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The Carbon Credit Environmental Integrity (CENVI) Model

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Glossary

Term	Explanation
Carbon credit category	A carbon credit category is a cohort of carbon credits defined by the following attributes: 1) the type of mitigation activity, 2) the carbon crediting programme and 3) the quantification methodology.
Carbon crediting programme	An organisation that registers mitigation activities and issues carbon credits for the emission reductions or removals they achieve (Schneider et al. 2022b).
Quantification methodology	Documents published by carbon crediting programmes that detail how to quantify emission reductions or removals. These documents may encompass the main methodology document, along with methodological tools or methodological guidelines (Schneider et al. 2022b).
Mitigation activity	An activity that is reducing emissions and/or enhancing removals and is registered, or is seeking registration, with a carbon crediting programme. The term encompasses mitigation activities implemented at the project level and at the jurisdictional level.
Mitigation Activity Design Document (also referred to as ‚Project Design Document' (PDDs))	One or several documents containing relevant information regarding the mitigation activity, such as a description of implemented activities, approaches used for the calculation of emission reductions, additionality assessment, and monitoring plans.

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1 Introduction and overview of the model

1.1 Purpose

This document describes the Carbon Credit Environmental Integrity (CENVI) model developed by Oeko-Institut. The model allows for the assessment of environmental integrity risks of different portfolios of mitigation activities and carbon credits. It includes two key components: first, a database with information on mitigation activities, which is based on publicly available information provided by carbon crediting programmes; and second, an assessment of the environmental integrity of carbon credits, based on publicly available literature and expert judgments. The two components are combined by applying the assessment of environmental integrity to the data on carbon credits, enabling detailed analyses of the carbon crediting market.

Specifically, the model aims to provide **information** on:

- **Environmental integrity risk grades of carbon credits**, i.e. aggregated assessments of the environmental integrity risks of different categories of carbon credits;
- **Number of carbon credits issued**, i.e. the amount of carbon credits issued to each mitigation activity, also taking into account contributions to pooled buffer reserves;
- **Number of carbon credits used**, i.e. the amount of carbon credits from each mitigation activity that have been cancelled;
- **Number of carbon credits available for use**, which is derived as the difference between carbon credit issuance and carbon credit already used;
- **Estimated annual emission reductions** for each mitigation activity;
- **Supplementary information on carbon credits** and the underlying mitigation activities, which is partially extracted from Mitigation Activity Design Documents, such as the installed capacity of renewable power generation activities;
- **Information on whether carbon credits are eligible under mandatory schemes**, such as the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).

Based on available information currently captured by CENVI, we can assess the distribution of the environmental integrity risks of registered mitigation activities in the voluntary carbon market based on their annual emission reduction or removal potential.

In addition, CENVI aims to allow conducting further types of **analyses**, such as:

- Estimating the future carbon credit issuances potential, i.e. the future potential for issuing carbon credits for each mitigation activity, based on the estimated annual emission reductions, including the corresponding distribution of environmental integrity risks;
- Assessing and comparing the integrity risk of the portfolio of carbon credits eligible under different schemes or initiatives, such as under CORSIA or the Integrity Council for the Voluntary Carbon market (ICVCM); and

- Assessing the implications for environmental integrity risks when imposing restrictions on the eligibility of carbon credits, such as date for the vintage of carbon credits, eligible mitigation activity types, etc.

This document describes an initial version of the model and the methodology to assess the environmental integrity risks of carbon credits. The document is structured as follows: After the introduction in section 1, section 2 describes CENVI's methodology for assessing environmental integrity risks of carbon credits and section 3 summarises the outcomes of the carbon credit integrity risk assessments for all categories of carbon credits that have been assessed so far.

The development of the model is funded by the EU HORIZON project 'ACHIEVE – Achieving High-Integrity Voluntary Climate Action' (grant agreement number 101137625).[1]

1.2 Coverage

Our assessment of the environmental integrity of carbon credits is structured along **carbon credit categories.** Consistent with the approach by the ICVCM and the CCQI, a category of carbon credits is defined as a combination of the following attributes: the mitigation activity type (e.g. wind power), the carbon crediting programme (e.g. the Verified Carbon Standard), and the applicable methodology for quantification of emissions reductions or removals (e.g. CDM ACM0002). These attributes are decisive for the environmental integrity of carbon credits. Where relevant for the assessment, we also consider additional attributes such as the capacity of renewable power generation plants or the host country in our assessment.

As of December 2025, CENVI covers mitigation activities registered under the following five carbon crediting programmes: ACR, Architecture for REDD+ Transactions (ART), Climate Action Reserve (CAR), Gold Standard (GS) and Verified Carbon Standard (VCS) by Verra. However, due to data limitations the carbon credit issuance potential is currently only estimated for ART, GS and VCS. This is because data on the expected annual emission reductions or removals is only available in the registries of GS and VCS but not for ACR and CAR. In the case of ART, we derive the expected annual emission reductions manually, given that only one mitigation activity is currently registered under ART as of December 2025. CENVI will be amended to cover more carbon crediting programmes over time.

CENVI establishes its own classification of types of mitigation activities, drawing on the classifications from the Berkeley Carbon Trading Project[2], the Carbon Credit Quality Initiative (CCQI)[3], Clean Development Mechanism (CDM)[4], the Integrity Council for the Voluntary Carbon Market (ICVCM)[5], and the UNEP DTU[6].

1 https://www.achieveproject.eu/
2 https://gspp.berkeley.edu/research-and-impact/centers/cepp/projects/berkeley-carbon-trading-project/offsets-database
3 https://carboncreditquality.org/
4 https://cdm.unfccc.int/
5 https://icvcm.org/
6 https://unepccc.org/cdm-ji-pipeline/

As of December 2025, CENVI has assessed most of the carbon credit categories for the following types of mitigation activities:

- Commercial Afforestation for Timber Harvest;
- Efficient Cookstoves;
- Establishment of Natural Forest;
- Grid-connected Solar PV;
- Household Biodigesters;
- Hydropower;
- Improved Forest Management;
- Industrial Biodigesters;
- Jurisdictional Avoided Deforestation and Forest Conversion (J-REDD);
- Landfill Gas Utilisation;
- Leak Repair in Natural Gas Transmission and Distribution System;
- Project-based Avoided Deforestation and Forest Degradation (REDD);
- Wind Power.

1.3 Data sources

To gather data on carbon credits, CENVI uses information from various sources. A key data source is information made available by carbon crediting programmes, which publish information on mitigation activities and carbon credits. This information is partially obtained from downloadable datasheets and partially collected from Mitigation Activity Design Documents made available by the carbon crediting programmes.

For the assessment of environmental integrity, a large variety of sources feed into our evaluation, including assessments from the ICVCM[7] and the CCQI[8], assessments from rating agencies that assess the integrity of specific mitigation activities[9], the Carbon Offset Guide[10], documents issued by carbon crediting programmes and scientific literature. Table 1 shows the various information sources used to assess the integrity of carbon credit categories, along with their limitations.

7 https://icvcm.org/assessment-status/
8 https://carboncreditquality.org/resources_evaluation.html
9 See, for example: BeZero Carbon (https://bezerocarbon.com/), Calyx Global (https://calyxglobal.com/) and Sylvera (https://www.sylvera.com/).
10 https://offsetguide.org/

Table 1 Information sources used to assess carbon credit categories

Information source	Type of information	Limitations
ICVCM assessments	• Assessment outcome for carbon crediting programmes and carbon credit categories (which includes an assessment of mitigation activity types and methodologies) • Informal board observations commenting approval decisions	• Assessment outcome is binary and does not differentiate quality within or between approved categories • Many assessments are still outstanding • Informal board observations do not include justifications why specific criteria are deemed to be satisfied
CCQI assessments	• Detailed scoring of categories of carbon credits against seven quality objectives • Publicly accessible and detailed justification for the scoring • Analysis of the likely risk of over- or underestimation for various methodologies • Assessment of additionality risk, non-permanence risk and double issuance risk for mitigation activity types • Assessment of carbon crediting programme provisions addressing additionality, non-permanence, and double issuance	• Coverage of about 80% of carbon credit issuances; yet certain categories of carbon types are not assessed
Publications by rating agencies	• Insights on critical integrity issues, e.g. risks associated with mitigation activity types or certain methodologies • Risk ratings are publicly available by some rating agencies	• Detailed information is not always publicly available
Carbon Offset Guide	• Risk classification of mitigation activity types	• Risk assessment does not differentiate between carbon crediting programmes and methodologies
Scientific literature	• Evaluation of the quality of methodologies, mitigation activity types and carbon crediting programmes	• Coverage limited to specific programmes, quantification methodologies and mitigation activity types
Carbon crediting programme provisions and quantification methodologies	• Detailed information on programme provisions publicly available	• Deriving integrity issues from programme documents is time-consuming and requires in-depth knowledge

Source: Authors‘ own compilation

These sources provide information in different formats and granularities. For our assessment, we prioritise empirical data on carbon credit integrity whenever available. However, in some instances, literature is not available or primarily provides qualitative assessments (e.g. on the quality of carbon crediting programme provisions). In these instances, we estimate individual parameters for our assessment based on our expert judgment. We aim to continuously increase the precision of estimates in the future based on emerging literature and technological advances that make comprehensive assessments of mitigation activity documentation possible, such as large language models.

Moreover, in conducting the integrity assessments, we always aim to identify the best estimate, i.e. we neither aim to be conservative (by overestimating underestimating a risk) nor lenient (by underestimating overestimating a risk). For example, if a literature source provides a range for a specific parameter, we choose the average value or the value that we deem the most accurate in our expert judgment.

