LANDFILLING OF WASTE
(September 17, 2013)

I. INTRODUCTION

The primary focus of this paper is to identify opportunities, challenges, and potential solutions to achieve greenhouse gas (GHG) and co-pollutant reductions from landfills. The sections that follow, describe the waste disposal and GHG emission trends for landfills in California, applicable regulations affecting landfills, California's GHG and waste reduction targets, the challenges in meeting and exceeding these targets, and what actions need to be taken to meet these challenges. This paper is one of several papers being prepared to provide information critical to the discussion about the role that the Waste Sector can and should play in meeting the goals of Assembly Bill (AB) 32.

II. GENERAL DESCRIPTION OF LANDFILLS IN CALIFORNIA

How many landfills are there and how much waste do they hold?

There are about 370 landfills in California which due to their waste-in-place or permitted volume, waste age, and other pertinent factors have the potential to emit significant quantities of methane. Methane is a GHG with a global warming potential of about 21[1] times that of carbon dioxide. About 220 of the 370 are likely to be subject to ARB's Landfill Methane Control Measure (Landfill Measure), an AB 32 discrete early action measure adopted in 2009. The remaining landfills are likely to be exempted because they: never accepted or ceased accepting municipal solid waste (MSW) prior to January 1, 1977, have waste-in-place that is below the 450,000 ton threshold, or are hazardous waste sites. Approximately 1.2 billion tons of solid waste have accumulated in the State's landfills with an additional 30 million tons being added each year (ARB, 2009; CalRecycle, 2013).

What are the greenhouse gas emissions from landfills?

MSW landfills are the second largest anthropogenic source of methane in California (ARB, 2009b). The organic portion of solid waste disposed in MSW landfills decomposes to form landfill gas. Landfill gas contains approximately between 40 to 60 percent methane, 40 to 60 percent carbon dioxide, and trace amounts of non-methane organic compounds (NMOCs).

Depending upon the assumptions (collection efficiency, waste type, oxidation potential, etc.) and models used, fugitive emissions of methane from MSW landfills represent about one[1] percent of the statewide GHG inventory. If not captured, combusted, or treated in controlled systems, landfill gas can either be released into the atmosphere as fugitive emissions or migrate underground to cause groundwater contamination, cause explosive hazardous conditions in structures and utilities, or adversely impact nearby agricultural crops.

[1] The global warming potential for methane is in the process of being updated. Once updated, the fugitive emissions of methane from MSW landfills may represent one to two percent of the statewide GHG inventory.

III. CURRENT STATUS OF LANDFILLS AND WASTE DISPOSAL TRENDS

How much and what type of materials are disposed of by landfilling?

About 37 million tons of MSW were disposed in California's landfills in 2010. The 37 million tons include disposal-related activities including: alternative daily cover, alternative intermediate cover, and beneficial reuse at California landfills; material combusted at the three MSW mass burn facilities; and tire derived fuel. The estimated composition of waste currently disposed is presented in Table 1.

Table 1. Composition of Currently Landfilled Solid Waste in California[1]

Material[2]	MM Tons[3]	Percentage of Solid Waste
Paper	5.4	15%
Glass	0.5	1.4%
Metal	1.5	4.0%
Plastics	3.0	8.2%
Food	4.8	13%
Green	4.0	10.9%
Lumber	4.4	12%
Other Organics	3.5	9.5%
Other Inerts	6.3	17%
Household Hazardous Waste	0.09	0.3%
Special Waste	2.2	6.0%
Electronics	0.17	0.5%
Mixed Residue	0.93	2.5%
Total	**37[4]**	**100%**

1. Source: CalRecycle (2013).
2. Definitions of material types are available at: http://www.calrecycle.ca.gov/wastechar/MatDefs.htm
3. Includes disposal related activities (ADC, AIC, and beneficial use), material combusted at MSW mass burn facilities; and tire derived fuel.
4. Numbers may not total exactly due to rounding.

What are the landfill disposal rates and trends?

- California residents generated a twenty-year average of 10.7 lbs/person/day of disposed materials from 1990 through 2010 (CalRecycle, 2012).

