up of pressure. Through ruptures in the final cover, or before the cap is installed, gas can escape directly into the atmosphere from the top and sides. Or, gas can migrate indirectly through subsurface routes, including via the landfills' own leachate collection system, and through ruptures in the bottom liner and its seals, sometimes reaching into adjoining structures through underground utility lines. These confounding conditions defy measurement, notwithstanding efforts at near infrared scanning that are being attempted.[2]

In addition to the lack of any factual support, EPA's claim has arisen out of a patently biased process that was derived from the wholly inappropriate selection of only the highest self-reporting and self-serving guesses by the private landfill industry. Inexplicably ignored were the many other low-end assumptions in technical reports and industry admissions, even when those citations were handed to the outside consultant who conducted the putative literature review.[3]

But, if the critical errors in definition discussed below are corrected, then a substantially more accurate basis for estimation can be made for landfill gas capture rates.

Definitional Errors

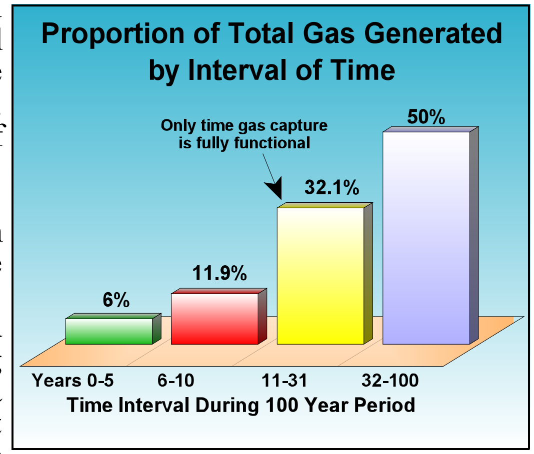
In addition to its arbitrary basis, there are also two fatal definitional errors underlying EPA's assumptions. The first error involves the time period contemplated, and the second, the use of the best case rather than the typical situation.

Lifetime, Not Point-in-Time, Efficiency Rate

EPA uses a definition about collection efficiency that is patently wrong. The 75% capture rate, is actually conceptualized as an *instantaneous* rate.[4] That is one which is only applicable for the year in which the calculation is made, and as applied, is for landfills in which the collection systems largely are installed and mostly functioning, rather than to the entire *lifetime* that landfills generate gas.

That distinction is of overriding importance because the regulations in EPA's landfill air rule do not require gas collection for the first five years of a landfill's life.[5] Moreover, recent fundamental changes in operational practices at landfills have served to both significantly increase near term gas generation while also severely worsening gas collection efficiency, as described in the note.[6]

Furthermore, those rules allow removal of the collection systems from service approximately 20 years after the site's closure. Following the post-closure period when the landfill is no longer actively managed, the barriers "will ultimately fail," as the EPA has repeatedly acknowledged. Once the barriers fail, precipitation will re-enter the landfill, and, in time, accumulating moisture will cause a second wave of decomposition and gas generation without any controls.[7]



Therefore, substantial volumes of gas will be generated in both periods before and after the time when there is no or little gas collection – all of which is ignored by an instantaneous rate. Because so much gas escapes without any or very limited controls, operators would have to capture 225% of the gas during the time gas collection is fully functional in order to achieve a lifetime rate of 75%. This is a mathematical impossibility, and it shows there is no way EPA's unsupported assumption can be considered within the realm of reasonableness once the correct definitions are used. *See* CHART above.

EPA's continued use of an instantaneous rate, in the face of repeated efforts to bring this to the attention of the agency's staff, is also incompatible with the protocols set forth by the IPCC. The international agency overseeing the rules of the road for GHG accounting specifically states that the analysis "should be based on the effects of the greenhouse gases over a 100-year time horizon."[8]

Moreover, EPA's use of an instantaneous rate for the capture rate – which makes collection efficiency seem substantially larger than it really is – is also contradicted by the agency's decision to use a 100-year time period in other GHG calculations – where the effect is to reduce landfills' responsibility for GHGs.[9]

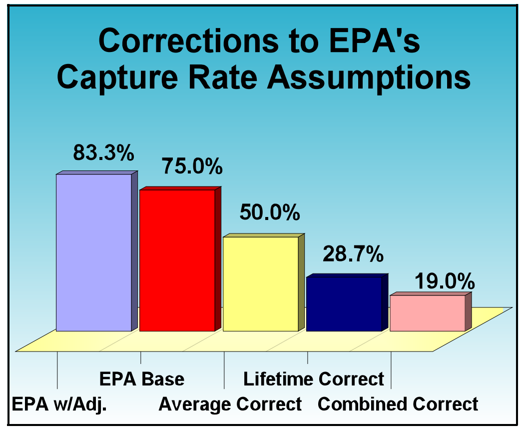
Correcting for the incorrect time frame definition – while leaving the EPA 75% value as an instantaneous rate – results in a corrected 100-year lifetime capture rate of only 28.5%. For there is no collection system for 56% of the gases landfills produce, and only a partially functional one for another 12% of the time.

Average Instead of Best Operation

EPA also used the wrong definition of the appropriate landfill population upon which to base collection efficiency. It uses a *best-case* construct to illustrate what in the real world is represented by the *average* landfill.

The Agency acknowledges that it defines its assumed collection efficiency rate to be for "well-managed sites," and what sites "should or could achieve," rather than what the weighted average of all landfills actually attains. This even though it previously acknowledged the self-evident fact that: "[t]o be useful for estimating methane emissions, the landfills in the data set must be representative of landfills generally in the U.S."