2 Methodology to assess carbon credit integrity

The environmental integrity risk assessment lies at the heart of the model. For each carbon credit category, the model assesses the environmental integrity risk by determining the estimated share of emission reductions or removals per carbon credit issued that represents additional, actual and lasting emission reductions or removals that are not subject to double issuance. We refer to this share as the **total integrity factor.** Based on the total integrity factor, we assign a risk grade to each carbon credit category. For now, we focus our assessment on the GHG emission impact, and do not consider sustainable development or environmental and social risks.

The total integrity factor is the product of four integrity factors, which correspond to the following **four integrity criteria**: additionality, quantification, permanence and double issuance. These are central criteria in all major integrity frameworks, including CORSIA, the ICVCM, the CCQI and the framework for assessing the environmental integrity of carbon credits developed by Haase et al. (forthcoming), which is based on Deliverable 1.1 under the ACHIEVE project. For now, we focus our assessment on the environmental integrity in the context of GHG emission impact, and do not consider sustainable development or environmental and social risks. However, we may expand our assessment to refine existing integrity criteria and include additional ones as part of future refinements of CENVI.

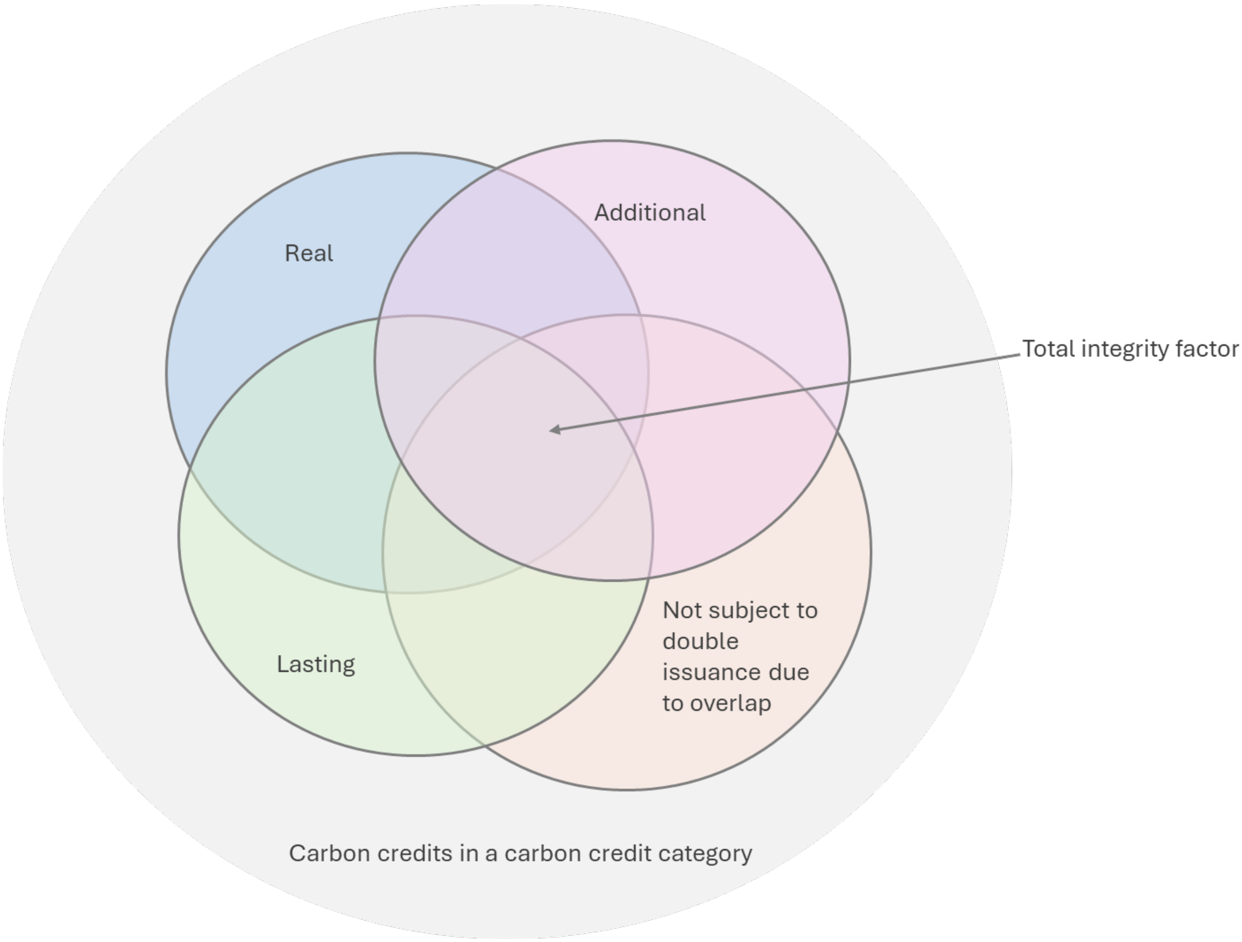
For each integrity criterion, we consider different attributes of a carbon credit category. For example, we usually consider only the quantification methodology to evaluate the integrity criterion ‘quantification’, as the quantification methodology mainly determines whether emission reductions or removals have been robustly quantified. In contrast, the risk assessment for ‘additionality’ considers both the mitigation activity type and the carbon crediting programme. This is because the additionality risks differ by mitigation activity types, and carbon crediting programmes’ provisions for assessing additionality vary in their stringency.

The remainder of the section is structured as follows: We first detail how we determine the total integrity factor (section 2.1). We then describe our assessment methodology for each integrity criterion: quantification (section 2.2), additionality (section 2.3), permanence (section 2.4), double issuance (section 2.5) and the limitations of the model (section 2.6).

2.1 Determining the total integrity factor and risk grade

The total integrity factor represents the estimated share of carbon credits in a carbon credit category that fulfil all four environmental integrity criteria (quantification, additionality, permanence and double issuance due to overlap), similar to the ‘Offset Achievement Ratio’ by Probst et al. 2024. Thus, the total integrity factor is the estimated share of emission reductions or removals per carbon credit issued in a carbon credit category that represent actual, additional and lasting emission reductions or removals that are not subject to double issuance. The concept of the integrity factor is visualised in Figure 1.

Figure 1 Conceptual visualisation of the total integrity factor



Under this approach we assume that the four criteria are independent from each other. We base our assumption on the understanding that each criterion addresses a separate aspect of carbon credit quality. For example, whether a project is additional depends, among other factors, on whether carbon credit revenues have a decisive impact in making the project financially viable. This consideration is independent of whether emission reductions are correctly estimated, which is determined by the quality of the emission quantification methodology. The risk of non-permanence depends on specific features of a project and the provisions of the carbon crediting programme to address non-permanence and therefore are very unlikely to be related to other quality criteria. Similarly, the risk of double issuance depends on whether other mitigation activities may claim the same emission reductions or removals and the provisions of carbon crediting programmes to address this risk and are hence also unrelated to the other quality criteria.

To calculate the total integrity factor for a carbon credit category, we multiply all individual integrity factors with each other, reflecting that carbon credits need to fulfil all four criteria to have a genuine emission impact (see Equation 1).

Equation 1 Total integrity factor per carbon credit category

$$IF_{Total,i} = IF_{Quantification,i} * IF_{Additionality,i} * IF_{Permanence,i} * IF_{Double\ issuance,i}$$

Where:

$IF_{Total,i}$	=	Total integrity factor for carbon credit category *i*, i.e. the estimated share of actual, additional and lasting emission reductions or removals that are not subject to double issuance
$IF_{Quantification,i}$	=	Integrity factor for quantification, i.e. the estimated share of carbon credits within carbon credit category *i* representing *actual* emission reductions or removals
$IF_{Additionality,i}$	=	Integrity factor for additionality, i.e. the estimated share of carbon credits within the carbon credit category *i* that represents additional emissions reductions or removals
$IF_{Permanence,i}$	=	Integrity factor for permanence, i.e. the estimated share of carbon credits within the carbon credit category *i* that are lasting, meaning that either no reversals occur, or reversals are compensated for
$IF_{DoubleIssuance,i}$	=	Integrity factor for the risk of double issuance, i.e. the estimated share of carbon credits within category *i* that are not subject to double issuance due to overlapping mitigation activities

The following example illustrates the calculation: A carbon credit category contains 100 carbon credits that were issued for emission reductions generated by wind power plants. For wind power plants, there is no risk of double issuance and non-permanence. However, the applied methodology leads to a slight overestimation; therefore, only 80 of carbon credits in this carbon credit category represent real emission reductions. In addition, wind power plants are often financially viable without carbon credits. Thus, in our example, only 20 carbon credits were generated by additional mitigation activities. Only those carbon credits that both represent real emission reductions *and* are based on additional activities can be considered to have a genuine emission impact. This means that in this case, the integrity factor would correspond to 16%.

To illustrate our findings, we assign a risk grade to the values of the total and individual integrity factors. For each risk grade we use a colour based on a traffic light system (see Table 2). We base these categories on the likelihood ranges of the IPCC (Mastrandrea et al. 2010).

Table 2 (Total) integrity factor and corresponding risk grade

Risk grade	(Total) integrity factor	Assigned colour
Low environmental integrity risk	More than 90%	Green
Medium environmental integrity risk	>66 – 90%	Yellow
High risk environmental integrity risk	33 – 66%	Orange
Very high environmental integrity risk	Less than 33%	Red

Source: Authors' own compilation

If information for a specific parameter is missing and we therefore cannot estimate an integrity factor for the respective criterion, we do not determine a total integrity factor for the respective carbon credit category. There is, however, one exception: for some categories, the assessment of one criterion might already indicate a total integrity factor that is lower than 33% (implying a very high environmental integrity risk). For example, literature has shown that most cookstove methodologies significantly overestimate emission reductions or removals. Therefore, the estimated share of carbon credits that represent actual emission reductions and removals is likely to be less than 33% for most categories containing cookstoves (Gill-Wiehl et al. 2024). In these cases, we classify the carbon credit category as ‘very high environmental integrity risk’, even if we do not have information regarding the other integrity criteria. We note that this might lead to a bias when aggregating data across various categories: categories with missing information but an integrity factor below 33% in a criterion are included, while categories with missing information but with an integrity factor above 33% are excluded. However, if a category has a very low integrity factor for one criterion, this cannot be compensated by high scores for one or more of the remaining criteria. Therefore, we can be certain that the category would have the lowest risk grade. In contrast, a category being evaluated higher than 33% in one criterion might still be brought down by the scores in other criteria. We therefore do not assign a risk grade for those categories.

