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:	Clean Development Mechanism (CDM) ACM0001, Versions 19, and relevant tools
Assessment based on carbon crediting program documents valid as of:	15 May 2022
Date of final assessment:	31 January 2023
Score:	2

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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 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

2 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

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

4 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

5 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

6 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.

7 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 methodology is assigned a score of 2.

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.”

Solely flaring of landfill gas (LFG), without any utilization, is thus not part of this assessment even though it is allowed under ACM0001.

Focus of assessment

The project boundary, project emissions and leakage are not a major source of uncertainty:

- Project boundary: the methodology requires clearly delimitating applicable solid waste disposal sites (SWDS), power plants, heat generating equipment etc. In addition, all relevant greenhouse gases of the baseline and project activity are included.
- Project emissions account for merely 0–1% of the ex-ante estimated emission reductions (according to various examined PDDs) and even if uncertainties on this part would be substantial, they would play an insignificant role overall.
- Leakage effects are not accounted for under this methodology, which we deem appropriate, as relevant “indirect” effects have been accounted for in the baseline or project emission calculation.

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 emission source and 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

ACM0001 prescribes using a fixed oxidation factor of 0.1 for all landfills.

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 for landfills with topsoil layers emission reductions are likely to be overestimated (given the literature suggests higher oxidation values than 10%). If the average oxidation factor of projects applying the methodology would correspond to the mean value of 36% observed in Source 7, the overestimation would be 40%. The methodology is mostly applied in developing countries. It is possible that the average thickness of topsoil layers might be somewhat lower in these countries. In this case, the degree of overestimation could be somewhat lower.

For landfills with a synthetic cover that encompasses the entire landfill, top-soil oxidation is not relevant. Under ACM0001, such landfills nevertheless must apply the oxidation factor of 0.1, which – for these cases – leads to an underestimation of emission reductions. The fraction of those projects is unknown. We assume that it is small, as synthetic covers are not particularly prevalent in countries where ACM0001 is mainly applied.[1]

Note that in Table 2 – for simplification – we do not differentiate these two cases. In aggregate, we assume that these two effects lead to an overestimation of emission reductions.

[1] Landfills in the United States, where synthetic covers are more prevalent, may apply CAR’s or ACR’s landfill methodology that allow to use an oxidation factor of 0 if the landfill has a synthetic cover that encompasses the entire landfill.

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 both creates increasingly anaerobic conditions and thus more methane). For that reason, the methodology has an applicability criterion that excludes projects in which the management is changed in order to increase methane generation[2] and there is a monitoring parameter “Management of SWDS”. Verifying this requirement may be difficult in practice. Therefore, we estimate that this may cause overestimation of emissions reduction (at a low degree, but with high variance among projects).

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

In ACM0001 the following relevant elements have a potential for underestimating emission reductions:

UE 1 Methane oxidation in the project through suction of additional air into the landfill

The installation of an LFG capture system under the project activity may result in the suction of additional air into the SWDS. In some cases, such as with a high suction pressure, the air may decrease the amount of methane that is generated under the project activity. As a conservative assumption, this oxidation is neglected in calculating emission reductions in ACM0001.

UE 2 Exclusion of GHG from the project boundary in the baseline

Several baseline emissions of greenhouse gases from various sources are excluded from the project boundary (e.g., N_2O emissions from the SWDS or upstream emissions associated with fossil fuel

[2] The methodology is not applicable “ff the management of the SWDS in the project activity is deliberately changed during the crediting in order to increase methane generation compared to the situation prior to the implementation of the project activity.”

use for electricity generation). This is in each case conservative, yet we estimate the effect to be relatively small.[3]

Elements with uncertain impact

Finally, the following describes elements, which introduce uncertainty but where the direction of the impact is unclear.

U1 Methane captured and destroyed in the baseline

In the baseline, methane could be captured and destroyed (by flaring) because

- of requirements (e.g. regulatory or contractual requirements or to address safety and odour concerns) or
- an LFG capture and destruction system is already in place.

For that reason, ACM0001 lists four cases which are summarized in the following Table 1. The table also provides an overview of the methodology's respective specifications on how to determine emission reductions in these cases.

[3] Upstream emissions may be in the order of 10-15%. For this assessment, however, it has been agreed not to analyse the CDM tools which are relevant in this context. In a refinement of this assessment, those TOOLs could be considered in more detail.