Because there is presently no way to measure landfill gas emissions, nor any emission rate or air quality standard to enforce even if there were,[10] in the real world the private sector would have little to no incentive to minimize gas emissions. The only constraint would be the palpable need to prevent subsurface migration into adjoining structures that cause explosions and to reduce offensive odors to nearby neighbors that cannot be achieved with misting or buyouts.



Nor, as discussed later, does EPA impose any specific design requirements for control systems other than it be an undefined "well-designed and well-operated gas collection system." Similarly neither have regulators prevented the new practice in the landfill industry that further reduces the effectiveness of the design and operation of typical collection systems over time.

Thus, there is little basis to contend that actual performance in the field resembles the best of what can theoretically be achieved.

No one knows what the average capture rate is for systems that are up and running. But, the weight of independent guesstimates in the technical literature are in the range of 40% to 50%.[11] If one conservatively uses an assumption of 50% for the average instantaneous rate to reflect typical conditions, that would reduce the 28.5% efficiency factor (which reflected the correction of the instantaneous 75% rate to a lifetime rate) to 19% (see CHART above).[12]

New Conventional Wisdom

There was a time when this conclusion – which puts landfill gas emissions four times greater than previously assumed – was controversial. That is no longer the case. The most recent draft solid waste report from the IPCC reflects a new consensus about the implications for capture rates once EPA's definitional flaws are recognized:

> "Some sites may have less efficient or only partial gas extraction systems, and there are fugitive emissions from landfilled waste prior to and after the implementation of active gas extraction; therefore estimates of 'lifetime' recovery efficiencies may be as low as 20%."[13]

With the adoption by the IPCC of a value essentially the same as ours when gas collection is properly defined, this once contrarian view has become the new conventional wisdom. A copy of the IPCC's final draft report, from which this quotation is extracted, is attached.

APPROPRIATE REMEDIES

Because, until now, conventional wisdom has considered EPA's assumption of a high collection efficiency rate to be correct, efforts at reducing GHGs in the U.S. have focused on recovering the energy value in that methane. In California, there has also been discussion about encouraging better gas collection practices. However, once the facts about landfill gases' very low capture rates is recognized, then the fatal shortcomings of these approaches can be understood. The more appropriate response by the European Union, which is being followed in the Bay Area, is to divert the source of the problem – the organics – from landfills in the first place.

Energy Recovery

The Congress, EPA and several states in the U.S. have actively encouraged landfill-gas-to-energy (LFGTE) as a means of reducing GHGs. This policy grew out of a belief that electricity generated at the wellhead of the gas collection systems displaces power production, and its associated emissions elsewhere, thereby turning landfills into "green energy parks."

When all of the input values are those used by EPA, 14% of the uncontrolled releases from landfills are assumed to be offset by avoided generation somewhere else. However, the presentment is wrong. There are four reasons why this facially cogent theory does not hold up upon examination.

Wrong Premise. The implicit – but unacknowledged – basis for the claim of offsetting benefits from LFGTE is that there are no alternatives to managing our wastes that do not produce significant volumes of methane. Therefore, this view continues, anything that can be done to lessen or offset the release of the methane from landfills into the atmosphere must be to the good.

However, because this premise is not correct, the wrong baseline is used for comparison. For there is no methane in our discards. Rather, only when a decision is made to dispose of organic matter in a lined landfill are the distinct oxygen starved conditions created that, alone, produce CH_4 as a byproduct of the resulting anaerobic decomposition. Otherwise, decomposition of organic material would usually occur aerobically, which is a process that does not produce significant methane.

Therefore, if landfilling decomposables were phased out, the organic material in lined landfills, which is the source of methane generation from wastes, would be largely eliminated. This is precisely the policy the European Community chose in 1999 in its Landfill Directive that ordered the phase out of organics in landfills, because it recognized they cannot be safely managed in the ground.[14]

In the U.S., a small but growing movement has developed, led by cities in California, to separate food and soiled paper at the source for composting and energy production in order to prevent organics from ever going into the landfill in the first instance. These efforts can be found concentrated in programs in the Bay Area around San Francisco, as well as in the Toronto area, and throughout the province of Nova Scotia, where the first efforts began.

The disproportionate benefit that comes from addressing climate change at its source, instead of with palliative end-of-pipe measures, can be better appreciated when it is recalled that the methane released from anaerobic decomposition in the ground has at least 23 times the warming potential as the CO_2 that is avoided – even if EPA's supporting numbers were true, which they are not. Thus, viewed from this perspective, EPA's numbers show that diverting one metric ton of organics from landfills will avoid the GHG generation of 0.273 metric tons carbon-equivalent (MTCE) of GHGs.

On the other hand, capturing the energy from that ton of waste will only avoid 0.04 MTCE, even if all of EPA's assumptions are used. That is to say, eliminating the problem at the source has at least seven times the impact – and that is only under the mathematically impossible collection efficiency guesstimates used by EPA.

Were the far lower capture rates recognized by the IPCC used, only 0.01 MTCE would be avoided. That is, keeping organics out of landfills is at least 25 times as important a factor in reducing GHGs as is landfill-gas-to-energy. Moreover, there are further corrections necessary in EPA's calculation of avoided emissions discussed below. These wind up reducing the hypothesized advantage to such a low a level that simply avoiding the landfilling of organics in the first place will be 67 times as powerful a tool to address climate change as LFGTE.