2.2 Quantification

Various factors may influence the degree to which emission reductions or removals or overestimated or underestimated, i.e., how many carbon credits are issued compared to the real emission reductions mitigation activities generate. These factors may include whether emission reductions and removals are quantified in a conservative manner, systematically taking into account uncertainties, and whether the quantification approach ensures that the calculated emission reductions or removals can be attributed to the mitigation activity (Schneider et al. 2022a; ICVCM 2025a; Schneider et al. forthcoming). We define the integrity factor for quantification as the estimated share of carbon credits in a carbon credit category that represents actual emission reductions or removals, i.e. the ratio between estimated actual emission reductions and issued carbon credits (see Equation 2).

Equation 2 Integrity factor for quantification

$$IF_{Quantification,i} = \frac{Q_{actual,,i}}{Q_{issued,ME,i}}$$

Where:

$IF_{Quantification,i}$	=	Integrity factor for quantification, i.e. the estimated share of carbon credits within carbon credit category *i* representing *actual* emission reductions or removals
$Q_{actual,i}$	=	Estimated amount of actual emission reductions or removals in category *i* (*t CO_2e*)
$Q_{issued,ME,i}$	=	Number of carbon credits issued in category *i* based on the quantification of emission reductions or removals using the methodology *ME*

We derive $Q_{issued,ME,i}$ by considering quantitative research assessing the degree of overestimation for each methodology, wherever available, or by applying an expert judgment based on the available information. For example, if literature shows that applying a methodology leads to 30% overestimation, this means that 130 carbon credits are issued for every 100 t CO_2e of actual emission reductions and removals. In this example, the integrity factor would be determined as follows:

$$IF_{Quantification,i} = \frac{100}{130} = 79\%$$

As the CCQI provides comprehensive assessments of almost all criteria that are also considered under CENVI, CCQI findings are often used as the basis for the evaluation. This is particularly relevant for the criterion quantification, as the CCQI provides in-depth assessments of various quantification methodologies. Thus, we developed a consistent approach to convert CCQI methodology assessments into the integrity factor for quantification when these assessments are the only literature source.

For the conversion, we take the average range of overestimation (in %) from the CCQI assessments as the basis for the integrity factor for quantification (see Table 3). Moreover, we assume that significant uncertainty in estimating emission reductions or removals would, on average, also lead to overestimation, due to two effects: first, mitigation activities with overestimated emission reductions or removals are more likely to be implemented compared to those that underestimate emission reductions or removals. This is because they receive a larger number of credits, making it more likely that they become financially viable due to the revenues from carbon credits. Second, among those mitigation activities that are implemented, those with overestimation may be able to offer carbon credits at relatively lower prices and may thus receive the necessary support to continue or expand their mitigation. These 'adverse selection' effects are likely to lead to overestimation across all mitigation activities.

For quantification methodologies with the lowest CCQI score, we derive an estimate based on the specific information in the CCQI assessment.

Table 3 Approach for translating the CCQI assessments on over- or underestimation of emission reductions or removals in quantification methodologies into CENVI assessments

CCQI-Score	CCQI assessment	$\frac{Q_{actual,i}}{Q_{issued,ME,i}}$	$IF_{Quantification,ME,i}$
5	'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.'	$\frac{>100}{100}$	>100%
4	'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%)'	$\frac{100}{100}$	100%
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 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%)'	$\frac{100}{105}$	95%
2	'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%)'	$\frac{100}{120}$	83%
1	'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%)'	Estimation derived from specific information in the CCQI assessment	

Source: Schneider et al. 2022a

2.3 Additionality

To ensure environmental integrity, it is central that mitigation activities would not have been implemented in the absence of the incentives from carbon credits. An emission reduction or removal is either additional or it is not additional; there are no different 'types' of additionality (as is sometimes suggested by literature).

In our model, the integrity factor for additionality is defined as the estimated share of carbon credits within a carbon credit category that represents additional emissions reductions or removals (represented by parameter $IF_{Additionality,i}$). We consider two aspects when assessing whether an emission reduction or removal is additional:

- Whether the mitigation activity is likely viable without carbon credits and whether carbon credit revenues have a decisive impact on its viability, which is connected to the question whether carbon credits were factored in when making the investment decision (commonly referred to as 'prior consideration'); and
- Whether emission reductions or removals are triggered by legal requirements (commonly referred to as 'regulatory surplus').

When determining the integrity factor for additionality, both aspects are represented by separate factors that are multiplied with each other (see Equation 3). Therefore, the integrity factor for additionality can be imagined like the overlapping area of two Venn diagrams: it is the overlap between the estimated share of carbon credits generated by mitigation activities for which carbon credit revenues were decisive and the estimated share of carbon credits generated by mitigation activities that were not triggered by legal requirements. The underlying assumption is that the viability of mitigation activities without carbon credits is independent from them being legally required.

Equation 3 Integrity factor for additionality

$$IF_{Additionality,i} = (1 - A_{viability,P,MA,i}) * (1 - A_{legalrisk,MA} * \left(1 - A_{legalprogramme,P,MA,i}\right)$$

Where:

$IF_{Additionality,i}$	=	Integrity factor for additionality, i.e. the estimated share of carbon credits within the carbon credit category *i* that represents additional emissions reductions or removals
$A_{viability,P,MA,i}$	=	Estimated share of carbon credits within carbon credit category *i* that are generated by mitigation activities of mitigation activity type *MA* which are likely viable without carbon credit revenues or for which carbon credit revenues do not have a decisive impact on their viability, also considering how prior consideration provisions of the carbon crediting programme *P* limit the registration of such activities with the carbon crediting programme
$A_{legalrisk,MA}$	=	Estimated share of emission reductions or removals that are generated by mitigation activities of mitigation activity type *MA* which would occur anyways due to legal requirements (not considering any carbon crediting programme provisions on legal requirements)
$A_{legalprogramme,P,MA,i}$	=	Extent to which the estimated share of emission reductions and removals within carbon credit category *i* that are generated by mitigation activities of mitigation activity type *MA* that would occur anyways due to legal requirements ($A_{legalrisk,MA}$) is reduced due to relevant provisions of the carbon crediting programme *P*

To interpret the formula, it is important to consider the direction in which each parameter affects the integrity factor. Starting from the complete carbon credit category, we subtract the estimated share of carbon credits that is *not* additional due mitigation activities being already viable without carbon credit revenues or for which carbon credit revenues do not have a decisive impact on their viability ($A_{viabiltiy,P,MA,i}$). We then subtract the estimated share of carbon credits that is *not* additional due to the mitigation activities generating them being legally required. The latter share may be reduced if the carbon crediting programme has provisions in place to address legal requirements. Thus, $IF_{Additionality,i}$ represents the remaining share of carbon credits, i.e. the estimated share of carbon credits within the carbon credit category *i* that represents additional emissions reductions or removals.

This is illustrated by the following example: In a carbon credit category, 20% of carbon credits are generated by mitigation activities that would already be viable without carbon credits ($A_{viability,P,MA,i}$ = 20%) and 60% of emission reductions and removals are generated by mitigation activities that are legally required ($A_{legalrisk,MA}$ = 60%). However, the carbon crediting programme restricts the registration of mitigation activities that are legally required and therefore reduces the share of $A_{legalrisk}$ by 85% ($A_{legalprogramme,P,MA,i}$ = 85%). In this example, the integrity factor would be determined as follows:

$$IF_{Additionality,i} = (1 - 0.2) * \left(1 - 0.6 * (1 - 0.85)\right) = 73\%$$

The remainder of this section describes the assessment of the individual parameters in detail.

2.3.1 Viability of mitigation activities ($A_{viabiltiy,P,MA,i}$)

If a mitigation activity is already viable without the revenue from carbon credits or if carbon credit revenues have no decisive impact on its viability, it is unlikely to be additional. Our assessment of additionality therefore considers the estimated share of carbon credits that are generated by mitigation activities of this mitigation activity type which are viable without carbon credit revenues or for which carbon credit revenues do not have a decisive impact on their viability.

The mitigation activity type is considered to be the main predictor for the viability of a mitigation activity. For example, certain mitigation activity types are more often financially attractive without carbon credit revenues (e.g. renewable energy activities) or are more likely to not need additional incentives to overcome non-financial barriers (e.g. cookstoves in urban areas) than others for which carbon credit revenues are more likely to be decisive (e.g. abatement of N_2O from nitric acid production) (Schneider et al. 2022b). We therefore consider the typical viability of mitigation activities of the respective mitigation activity type, and the impact that carbon credit revenues have on them.

It is important to note that in assessing the viability of mitigation activity types, we consider do not limit our analysis to mitigation activities registered under carbon crediting programmes. For example, in the case of the mitigation activity type wind power, we take the overall financial attractiveness of wind power activities into account, not just wind power activities registered with carbon crediting programmes.

Moreover, we assume that the provisions of a carbon crediting programme for prior consideration reduce the number of mitigation activities that would already be viable without carbon credits but still register with a carbon crediting programme. This is because provisions on prior consideration aim to ensure that the revenues of carbon credits were considered in the mitigation activity proponent's decision to invest in the mitigation activity. If the proponent did not consider carbon credits in its investment decision but still proceeded with the implementation of the mitigation activity, the activity was already viable without carbon credits, or carbon credit revenues had no decisive impact on their viability. Therefore, they are not additional. Hence, we assume that the more stringent the carbon crediting programme provisions on prior consideration are, the more they reduce the share of mitigation activities that would already be viable without carbon credits.

