Comments on:
Short-Lived Climate Pollutant Reduction Strategy
California ARB
May 2015 Concept Paper

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Comments will focus on landfill CH_4 emissions in the context of the alternative waste management strategies for California emphasized in this concept paper. In addition, selected alternative strategies will also be briefly addressed.

I applaud the broader discussion contained in this paper with regard to waste management strategies. Communities can support a variety of reduce, reuse, composting, anaerobic digestion, and other waste management strategies to reduce the mass of landfilled organic waste with the potential to generate and emit CH_4. All of the landfilling alternatives have advantages, disadvantages, regional unit costs, & infrastructure constraints (e.g., transport, pre-processing) which need to carefully evaluated by California communities in the context of current and future state regulatory guidance and rules. I am also a realist: back-up landfill capacity will continue to be required in California during the next decades. This has been the lesson of the European Community "Landfill Directive" to divert organic waste from landfills over the last 20 years--a number of European countries continue to have large percentages of waste going to landfill.

The first comments below specifically address the current California inventory numbers for landfill CH_4 emissions from specific sites. It is important to note that the current numbers have significant shortcomings based on outdated science.

Briefly, the IPCC (2006) methodology** used for the California landfill CH_4 emissions inventory:
1) was never directly field-validated for emissions. Rather, modeled CH_4 generation using a first order kinetic model was compared to CH_4 recovered from engineered landfill gas extraction systems, mainly in the 1990's at 9 Dutch landfills.

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Intergovernmental Panel on Climate Change (IPCC). 2006. IPCC guidelines for national greenhouse gas inventories. Available at www.ipcc-nggip.iges.or.jp/public/2006gl/index.html (verified 1 Mar. 2011). IPCC/IGES, Hayama, Japan.

2) predated the majority of field measurements for actual CH_4 emissions now in the refereed literature.
3) does not include the major drivers for landfill CH_4 emissions now known from literature.
Those drivers are: a) the thickness, composition, and surface area of the various cover materials; b) the direct physical effect of engineered gas recovery on emissions; and c) seasonal climate effects on both gaseous transport and microbial CH_4 oxidation in landfill cover materials.

During 2007-2010, with support from the California Energy Commission PIER [Public Interest Energy Research] Program, we developed and field-validated an improved inventory methodology for landfill CH_4 emissions from specific California sites. This methodology is CALMIM, for **CA**lifornia **L**andfill **M**ethane **I**nventory **M**ethodology, which consists of a 1-D JAVA tool in which bidirectional diffusive CH_4 and O_2 transport are modeled in user-described landfill cover soils at any California landfill. The oxidation of CH_4 in any cover soil is scaled to maximum rates for 10-min. time-steps and 2.5 cm depth increments over a typical annual cycle. The model has 0.5 deg. latitude/longitude reliability based on embedded USDA (U.S. Dept. of Agriculture) climate models with global validation [air temperature, precipitation, surface energy balance, soil moisture & temperature]. The CALMIM model, currently v. 5.4, is user-friendly for inventory applications and freely available at www.ars.usda.gov.

Our results were summarized in the following journal articles:

Spokas, K., Bogner J., and Chanton, J., A Process-Based Inventory Model for Landfill CH_4 Emissions Inclusive of Soil Microclimate and Seasonal Methane Oxidation, J. Geophysical Research-Biogeosciences, 116: paper G04017, 19 p. (2011). Contains a detailed description of the CALMIM model and field validation for California.

Bogner, J., Spokas, K., and Chanton, J., Seasonal Greenhouse Gas Emissions (methane, carbon dioxide, nitrous oxide) from Engineered Landfills: Daily, Intermediate, and Final California Landfill Cover Soils, J. Environ. Quality 40:1010-1020 (2011). Describes in additional detail the seasonal CH_4 [& N_2O, CO_2] emissions from the various cover materials at northern and southern California landfill sites, including intensive monitoring at 2 sites and more limited monitoring at 5 additional sites.

Spokas, K., and Bogner, J., Limits and dynamics of methane oxidation in landfill cover soils, Waste Management 31:823-832 (2011). Describes extensive laboratory studies of CH_4 oxidation rates in California landfill cover soils over the full dynamic range of expected soil moistures and temperatures, providing the framework for modeling oxidation inclusive of seasonal climate within the CALMIM model.