Landfill-gas-to-energy is a non-productive approach that fails to overcome the fact that, especially in a world concerned with climate change, land disposal alone, of all the other options to manage discards, creates the enormous volumes of methane that are among the most significant contributors to anthropogenic greenhouse gas emissions.

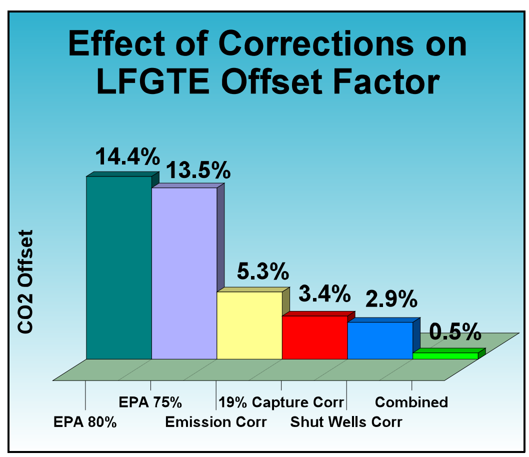
Low gas capture lowers offsets. Once low landfill gas collection efficiency is recognized, then most of the gases generated in landfills escape uncontrolled. The more GHGs that escape, the less that is actually collected and utilized for energy generation to offset production on the utility system. Ultimately, a point is passed when LFGTE no longer provides sufficient net benefits with which to soften the impact of its direct emissions, even on its own terms that use the wrong basis of comparison.

If we were to use all of the other EPA assumptions, other than correcting collection efficiency from 75% to 19%, the *net* GHG gains from avoiding emissions elsewhere would only be 3% instead of 14%. Three percent – when using all the agency's other assumptions – is a negligible advantage, even if the other estimates were correct, which they are not.

Displaced plants cleaner than LFGTE. As another example, the power plants that are displaced from the utility grid, in general, are no longer dirtier than the small generating units used at landfills. This further undermines the entire basis for the offset thesis, on top of the distinct impact of low collection efficiency.

Prior to deregulation, the more common impact when LFGTE was dispatched onto the utility system was for mostly polluting coal units to be replaced. However, for complex reasons involving changes in how power is now priced and dispatching performed, the more typical situation under deregulation is for the cleanest and advanced combined-cycle natural gas units to be displaced instead. At the same time, in practice it has turned out that almost all of the LFGTE units have been internal combustion engines (ICE), which are highly polluting machines. That is to say, today the offset factor actually results in worse air pollution in more instances.[15]

The effect of correcting for the change in regulation, and the consequent reordering of base load units that LFGTE displaces, is to decrease the amount of carbon dioxide emissions that are actually avoided. On the basis of how much CO_2 is emitted per kilowatt hour generated, the offset is reduced from 14% to 5%.[16]



When the earlier correction for lower capture rates is added to the lower estimates of avoided emissions elsewhere, the remaining offset is reduced from the original 14% to 1%.

Energy recovery landfills operated differently. As yet another example, when a landfill is operated for energy recovery, the objective of maximizing gas capture is sacrificed. This is because the generators that recover the energy from landfill gas require the gas to have a high Btu content, which cannot be met when the methane portion is not close to 50% of the gas produced in landfills. The other half of landfill gas is largely carbon dioxide with only a fifth the energy value of methane.

Continuous extraction of landfill gas can make it impossible to maintain high Btu gas. For when a vacuum is exerted to extract methane out of the waste load, significant volumes of condensed moisture — which are necessary for further methane production — get drawn out of the refuse at the same time. The surrounding field soon becomes tapped out as a source of CH_4 for producing power.

To prevent that from happening, operators throttle back on those wells where low methane ratios are recorded to give the surrounding field time to recharge. But, when gas collection around a well is damped down, more landfill gases escape uncontrolled into the atmosphere. The fact that the escaping gases may only contain 40%, instead of 50%, methane slightly reduces, but does not substantively avoid, major GHG emissions. There is no reporting of how often throttling is utilized, but anecdotal evidence suggests that about 15% of the fields at a LFGTE landfill will be turned down at any point in time. This would reduce lifetime capture rates from 19% to 16%, and equate to a loss in the offset, after combining all these corrections, to just one-half of 1% (*see* CHART above).

Improved Gas Collection

California is considering a proposal to encourage improvements in gas collection as a part of its greenhouse gas strategy. However, the realities of the regulatory environment and industry practice do not provide confidence that this will be a productive endeavor.

As noted earlier, even if there was a will to do so, there is no practical means to enforce any significant and sustained improvement in gas collection practices. For landfills are a non-point source that defy reliable measurement.[17] Neither is there any evidence of the necessary will to regulate, as the following history of landfill gas regulation shows.

Its roots began in 1969, when twenty-five soldiers were almost burned alive in the Winston-Salem National Guard Armory. Methane from an adjoining landfill migrated into the building through underground utility pipes and was ignited by someone lighting a match. Through the 1970s, across the country, hundreds more narrowly escaped death from gas explosions caused by landfills.

The cause of this problem laid in the fact that, in that period, the sites were covered with dirt and then compacted in order to reduce odors and vermin, which were the source of public complaints. But, efforts to engineer around the inherent challenges from burying biologically active and dangerous materials in the ground have persistently created whole new problems. In this case, the covers led to the very anaerobic, or oxygen starved, conditions in landfills that, for the first time, generated major volumes of methane, which can be explosive, as well as a greenhouse gas.