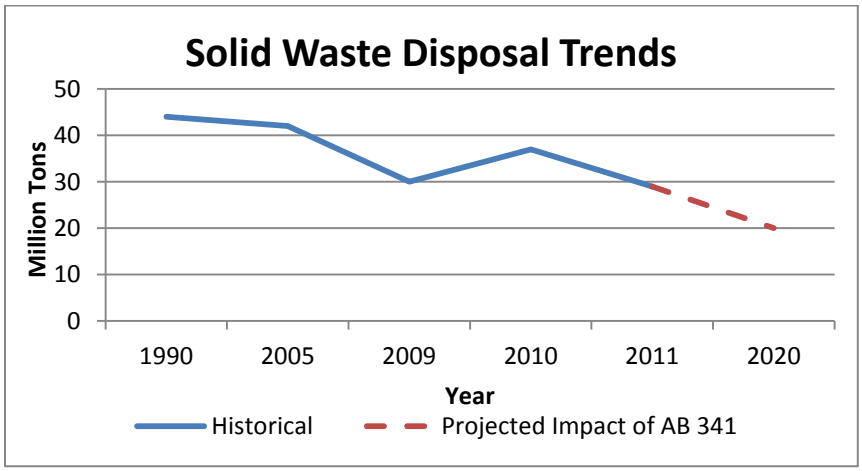
- Approximately 30.4 million tons of MSW were disposed in California's landfills in 2010, and another 5.8 million tons of waste materials were used in disposal-related activities at landfills including alternative daily and intermediate cover, and other beneficial reuse (as defined by Title 27 California Code of Regulations, section 20686), and as fuel (waste tires and solid waste residuals).

- About 0.9 million tons were burned (transformed) at three permitted MSW mass burn facilities in California. Provisions in the Public Resources Code, sections 40201 and 41783 allow limited diversion credit for transformation.

- Almost all (99 percent) of the California-created solid waste that is not recycled or diverted from waste disposal is landfilled in California. It is estimated that there is a potential of about 1.5 to 3 billion tons of landfill capacity available statewide should all permitted capacity be built and utilized. According to the American Society of Civil Engineers, California has sufficient landfill capacity through 2037. However, there may be some localized or regional landfill capacity issues. Should the 75 percent recycling goal be reached, the localized capacity issues will diminish and the overall state capacity will be extended.

- There has been an overall decline in waste disposal by landfilling over time. The decrease in tonnage is primarily related to both increased recycling efforts (e.g., AB 939 discussed is Section IV.) and the economic downturn. This trend is shown below in Figure 1. It includes material disposed in landfills, used in disposal related activities, material combusted at MSW mass burn facilities and tire derived fuel. With medium growth projections, landfill disposal is estimated to increase to 43 million tons in 2020. If the 75 percent recycling goal is met, disposal would decrease to approximately 21 million tons of material disposed in landfills in 2020.

Figure 1. Waste Disposal Trends in California



1. Data from 2010 forward includes both disposal and disposal-related trends.

How much greenhouse gas emissions do landfills emit?

ARB staff estimates that landfills in California emitted approximately 6.72 MMTCO2e in 2010. Based on 2006 data, GHG emissions from MSW landfills were estimated to be about 6.3 MMTCO2e in 1990. In 2000, the GHG emission level dropped to 5.8 MMTCO2e. However, landfill methane emissions are extremely difficult to estimate and are subject to substantial uncertainty. Recent limited direct measurement studies and computer modeling (CALMIM) indicate that landfill methane emissions may be higher than previously estimated (CalRecycle, July 2012). However, additional work is needed to evaluate the results of these limited studies and determine if it is appropriate to modify existing or develop new models to more accurately estimate landfill methane emissions.

During the time period 1990 to 2008, several landfill gas control measures were adopted [e.g., ARB's suggested control measure for landfill gas emissions (1990), local air district landfill gas rules, and federal new source and hazardous air pollutant standards] to reduce landfill gas emissions. Although these measures targeted primarily NMOCs and volatile organic compounds (VOCs), they had the added benefit of reducing GHG emissions such as methane. In 2009, ARB adopted the Landfill Measure to reduce methane emissions from landfills by 1.5 MMTCO2e per year.