During 2011-2014, a followup project “International field validation of a site-specific process-based model for landfill methane emissions” was funded by the Environmental Research and Education Foundation (EREF). As with the previous project, this was a collaboration between UIC and Dr. Kurt Spokas, U.S. Dept. of Agriculture, ARS (Agricultural Research Service), St. Paul, Minnesota, as well as research groups in the U.S., Australia, Africa, Europe, and Asia. In this project, an improved (v. 5.4) CALMIM model was field validated at 29 sites in Europe, Asia, Africa, N & S America, and Australia. In addition, we modeled expected latitudinal gradients for emissions as well as future emissions inclusive of oxidation under selected climate change scenarios. The final report is publically available at the following link:
http://erefdn.org/index.php/grants/fundedresearchinfo/international_field_validation_of_a_new_ipcc_model_for_landfill_methane_emi/.

The following journal articles address specific aspects of this work, and additional journal articles are in preparation:

Cambaliza, M.O., Shepson, P.B., Bogner, J., Daulton, D., Stirm, B., Sweeney, C., Montzka, S., Gurney, K., Spokas, K., Salmon, O., Lavoie, T., Hendricks, A., Mays, K., Turnbull, J., Miller, B., Lauvaux, T., Davis, K., Karion, A., Moser, B., Miller, C., Obermeyer, C., Whetstone, J., Prasad, K., Crosson, E., Miles, N., and Richardson, S., Quantification and Source Apportionment of the Methane Emission Flux from the City of Indianapolis, Elementa: Science of the Anthropocene, 3:000037, doi: 10.12952 (2015). A major conclusion was that one landfill accounted for approximately 30% of total Indianapolis CH_4 emissions. As part of the analysis, please note that CALMIM modeled emissions were compared to measured emissions using an aircraft mass balance technique at 5 Indiana landfill sites.

Spokas, K., Bogner, J., Corcoran, M., and Walker, S. From California Dreaming to California Data: Challenging Historic Models for Landfill CH_4 emissions, Elementa: Science of the Anthropocene. accepted May 2015.
We used new California state data for 129 full-scale landfills [from CalRecycle, 2012] to refute the historic reliance of CH_4 generation and recovery on a first order model with kinetic constants related to climate (e.g., IPCC, 2006). Rather, a statistically-significant steady rate of CH_4 generation and recovery is derived based solely on a robust linear relationship to the mass of waste at specific sites…& independent of waste age, site status (open/closed), regional climate, or regional waste composition. In addition, we re-do the 2010 California inventory for landfill CH_4 emissions from specific sites using CALMIM. Results indicate large variations for specific sites when compared with 2010 California inventory estimates for landfill CH_4 using the prescribed IPCC (2006) “mathematically exact” methodology. These are due, in large part, to the significant climate influence on microbial CH_4 oxidation in the various cover soils at specific sites.

Importantly, the sites with the highest emissions shift from the sites containing the largest mass of waste to sites with large areas of thinner intermediate cover and low seasonal oxidation (i.e., too hot, too dry).

We would also suggest that the research work & California data cited above be consulted with respect to statements within the concept document which advocate for improved understanding of landfill CH_4 emissions and increased landfill gas capture by engineered systems, e.g.,

p. 16 top of page:
"In addition to identifying current research efforts underway to advance the understanding of sources and emissions of SLCPs in California, the Strategy will explore potential reporting methods and requirements that could improve understanding of SLCP emissions and impacts in California. This may include **activities to improve understanding of methane emissions from** natural gas and oil supplied to California, dairy operations, **landfills**, as well as various sources of F-gas and black carbon emissions."

p. 17 middle of page:
"Methane is the principal component of natural gas and is also produced biologically under anaerobic conditions in ruminant animals, landfills and waste handling. Since methane emissions come from many sources, including complex biological processes, it can be difficult to measure emissions from major sources. Coordinated research efforts between ARB and the California Energy Commission to refine emission estimates have led to the development of the only subnational methane monitoring network in the world. In addition, researchers at ARB and at NASA's Jet Propulsion Laboratory are currently collaborating to identify large "hot spot" methane sources in the San Joaquin Valley. This research will aid in future control and regulatory plans to reduce GHG emissions in California. The Strategy will catalog ongoing **research efforts related to methane emission detection** and highlight **remaining research gaps**."

Additional comments are given below, after cited sections of the concept document, e.g.,

p. 18:
"As California continues to rely on natural gas for a large fraction of its energy supply, it is critical to increase supplies of renewable natural gas and minimize fugitive emissions of methane from natural gas infrastructure. **Renewable natural gas can be captured at landfills**, wastewater treatment plants, commercial food waste facilities, agricultural operations, or other sources, treated, and used as a renewable energy source to displace fossil fuel consumption."