Also in those sites of the time, the less permeable cover on top would often make it easier for that gas to escape by migrating underground into adjoining buildings. This was something that had been widely documented as far back as 1959. Yet, for over a decade after that Armory explosion, EPA limited its reaction over the near loss of human life to studying the causes of the problem. The reports culminated not in any regulations to control gas migration, but in a recommendation, swiftly rejected by real estate interests, that restrictions be placed on siting building structures near landfills.

Not until the end of the 1980s was any serious contemplation given to the installation of the commercially available active gas collection systems. Those systems had been developed in 1974 when the Los Angeles County Sanitary District's (LACSD) Palos Verdes landfill caused an explosion at the next door Covenant Church the prior year, just a few hours before the congregation was to arrive for service. By the next year, the LASCD engineered rigid vertical pipes that were perforated so gases could be drawn out of the surrounding waste mass when the several wells were connected by headers at the surface and subjected to a vacuum.

However, the fact that these collection systems did not expand much beyond a few publicly owned landfill until more than twenty years after the Armory explosion was peculiar. It suggested that the motivation was more for reasons of self-interest, unrelated to preventing people from being killed.

A decade after the threats from gas leaks were recognized, composite liners were beginning to be required in the 1980s to reduce groundwater pollution unrelated to the gas problem. These liners consisted of 2 feet of compacted clay overlaid with a geomembrane, or a $^1/_{16}$" sheet of plastic, and were also installed on top as covers to keep out rain.[18] That sheet at the bottom was less permeable to gas transmission, and, therefore, also serendipitously succeeded, for the moment, in blocking the troubling subsurface gas migration. However, again, the gain was at the price of creating another new problem that worked to encourage the use of gas collection, because the barriers provided no ready way for major volumes of gas to be safely released as a new era of mega-sized landfills began.

With the requirement for costly engineered liners in the offing, the industry had begun to build bigger landfills in order to achieve economies of scale that could overcome the cost of those liners on a per ton basis, as well as to reduce the number of sites needing to be permitted. But, with massive size, the sheer volume of gas became too great for passive venting to relieve the pressure. Expanding gases generated in the confined wastes of megafills had no where to go, and began to bulge open the covers on top of the landfills, especially in those larger megafills with the mass to generate upwards of 200 million cubic feet of gas annually. At these lined, super-sized landfills, the cost to install active gas collection systems became less than continually repairing the caps.

By 1990, the need for gas collection systems had already begun to be internalized at major facilities in order to protect their owners' investment just as new laws required some action. In that year, the Clean Air Act Amendments (CAAA) imposed "new source performance standards" (NSPS) on new sources, including landfills, for criteria and hazardous air pollutants, not then understood to include methane. The following year, EPA issued its proposed landfill air rules, which were largely based upon the work of California's South Coast Air Quality Management District (SCAQMD) from the early 1980s, except that EPA's proposal was to apply to only large landfills.

However, the practices that South Coast had developed, while advanced in their day, had solely been intended and validated for the limited purpose of addressing the only air issue of that time, namely odors. They had nothing to do with any particular level of atmospheric methane, smog or non-methane organic compounds, which only became landfill issues later. Nor did they have anything to do with what constituted a reasonable control strategy in 1991 as global warming was recognized, nonetheless what might be needed 20 years later to dramatically reduce greenhouse gas emissions as the issue became prominent. But, at least the proposal had some enforceable standards requiring a specific design system that had to be installed within two years after wastes were deposited.

By the time the final rules came out in 1996, each of the specific design requirements in the proposed rule had been stripped from the code in response to industry objections. All that remained was an essentially meaningless and unenforceable admonition for there to be "a well-designed and well-operated gas collection system," and that, only after five rather than two years. Also, the thresholds that determined how large a landfill needed to be to be covered by the rule were raised by 40%, restricting the putative requirements to only 5% of all landfills. Essentially, the final product reduced the effect of the rules to what was becoming the industry practice anyway for the purpose of avoiding damage to the caps in the very large landfills where passive venting was inadequate. But that had no necessary relation to societal concerns about global warming.

Even worse was EPA's decision to violate a key CAAA requirements. Section 112 required far stricter standards for hazardous air pollutants (HAP), than for non-hazardous criteria pollutants. Sources that release HAPs had to employ the maximum abatement system (MACT), rather than just the typical system (BDT), because toxic emissions directly affected human health.

EPA did acknowledge that "vinyl chloride [from landfills] can adversely affect the central nervous system and has been shown to increase the risk of liver cancer in humans, while benzene is known to cause leukemia in humans [and the] degree of adverse effects to human health from exposures to these HAP can range from mild to severe." Yet, notwithstanding the CAAA's peremptory requirements, EPA did nothing about the impacts on landfills neighbors, which epidemiological studies suggested might be associated with observed higher rates of leukemia, gastroschisis and exomphotos, and, in babies, low birth weights and abdominal wall defects.[19]

When, nine years later, the agency did issue rules in 2003 that it claimed were intended to comply with the law's higher requirements for HAPs, it imposed nothing on 99% of the 2,500 or so permitted landfills. Only a few dozen new "bioreactor" landfills were ostensibly affected. Landfills operated as bioreactors deliberately flooded the waste with sewage sludge, as well as runoff and recirculated leachate, in order to more aggressively accelerate the rate of decomposition.

