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Application of the Oeko-Institut/WWF-US/ EDF methodology for assessing the quality of carbon credits

This document presents results from the application of version 3.0 of a methodology, developed by Oeko-Institut, World Wildlife Fund (WWF-US) and Environmental Defense Fund (EDF), for assessing the quality of carbon credits. The methodology is applied by Oeko-Institut with support by Carbon Limits, Greenhouse Gas Management Institute (GHGMI), INFRAS, Stockholm Environment Institute, and individual carbon market experts. This document evaluates one specific criterion or sub-criterion with respect to a specific carbon crediting program, project type, quantification methodology and/or host country, as specified in the below table. Please note that the CCQI website Site terms and Privacy Policy apply with respect to any use of the information provided in this document. Further information on the project and the methodology can be found here: www.carboncreditquality.org

Sub-criterion:	1.3.2 Robustness of the quantification methodologies applied to determine emission reductions or removals
Project type:	Landfill gas utilization
Quantification methodology:	CAR Landfill Project Protocol, Version 5.0
Assessment based on carbon crediting program documents valid as of:	15 May 2022
Date of final assessment:	31 January 2023
Score:	3

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Assessment

Relevant scoring methodology provisions

The methodology assesses the robustness of the quantification methodologies applied by the carbon crediting program to determine emission reductions or removals. The assessment of the quantification methodologies considers the degree of conservativeness in the light of the uncertainty of the emission reductions or removals. The assessment is based on the likelihood that the emission reductions or removals are under-estimated, estimated accurately, or over-estimated, as follows (see further details in the methodology):

Assessment outcome	Score
It is very likely (i.e., a probability of more than 90%) that the emission reductions or removals are underestimated, taking into account the uncertainty in quantifying the emission reductions or removals	5
It is likely (i.e., a probability of more than 66%) that the emission reductions or removals are underestimated, taking into account the uncertainty in quantifying the emission reductions or removals OR The emission reductions or removals are likely to be estimated accurately (i.e., there is about the same probability that they are underestimated or overestimated) and uncertainty in the estimates of the emission reductions or removals is low (i.e., up to ±10%)	4
The emission reductions or removals are likely to be estimated accurately (i.e., there is about the same probability that they are underestimated or overestimated) but there is medium to high uncertainty (i.e., ±10-50%) in the estimates of the emission reductions or removals OR It is likely (i.e., a probability of more than 66%) or very likely (i.e., a probability of more than 90%) that the emission reductions or removals are overestimated, taking into account the uncertainty in quantifying the emission reductions or removals, but the degree of overestimation is likely to be low (i.e., up to ±10%)	3
The emission reductions or removals are likely to be estimated accurately (i.e., there is about the same probability that they are underestimated or overestimated) but there is very high uncertainty (i.e., larger than ±50%) in the estimates of the emission reductions or removals OR It is likely (i.e., a probability of more than 66%) or very likely (i.e., a probability of more than 90%) that the emission reductions or removals are overestimated, taking into account the uncertainty in quantifying the emission reductions or removals, and the degree of overestimation is likely to be medium (±10-30%)	2
It is likely (i.e., a probability of more than 66%) or very likely (i.e., a probability of more than 90%) that the emission reductions or removals are overestimated, taking into account the uncertainty in quantifying the emission reductions or removals, and the degree of overestimation is likely to be large (i.e., larger than ±30%)	1

Information sources considered

1 CAR Landfill Project Protocol, Version 5.0, 24. April 2019.

2 Abushammala et al 2014 “Methane Oxidation in Landfill Cover Soils: A Review” https://www.researchgate.net/publication/264153104_Methane_Oxidation_in_Landfill_Cover_Soils_A_Review

3 Cames et al, 2015 “How additional is the Clean Development Mechanism? Analysis of the application of current tools and proposed alternatives.” https://ec.europa.eu/clima/sites/clima/files/ets/docs/clean_dev_mechanism_en.pdf

4 Kühle-Weidemeier und Bogon 2008 “Wirksamkeit von biologischen Methanoxidationsschichten auf Deponien.“ http://www.wasteconsult.net/files/referenzen/Bimetox.pdf

5 Aghdam et al., 2018 “Determination of gas recovery efficiency at two Danish landfills by performing downwind methane measurements and stable carbon isotopic analysis” https://www.sciencedirect.com/science/article/abs/pii/S0956053X17309303

6 De la Cruz et al., 2015 “Comparison of Field Measurements to Methane Emissions Models at a New Landfill” https://pubs.acs.org/doi/pdf/10.1021/acs.est.6b00415

7 Chanton et al. (2009) “Methane oxidation in landfill cover soils, is a 10% default value reasonable?” https://pubmed.ncbi.nlm.nih.gov/19244486/#:~:text=One%20study%2C%20conducted%20in%20New,values%20of%2010%25%20or%20less.