How can GHG and co-pollutant emission be reduced at landfills?

The GHGs and co-pollutant emissions from landfills are reduced in two ways; either by capturing landfill gas or by reducing organics going into landfills. Landfill gas can be controlled by installing and operating an active gas collection and control system. The captured gas is then routed to a control device where it is combusted with or without energy recovery. The gas can also be sent to a pretreatment unit where it is processed and used as a product or shipped offsite for further processing or use. Optimizing gas collection efficiency is dependent on landfill design, operation and maintenance of the gas collection system, and closure/post-closure practices. Reducing the amount of organic materials going to landfills will help reduce future methane emissions. This is particularly true of materials that tend to decompose rapidly such as green waste and food waste.

What is the current status of emissions control at landfills?

Due to federal and local landfill gas rules, most of the approximate 220 landfills subject to the Landfill Measure have landfill gas collection and control systems. About 20 of the 220 have submitted plans to upgrade their existing gas collection and control systems to meet the requirements of ARB's Landfill Measure. Also, because of age and/or older technology, additional existing gas collection and control systems could be upgraded to maximize system efficiencies. We anticipate that about 14 landfills without gas collection systems will be required to install gas collection and control systems or demonstrate that their emissions are too low to support such a system.

IV. GOALS FOR REDUCING GHG EMISSIONS FROM LANDFILLS

A. Legislation and Regulations

Two key pieces of legislation – AB 32 and AB 341 – provide the framework for reducing GHG emissions from the Waste Sector and meeting California's waste reduction goals. AB 32 established a goal of reducing GHG emissions to 1990 levels by 2020 and then further reducing

GHG emissions 80 percent below the 1990 levels by 2050. The 2008 AB 32 Scoping Plan initiated the process of identifying opportunities to achieve GHG emission reductions from the Waste Sector. Control of landfill methane emissions was identified as an early action measure. The 2008 Scoping Plan also identified the need for mandatory commercial recycling and other programs for developing and implementing alternatives to landfilling.

The ARB Landfill Measure (adopted in 2009 and effective June 17, 2010) imposes landfill gas collection and control system requirements (new systems for landfills without systems meeting thresholds and higher standards for existing systems) to reduce methane emissions from landfills. The implementation and enforcement of the Landfill Measure is expected to result in a GHG emission reduction of 1.5 MMTCO2e, which exceeds the established goal of 1.0 MMTCO2E presented in the 2008 AB 32 Scoping Plan and would represent a 20 percent reduction in landfill methane emissions compared to the 1990 levels. Larger MSW landfills are also subject to the federal New Source Performance Standards and Emission Guidelines (implemented by local air districts) to reduce NMOC, VOC and methane emissions.

AB 341 established a goal of 75 percent reduction in waste through recycling, composting, and other waste reduction efforts by 2020. To achieve this goal, about 22 million tons per year of solid waste would need to be shifted to non-landfilling alternatives by 2020. Preliminary analysis using one model (ARB's Landfill Emissions Tool) indicates that an additional 0.61 to 0.74 MMTCO2e reduction in 2020 and 3.8 to 5.5 MMTCO2e in 2050 is possible if the AB 341 policy goal is met.[2] Using other models and/or assumptions will generate different results. However, in all cases diverting organic waste from landfilling will reduce methane generation and subsequent emissions from landfills.

Shifting material from landfills and using this material as feedstock in recycling and remanufacturing will also achieve significant upstream GHG emission reductions. Re-introducing recyclables with intrinsic energy value back into the manufacturing process reduces GHG emissions from multiple phases of product production including extraction of raw materials, preprocessing, and manufacturing. To the extent that recycling/remanufacturing occur in California, it would further support AB 32 goals of creating jobs in California and reducing our reliance on export markets to handle waste.