That moisture also dramatically increased gas generation in the early years. For these few facilities, the new rule required gas collection to begin after six months, instead of after the five years required of dry tomb landfills, because the onset of gas generation was so much sooner. On the other hand, the far larger number of landfills that do not add outside liquids, but instead follow the increasingly common practice of just recirculating leachate, also advances the onset of gas generation. Yet they were not covered by the six-month rule that only applied to bioreactors.

Had MACT procedures been followed, all landfills would have had to do things deployed at the best sites, such as double the well density, horizontal pipes with each lift and each cell capped when full. These would have achieved substantive reductions in GHGs at the same time. But, nothing like what MACT required was done.

Moreover, neither did the rule substantively require much of anything for the few bioreactor landfills that it did apply to. The same flexible horizontal tubes, which are laid down with each day's lift to inject moisture into the landfill and accelerate decomposition, could also be counted as a gas extraction system if their use was alternated between liquid injection and gas extraction. Effective gas collection under these conditions – involving co-utilization of the piping system, flexible pipes that often collapse, saturated conditions and rapid differential settlement, all without a seal on top to prevent oxygen infiltration – is impossible. Or, to use the words of bioreactor's proponents, the task is "challenging." The learned professions often use such euphemisms to describe untoward results, such as the accounting profession's characterization of offshore tax havens as "aggressive" accounting, rather than "illegal" as determined by the IRS.

In tandem with the frayed fabric of regulation, industry practice under EPA's deregulatory philosophy have continued to degrade gas collection performance. For example, the first vertical gas collection pipes in the early 1990s had been spaced about 150 feet apart. But, over time their density was reduced to approximately every 350 feet, with a concomitant reduction in coverage. This was not done because anyone had data to show that the same proportion of methane could be collected with less than half the piping, but only because, in conjunction with aggressive misting during hot and humid summer day, odor complaints could be kept within politically manageable levels.[20]

A worse example involved prolonged delays in the installation of the final cover. In practice caps were not installed at the same time as the gas collection equipment was installed, even though these covers are essential for the systems to function properly. This is because, without a seal on top, gas collection pipes will also draw oxygen from the surface, along with landfill gas from the wastes surrounding the well. If more than 5% oxygen is in the collected gas, the mixture becomes combustible, and the system must be throttled back to reduce the draw from the surface to prevent landfill fires and explosions. As mentioned earlier, in an effort to improve profitability by recovering air space, the common industry practice today is to delay the installation of the final cap for as long as possible, ten years and more, at a significant cost in dramatically reduced collection efficiency.[21]

Over the course of those twenty years before self interest forced megafill operators to capture gas, even the direct loss of human life was insufficient to motivate regulators or private industry to address this issue, other than in isolated cases, such as at publicly owned LACSD landfills. And, this prolonged period of inaction involved an issue in regard to which the problem was known and the consequences were palpably visible, and indeed fatal. That is in contrast to something like methane in its manifestation as a greenhouse gas. For methane's release from landfills into the atmosphere cannot be measured, and it produces neither smoke, odor nor fatalities that can be readily detected.

There are many inspiring success stories in the annals of regulation. This does not number among them. Reliance improved gas collection to meet California's climate change strategy is exceedingly unlikely to be met unless the entire regulatory edifice is reformed first.

The Compost Alternative

For the past nine years, the European Union, recognizing those inherent limits on controlling landfill gas emissions, has focused on removing decomposable material from the landfill. In 1999, Brussels ordered phasing out the land disposal of decomposable discards. Without the decomposition of organics under anaerobic conditions, little or no methane will be generated in the first instance.

One way to do this is by separating food scraps and soiled paper in our homes, offices and stores for composting or energy, just as we already successfully separate our bottles, cans and newspaper for recycling. A problem can be transmuted into a solution by using the nutrient value to restore fertility to depleted soils. Many cities in California have moved in this direction or are actively planning to do so, including: Alameda, Albany, Arvin, Berkeley, Castro Valley, Dixon, Dublin, Emeryville, Fremont, Gilroy, Hayward, Healdsburg, Livermore, Morgan Hill, Newark, North Hollywood, Oakland, Pleasanton, Portola Valley, San Francisco, San Juan Bautista, San Leandro, San Lorenzo, Sonoma County and Stockton. So, too, are the provinces of Ontario and Nova Scotia.

As Mr. Kenneth Newcombe, founder of the Prototype Carbon Fund, stated for the World Bank in a FOREWORD to our upcoming report on landfill gas, when he was presented with the facts showing that gas collection efficiency is extremely poor:

> "That revelation has enormous implications for policy makers, especially when we recall where all that CH_4 comes from.
>
> "For there is no methane in household or commercial garbage. Ironically, those emissions only occur when we bury our unsorted trash in lined landfills intended to isolate the waste. Although once considered state-of-the-art, not only will the barriers eventually deteriorate, threatening groundwater, but also they foster the oxygen-starved conditions in which methanogenic microbes thrive...
>
> "Simply put, in order that methane never gets generated in the first place, we should stop dumping decomposable material into landfills. Tinkering with ultimately ineffective gas collection regimens, as we are doing, is not a productive enterprise ...
>
> "As Europe recognized six years ago, safe management of organic matter in the ground is currently not feasible. For real progress to be made in alleviating the threat of global warming, those decomposable materials will need to be separated at the source so that only inert matter winds up buried. Once diverted, the grass, leaves, food and soiled paper we discard can be safely used for their value as compost to restore fertility to our land, or for producing methane to generate power.
>
> "That is the constructive path many of us in the World Bank hope to follow in creating markets for greenhouse gas emissions under the Kyoto Protocols."[22]

CONCLUSION

The first years of the 21st century have been a transcendent experience for regulators as the evidence of global warming has become palpable.