The stringency of the carbon crediting provisions depends on what exactly is required to demonstrate prior consideration. For example, some carbon crediting programmes require mitigation activity proponents to provide public documentation of their intent to register a mitigation activity, while other programmes merely have time restrictions for the registration of mitigation activities after they start to generate emission reductions or removals.

Furthermore, the carbon crediting programmes' provisions on conducting viability analysis could also affect the parameter $A_{Viability,P,MA,i}$. However, we currently do not consider these provisions in our assessment. Examples of such viability analyses are financial attractiveness analyses, which demonstrate that a mitigation activity would not be financially attractive without the revenues from carbon credits, or barrier analyses, which demonstrate that carbon credits help to overcome barriers that would otherwise prevent the implementation of a mitigation activity. These analyses are, however, rather subjective, as they rely on a variety of assumptions, such as the cost of capital or the development of electricity prices over time (Haya and Parekh 2011). In addition, information asymmetry between mitigation activity proponents and third-party auditors or carbon crediting programmes has been identified as a major challenge of these analyses (Schneider 2009). Given the difficulty of objectively assessing the accuracy of these analyses, we currently do not consider differences in respective programme requirements in our assessment. We might revisit this in the future, as stricter standards are currently being developed for the Article 6.4 mechanism under the Paris Agreement.

2.3.2 Regulatory surplus ($A_{legalrisk,MA}$ and $A_{legalprogramme,P}$)

If emission reductions and removal are triggered by legal requirements, they are not additional. Therefore, another aspect central to assessing additionality is regulatory surplus, i.e. determining whether the implementation of a mitigation activity was triggered by legal requirements. The risk that emission reductions or removals are triggered by legal requirements varies by mitigation activity type. For example, whereas the use of efficient cookstoves is rarely mandated by laws, many developed countries require capturing and destroying methane from landfills. We therefore estimate the share of carbon credits that are issued for mitigation activities that are triggered by legal requirements for each mitigation activity type, represented by the parameter $A_{legalrisk,MA}$. As for the assessment of the viability of mitigation activities, it is important to note that we consider the risk of mitigation activities being legally required *in general*, not the risk of those mitigation activities that are registered with a carbon crediting programme.

In addition, we assume that this share also depends on the stringency of carbon crediting programme provisions for assessing regulatory surplus. As in the viability assessment, we assume that carbon crediting programme provisions act as a filter, reducing how many mitigation activities that are triggered by legal requirements register with a carbon crediting programme. The stringency of the programme's provisions influences this reduction, the extent of which is represented by the parameter $A_{Legalprogramme,P,i}$.

Most carbon crediting programmes already require that no carbon credits are issued for emission reductions or removals that are triggered by legal requirements if those legal requirements were already in place at the time a mitigation activity was registered. However, carbon crediting programmes provisions differ in important nuances, which we consider in our assessment. For instance, some carbon crediting programmes allow for exceptions when legal requirements are not widely enforced or do not consider legal requirements that are introduced after the start of a mitigation activity.

2.4 Permanence

To ensure environmental integrity, emissions reductions and removals need to either be permanent, meaning that they cannot be reversed at a later point in time, or any emission reductions or removals that are reversed ('reversals') need to be compensated for to avoid a net negative effect on the atmosphere. We refer to emission reductions and removals that fulfil these conditions as 'lasting'.

A key consideration for this integrity criterion is the time horizon for which any reversals are assessed. While from a climate change mitigation perspective, emission reductions or removals must be permanent for thousands of years, in practice, it is difficult to ensure that reversals are addressed for such a long time. We therefore consider 'lasting' to imply a timeframe of at least 100 years after the emission reductions or reversals occurs, given that this aligns with the strictest definition among carbon crediting programmes (FAO 2023).

We define the integrity factor for permanence, represented by the parameter $IF_{Permanence,i}$, as the estimated share of carbon credits within a category for which either no reversals occur or, if any reversals occur, these are compensated for (see Equation 4).

Equation 4 Integrity factor for permanence

$$IF_{Permanence,i} = 1 - (P_{reversal,MA} * (1 - P_{programme,P,MA,i}))$$

Where:

$IF_{Permanence,i}$	=	Integrity factor for permanence, i.e. the estimated share of carbon credits within the carbon credit category *i* that are lasting, meaning that either no reversals occur, or reversals are compensated for
$P_{reversal,MA}$	=	Estimated share of the emission reductions or that are generated by mitigation activities of the mitigation activity type *MA* that would be reversed over a time horizon of 100 years (not considering any carbon crediting programme provisions to address reversals)
$P_{programme,P,MA,i}$	=	Extent to which the estimated share of emission reductions or removals within carbon credit category *i* that are generated by mitigation activities of the mitigation activity type *MA* that would be reversed over a time horizon of 100 years ($P_{reversal,MA,i}$) is decreased, considering the degree to which provisions of the carbon crediting programme P 1) reduce the amount of mitigation activities with a high reversal risk register with the programme, 2) reduce the reversal risk of registered mitigation activities, and 3) ensure the compensation of reversals

To interpret the formula, it is important to consider the effect that each parameter has on the integrity factor. Starting from the complete carbon credit category, we deduct the estimated share of carbon credits that are reversed over a time horizon of 100 years ($A_{reversal,MA}$). This share may be reduced due to programme provisions reducing reversal risk and addressing reversals ($P_{programme,P,MA,i}$). Thus, $IF_{Permanence,i}$ represents the remaining share of carbon credits, i.e. the estimated share of carbon credits within the carbon credit category *i* that are lasting, meaning that either no reversals occur or reversals are compensated for.

This is illustrated by the following example: 60% of emission reductions or removals are generated by a mitigation activity type are assumed to be reversed over the next 100 years ($P_{reversal,MA}$ = 60%). Furthermore, programme provisions reduce this share by 40% ($P_{programme,P,MA,i}$ = 40%), by reducing the number of mitigation activities with a high reversal risk that register with the programme, reducing the reversal risk of registered mitigation activities, and ensuring the compensation of reversals. In this example, the integrity factor would be determined as follows:

$$IF_{Permanence,i} = 1 - (0.6 * (1 - 0.4)) = 64\%$$

The remainder of this section describes the assessment of the individual parameters in detail.

2.4.1 Reversal risk of mitigation activities ($P_{reversal,MA}$)

The risk of non-permanence differs considerably between mitigation activity types. We therefore evaluate the mitigation activity type's typical reversal risk (represented by parameter $P_{reversal,MA}$). For this parameter, we consider the reversal risk of the mitigation activity type in general, not only of those mitigation activities that have registered with a carbon crediting programme.

Some mitigation activity types have no or minimal reversal risk. For instance, some mitigation activities destroy or avoid the formation of non-CO_2 GHG (e.g. methane, nitrous oxide, and other gases) in a physically irreversible process (FAO 2023). Other activity types address the drivers of the depletion of carbon reservoirs directly, making a reversal unlikely. These mitigation activities include, for example, renewable energy activities, which reduce the demand for fossil fuels (Schneider et al. 2022b). We here use the classification adopted under the Article 6.4 Paris Agreement Crediting Mechanism (PACM) to identify which types of mitigation activities are subject to reversal risks (UNFCCC 2025). For mitigation activity types without a material reversal risk, $P_{reversal,MA}$ is assigned a value of 0.

For mitigation activity types that have a material reversal risk, such as activities that either enhance or protect carbon stocks in biogenic reservoirs (e.g. afforestation or avoided deforestation) or enhance carbon in a reservoir in other ways (e.g. carbon storage in products), we assign a respective value for $P_{reversal,MA}$. For mitigation activities with a material reversal risk, the parameter $P_{reversal,MA}$ represents the estimated share of the emission reductions or removals that would be reversed over a time horizon of 100 years, assuming that there are no carbon crediting programme provisions to reduce reversal risk or compensate for reversals.

To derive values for $P_{reversal,MA}$, we consider general factors that influence reversal risk of the mitigation activity type as well as empirical data and literature. General factors influencing the risk of reversal are a) the size of the reservoir (with larger reservoirs being less susceptible to reversals), b) whether the mitigation activity addresses the anthropogenic drivers of depletion, and c) the susceptibility of the reservoir to natural and human-caused depletion (FAO 2023). These factors are taken into account in estimating the magnitude of reversals for each mitigation activity type.

It is important to note that there is no comprehensive empirical data on the frequency and number of reversals for different types of mitigation activities. Some carbon crediting programmes make assumptions on the likelihood of reversals to determine their buffer pool contributions. For example, the California Air Resources Board (CARB) assumes that 2-4% of emission reductions and removals are at risk of being reversed due to wildfires over a 100-year period (ARB 2014). However, a recent study suggests that these assumptions likely underestimate the reversal risk. It found that a wildfire outbreak in 2022 likely depleted all carbon credits that were set aside in CARB's buffer pool to compensate reversals in case of wildfires in the next 100 years (Badgley et al. 2022). Therefore, we base our assessment on the limited available empirical analysis, such as case studies, as well as our expert judgment. It should be noted that these estimates are associated with high uncertainties.

2.4.2 Programme provisions regarding non-permanence ($P_{Programme,P,MA,i}$)

In a next step, we consider the extent to which carbon crediting programme provisions reduce reversals or require their compensation, represented by the parameter $P_{Programme,P,MA,i}$.

These provisions include:

- **Excluding mitigation activities with a high reversal risk:** Programmes may either reject individual activities based on the results of a risk assessment or exclude categories of high-risk activities through eligibility criteria;
- **Requiring risk mitigation measures:** Programmes may require or provide incentives for reducing reversal risks, which affects mitigation activities already registered with the carbon crediting programme; and
- **Compensation provisions**: Programmes may require that reversals are compensated for. In this context, the duration of monitoring and compensation, the liability assignment to compensate for reversals, and the compensation approach (e.g. buffer reserves) are key considerations. They affect carbon credits already registered with the carbon crediting programme.

