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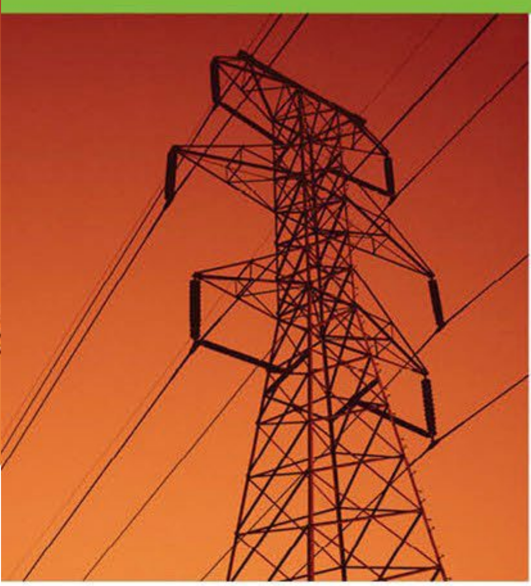
Updated California Landfill Capture Rate Determination

January 27, 2022



Anaergia Services, LLC
705 Palomar Airport Rd, Suite 200
Carlsbad, CA 92011 USA

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Executive Summary

We strongly encourage the California Air Resources Board (ARB) to incorporate new methodologies to update the default landfill collection efficiency rate utilized in its Tier 1 Simplified LCFS Calculator. Using the latest scientifically-based, site-specific landfill gas emissions measurement data, we have determined that a more accurate landfill capture efficiency to be **34%**. This capture rate was established by accounting for methane emissions measured directly from point-sources at landfills within California, and estimating total methane produced in landfills utilizing ARB's landfill GHG Inventory Waste-In-Place (WIP) methodology.

Climate change is a grave threat to our environment and economy. California has set an ambitious climate strategy to achieve carbon neutrality by 2045 and has tasked ARB with establishing a plan to help the state to achieve this goal. In ARB's latest scenarios for its 2022 Scoping Plan Update, it has set a target to "Divert 75% of organic waste from landfills by 2025" to support the reduction of Non-combustion Methane Emissions within the state.[1] Incorporating the latest science to update the landfill capture efficiency will have a significant impact on facilitating the diversion of organics from landfill, mitigating methane emissions – a potent short-lived climate pollutant – and helping ARB and California achieve its carbon neutrality goals.

California Greenhouse Gas Inventory

The Global Warming Solutions Act of 2006 (AB 32), required that ARB determine the statewide 1990 greenhouse gas (GHG) emissions level and approve a statewide GHG emissions limit to be achieved by 2020. Since 2006, ARB has been made responsible to prepare, adopt, and update California's GHG inventory per H&SC section 39607.4.[2]

Conducting an annual inventory is key to establish emission trends and tracking California's progress in reducing GHGs. The inventory provides estimates of anthropogenic GHG emissions and includes estimates for carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases with high global warming potentials that include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3).

One key source of statewide anthropogenic GHG emissions includes the waste sector. Specifically, landfills that have been shown to emit significant amounts of methane into the atmosphere due to the anaerobic degradation of biodegradable, carbon-bearing organic waste. In 2019, ARB estimates that landfills contributed to 21% of the state's methane emissions inventory, equivalent to 8.38 million tons of CO_2 emitted annually.[3] Per ARB's 2016 Edition Technical Support Document, "staff opted to use a model to estimate landfill emissions" from landfills due to a lack of site-specific landfill gas data.[4] Staff used the Mathematically Exact First-Order Decay (FOD) model from the 2006 IPCC Guidelines (IPCC 2006f) to model the amount of landfill gas produced and emitted by landfills throughout the state.