8 Delkash, M. & Haya, B.K. (June 8, 2022). Comments on CAR’s draft U.S. Landfill Protocol v6.0, baselines adjustments. Berkeley Carbon Trading Project. Berkeley, California. https://gspp.berkeley.edu/assets/uploads/page/Comments_to_CAR_on_US_LFG_protocol_v6-Delkash_and_Haya.pdf

Assessment outcome

The quantification methodology is assigned a score of 3.

Justification of assessment

Project type

This assessment refers to the project type “Landfill gas utilization” which is characterized as follows:

“Capture and utilization of gas from an existing and closed solid waste disposal site. The collected gas is mainly used for energy purposes, such as for electricity and/or heat generation. A smaller fraction of the gas may be flared (e.g., during maintenance of an on-site electricity generation plant). The project type reduces emissions by destroying methane and displacing more greenhouse gas intensive energy generation.” Pure flaring of LFG is thus not part of this assessment even if it is allowed under the CAR Landfill Project Protocol.

Focus of assessment

The project boundary, project emissions and leakage are not a major source of uncertainty. Regarding the project boundary, the methodology clearly delimitates applicable landfills (e.g. only those without regulation or other legal requirements to destroy landfill gas). Possible project emissions are accounted for and we estimate that they contribute only insignificantly to overall emission reduction calculations. Leakage effects do not play a role.

In the following, we thus focus the assessment on the determination of the baseline emissions. The overall score depends on the balance of elements with the potential for over- as well as underestimation of emission reductions. We focus on these elements, as well as elements that introduce uncertainty. The methodology contains further elements, which are not discussed however, as they introduce presumable little uncertainty (e.g. the baseline emissions associated with heat generation).

General information on landfill gas formation and the oxidation factor

Solid waste disposal sites emit landfill gas (LFG) which is a mixture of methane and carbon dioxide (it is essentially the same as biogas). The methane originates in the landfill's interior from the anaerobic microbial decomposition of the waste's biodegradable organic substances. This methane diffuses through the landfill and usually passes through a topsoil layer before entering the atmosphere. In this topsoil layer, the methane is partly oxidized to carbon dioxide by methanotrophic micro-organisms. If landfills do not have a topsoil layer but are covered by a biological inert material (like a synthetic cover or possibly compacted clay), such oxidation does not occur.

The amount of methane emitted in the baseline thus depends on how much methane is generated in the landfill's interior in the first place and on how much of this methane is oxidized in the topsoil. Especially relevant for this assessment is the topsoil oxidation, which cannot be measured in the project. This is because methane that is measured and destroyed in the project is captured in the interior of the landfill using pipes and never crosses the topsoil. The baseline's topsoil oxidation must thus be estimated.

Topsoil oxidation is a complex biological process that depends on the type of the landfill and its management, soil texture, soil thickness, soil organic content, soil moisture or the prevailing climate (see Sources 2-4 and 7). It also depends on the methane flux rate which in turn is a function of the waste composition and the age of the landfill.

Measurements of oxidation rates are not straightforward, as there are significant short-term variations (e.g., the flux rate depends on the prevailing barometric pressure; there is impact from wind speed or temperature, etc.). Thus, long-term measurements would be needed, which are however costly. In addition, there is uncertainty related to the measurement method. Source 7, table 1, lists the strength and weaknesses of six methods to measure oxidation rates that have been applied in the literature.

Values of oxidation rates estimated in the literature include 6-37% (source 5) or 26-57% (Source 6, table 3). Our main reference is Source 7, which collected literature findings from 42 landfills with a variety of soil types and landfill covers. Oxidation rates range from essentially 0% to 100% (see Source 7, Table 2). The overall mean fraction oxidized is 36% with a standard error of 6%. Only four landfills report values of 10% or less (see also Source 8).

To sum up, oxidation rates vary considerably among landfills as well as over time for a given landfill. To account for the oxidation, landfill gas methodologies define an "Oxidation Factor" (OX). It is defined as the fraction of methane that is oxidized in the soil layer. Source 7 provides a good overview of the history of the oxidation factor, focusing on the IPCC Guidelines for National Greenhouse Gas Inventories. It shows that even though already in 1990 a study estimated the oxidation factor to be approximately 50%, an oxidation factor of 10% was only introduced in the 2006 IPCC Guidelines — if this could be justified for covered, well-managed solid waste disposal sites. The value of 10% was based on an expert judgement with little empirical foundation and has not been changed since.

In the context of climate mitigation projects, a lower oxidation factor increases quantified emission reductions. The level of over- or underestimation depends on how the real oxidation rate of the project, which is unknown, differs from the value used by a project. If the real oxidation of a landfill would correspond to the above cited mean value of 36% from Source 7, using an oxidation factor of 10% would lead to an overestimation of the methane generation by about 40% (90% divided by 64%).