We determine the stringency of programme provisions and their ability to reduce the reversal risk based on an expert judgement.

2.5 Double issuance due to overlapping mitigation activities

To ensure environmental integrity, each emission reduction or removal should only be counted once towards climate targets or goals, i.e., double counting of emissions reductions or removals should be avoided. Double counting can result from double issuance (i.e. if a mitigation activity is registered more than once or if two or more mitigation activities claim the same emissions reductions or removals), from double use (i.e. the same carbon credits being counted more than once towards climate targets or goals) and from double claiming (i.e. the same mitigation outcome being claimed by a country or entity reporting lower emissions or the user of the carbon credit claiming the same mitigation outcomes). Our analysis focuses on the risk of double issuance due to overlapping of mitigation activities, as this type of double counting is relevant for some of the most common mitigation activity types (e.g. avoided deforestation). In this version of the model, we do not consider other forms of double counting, as they are largely addressed through programme provisions or would need to be addressed through approaches beyond the carbon crediting programme rules, such as the application of corresponding adjustments under Article 6 of the Paris Agreement.

Double issuance due to overlapping mitigation activities occurs when two or more activities claim emission reductions or removals from the same GHG emission source or sink. For example, both the producer and the consumer of biofuel may claim carbon credits for the same emission reductions or removals (Schneider et al., forthcoming; ICVCM 2024; Schneider et al. 2022a). Other examples of mitigation activity types at risk of overlap are efficient biomass cookstoves, avoided deforestation, improved forest management, landfill gas utilisation, wind, grid-connected solar PV, hydropower, biomass, and composting (Schneider et al. 2022b).

We define the integrity factor for double issuance, represented by the parameter $IF_{DoubleIssuance,i}$, as the estimated share of carbon credits in a carbon credit category *i* that is not subject to double issuance due to overlapping mitigation activities. Equation 5 sets out how this parameter is calculated.

Equation 5 Integrity factor for double issuance

$$IF_{DoubleIssuance,i} = 1 - (DI_{risk,P,MA,ME,i} * 0.5)$$

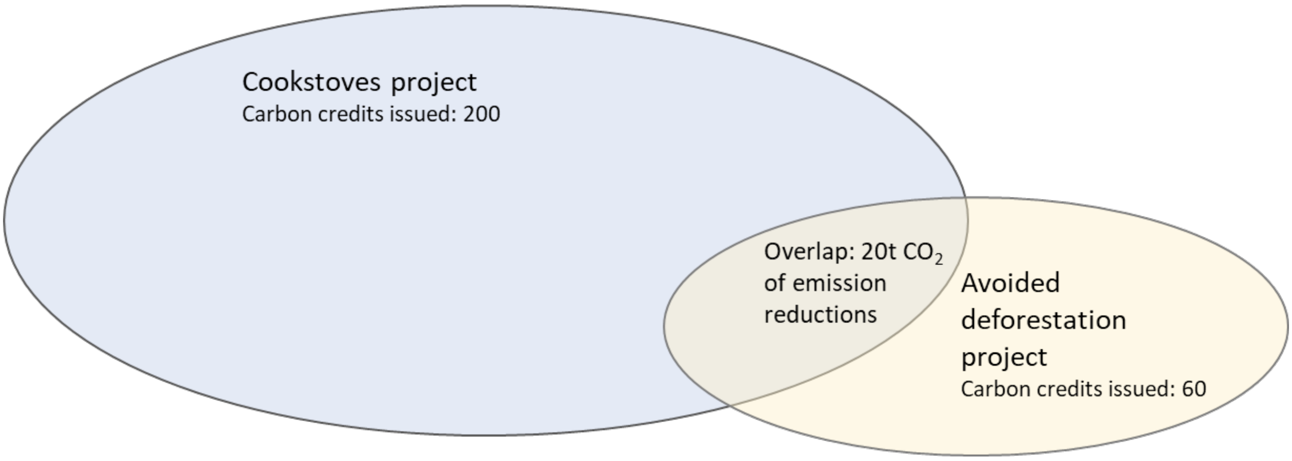
Where:

$IF_{DoubleIssuance,i}$	=	Integrity factor for the risk of double issuance, i.e. the estimated share of carbon credits within category *i* that are not subject to double issuance due to overlapping mitigation activities
$DI_{risk,P,MA,ME,i}$	=	Estimated share of emission reductions or removals generated within carbon credit category *i* that are generated by mitigation activities of the mitigation activity type *MA* that are subject to double issuance due to overlapping mitigation activities, also considering how respective general provisions of the carbon crediting programme *P* or the quantification methodology *ME* limit the occurrence of double issuance
0.5	=	Constant reflecting the assumption that the emission reductions and removals are equally allocated to both overlapping mitigation activities

To determine the parameter $DI_{risk,P,MA,ME,i}$, we evaluate in a first step whether the mitigation activity type has a material risk of double issuance due to overlap of mitigation activities. For mitigation activity types without a material risk of overlap, $DI_{risk,P,MA,ME,i}$ is assigned a value of 0.

For mitigation activity types with such a risk, we take the following approach: we first consider the average share of mitigation activities of the mitigation activity type that are subject to such overlap. In a second step, we estimate the average share of emission reductions and removals per affected mitigation activity that overlaps with another mitigation activity. This is illustrated in Figure 1 for the example of a cookstove project that overlaps with an avoided deforestation project. In the example, 20 carbon credits are issued twice for the same emission reductions: once for the cookstove project that reduces the consumption of biomass from a forest, and once for the avoided deforestation project that protects the same forest. As the cookstove project generates more emission reductions than the avoided deforestation project, these 20 carbon credits represent different percentages of each project's total emission reductions and removals (30% for the avoided deforestation project, 10% for the cookstove project).

Figure 2 Example illustration of an overlap between a cookstove and an avoided deforestation project



Source: Authors' own illustration

When two mitigation activities overlap and some underlying emission reductions or removals are assigned to both mitigation activities, it is unclear which of the mitigation activities is responsible for avoiding or addressing the overlap and hence which project causes which amount of double counted emission reductions. In our model, we allocate the overlapping emission reductions or removals equally to both mitigation activities (reflected by the constant 0.5 in Equation 5).

Moreover, in this example, we assume that 30% of all cookstove activities in a category are subject to overlap with avoided deforestation activities. In this case, the integrity factor would be calculated as follows:

$$IF_{DoubleIssuance,i} = 0.4 * 0.1 * 0.5 = 1.5\%$$

Please note that, in theory, there is also the possibility that more than two mitigation activities overlap. To simplify our analysis, we do not consider this possibility.

In a third step, we consider whether the carbon crediting programme or the quantification methodology applied by the programme addresses this risk. Some of the major carbon programmes address the risk of overlap, though this often differs between types of mitigation activities. For example, some programmes exclude mitigation activities with a material risk of overlap, or their quantification methodologies define the mitigation activity boundaries in a way that avoids overlap (Schneider et al. 2022b). Thus, our assessment considers how these provisions reduce the risk of double issuance due to overlap.

2.6 Limitations

CENVI has several limitations that should be considered when interpreting the results. First, quantitative empirical research is sparse for some criteria and parameters, making it necessary to rely on qualitative research and expert judgments for various parameters. These judgements may be subject to biases. Second, the assessment of criteria, such as additionality, that require considering a counterfactual scenario is inherently associated with uncertainty, as it is not possible to reliable derive what would have happened in absence of a mitigation activity. Third, the environmental integrity risks of carbon credits depend on a variety of criteria that are currently not considered in our model, such as the governance arrangements of carbon crediting programmes (Schneider et al. 2022a; ICVCM 2024). Fourth, in most instances we assess integrity for *categories* of carbon credits and not for *individual* mitigation activities. However, the circumstances of each mitigation activity are different; they may depend on, for instance, the mitigation activity proponent, the socioeconomic conditions of the region, and the political framework of the respective country. In most instances, our approach only determines an average environmental integrity risk of carbon credit categories and thus does not reflect the specific circumstances of each mitigation activity.

3 Outcomes of carbon credit integrity risk assessments

In this section, we summarise the outcomes of the carbon credit integrity risk assessments for all mitigation activity types that have been assessed so far. This summary outlines key factors that influence the outcome of the environmental integrity assessment, identifies the primary information sources used in our assessment, and summarises key findings. Due to the uncertainty associated with the estimates regarding individual or total integrity factors, we do not present the specific values in this section. Instead, we provide the risk grade or risk grade range for each criterion and the total categories (see section 2.1).