[1] https://ww2.arb.ca.gov/sites/default/files/2021-12/Revised_2022SP_ScenarioAssumptions_15Dec.pdf
[2] https://ww2.arb.ca.gov/ghg-inventory-data
[3] https://ww3.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_scopingplan_2000-19ch4.pdf
[4] https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2014/ghg_inventory_00-14_technical_support_document.pdf (pg 126)

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Current default landfill gas collection efficiency

Critically, each landfill site was assigned a default 75% collection efficiency. This collection efficiency was established by the USEPA in 1997 through its Landfill Air Emissions Estimation Model to establish the emissions factors of municipal solid waste landfills.[5] The EPA's model acknowledged there was significant variability in landfill collection efficiencies and admitted that a default of 75% was chosen as it was the "most commonly assumed[6]" rate. The EPA's model goes on to encourage the reader to use "site-specific collection efficiencies instead of the 75 percent average,[7]" if they are available. ARB staff also recognized the debate surrounding the default 75 percent collection efficiency and acknowledged that the collection efficiency could be updated "as better data become available through current and future research.[8]"

Direct landfill gas emissions measurements

Advances in direct measurement capabilities, namely surface sampling, flyover sampling, or airborne imagining, have shed new light on the level of methane currently being emitted at landfills. In particular, a 2019 study by the NASA JPL estimates that landfills' contribution to the state's methane inventory is double current estimates – approximately 41% of all point source emissions in California.[9] The updated estimates were facilities by the deployment of specialized airborne imaging spectrometers attached to drones, which could rapidly map methane plumes.[10] Deploying this remote sensing technology significantly improved the determination of methane emissions associated with landfills. NASA JPL's conclusions are also supported by a report published by the Maryland Department of Energy finding that emissions from landfills were "four times greater" than previous estimates and were the leading source of methane emissions (37%) in the state.[11] USEPA staff has also indicated recently that the EPA's methane estimation methods have "been understating methane emissions from landfills by a factor of two.[12]" We strongly encourage ARB to utilize the latest direct landfills methane emissions data to update the default 75% landfill capture rate utilized in the LCFS Tier 1 Simplified Calculator.

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[5] https://www3.epa.gov/ttnchie1/ap42/ch02/bgdocs/b02s04.pdf
[6] https://www.epa.gov/sites/default/files/2020-10/documents/c02s04.pdf (pg 11)
[7] https://www.epa.gov/sites/default/files/2020-10/documents/c02s04.pdf (pg 11)
[8] https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2014/ghg_inventory_00-14_technical_support_document.pdf (pg 133)
[9] Duren, R.M., Thorpe, A.K., Foster, K.T. *et al.* California's methane super-emitters. *Nature* **575,** 180–184 (2019). https://doi.org/10.1038/s41586-019-1720-3
[10] Duren, R.M., Thorpe, A.K., Foster, K.T. *et al.* California's methane super-emitters. *Nature* **575,** 180–184 (2019). https://doi.org/10.1038/s41586-019-1720-3
[11] https://environmentalintegrity.org/wp-content/uploads/2021/06/MD-Landfill-Methane-Report-6.9.2021-unembargoed_with-Attachments.pdf
[12] https://www.npr.org/2021/07/13/1012218119/epa-struggles-to-track-methane-from-landfills-heres-why-it-matters-for-the-clima

Proposed updated landfill gas collection efficiency methodology

Capture Rate Methodology

We propose to utilize direct landfill methane emission data to provide an updated landfill capture efficiency value for landfills in California. To achieve this, the capture rate was determined to be the ratio between methane capture and methane formed.

$$Capture\ Rate\ = \frac{Methane\ Captured}{Methane\ Formed}$$

It was assumed that the methane formed at landfills was equivalent to the sum of methane captured, methane oxidized in soil, and methane emitted.

$$Methane\ Formed\ = Methane\ Emittted\ + Methane\ Captured\ + Methane\ Oxidized\ in\ Soil$$

A methane oxidation rate of 10% of total methane emitted was also utilized.

$$Methane\ Oxidized\ in\ Soil\ = 0.1 * Methane\ Emitted$$

These relationships enabled the determination of the total methane captured, and subsequently the capture rate, in terms of methane formed and methane emitted and result in an updated capture rate.