No longer are the consequences of those debilitating political compromises that cripple progress localized somewhere else. Unlike regulatory decisions of the past, in matters affecting significant greenhouse gas emissions, business-as-usual means leaving an highly uncertain world as the legacy for all our children, not just for the offspring of the powerless.

To continue ignoring the long term consequences of regulatory failures would be especially unfortunate today, because climate change has redrawn the lines that define political interests.

The imposition of a carbon cap means that each industrial sector will be required to reduce their emissions (or pay for others to do so for them) by some percentage. If one sector, like the landfill industry, is drastically undercounting its base line emissions, then it will need do little. But others, like the utility industry, will have to do that much more to compensate.

Because of AB 32, California is now largely in a zero sum game among the different sectors of its economy, and inappropriate political compromises to benefit one are at others' expense.

The sooner that this new inescapable reality can be understood, the sooner real progress can be made to achieve the law's intent. ❐

ENDNOTES

1 EPA makes three upward adjustments in its base 75% capture rate, none of which are supportable. First, the actual averaging process generates a rate of 78%. An examination of its data base and conversations with staff shows that it uses 75% as the default assumption, but accepts higher self-reports from operators when provided by those with sites exhibiting higher performance, ignoring the probability that those with worse performance are exceedingly unlikely to volunteer that fact.

Second, EPA assumes that 10% of the methane is oxidized in the overlying soil layer on top of a closed landfill. U.S.E.P.A., *Greenhouse Gas Emissions from Management of Selected Materials in Municipal Solid Waste* (EPA 530-R-98-013)(September 1998), at p. 106. Based upon a study by Czepiel, which found in field and laboratory studies during 1994 that 10% of the methane generated in a landfill was oxidized in the cover soil over the course of a year. P. M. Czepiel, et al., "Quantifying the effect of oxidation on landfill methane emissions," *Journal of Geophysical Research* (July, 20, 1996)., at p. 16,720. See, also, David Kightley, *et al*, "Capacity for Methane Oxidation in Landfill Cover Soils Measured in Laboratory-Scale Soil Microorganisms," 61 *Applied and Environmental Microbiology* 592 (February 1995). Alex de Visscher, et al, "Methane Oxidation in Simulated Landfill Cover Soil Environments," 33 Environmental Science & Technology 1854 (1999). When the gases are diffused throughout the overlying soil blanket, as would have been the case with most properly maintained clay cover landfills constructed before 1991, this study would be applicable. However, modern landfills gases are not diffused at the surface throughout that earthen layer, because, in most cases, since 1991 a composite cap has been required under that soil blanket, including in practice a 60-mil (or $^{1}/_{16}$") high density polyethylene plastic membrane that effectively impedes the passage of gases from the waste into that cover soil. This is key. It means that instead of the methane diffusing throughout the topsoil for maximum oxidizing effect, the gases that are released above the landfill not using alternative covers are concentrated in high fluxes at a handful of cracks and tears in the plastic sheet. Concentrated high flux emissions quickly overwhelm the capacity of the topsoil to oxidize the escaping methane through these hot spots. Czepiel expressly stated that not only was his study not done at a landfill with a synthetic geomembrane, but also, "[p]eriodic maintenance of the cover materials has minimized significant surface cracks" in the clay layer, as well. That is to say, nothing in his study can be used to describe what happens to the methane that flashes through a small number of hot spots on the top face of the landfill. He further reemphasized again in his conclusion that his findings did not apply when gases are released in high fluxes through narrow cracks:

> "Waste settlement, surface erosion and soil dessication often promote significant surface cracking, providing paths of minimal resistance to gas flow, effectively bypassing microbial influence. Our study generally lacked surface cracks, although his characteristic may not be representative of the entire spectrum of landfill surfaces."

Third, for landfills with energy recovery, EPA makes incorrect assumptions concerning the amount and concentration of emissions avoided elsewhere when power is generated with landfill gas, which is described later in the text at p.5

2 Stephen Piccot, "Field Assessment of a New Method for Estimating Emission Rates from Volume Sources Using Open-Path FTIR Spectroscopy," 46 *Journal of the Air & Waste Management Association* 159 (February 1996), at p. 159; Gunnar Borjesson, *Methane Fluxes from Swedish Landfills* (Swedish EPA AFR-Report 263, October 1999). Ram Hashmonay, *et al.*, "Field Evaluation of a Method for Estimating Gaseous Fluxes from Area Sources Using Open-Path Fourier Transform Infrared," 35 *Environmental Science & Technology* 2309 (2001). Bo Galle, *et al.*, "Measurements of Methane Emissions from Landfills Using a Time Correlation Tracer Method Based on FTIR Absorption Spectroscopy," 35 *Environmental Science & Technology* 21 (2001). P.M.Czepiel, "Landfill methane emissions measured by enclosure and atmospheric tracer methods," *Journal of Geophysical Research* (July 20, 1996), at p. 16,711.