3.1 General results

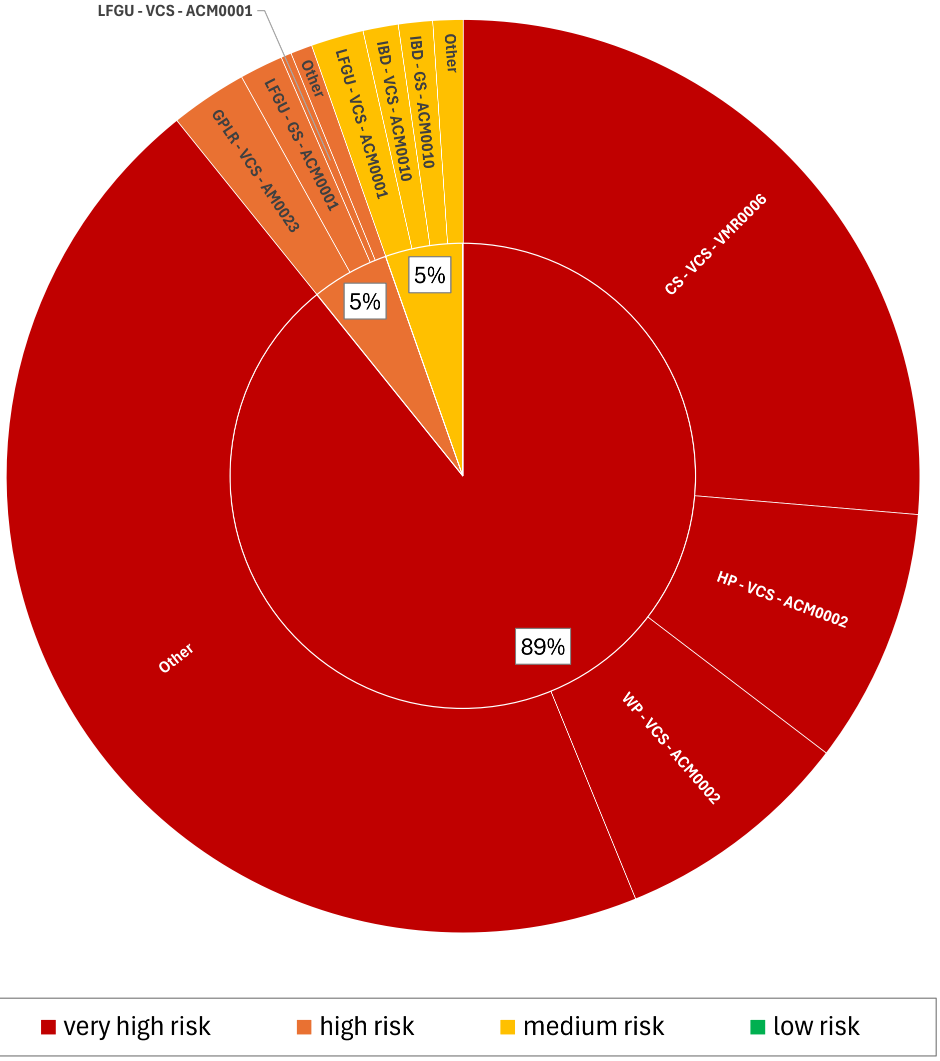
As of December 2025, information on the issuance potential is available for 5,199 mitigation activities registered under ART, GS, and VCS in its database.[11] Out of those, 2,779 mitigation activities are registered under the GS, 2,419 are registered under the VCS and one mitigation activity is registered under ART. These mitigation activities are expected to generate annual emission reductions or removals of about 768 Mt CO_2e.

CENVI currently assesses the environmental integrity of categories of carbon credits that comprise 3,014 out of the 5,199 mitigation activities, i.e. 57% of all mitigation activities for which information on the issuance potential is available. These mitigation activities are expected to generate annual emission reductions or removals of about 419 Mt CO_2e, i.e. 55% of total expected annual emission reductions or removals from ART, GS and the VCS.

Figure 3 shows the distribution of environmental integrity risk grades of expected annual emission reductions or removals generated by mitigation activities that are covered by the assessed categories of carbon credits.

[11] In addition, 1,379 mitigation activities registered under ACR and CAR are included in the database.

Figure 3 All assessed categories of carbon credits: Estimated annual emission reductions or removals by risk grade



Source: Authors' own compilation

Notes: The figure illustrates for each risk grade the three largest carbon credit categories. Categories consist of combinations of the mitigation activity type, the carbon crediting programmes, and the quantification methodologies,. Mitigation activity types: CS = cookstove activities whose fuel types in the baseline and mitigation activity scenario are not identified, HP = Hydropower, WP = Wind Power, GPLR = Leak Repair in Natural Gas Transmission and Distribution Systems, LGFU = Landfill Gas Utilisation, IBD = Industrial Biodigesters. Carbon crediting programmes: VCS = Verified Carbon Standard, GS = Gold Standard. Methodologies: VMR0006 = Verified Carbon Standard VMR0006 Energy Efficiency and Fuel Switch Measures in Thermal Applications, ACM0002 = Clean Development Mechanism ACM0002 Consolidated baseline methodology for grid-connected electricity generation from renewable sources, AM0023 = Clean Development Mechanism AM0023 Leak reduction from natural gas pipeline compressor or gate stations, ACM0001 = Clean Development Mechanism ACM0001 Flaring or use of landfill gas, ACM0010 = Clean Development Mechanism ACM0010 Consolidated methodology for GHG emission reductions from manure management systems.

The three categories with the highest total integrity factor are: 1) Industrial Biodigesters – GS – ACM0010, 2) Industrial Biodigesters – GS – Gold Standard GHG Emission Reductions from Manure Management Systems and Municipal Solid Waste, and 3) Industrial Biodigesters – VCS – ACM0010. These categories are assigned the medium risk grade.

3.2 Commercial Afforestation for Timber Harvesting

Similar to the CCQI, we define this mitigation activity type as the establishment of a planted forest on non-forest land areas that are ecologically appropriate for forests, excluding naturally non-forested biomes, semi-natural grasslands, as well as the boreal region due to albedo-effects. The established forest is primarily used for commercial timber harvesting, but activities may additionally involve non-timber harvesting (e.g. fruits, nuts). Accordingly, the tree species composition may differ from the natural forest type in the area. This mitigation activity type includes neither the establishment of agroforestry and marine coastal ecosystems, such as mangroves, nor the management of the project area through community forestry. The mitigation activity type leads to removals by increasing forest carbon stocks and possibly carbon stored in harvested wood products (derived from CCQI 2024ad).

We assess the environmental integrity of carbon credit categories consisting of this mitigation activity type, considering all possible combinations of the following attributes:

- **Carbon crediting programmes:** Gold Standard (GS) and Verified Carbon Standard (VCS);
- **Quantification methodologies:** CDM AR-ACM0003 Afforestation and reforestation of lands except wetlands (short: CDM AR-ACM0003) and the Gold Standard Afforestation-Reforestation GHG Emission Reductions & Sequestration Methodology.

Another attribute by which we differentiate our assessment is:

- **Location:** We differentiate our assessment between countries in which cooking with biomass is common and countries in which it is not. This distinction is relevant for the criterion double issuance due to overlap.

3.2.1 Key issues for each integrity criterion

Quantification: According to CCQI analyses, applying the analysed methodologies likely leads to a low to moderate degree of overestimation of removals. CCQI found that the methodologies' lack of comprehensive requirements regarding the baseline setting and baseline updating are a central source of overestimation, which is particularly relevant as commercial afforestation activities tend to have longer crediting periods than other mitigation activity types. Moreover, the GS Methodology Afforestation-Reforestation GHG Emission Reductions & Sequestration allows mitigation activity proponents to assume that there is no growth of carbon stocks in the baseline scenario, which we assume leads to a slightly higher overestimation than the methodology CDM AR-ACM0003 (CCQI 2024v; 2023j).

Overall, we assess the integrity risk for this criterion to be very high.

Additionality: The CCQI found that mitigation activities may already be financially viable without carbon credits and thus have very high additionality risks. As the mitigation activities involve commercial timber harvesting, they generate income streams beyond revenues from the sale of carbon credits. This means that this mitigation activity type may be profitable without the revenues of carbon credits, depending on the project's location and the cultivated tree species. This notion is underpinned by a CCQI analysis of the financial viability of commercial afforestation activities based on a sample of CDM projects and data from additional literature sources (CCQI 2024u). The results show a high variance in financial viability, depending on the tree species and country. In addition, the analysis found that 14 out of 25 combinations between countries and tree species are financially attractive without carbon credits, implying that mitigation activities belonging to this mitigation activity type are likely viable without carbon credits.

We also consider how carbon programme provisions reduce the risk of registering already viable mitigation activities. Based on CCQI analyses, we generally assume that programme provisions only lead to a slight reduction in additionality risks since they are not able to prevent registration of already viable carbon credits entirely: mitigation activities may demonstrate prior consideration aligned with the programme's requirements but still be viable without carbon credits. The analyses show that while the VCS' provisions do not prevent the registration of activities after their project start, the GS has such provisions in place and is therefore more likely to reduce the share of mitigation activities that are already viable without carbon credits (CCQI 2022a; 2024t).

Commercial afforestation mitigation activities might be implemented in response to legal requirements, in which case they would not be additional (CCQI 2024ad). Regarding programme provisions to address legal requirements, CCQI analyses show that both GS provisions and VCS provisions lead to an exclusion of mitigation activities that are mandated by legal requirements but allow for exceptions in the case of non-enforcement of laws and regulations (CCQI 2024s; 2024r). We assume that these and other provisions lead to a substantial reduction of registered mitigation activities that are legally required.

Permanence: This mitigation activity type has material non-permanence risks, as forests may be destroyed through anthropogenic forces, such as land conversion, or natural disturbances, such as wildfires (Schneider et al. 2024; CCQI 2024p). We used an expert judgement to estimate the share of credited removals that will be reversed over a 100-year period in the absence of carbon crediting provisions.

The risk of non-permanence may be addressed through various programme provisions, whose effectiveness we evaluate based on CCQI assessments. These show that the VCS and the GS have several provisions in place to address non-permanence, notably including provisions regarding monitoring and compensation of reversals. However, the required monitoring periods are substantially shorter than 100 years: 40 years under the VCS and 30 to 50 years under the GS (CCQI 2024w; 2024x; 2024q; 2024y). Thus, we assume that the programme provisions address reversals only to some extent.

Double issuance due to overlap: This mitigation activity type has a material risk of double issuance due to overlapping mitigation activities. Overlaps can occur if an activity aiming to reduce the consumption of firewood (e.g. cookstove activities) is located close to an afforestation project, and both activities claim the same emission reductions or removals from the increased forest carbon stock (CCQI 2024ad).

To estimate the average share of emission reductions and removals that is subject to double issuance due to overlap, we apply an expert judgement based on an own analysis and a report by Calyx Global (Calyx Global 2023). We estimate this risk only for located in countries where cooking with biomass is common. However, we assume that double issuance risks are lower for Commercial

Afforestation activities than for avoided deforestation, as they are on managed lands and therefore often have an incentive to implement stricter measures against firewood collection.