A key component in implementing the 75 percent goal in AB 341 is CalRecycle's Mandatory Commercial Recycling regulation which became effective May 7, 2012. The Mandatory Commercial Recycling regulation builds on the existing AB 939 residential recycling framework. The goal of AB 939 was to require each city or county to divert 50 percent of all solid waste by January 1, 2000, through source reduction, recycling, and composting activities. The Mandatory Commercial Recycling regulation establishes a statewide mandatory commercial recycling program which requires that business and multifamily residential dwellings (of five units or more) that generate four cubic yards or more of commercial solid waste per week to arrange for recycling services.

Two recently enacted bills, AB 1900 and AB 2196, may impact the use of landfill gas. AB 1900 (Gatto, Statutes of 2012) requires the California Public Utilities Commission (CPUC) to develop standards for constituents in biogas to protect human health and pipeline integrity and safety. In support of the CPUC standards development efforts, the Office of Environmental Health Hazard Assessment (OEHHA) and ARB, in consultation with other State agencies, are to undertake

[2] The estimated emissions reductions are based on results from the ARB Landfill Emissions Tool using CalRecycle estimated disposal tonnages through 2050. Scenarios evaluated a baseline with no increased recycling, a scenario meeting the 75 percent recycling goal by 2020, and a scenario meeting the 2020 75 percent recycling goal with significant reductions in the organic fraction of the landfilled waste stream.

certain actions. Specifically, OEHHA is tasked with compiling a list of constituents of concern found in biogas that could pose a health risk and that are at levels that significantly exceed the concentrations of those constituents in natural gas. OEHHA is also to determine health protective levels for these constituents, after considering potential health impacts and risks. ARB is tasked with developing realistic exposure scenarios and identifying the associated health risk to utility workers and end users; determining the concentrations of these constituents in biogas necessary to protect public health; and identifying monitoring, testing, reporting, and recordkeeping requirements necessary to ensure that health protective levels are maintained. ARB and OEHHA submitted their recommendation to the CPUC on May 15, 2013. The CPUC is to adopt a final regulation by December 31, 2013.

The Statutes of 2012 impose certain requirements for eligibility of biomethane under the Renewable Portfolio Standards (RPS) program. It establishes minimum electricity targets for electrical corporations in their annual procurement updates to procure electricity from landfill gas. Moreover, the legislation requires the adoption of policies to promote in-state development of biomethane from wastewater treatment facilities and dairy farms.

B. Permitting and Regulation of Landfills

Before a landfill begins operation, landfill operators/owners are required to obtain permits and satisfy regulations pertaining to landfills. For example, landfills are required to obtain local Land Use Approvals from local planning (land use) agencies; State Solid Waste Facility Permits which are typically issued by Local Enforcement Agencies operating under CalRecycle regulatory oversight; waste discharge requirements (WDRs) from the appropriate Regional Water Quality Control Board; and air quality permits from local air districts. Furthermore, landfill operators need to meet hazardous waste requirements from the Department of Toxic Substances Control for Class I landfills, which are exempted from ARB's early action Landfill Measure.

V. CHALLENGES TO MEETING GOALS

A. Short-Term

The challenges to further reduce GHG emissions from landfills and solid waste going into landfills are both short-term and long-term. The following provides a brief discussion of the short-term challenges.

Uncertainly in Landfill Emissions

Landfills are complex sources of methane (GHG) emissions. Depending upon site specific conditions, methane may be released for decades (and potentially centuries) after material is placed into the landfill. Current law also allows (pending several conditions being met) for decommissioning of gas systems before all the waste has been completely degraded.[3] Given the scale and scope of landfills and the variability in landfill sites, accurately predicting methane emissions from landfills with a high degree of certainty is difficult. Additional research is needed

[3] ARB's landfill methane control measure only permits gas collection and control equipment removal after 15 years provided surface emissions standards are consistently being met. In some cases, landfills may be required to submit additional data supporting a request for equipment removal. In addition CalRecycle regulations require the landfill operator to demonstrate that subsurface migration of landfill gas above regulatory standards will not occur before the gas control equipment may be removed.

to improve both direct measurement and model estimation techniques of landfill methane emissions.

