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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 a methodology, developed by Oeko-Institut, World Wildlife Fund (WWF) 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
Quantification methodology:	American Carbon Registry (ACR) Landfill gas destruction and beneficial use projects, Versions 2.0 Project type "Landfill gas utilization"
Date of final assessment:	08 November 2022
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

Further literature:

1 TOOL: none: The methodology does not refer to any tools.

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.

Assessment outcome

The 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 ACR methodology is also applicable to the following type of activities, which are however not part of this assessment:

- Pure flaring of landfill gas (without any utilization); and
- Increase of landfill gas collection efficiency (most equations of the quantification methodology are related to this possibility).

Focus of assessment

In the following, we focus the assessment on elements that influence the scoring. Elements that we assume to be neutral are not further discussed. These are elements where the method is rather accurate, which presumable introduce little uncertainty, have little overall impact or which are related to options that are rarely used[1] are not a focus.

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 liner 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.

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.

[1] For example, the baseline emissions associated with heat generation.

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

Citing recommendations by the U.S. EPA[2], ACR's methodology prescribes oxidation factor values ranging from 0% to 35%, depending on the cover type and the methane flux rate. In addition, landfills without a synthetic cover "that are not required to determine methane flux" may apply a value of 10%.

We evaluated how ACR's requirement is applied in practice. ACR currently has 16 LFG projects:

- 12 are already complete. 11 of those are from 2005-2008 and use an oxidation factor of 0%; one is from 2011 and uses 10%). In this time period, above mentioned requirements have not been in place yet.
- 2 are listed and do not yet provide detailed information.
- 2 are currently registered and the PDDs are from 2019 and 2022, where above-mentioned requirements have already been in place. They both use 10%.
    - One project does not provide any justification regarding this choice, which suggests that the validation process has been inadequate.
    - The other project cites the requirement and mentions that the "methane flux rate is not required to be calculated for this project" and thus uses 10%.

These latter two cases are not representative. The reason for a value of 10% could be specific to the respective site. No conclusion can thus be drawn from the application by projects.

Overall, ACR's approach is an improvement compared to other LFG methodologies (e.g., CDM ACM0001 or CAR Landfill Project Protocol) that use a fixed default value of 10% (or 0% for an inert cover), following the IPCC 2006 Guidelines for National Greenhouse Gas Inventories. However, there are two factors that may still result in a certain degree of over-estimation of emission reductions:

- The possibility to use a default value of 10% in cases where the methane flux is not measured may potentially overestimate emission reductions given that the average oxidation factor from the literature is higher;
- The overall range used by ACR (0 – 35%) is lower than the range observed from values in the literature, noting that the upper end of the range used by ACR (35%) corresponds approximately to the mean (36%) identified in the literature.

[2] No clear reference is provided, however.

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 at a bioreactor landfill or a landfill that recirculates leachate. There is also a disincentive to manage landfills to reduce methane production, such as increasing oxidation by increasing the soil layer. Therefore, this may cause overestimation of emissions reduction (likely 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[3] to engage less in recycling (or other ways of preventing waste generation), compositing of organic material or even to prevent waste incineration. 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

The following relevant elements have a potential for underestimating emission reductions:

UE1 Utilization of landfill methane – electricity and heat generation

Projects utilize landfill methane for energy generation and thus substitute GHG emissions associated with fossil fuel combustion. Under ACR'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 this assessment does not include projects that only flare landfill gas.

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[3] In the United States, if the landfill is owned by the local government, the local government can be the project developer and have a direct incentive not to divert waste.

[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-

UE2 Methane oxidation in the project through suction of additional air into the landfill

The installation of a capture system under the project activity may result in the suction of additional air into the landfill. This air may decrease the amount of methane that is generated under the project activity compared to the situation in the baseline scenario. This oxidation is not considered in calculating emission reductions.

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 regulatory or contractual requirements or to address safety and odour concerns, or an LFG capture and destruction system could already be in place. ACR's methodology accounts for this by introducing a variable "Emissions from a pre-project, non-eligible device". There are, however, no further requirements or specifications on how to determine these emissions. It is thus not possible to assess the impact of this element on under-estimation or over-estimation. Yet, this is a potential source for large 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.

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 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	All	Low-Medium	High
OE2a Perverse incentives: management	Unknown	Low	High
OE2b Perverse incentives: overall policy/action related to waste	Unknown	Medium-High	High
Elements likely to contribute to underestimating emission reductions or removals			
UE 1 Utilization of landfill methane – electricity and heat generation	ALL	Medium (10-20%)	Medium
UE2 Methane oxidation in the project through suction of additional air into the landfill	Medium	Low	Medium
Elements with unknown impact			
U1 Methane captured and destroyed in the baseline	Unknown	Unknown	Unknown

We assign a score "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

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%.

elements. Moreover, the lack of appropriate consideration of existing methane destruction at the landfill introduces further uncertainty. 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 30%). This corresponds to a score of 3.