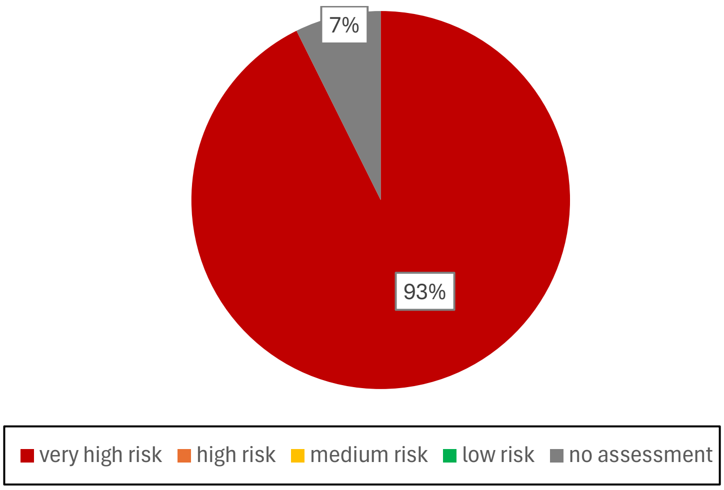
Neither the VCS nor the GS address this risk at the time of this assessment (CCQI 2024ad).

3.2.2 Results

As of December 2025, the CENVI model contains 95 registered Commercial Afforestation for Timber Harvesting activities with an annual removal enhancement potential of about 16 Mt CO_2e.[12] This accounts for 2.1% of estimated annual emission reductions or removals of all mitigation activities included in CENVI. We have sufficient information to assess the integrity of categories encompassing 67 of the 95 mitigation activities, corresponding to 93% of the annual removals belonging to this mitigation activity type.

All assessed carbon credit categories belonging to this mitigation activity type are classified as having very high environmental integrity risks (see Figure 4). This is primarily driven by high risks of non-additionality combined with medium to high risks of non-permanence.

Figure 4 Commercial Afforestation for Timber Harvesting: Estimated annual removals by risk grade



Source: Authors' own compilation

3.3 Efficient Cookstoves

Similar to the CCQI, we consider cookstove activities to be the distribution of new cookstoves to households or institutions (e.g. schools) to replace less efficient or fossil fuel cookstoves (derived from CCQI 2023c). Moreover, we distinguish between different types of efficient cookstove activities, based on the type of cookstove and fuel used in the original and the new cookstoves. For example,

[12] The estimated annual emission reductions are included in the GS' and VCS' registries and stem from the mitigation activities documentation.

a project might replace traditional biomass cookstoves with liquified petroleum gas (LPG) cookstoves. The type of cookstove project influences the assessment results. However, due to the overarching similarities, we summarise the results for all cookstove mitigation activity types in this section.

We assess the environmental integrity of carbon credit categories consisting of this mitigation activity type, considering all possible combinations of the following attributes:

- **Mitigation activity types:** Replacing biomass cookstoves with more efficient biomass cookstoves; replacing biomass cookstoves with efficient biofuel cookstoves; replacing biomass cookstoves with efficient fossil fuel cookstoves; and cookstove activities whose fuel types in the baseline and mitigation activity scenario are not identified ('cookstoves unassigned'). The latter is assessed the same as activities that replace biomass with more efficient biomass, as we assume most unidentified cookstove activities fall under that mitigation activity type;

- **Carbon crediting programmes:** Gold Standard (GS) and Verified Carbon Standard (VCS);

- **Quantification methodologies:** Gold Standard Technologies and Practices to Displace Decentralized Thermal Energy Consumption (GS TPDDTEC), CDM AMS-II.G, CDM AMS-I.E, the GS Simplified Methodology, and the GS Metered and Measured Methodology.[13]

3.3.1 Key issues for each integrity criterion

Quantification: Several sources identify the overestimation of emission reductions as the key environmental integrity risk of cookstove projects. All assessed quantification methodologies share, to a large extent, the same issues that may lead to an overestimation (Gill-Wiehl et al. 2024). Methodologies often allow mitigation activity proponents to use the CDM TOOL30 to determine f_{NRB}, which offers considerable leeway for how to estimate this parameter. Studies show that most mitigation activity proponents assume f_{NRB} values of 80% or higher which are substantially above estimates derived from independent models using satellite-based and ground data, such as the Modelling Fuelwood Savings Scenarios (MoFuss) model[14]. In May 2025, the CDM Executive Board withdrew TOOL30 and adopted default values for f_{NRB} based on the MoFuss model.[15] In addition, behavioural factors of the target population also play a significant role in overestimation. These include adoption and usage rates of the new cookstoves, the continued use of the pre-project cookstove ('stove stacking'), and rebound effects, all of which affect a project's fuel savings. Common monitoring methods to determine stove efficiency, such as the Water Boiling Test, have been shown to be unreliable and likely lead to an overestimation of fuel savings, whereas the direct

13 The full names of the methodologies and the versions we analysed are: Gold Standard Reduced emissions from cooking and heating – technologies and practices to displace decentralized thermal energy consumption (TPDDTEC) (version 1.0 – version 4.0); Clean Development Mechanism AMS-II.G. Energy efficiency measures in thermal applications of non-renewable biomass (version 1.0 – version 13.1); Clean Development Mechanism AMS-I.E. Switch from non-renewable biomass for thermal applications by the user (version 1.0 – version 12.0); Gold Standard Simplified methodology for clean and efficient cookstoves (version 1.0 – version 3.0) and the Gold Standard Methodology for metered & measured energy cooking devices (version 1.0 – version 1.2).

14 https://www.mofuss.unam.mx/

15 CDM Executive Board, report of the 125th meeting. https://cdm.unfccc.int/UserManagement/FileStorage/CTVUINODJZP8LRWAYX305SK7H9M216

measurement of stove use and Kitchen Performance Tests (KPTs) provide more accurate results (Gill-Wiehl et al. 2024). The analysis by Gill-Wiehl et al. (2024) considers these and additional factors for estimating the likelihood of overestimation for different quantification methodologies.

Overall, we assess the integrity risk for this criterion to be very high.

Additionality: Calyx Global's analysis of 50 cookstove activities shows that these mitigation activities have low additionality risks (Carbon Credit Quality Initiative (CCQI) 2023c; CCQI 2022c; Schneider et al. 2023; Carbon Credit Quality Initiative (CCQI) 2022; The Integrity Council for the Voluntary Carbon Market (ICVCM) 2025).

We also consider how carbon programme provisions reduce the risk of registering already viable mitigation activities. Based on CCQI analyses, we generally assume that programme provisions only lead to a slight reduction in additionality risks since they are not able to prevent registration of already viable carbon credits entirely: mitigation activities may demonstrate prior consideration aligned with the programme's requirements but still be viable without carbon credits. The analyses show that while the VCS' provisions do not prevent the registration of activities after their project start, the GS has such provisions in place and is therefore more likely to reduce the share of mitigation activities that are already viable without carbon credits (CCQI 2022a; 2024t).

Moreover, according to the CCQI there is no known case of cookstove activities being legally required (CCQI 2024r).

Overall, we assess the integrity risk for this criterion to be low.

Permanence: Cookstove project types that displace non-renewable biomass have a material non-permanence risk, as they aim at reducing the consumption of non-renewable biomass, thereby conserving carbon stocks in forests, croplands, or grasslands. These stocks are at risk of being destroyed or depleted later on (Carbon Credit Quality Initiative (CCQI) 2023c). Such an overlap may happen if a cookstove project decreases the use of renewable biomass and therefore conserves carbon stocks on nearby forest lands, and a forestry project claims emission reductions or removals for conserving the same forest. To estimate the integrity factor for double issuance, we determine the likelihood of double issuance for cookstove activities based on an analysis of Calyx Global (Schneider et al. 2023) and an own analysis of cookstove activities. Neither the GS nor the VCS has measures in place to address the risk of overlap (CCQI 2024ad).

Overall, we assess the integrity risk for this criterion to be low.

3.3.2 Results

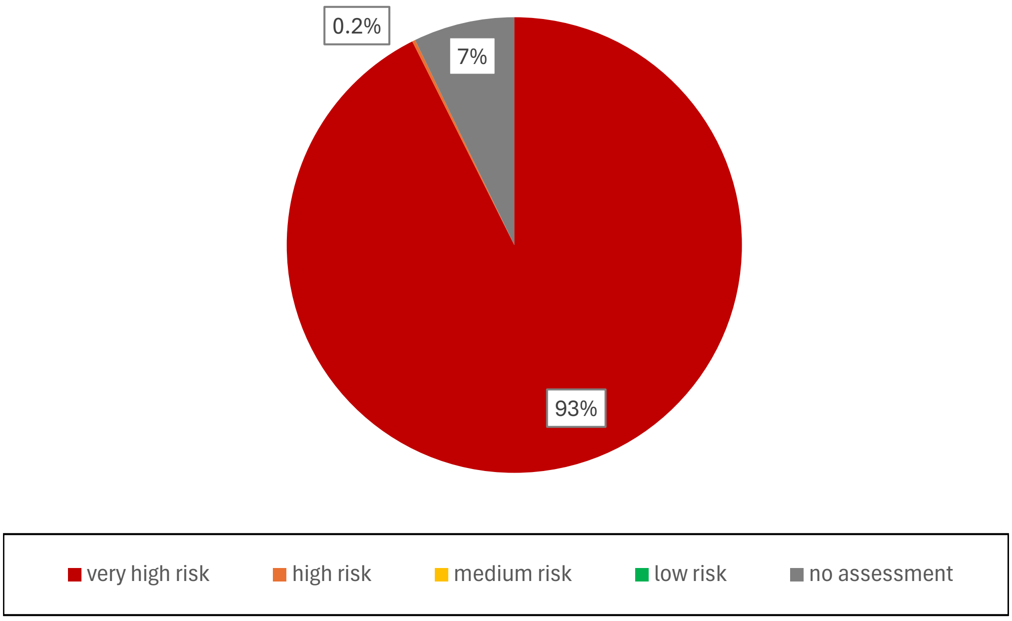
As of December 2025, the CENVI model contains 1,180 registered cookstove activities with an annual emission reduction potential of about 225 Mt CO_2e.[16] This accounts for 29.3% of the estimated annual emission reductions or removals of all mitigation activities included in CENVI. We have sufficient information to assess the integrity of the categories encompassing 990 of the 1,180 mitigation activities, corresponding to 93% of the annual emission reductions belonging to this