3 First, EPA's internal survey refused to consider any work suggesting low collection efficiencies when the systems are operating. Proctor & Gamble's scientists did a comprehensive survey of anecdotal reports in 1999, which found that the reasonable self-reported assumed values fell largely in the 40% - 50% range. Peter White, *Integrated Solid Waste Management: A Lifecycle Inventory* (Aspen Pub. 1999), at p. 275, as did a wide range of other neutral studies referenced in note ? . These citations have been provided to EPA staff not only have the authors and other private parties, but also by its own Region 9 office, which it also ignored. EPA has not advanced its credibility by pretending that low estimates do not exist. Neither has its consultant, ICF Consulting, when it attempted to buttress the Agency's 75% assumption by claiming that it was supported by all four commenters of the Agency's original 1998 global warming report in which the 75% assumption was used for estimating landfills' contribution to global warming. ICF's Randy Reed placed special emphasis on the fact that Ms. Maria Zannes from the Integrated Waste Services Association (IWSA), the trade association for the waste-to-energy industry, also supported it. Exhumation of the peer reviewers' written comments show nothing of the kind. As concerns the ISWA comments, not only did Ms. Zannes make no comment that could be construed as supporting 75%, she said she was "*baffled* by this assumption" EPA used concerning overall capture rates. With regard to the only other non-landfill industry comments of Karen

Harrington for the Minnesota Office of Environmental Assistance (MOEA), neither did she concur in a 75% lifetime capture rate. Ms. Harrington actually supports the view that most of the gas is produced when there are no collection systems functioning after the post-closure period ends, the gas and liquid removal systems are turned off, the barriers deteriorate, water reenters the site and gas production resumes of the undecomposed fraction of the waste load.

4 Interviews with Henry Ferland, Dina Kruger and Elizabeth Scheele at U.S.E.P.A.

5 40 C.F.R. §60.755(b).

6 In the first 10 years of a landfill's life, the amount of landfill gas that is generated, and the proportion of that which is uncontrolled, is greater today than was ever contemplated under the terms of the agency's landfill rules.

As created, the rules in 1991 provided for the early use of liners and covers to isolate the wastes from moisture in a so-called "dry tomb." 40 C.F.R. §258.28. The intent was to minimize biological activity that generates leachate and gas that are difficult to manage. For the period of time that the barriers retained their integrity, these efforts minimized gas generation by minimizing moisture. Later in 1996, rules were promulgated requiring the installation of active gas capture systems after five years of the first waste emplacement. 40 C.F.R. §60.755(b). This supplemental rule was intended to collect the gas generated from moisture entrained with the incoming waste and from rainfall on the active working face, beginning in that fifth year.

However, in a more recent effort to recover air space and increase profits, over the past several years the common industry practice has reversed the rules' original intention by the deliberate addition of as much moisture as possible before covering the site in an effort to accelerate decomposition. This has been accomplished by deliberately maximizing the liquids funneled into the landfill in a number of ways. These include recirculating leachate, delaying installation of the cover so more rainfall can be captured, re-grading to maximize runoff, and sometimes injecting sewage sludge.

Effective gas collection is impossible in the rapid differential settlement that ensues. For example, often the same piping is used to inject liquids and to remove gas in order to reduce costs, but most importantly, the essential seal on top of the landfill to prevent oxygen infiltration into the gas collection system is delayed by as much as ten years and possibly longer.

Landfill regulators have yet to address the profound implications for global warming of the deliberate decision to shift methane generation from decades' hence to the present, and at a time and under conditions when gas collection is ineffective. At the same as the basis for the current rules rely upon so-called dry tomb principles, EPA has, under the false pretext of allowing for limited research and testing, effectively allowed the industry to unilaterally convert over to an entirely different wet cell basis without consideration of the cumulative impacts.

7 53 FEDERAL REGISTER. 168, at pp. 33344-33345 (August 30, 1988). 46 FEDERAL REGISTER 11128-11129 (February 5, 1981). Similar: "A liner is a barrier technology that prevents or greatly restricts migration of liquids into the ground. No liner, however, can keep all liquids out of the ground for all time. Eventually liners will either degrade, tear, or crack and will allow liquids to migrate out of the unit. Some have argued that liners are devices that provide a perpetual seal against any migration from a waste management unit. EPA has concluded that the more reasonable assumption, based on what is known about the pressures placed on liners over time, is that any liner will begin to leak eventually." FEDERAL REGISTER (July 26, 1982), at pp. 32284-32285.

8 International Panel on Climate Change, *Second Assessment - Climate Change 1995* (1995).

9 In calculating greenhouse gas emissions, the different types of warming gases are converted into a carbon dioxide-equivalent basis for ease of comparison. To do this, the fact that methane breaks down in the atmosphere over a shorter interval than CO_2 must be accounted for. EPA uses a 100 year time to recognize CO_2's longer residence time than CH_4. If instead, EPA consistently used a single year as the time period for calculation, the multiplier to convert CH_4 to a CO_2-equivalent basis would be more than *twenty times* the 23× conversion factor that EPA currently uses in estimating landfills' GHG responsibility. EPA's use of diametrically opposite time periods for comparison, applied improbably in a way that consistently minimizes landfills' responsibility for GHGs, is not easily explained on a rational basis.

10 The only actual test for landfill air emissions uses a protocol that statistically is unable to detect significant leaks, and, in any event, has no relation to minimizing methane emissions as opposed to offensive odors to neighbors.