$$Methane\ Captured\ = Methane\ Formed\ - Methane\ Emittted\ - Methane\ Oxidized\ in\ Soil$$

$$Methane\ Captured\ = Methane\ Formed\ - Methane\ Emittted\ - 0.1 * Methane\ Emitted$$

$$Capture\ Rate\ = \frac{Methane\ Formed\ - Methane\ Emitted\ - 0.1 * Methane\ Emitted}{Methane\ Formed}$$

Methane Formed

The total methane formed was established by utilizing ARB's GHG Inventory Technical Support Document Waste-In-Place (WIP) methodology and ARB's Tier 1 Simplified Calculator. The Tier 1 Simplified Calculator for Organic Waste identifies Paper, Textiles, Wood (branches & stumps), Food Scraps, and Yard Trimmings (leaves, grass clippings, plants, prunings & shrubs) as the primary organic components in municipal waste. The corresponding Degradable Organic Carbon (DOC) content and Decomposable Anaerobic Fraction (DANF) of for each of the disaggregated organic components were identified using ARB's Technical Support Document.[13] A summary of the relevant values can be found below.

Table 1 – DOC and DANF of organic components found in MSW

Waste Component	Degradable Organic Carbon (DOC) content (Mg DOC / Mg wet waste)	Decomposable anaerobic fraction (DANF) of DOC
Paper - Newspaper	0.471	0.150
Paper - Office Paper	0.385	0.870
Paper - Corrugated Boxes	0.448	0.442
Paper - Coated Paper	0.330	0.243

[13] https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2014/ghg_inventory_00-14_technical_support_document.pdf (pg 129,130)

Food Scraps	0.148	0.865
Yard Trimmings - Grass & Leaves	0.291	0.073
Wood - Branches & Stumps	0.442	0.231
Textiles	0.240	0.500

The total amount of landfilled material was then determined using CalRecycle's Facility-Based Characterization of Solid Waste in California. As part of this study, CalRecycle determined that a total of 39,304,457 tons of MSW were landfilled in 2018.[14] CalRecycle also conducted a waste characterization and determined the composition of the overall disposed waste stream. A breakdown of the estimated percentages can be found below.

Table 2 – CalRecycle 2018 Waste Characterization Estimates and estimated landfilled short tons

Waste Component	CalRecycle 2018 Waste Characterization Estimate (%)	Amount Landfilled (short tons)
Paper - Newspaper	0.7	275,131
Paper - Office Paper	0.4	157,217
Paper - Corrugated Boxes	5.2	2,043,831
Paper - Coated Paper	10.3	4,048,359
Food Scraps	14.9	5,856,364
Yard Trimmings - Grass & Leaves	5.4	2,122,440
Wood – Branches & Stumps	1.5	589,566
Textiles	1.1	432,349

The methane yield (kg CH4/m.t. waste) was then determined for each waste component using the same methodology provided in ARB's LCFS Tier 1 Simplified Calculator.[15] The total annual methane emissions for each category were then determined and can be found in Table 3.

$$CH4\ yield\ (\frac{kg\ CH4}{m.t.waste}) = DOC * DANF * CH4\ Conc\ in\ LFG\ (by\ volume) * \frac{molar\ mass\ CH4}{molar\ mass\ C}$$

Table 3 – Anticipated methane yields of organic waste compounds

Waste Component	Methane yield (kg CH4/m.t. wet waste)	Total Methane (m.t. / year)
Paper - Newspaper	47	11,753
Paper - Office Paper	223	31,841
Paper - Corrugated Boxes	132	244,715
Paper - Coated Paper	53	196,297
Food Scraps	85	453,337
Yard Trimmings - Grass & Leaves	14	27,262
Wood – Branches & Stumps	68	36,398
Textiles	80	31,371
		1,032,978

[14] https://www2.calrecycle.ca.gov/Publications/Details/1666
[15] https://ww2.arb.ca.gov/resources/documents/lcfs-life-cycle-analysis-models-and-documentation

Summing all the annual methane yields for each waste component resulted in an estimated total methane produced of 1,032,978 m.t. CH4.

$$Total\ Methane\ Produced\ =\ 1{,}032{,}978\ m.t.\ CH4$$

Methane Emitted

Direct methane emissions measurements, published in NASA JPL's study, were used as a basis for determining statewide landfill methane emissions. NASA JPL identified point source methane emissions at 30 landfills and 2 compost facilities in California, totaling 0.229 Tg CH4/yr.[16] Landfill emissions accounted for 95% of the total methane emissions associated with NASA JPL's Managed Waste Disposal, or 0.218 Tg CH4/yr.