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

Situation at the start of the project activity	Requirement to destroy methane	Existing LFG capture and destruction system	Specification to determine amount of methane in the LFG which is flared in the baseline $F_{CH4,BL,y}$
Case 1	No	No	=0
Case 2	Yes	No	Depends on requirement a) = absolute amount required or b) = percentage required x captured methane[4] c) = 0, if installing a capture system is required but flaring is not (i.e. no specified amount or percentage)[5] d) = 0.2 x captured methane, if flaring is required without any specified amount/percentage
Case 3	No	Yes	a) = amount flared, if baseline-methane can be measured separately b) = fraction destroyed last year x methane flared and/or used in project activity, if no explicit monitoring is possible c) 0.2 x methane flared and/or used in project activity, if no explicit monitoring possible and no historic data available[6]
Case 4	Yes	Yes	= Maximum from Case 2 and Case 3

These four cases and their subcases provide in principle a reasonable framework for the analysis. However, several aspects indicate that this assessment may not lead to a conservative assessment and that the amount of LFG in the baseline may be underestimated:

- The determination and validation of the correct case and subcase may be difficult in many circumstances. Consequently, case 1, or cases 2 and 3 with the fallback factor of 0.2, may be used too often.
- It is unclear whether the fallback factor of 0.2 is appropriate. The respective footnote 4 in ACM0001 does not provide any sources to justify these assumptions.[7] In particular it is not clear what the basis is for the assumption that in the existing system much less methane is collected than under the project activity.
- The fallback factor applies for both Case 2 and Case 3 and as a consequence also in Case 4. As Cases 2 and 3 are different situations, it seems inappropriate to use the same factor for Case 4. In addition, for Case 2 it seems at first glance not conservative to assume that regulation

[4] There are two options to determine captured methane: Option 1: captured methane = measured directly; Option 2: captured methane = determined as methane flared and/or used in project activity
[5] This subcase hardly fits into case 2. Nevertheless, the assigned value is reasonable.
[6] E.g. in case of passive flares for odor control or intermittent usage.
[7] Footnote 4 reads: “This default value of 20 per cent is based on assuming a situation in which: the efficiency of the LFG capture system in the project is 50 per cent; the efficiency of the LFG capture system in the baseline is 20 per cent; and, the amount captured in the baseline is flared using an open flare with a destruction efficiency of 50 per cent (consistent with the default value provided in the tool “Project emissions from flaring”). Project participants may propose and justify an alternative default value as a request for revision to this methodology.”

would require to destroy merely 20% of the methane (even though there is no existing LFG capture and destruction system).

- The uncertainty regarding the oxidation factor $OX_{top\_layer} = 0.1$ (see above) is of less relevance if there is a LFG capture and destruction system in the baseline (Cases 2-4), as in this case less methane leaves the SWDS through the top soil layer.

The impact of the following aspects has not been analysed any further:

- An analysis whether the fallback factor of 0.2 is conservative would require in-depth research of regulatory frameworks in several jurisdictions;
- It is unclear, how often cases and subcases are chosen incorrectly;
- It is unclear how often the critical cases 2,3,4 and therein especially the fallback factor of 0.2 are chosen.

It is thus not possible to assess the impact of this element on under-estimation or over-estimation, respectively. Yet, clearly this is a potential source for introducing uncertainty.

Summary and conclusion

Table 2 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[8]	Average degree of under- or overestimation where element materializes[9]	Variability among projects where element materializes[10]
Elements likely to contribute to overestimating emission reductions or removals			
OE1 Oxidation factor	All	Medium	High
OE2a Perverse incentives: management	Unknown	Low	High
OE2b Perverse incentives: overall policy/action related to waste	Unknown	Medium to High	High
Elements likely to contribute to underestimating emission reductions or removals			
UE1 Methane oxidation in the project through suction of additional air into the landfill	Medium	Low	Medium
UE2 Exclusion of GHG from the project boundary in the baseline	All	Low	Low
Elements with unknown impact			
U1 Methane captured and destroyed in the baseline	Unknown	Unknown	Unknown

We assign a score of 2 to the methodology. There are elements that may lead to underestimation and overestimation. The latter elements have a higher overall impact, due to the non-conservative choice of the oxidation factor and the potential impact of perverse incentives. It is thus likely that the emission reductions across all projects are overestimated. The degree of overestimation mostly

[8] 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.

[9] 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.

[10] 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%.

depends on the inaccuracy introduced by the oxidation factor and the extent to which perverse incentives materialize. We estimate that the overall degree of overestimation is likely in a range of 10-30%. This corresponds to a score of 2.

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.