11 See, *e.g.,* Peter White, *Integrated Solid Waste Management: A Lifecycle Inventory* (Aspen Pub. 1999), at p. 275. See, also, European Commission, *A Study on the Economic Valuation of Environmental Externalities from Landfill Disposal and Incineration of Waste* - FINAL APPENDIX REPORT (October 2000), at p. 144; and Ofira Ayalon, *et al.*,

"Solid Waste Treatment as a High-Priority and Low Cost Alternative for Greenhouse Gas Mitigation," 27 *Environmental Management* 5 (May 2001), at p. 699, TABLE 1.

12 The mathematics for these calculations are as follows. To correct the 75% assumed instantaneous capture rate to a lifetime rate, more than 60% of the gases generated occur either before or after effective gas collection systems are operating, with at least one half of the potential gas emissions after the systems may be removed from service, and, when using the EPA First Order Decay model, 6% before the pipes are required to be installed. From year 5 to about year 10 when final covers may be installed, there will be ineffective collection about 12% of the time, during which capture efficiency, at best, might be half of what normally might be achieved.

Calculation: 0.75 * (1 - 0.60) = 0.28.5

To correct the assumption of what the best operator might achieve instead of what actual operators do achieve inasmuch as there are no measurements taken of violations that could lead to enforcement, 50% is used.

Calculation: 0.285 * [(1- 0.75- 0.50)/0.75] = 0.19.

13 IPCC Final Draft Chapter 10, at p. 22, lines 23-25. A copy of the full chapter is attached.

14 The European Community also reached this conclusion based on the further fact that the entire theory of lined landfills is fatally flawed in that all manmade barriers will, as EPA has recognized as well, "ultimately fail." This means we have only postponed, not prevented, groundwater pollution.

15 Prior to deregulation, when the utility dispatcher purchased base load electricity from an Independent Power Producer, such as a LFGTE generator, he or she would have displaced an equivalent quantity of power from the utility's most operationally expensive base load plant. That would often be old, inefficient, and expensive to operate, coal plants. EPA uses the composite emissions profile for all fossil plants in 1996 to calculate LFGTE's offsetting effects. At the time, that was a reasonable proxy.

Since 1996, however, there have been two major changes that upend the original assumptions. First, a significant part of U.S. base load capacity now comes from cleaner natural gas, instead of more polluting coal, and much of that from very efficient units. Second, the wholesale utility markets have been largely deregulated, moving dispatching to Independent System Operators, who purchase power in a spot market from utility and non-utility independent power producers.

While many of the dirtiest old coal plants have been largely depreciated so that they can be bid on their operating costs alone, the newer ones will not, and therefore will need to be priced based upon both their capital and operating costs. The effect, increasingly, is to displace these more efficient gas units that exhibit very low emissions.

On the other hand, 90.2% of installed LFGTE capacity is polluting internal combustion engines (ICE), burning landfill gas, which is significantly dirtier than pipeline natural gas.

16 The 2,010 pounds of CO_2/MWH assumed in EPA's estimates would be reduced to 790 lbs. CO_2/MWH. LFGTE's generators, incidently, emit 2,040 lbs. CO_2/MWH, but that is generally considered to be part of the carbon cycle, which does not add new CO_2 into the atmosphere.

17 There is one putative standard in the air rule that is intended to limit concentrations of methane at the surface to 500 ppm, the so-called "sniff test." 40 C.F.R. §60.753(d) and §60.755(c). But, first, the sniff test was developed by the South Coast Air Quality Management District in the early 1980s because methane was believed to be a precursor of odor complaints by neighbors, and at levels greater than 500 ppm, odor complaints were noted. But, there is no relationship whatever between 500 ppm and what needs to be done to truly minimize GHG emissions from landfills to meet the demands of a coherent global warming strategy. Second, this test is predicated upon a regimen that only works if emissions are diffused across the entire face of the landfill, which is longer the case at Subtitle D landfills. Most of them have low permeable geomembranes that limit most releases to a few localized tears in the liners. Using a Poisson Distribution, the statistical probability of detecting 10 leaks at a landfill is 2.3974227905e-38, and that is even if the test could not be gamed, which it can and is.

18 40 C.F.R. §258.40(a)(2)(b), for the liner, and 40 C.F.R. §258.60(a)(1), for the cover (which strictly speaking does not directly require a composite liner, if a bottom liner is approved with less barrier performance). Also, alternative covers are authorized as part of Research, Development and Demonstration permits, 40 C.F.R. 258.4(b).

[19] State of New York Department of Health, *Investigation of Cancer Incidence and Residence Near 38 Landfills With Soil Gas Migration Conditions, New York State, 1980-1989* (1998); Paul Elliot, "Risk of adverse birth outcomes in populations living near landfill sites," 323 *British Medical Journal* 363 (Aug. 2001); 56 FEDERAL REGISTER 24472 (May 3, 1991).

[20] Note that the common practice by private industry of reducing collection performance was not followed by many in the public sector, many of whose landfills continued to use narrow spacing.

[21] This inappropriate operating practice has been further encouraged because, following promulgation of EPA's first national landfill standards in 1991, experience showed that the final covers contemplated in the code did not work. The very geomembrane, which was found necessary to reduce infiltration, exhibited too slippery a surface to stabilize the overlying soil layer. As a result, there are very few large landfills today that have capped any of their completed cells because there is no known way to properly do so.

[22] Center for a Competitive Waste Industry, *from Beneath the Ground: Gas from Landfills Threaten to Overheat the Earth* (upcoming Fall 2007).