The EPA's Landfill Methane Outreach Program (LMOP) California Database was then used to determine the cumulative WIP for the identified landfills, which totaled 687,522,336 short tons.[17] Using this same database, it was determined that the landfills identified in NASA JPL's study amounted to 35% of the 1,950,316,594 WIP short tons for the entirety of California.

Table 4 – Identified landfills with corresponding WIP tonnage

Identifier	Source Latitude (deg)	Source Longitude (Deg)	WIP (short tons)
SLF001	37.7488	-121.655	63,798,959
SLF002	34.5685	-118.154	10,115,687
SLF003	35.3483	-118.764	10,814,230
SLF004	34.3064	-116.822	540,000
SLF005	34.0867	-117.221	2,933,337
SLF006	34.4322	-118.649	42,004,497
SLF007	34.4322	-118.649	42,004,497
SLF008	37.4984	-122.408	35,309,558
SLF009	37.8778	-121.187	27,940,598
SLF010	33.7216	-117.701	57,681,443
SLF011	33.6133	-117.823	38,999,999
SLF012	36.5298	-121.405	3,333,764
SLF013	37.1853	-121.664	11,356,764
SLF014	38.5295	-121.374	N/A*
SLF015	36.7101	-121.759	12,435,937
SLF016	37.4598	-121.945	32,026,031
SLF017	33.9404	-117.832	86,320,460
SLF018	38.2092	-121.972	19,508,129
SLF019	38.1691	-122.566	16,076,533
SLF020	38.5183	-121.185	31,475,089
SLF021	35.5082	-119.405	3,164,654
SLF022	32.7339	-117.066	4,750,000

16 Duren, R.M., Thorpe, A.K., Foster, K.T. *et al.* California's methane super-emitters. *Nature* **575,** 180–184 (2019). https://doi.org/10.1038/s41586-019-1720-3
17 https://www.epa.gov/lmop/project-and-landfill-data-state

SLF023	34.3271	-118.516	65,207,800
SLF024	34.4830	-120.124	11,189,599
SLF025	34.4061	-118.992	9,691,635
SLF026	38.0264	-122.168	N/A*
SLF027	37.7594	-121.728	27,597,167
SLF028	34.7594	-117.267	11,843,992
SLF029	36.3876	-119.380	6,721,205
SLF030	32.8530	-117.168	44,685,269

*WIP not identified in EPA database so emissions and WIP were removed from calculation

35% was then used as a scalar to determine the total methane emissions associated from the whole WIP for California. This amounted to 0.618 Tg/yr, or 618,407 m.t. CH4 emitted.

$$CH4\ emissions\ total\ WIP\ (m.t.) = \frac{CH4\ emissions\ identified\ WIP\ (m.t.)}{Fraction\ of\ WIP\ in\ study}$$

$$Total\ Methane\ Emitted = 618{,}407\ m.t.CH4$$

Proposed Updated Landfill Capture Rate

Having determined the methane formed and methane emitted, an updated landfill capture rate was determined to be 34%.

$$Capture\ Rate = \frac{Methane\ Formed - Methane\ Emitted - 0.1 * Methane\ Emitted}{Methane\ Formed}$$

$$Capture\ Rate = \frac{1{,}032{,}978\ m.t.CH4 - 618{,}407\ m.t.CH4 - (0.1 * 618{,}407\ m.t.CH4)}{1{,}032{,}978\ m.t.CH4}$$

$$Capture\ Rate = 34\%$$