Regulatory Actions and Interagency Collaboration

Implementation of "Best Management Practices" (BMPs) for landfills may provide even greater reductions of GHG emissions from landfills. Such actions may include: specific requirements for gas collection system design, construction, timing, and operation; landfill unit and cell design and construction; waste placement methods; daily and intermediate cover materials and practices; use of compost or other biologically active materials in cover soils; phased closure or early landfill closure; and management of organic materials via composting or anaerobic digestion.

The feasibility of a more stringent surface methane emissions limit should be evaluated. The Landfill Measure establishes an instantaneous surface methane emission limit of 500 parts per million by volume (ppmv). ARB staff had initially proposed a more stringent instantaneous surface methane standard of 200 ppmv; however, stakeholders expressed the concern that this may cause potential subsurface fires to occur due to overdraw on their gas collection systems. ARB staff will be evaluating data collected via required regulatory reporting on all instantaneous readings of 200 ppmv and greater to determine if a more stringent limit can be met.

Promote the Beneficial Use of Landfill Gas

Most of the landfill gas captured in the State is done so without energy recovery or the gas being used as a product. Local air district rules and emission offsets requirements along with expensive pretreatment costs to remove impurities from landfill gas may be factors in limiting or making some landfill gas-to-energy (LFGTE) projects unfeasible. Furthermore, most landfills are typically located in remote areas and not close to pipelines making it difficult to inject the gas (after proper processing) directly into a common carrier pipeline. These issues need to be addressed in order to further promote the beneficial use of landfill gas.

Landfill gas from existing waste in place may provide a viable source of liquefied natural gas (LNG) or compressed natural gas (CNG) vehicle fuel with carbon benefits under ARB's Low Carbon Fuel Standard. Landfill gas from existing waste in place is also being evaluated along with anaerobic digester gas for potential treatment and use in California as renewable high Btu to inject in natural gas pipelines.

A consequence of diverting organics from landfills would be a decline in future methane generation (beyond that already anticipated from existing waste in place). While this may negatively impact the economic viability (and capital investments by public and private parties) of both existing and potential landfill gas to energy projects, reducing the amount of organic waste being landfilled would also result in significant GHG emission reductions. Furthermore, these same organic materials could instead be used in composting and anaerobic digestion activities.

Greater Diversion of Readily Recyclable Materials

Achieving additional reductions in GHG emissions from landfills will require greater removal of recyclables, compostable, and digestible materials. To assist in prioritizing actions additional emission reduction factors need to be developed and some of the existing factor need to be updated.

B. Long-Term

Identified long-term challenges in effectively meeting, implementing, and exceeding the requirements and goals that are in place, and therefore reduce GHG emissions and solid waste going into landfills, are summarized here:

Further Evaluate Landfill Gas Collection Efficiencies for California Landfills

Data on landfill gas collection efficiency is limited and further research is needed. However, measuring uncontrolled landfill gas emissions is problematic because the emissions vary over space and time making it very difficult to accurately quantify emissions. Landfill gas generation rates are highly variable due to several site specific factors including: rainfall, landfill temperature, waste composition, age of the waste, and other factors. The impact on gas collection efficiencies from implementation of the Landfill Measure should also be evaluated.

Improved Emissions Inventory Data

More complete California-specific data on landfill gas collection and composition will help improve emission estimates from the model used by ARB staff. Better information on the cover types present at landfills and further details on gas collection systems will allow for better collection and oxidation factor estimates.

Landfill methane emissions are extremely difficult to characterize and subject to substantial uncertainty. Recent limited direct measurement studies and modeling methods (CALMIM) indicate that landfill methane emissions may be higher than previously thought (CalRecycle July 2012 Report on Landfill Avoided Emissions and WtE). Additional resources/research would be needed to improve landfill methane estimations techniques (both direct measurement and modeling).