Elements potentially overestimating emission reductions

OE1 Oxidation factor

The CAR Landfill Project Protocol uses an oxidation factor of 0.1 but allows a value of zero for landfills that have a synthetic cover that encompasses the entire landfill.

For landfills with such a synthetic cover, the oxidation factor of zero is reasonable, as in those cases there is no top-soil oxidation. The CAR methodology is only applied in the United States, where a substantial fraction of landfills has synthetic covers. This fraction is however unknown.[1]

For other landfills, top-soil oxidation is relevant. Noting the assumptions and the range of values in the literature (see "General information on landfill gas formation and the oxidation factor"), we estimate that emission reductions in these cases are likely to be overestimated, given that the literature suggests higher oxidation values than 10%.[2] The degree of overestimation is uncertain; we assume it to be medium to high (see Table 1 below).

OE2 Perverse incentives

Landfill gas projects can potentially generate two types of perverse incentives, which may lead to an overestimation of baseline emissions:

a. A project owner may change the management in landfills to generate more methane (e.g., increasing the height of a landfill or injecting water/leachate into a landfill which creates increasingly anaerobic conditions and thus more methane). For that reason, the methodology explicitly excludes landfills that are bioreactors. By EPA definition[3] bioreactors are designed to increase and accelerate the decomposition and increase LFG production (at least in the initial

[1] We are not aware of data on how frequently landfills use a synthetic cover. For example, the EPA's LMOP Database does not contain information on cover type (see https://www.epa.gov/lmop/lmop-landfill-and-project-database; accessed 25 January 2023).

[2] The cited literature does not allow us to further constrain the possible range of oxidation factors for the US specifically. We assume that there might be some differences between landfills in the United States and other countries. For example, more landfills in the United States might have an existing collection system which in the baseline would have been used to vent LFG (without a destruction device). This could imply that the low oxidation factors in the US is lower than globally. On the other hand, topsoil layers might be thicker in the United States than in the global average, thus increasing the oxidation in the baseline. However, we are not aware of any data to back up these considerations such that they do not impact our assessment.

[3] https://www.epa.gov/landfills/bioreactor-landfills (accessed 23 March2022)

phase). As this requirement can arguably be monitored rather stringently, we assume this type of perverse incentive is less relevant under this methodology. We therefore do not classify this as a risk of over-estimation. It should be noted, however, the leachate may still be re-circulated, which might increase methane generation. The conclusion may thus need to be updated when more research on this matter becomes available.

b. In order to increase the potential for issuing carbon credits, carbon revenues' beneficiaries may influence policy makers and private actors to engage less in recycling (or other ways of preventing waste generation), compositing of organic material or even to prevent waste incineration. In cases where a landfill is owned by a local government, the local government could be the project developer and might thus have a direct incentive not to pursue other handling practices. Policy related perverse incentives can hardly be accounted for in a methodology. It is thus likely that a substantial overestimation occurs if this perverse incentive would prevent the use of other waste handling practices (especially if the installation of a waste incineration plant would be prevented). It is unclear how many projects are affected by this type of perverse incentive, as it is unknown to what extent the carbon revenues' beneficiaries can influence the recycling sector and the policy process. It depends on how prone the policy system is to be influenced by particular interests. The methodology does not include any elements to address this potential perverse incentive (e.g., by limiting applicability to solid waste disposal sites that have been closed).

Elements potentially underestimating emission reductions

UE1 Utilization of landfill methane

Projects utilize landfill methane for energy generation and thus substitute GHG emissions associated with fossil fuel combustion. Under CAR's methodology, projects do not receive credit for the displaced fossil fuel use. This leads to an underestimation of emission reductions by approximately 10-20%.[4] This is relevant for all projects, as the project type considered in the assessment does not include projects that only flare landfill gas.

UE2 Baseline LFG destruction

The methodology is not applicable in cases where regulation or other legal requirements to destroy the landfill methane gas exists (in CDM's ACM0001 such projects are not excluded). Existing collection or destruction devices may be in place and have to be accounted for according to the following **Table 1**.

[4] A ton of destroyed landfill gas methane has a global warming potential of 25 according to the 4th IPCC assessment report and the value is 28 according to the 5th IPCC assessment report. If in addition, the bio methane is used to replace fossil methane, this lowers fossil CO_2 emission by approx. 2,75 tCO_2 per tCH_4. The utilization thus contributes approx. 10% to the overall emission reduction. In case bio methane replaces coal, the contribution is rather 15%, as coal's emissions per energy content are approximately 65% higher than methane's (not considering different efficiencies). Renewables within the grid's energy mix decrease the contribution if electricity is replaced. Finally, upstream emissions from fossil fuel extractions increase the contribution. Upstream emissions are estimated to be 5-37% depended on type of fuel and location of extraction (see https://www.wri.org/data/upstream-emissions-percentage-overall-lifecycle-emissions; this number does not include refining or construction of electricity generation plants). Summing up these aspects, we estimate a contribution of 10-20%.