Comment: Based on data supplied by CalRecycle (2012), approximately 90% of the waste in place in currently-permitted California landfills has engineered gas extraction and recovery. Thus, an extraordinarily high rate of engineered recovery already exists. It is also important to point out that the economic feasibility of upgrading recovered landfill gas (biogas containing CH_4 and CO_2 with numerous trace components) to a renewable natural gas is highly dependent on the market price of natural gas, which can experience large short-term fluctuations.

p. 19-20, selected sentences:
"*Effectively Eliminate Disposal of Organic Materials at Landfills."*
"Organic waste constitutes more than one-third of California's waste stream. Food waste alone accounts for about five million tons of landfilled organics each year. Efforts to divert organics from landfills, and to develop an organics infrastructure that makes best use of the material, are a key element of integrated strategies to increase production and access to renewable energy, reduce air pollution, improve agricultural soil health, and reduce GHG emissions from a broad array of sources throughout California."
"California has clear goals to reduce waste, and to divert organic material from landfills and put it to beneficial use. The State has a target to reduce landfilling of solid waste by 75 percent in 2020 through the use of recycling, composting, and source reduction."
"Additionally, the 2014 Scoping Plan Update called for eliminating disposal of organic materials at landfills, which has the potential to virtually eliminate methane emissions from landfills over time, once existing organic "waste-in-place" has decomposed. The Legislature has taken steps to increase organics diversion from landfills, through AB 1826 (Chesbro, Chapter 727, Statutes of 2014) and AB 1594 (Williams, Chapter 719, Statutes of 2014). This legislation represents important steps forward."
"Building on this foundation, the Strategy will explore additional measures to accelerate organics diversion and GHG emission reductions to meet an initial goal of diverting 75 percent of organics from landfills through source reduction and organics recycling by 2020. This amounts to a 50 percent additional reduction from current levels, and is in line with existing goals set forth in AB 341 (Chesbro, Chapter 476, Statutes of 2011). Further, the Strategy will consider measures to meet a goal of diverting 90 percent of organics from landfills through source reduction and organics recycling by 2025 (80 percent reduction from current levels). Achieving these levels of diversion would effectively eliminate the disposal of organic materials in landfills in California, as called for in the Scoping Plan Update, by the middle of the next decade."

Comment: These are ambitious goals. I would advise examination of various country-specific European strategies to achieve reductions in organic waste to landfills under the EU Landfill Directive mentioned above. To give just one example, the widespread implementation of MBT (mechanical and biological "pre" treatment) in some countries to significantly reduce the organic C content of waste prior to landfilling was expensive, could generate significant offsite odors, and did not eliminate the potential for downstream CH_4 generation and emissions. However, the resulting CH_4 generation rate was not sufficiently large to justify installation of an engineered landfill gas recovery system. In addition, it is important to note that incineration of waste, typically with energy recovery, increased significantly in various EU countries in order to comply with the Landfill Directive. Finally, our recent work discussed above indicates that older landfills can continue to produce landfill gas at a relatively steady rate [relative to the mass of waste] even after several decades. Hence, the assumed reductions based on current models (e.g., IPCC, 2006) may not materialize.

Finally, I want to briefly address the suggestion that organic waste can be directly diverted to existing anaerobic digesters at wastewater treatment plants, e.g., p. 22:

"Wastewater treatment plants are used to treat or reclaim sewage or liquid waste streams from residential, commercial and industrial sources. These plants represent a relatively small amount of California's methane inventory (four percent). Most wastewater treatment plants already use anaerobic digestion in their processing, and many have large amounts of spare capacity to potentially take in new sources of waste. As such, wastewater treatment presents a tremendous opportunity to divert organics from landfills and utilize them for producing energy and soil amendments. Many of the treatment plants are located fairly close to population centers and could utilize potentially significant amounts of food and other organic waste streams that come from cities and towns."

Comment: I would suggest that the authors review existing literature to assess the technical and economic feasibility of the direct diversion of untreated organic waste from landfills to existing anaerobic digesters at WWTP's. The following need to be taken into consideration: organic waste substrates with diverse chemical and physical properties that cannot simply be exchanged for the current biosolids substrate; diverse choices for more appropriate AD processes for individual source-separated waste substrates; choices for process scales with scale-specific economics; process material & energy balances; transport options & costs to centralized digesters; process pre-treatment and post-treatment needs; use &/or disposal of biosolids.