Markets

More markets and more stable markets for recycled, reprocessed, or remanufactured goods are needed within California to achieve our GHG emissions and waste reduction goals. To obtain future reductions of GHG emissions from landfills, recyclables must be shifted from landfills. This will require markets for compost and recycled materials. While the State can utilize its purchasing power to increase demand for compost and recycled materials, additional incentives are needed. Compared to landfilling, these environmentally beneficial alternatives are more expensive. The prevalence of less expensive landfilling makes composting and anaerobic digestion economically marginal industries, even though they create jobs and beneficial products, and reduce emissions.

To further reduce landfill emissions from landfills that utilize flares for methane destruction from existing in-place waste, markets for produced electricity and landfill gas energy products would need to be developed to assist in shifting to energy producing projects that would possibly replace fossil fuels. Markets will be needed to purchase the electricity produced by LFGTE projects and/or other uses, such as landfill gas being used as a product (e.g., LNG, CNG, pipeline quality gas), or for shipment offsite for use in energy production.

VI. Potential Solutions for Meeting Goals

Some potential solutions for overcoming the challenges to further reduce GHG emissions and solid waste going into landfills are summarized here:

A. Short-Term

Uncertainly in Landfill Emissions

The Landfill Measure requires the collection of data on an annual basis that will be used to improve estimation of GHG emissions from existing waste in landfills. This information will be provided to emissions inventory staff to further update the landfill inventory.

Although reducing organics disposal into landfills will produce the greatest GHG emissions reductions, to quantify these GHG emissions reductions, new and updated emission reduction factors will need to be developed, especially with respect to avoided methane emission for organics shifted to non-landfill alternatives. For example, an emission reduction factor for carpet is needed.

Regulatory Actions and Interagency Collaboration ("Phase II")

ARB staff will review its early action Landfill Measure and CalRecycle regulations and work with CalRecycle staff to investigate what regulatory actions can be taken to further reduce GHG emissions at landfills. These actions may include incorporating the BMPs identified under the short-term goals section of this report into the Landfill Measure. Additionally, ARB staff has collected approximately two years of surface methane emissions monitoring data from MSW landfills pursuant to the Landfill Measure. ARB staff will analyze the data to determine if the analysis indicates whether a 200 ppm instantaneous surface methane standard is feasible and does not result in potential adverse impact(s) on landfills and their control systems.

CalRecycle staff continues collaboration with ARB, OEHHA, California Energy Commission, and the CPUC in implementing AB 1900 and AB 2196 to maximize the safe and economically viable recovery of solid waste-related bioenergy resources.

Promote the Beneficial Use of Landfill Gas

Special incentives, such as tax breaks or grants, may encourage landfill owners/operators to switch from installing inexpensive flares to more costly LFGTE systems. Landfills located close to pipelines should be identified and the feasibility of using their gas for injection into pipelines evaluated.

To incentivize and negate profitability issues, it would be helpful to have incentive payments and/or grant programs for projects that would reduce waste to landfills and also reduce GHG and co-pollutants emissions.

However, incentives for LFGTE systems may have an unintended consequence of promoting landfilling of organic waste in lieu of moving organics to composting, anaerobic digestion, and other non-landfilling alternatives and impacting the 75 percent recycling goal.

Greater Diversion of Readily Recyclable Materials

It would be helpful to increase markets for compost and remanufactured products and accelerate the deployment of anaerobic digestion projects. This may be accomplished via incentives or requirements for the targeted increased procurement by state agencies.

Consider ARB regulations requiring phasing organics out of landfills and moving toward inert only landfilling practices.

Consider whether landfills should be included in the Cap-and-Trade.

B. Long-Term

Further Research

- Research to improve our understanding on landfill gas collection efficiencies should be solicited in order to evaluate "typical" collection efficiencies at landfills within California. The impact on collection efficiencies for these landfills resulting from implementation of the Landfill Measure should be further evaluated.

- Research on the technologies needed, as well as education, to provide the needed education and outreach of contamination free feedstock for the processes.

- Develop contract concept(s) and funding source for statewide characterization of landfill methane emissions by best available direct measurement methods and validation of Inventory models.

- Research and demonstration projects for methane capture equipment(s) and technology to convert it to commercial LNG are needed.