Table 1 Cases for determining methane captured and destroyed in the baseline

In place prior to the project	Deduct methane oxidized by soil bacteria w/o project	Deduct amount of methane destroyed
No collection or destruction	Yes	No
Collection and/or destruction in non-qualifying destruction device	Yes	Yes by the non-qualifying destruction device
Collection and destruction in qualifying destruction device	Yes	Yes Amount that could have been destroyed if the baseline destruction device was operating at full capacity
Closed landfills with collection and destruction in qualifying flare	Yes	Yes Amount of methane collected by baseline landfill gas wells and destroyed in the qualifying flare.

If collection and/or destruction are already in place, there are detailed requirements on how to measure and account for the corresponding destruction in the baseline. For example, the methane emissions flow has to be measured and the 90% upper confidence limit in the metered period must be used. This is a conservative element and there are no fall-back values. Baseline emissions are calculated once as absolute values at the beginning of the project. Methane production from landfills typically decreases over time. The methodology applies, however, a fixed value such that the baseline remains constant, which likely lead to successively higher underestimation of emission reductions over time.

We therefore estimate that the methodology's treatment of methane destruction in the baseline leads to an underestimation of emission reductions.

Summary and conclusion

Table 1 summarizes the assessment. For each of the previously discussed elements it estimates the potential impact on emission reduction quantification.

Table 2 Relevant elements of assessment and qualitative ratings

Element	Fraction of projects affected by this element[5]	Average degree of under- or overestimation where element materializes[6]	Variability among projects where element materializes[7]
Elements likely to contribute to overestimating emission reductions or removals			
OE1 Oxidation factor	Medium	Medium to High	High
OE2 Perverse incentives: overall policy/action related to waste	Unknown	Medium	High
Elements likely to contribute to underestimating emission reductions or removals			
UE1 Utilization of landfill methane	All	Medium (10-20%)	High
UE2 Baseline LFG destruction	Unknown	Medium	Medium
Elements with unknown impact			
None	-	-	-

We assign a score of 3 to the methodology. There are elements that may lead to underestimation and overestimation. However, the degree of under- or overestimation is difficult to estimate for many elements (an exception is UE1, which can be quantified rather precisely). Overall, it is not clear whether these effects lead to over- or underestimation. In our judgement, the emission reductions are likely to be estimated accurately but are associated with significant uncertainty (here estimated to be in the range between 10% and 50%). This corresponds to a score of 3.

5 This parameter refers to the likely fraction of individual projects (applying the same methodology) that are affected by this element, considering the potential portfolio of projects. “Low” indicates that the element is estimated to be relevant for less than one third of the projects, “Medium” for one to two thirds of the projects, “High” for more than two third of the projects, and “All” for all of the projects. “Unknown” indicates that no information on the likely fraction of projects affected is available.

6 This parameter refers to the likely average degree / magnitude to which the element contributes to an over- or underestimation of the total emission reductions or removals for those projects for which this element materializes (i.e., the assessment shall not refer to average over- or underestimation resulting from all projects). “Low” indicates an estimated deviation of the calculated emission reductions or removals by less than 10% from the actual (unknown) emission reductions or removals, “Medium” refers to an estimated deviation of 10 to 30%, and high refers to an estimated deviation larger than 30%. “Unknown” indicates that it is likely that the element contributes to an over- or underestimation (e. g. overestimation of emission reductions in case of an omitted project emission source) but that no information is available on the degree / magnitude of over- or underestimation. Where relevant information is available, the degree of over- or underestimation resulting from the element may be expressed through a percentage range.

7 This refers to the variability with respect to the element among those projects for which the element materializes. “Low” means that the variability of the relevant element among the projects is at most ±10% based on a 95% confidence interval. For example, an emission factor may be estimated to vary between values from 18 and 22 among projects, with 20 being the mean value. “Medium” refers to a variability of at most ±30%, and “High” of more than ±30%.

Annex: Summary of changes from previous assessment sheet versions

The following table describes the main substantive changes implemented in comparison to the assessment from 31 May 2022.

Topic	Rationale
Oxidation factor	The assessment in relation to the oxidation factor has been changed to reflect more literature on this topic.
Drafting	The drafting has been improved in several cases, without any material consequences.
Overall score	The overall score has been downgraded from 4 to 3, due to the updated information on the oxidation factor.