[16] The estimated annual emission reductions are included in the GS' and VCS' registries and stem from the mitigation activities documentation.

mitigation activity type. However, in our assessment, we assume that most cookstove activities are located in rural areas (Calyx Global 2025; Gill-Wiehl et al. 2024; CCQI 2022e; 2022d). Similar to the CCQI, we consider cookstove activities to be the distribution of new cookstoves to households or institutions (e.g. schools) to replace less efficient or fossil fuel cookstoves (derived from CCQI 2023c). Moreover, we distinguish between different types of efficient cookstove activities, based on the type of cookstove and fuel used in the original and the new cookstoves. For example, a project might replace traditional biomass cookstoves with liquified petroleum gas (LPG) cookstoves. The type of cookstove project influences the assessment results. However, due to the overarching similarities, we summarise the results for all cookstove mitigation activity types in this section.

Nearly all assessed carbon credit categories involving cookstoves are classified as having very high environmental integrity risks (see Figure 5). This is primarily driven by the very high risk of overestimating emission reductions. The GS Metered and Measured methodology is an exception: it also has a risk of overestimation, but to a much lesser extent than the other assessed methodologies (Gill-Wiehl et al. 2024). Carbon credit categories that include this methodology fall into the high risk grade, but only account for 0.2% of all estimated annual emission reductions from assessed cookstove activities.

Figure 5 Efficient Cookstoves: Estimated annual emission reductions by risk grade



Source: Authors' own compilation

3.4 Establishment of Natural Forest

We define this mitigation activity type according to the CCQI as the '[e]stablishment of a forest on non-forest land areas that are ecologically appropriate for forests, excluding naturally non-forested biomes and semi-natural grasslands as well as the boreal region due to albedo-effects. The forest will not be used for any commercial purposes, such as harvesting, but may be used for sustainable subsistence. The tree species composition is based on the natural forest type of the area. This mitigation activity type does not include the restoration of marine coastal ecosystems, such as mangroves. The mitigation activity type removes greenhouse gases by increasing forest carbon stock.' (CCQI 2023d)

We assess the environmental integrity of carbon credit categories consisting of this mitigation activity type, considering all possible combinations of the following attributes:

- **Carbon crediting programmes:** Gold Standard (GS) and Verified Carbon Standard (VCS);
- **Quantification methodologies:** CDM AR-ACM0003 Afforestation and reforestation of lands except wetlands (short: CDM AR-ACM0003) and the Gold Standard Afforestation Reforestation GHG Emission Reductions & Sequestration Methodology.

3.4.1 Key issues for each integrity criterion

Quantification: According to CCQI analyses, applying the analysed methodologies likely leads to a low to moderate degree of overestimation of removals. CCQI found that the methodologies' lack of comprehensive requirements regarding the baseline setting and baseline updating are a central source of overestimation, which is particularly relevant as commercial afforestation activities tend to have longer crediting periods than other mitigation activity types. Moreover, the GS Methodology Afforestation-Reforestation GHG Emission Reductions & Sequestration allows mitigation activity proponents to assume that there is no growth of carbon stocks in the baseline scenario, which likely leads to a slightly higher overestimation than the methodology CDM AR-ACM0003 (CCQI 2024v; 2023j).

Overall, we assess the integrity risk for this criterion to be low to medium.

Additionality: The CCQI found that no or very few mitigation activities were already viable without carbon credits, as Establishing Natural Forest activities usually have no additional revenues or cost savings other than carbon credit revenues (CCQI 2022b). Therefore, we assume that carbon credit revenues are frequently considered when making the investment decision.

Commercial afforestation activities might be implemented in response to legal requirements, in which case they would not be additional (CCQI 2024ad). Regarding programme provisions to address legal requirements, CCQI analyses show that both GS provisions and VCS provisions lead to an exclusion of mitigation activities that are mandated by legal requirements but allow for exceptions in the case of non-enforcement of laws and regulations (CCQI 2024s; 2024r). We assume that these and other provisions lead to a substantial reduction of registered mitigation activities that are legally required.

Overall, we assess the integrity risk for this criterion to be low.

Permanence: This mitigation activity type has a material non-permanence risks, as forests may be destroyed through anthropogenic forces, such as land conversion, or natural disturbances, such as wildfires (Schneider et al. 2024; CCQI 2024p). We use an expert judgement to estimate the share of credited removals that will likely be reversed over a 100-year period in the absence of carbon crediting provisions. We assume that the risk for reversals for Establishment of Natural Forest activities is lower than for other forest-related mitigation activity types, as the forest accumulates carbon even after the crediting period ends and it is therefore less likely that disturbances cause reversals of the emission removals for which carbon credits were issued.

The risk of non-permanence may be addressed through various programme provisions, whose effectiveness we evaluate based on CCQI assessments. These show that the VCS and the GS have several provisions in place to address non-permanence, notably including provisions regarding monitoring and compensation of reversals. However, the required monitoring periods are substantially shorter than 100 years: 40 years under the VCS and 30 to 50 years under the GS (CCQI 2024w; 2024x; 2024q; 2024y). Thus, we assume that the programme provisions address reversals only to some extent.

Overall, we assess the integrity risk for this criterion to be low to medium.

Double issuance due to overlap: This mitigation activity type has a material risk of double issuance due to overlapping mitigation activities. Overlaps can occur if an activity aiming to reduce the consumption of firewood (e.g. cookstove activities) is located close to an afforestation project, and both activities claim the same emission reductions or removals from the increased forest carbon stock (CCQI 2024ad).

To estimate the average share of emission reductions and removals that is subject to double issuance due to overlap, we apply an expert judgement based on an own analysis and a report by Calyx Global (Calyx Global 2023). We estimate this risk only for countries where cooking with biomass is common.

Neither the GS nor the VCS address this risk at the time of this assessment (CCQI 2024ad).

Overall, we assess the integrity risk for this criterion to be low.

3.4.2 Results

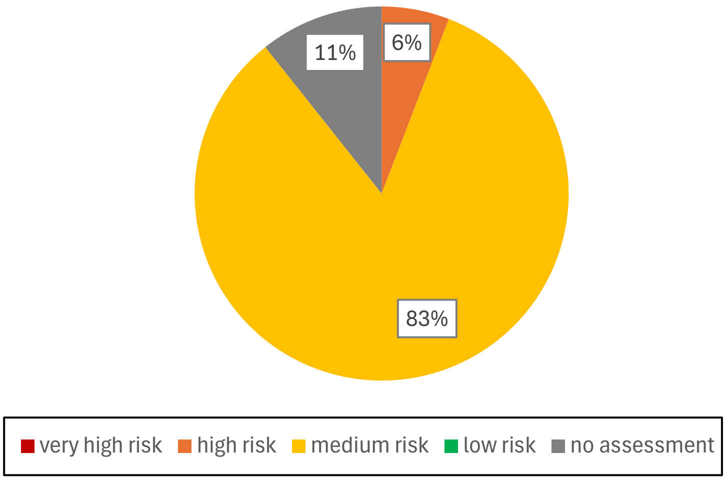
As of December 2025, the CENVI model contains 66 registered mitigation activities establishing natural forest with an annual removal enhancement potential of about 7 Mt CO_2e.[17] This accounts for less than 1% of estimated emission reductions and removals of all registered mitigation activities included in CENVI. We have sufficient information to assess the integrity of the categories encompassing 43 of the 66 mitigation activities, corresponding to of 89% of annual removal enhancements belonging to this mitigation activity type.

The majority of annual emission reductions belonging to this mitigation activity type are generated by categories with medium environmental integrity risks. The remaining annual emission

[17] The estimated annual emission reductions are included in the GS‘ and VCS‘ registries and stem from the mitigation activities documentation.

reductions are generated by categories with high risks (see Figure 6). This is due to a combination of low to medium risks for all integrity criteria, which lead to medium risks overall.

Figure 6 Establishment of Natural Forest: Estimated annual removals by risk grade



Source: Authors‘ own compilation

3.5 Grid-connected Solar PV

Similar to the CCQI, we define this mitigation activity type as the installation of a centralised solar photovoltaic power plant. The electricity is fed into a national or regional electricity grid. The mitigation activity type reduces emissions by displacing more greenhouse gas intensive electricity generation (derived from CCQI 2023e).

We assess the environmental integrity of carbon credit categories consisting of this mitigation activity type, considering all possible combinations of the following attributes:

- **Carbon crediting programmes:** Gold Standard (GS) and Verified Carbon Standard (VCS);
- **Quantification methodologies:** Clean Development Mechanism ACM0002 Consolidated baseline methodology for grid-connected electricity generation from renewable sources (short: CDM ACM0002) and Clean Development Mechanism AMS-I.D. Grid connected renewable electricity generation (CDM AMS-I.D).

3.5.1 Key issues for each integrity criterion

Quantification: According to CCQI analyses, applying the analysed methodologies likely leads to a low to moderate degree of overestimation of emission reductions. The methodology CDM AMS-I.D. is the small-scale version of methodology CDM ACM0002 and uses largely the same approaches, except for some minor simplifications.

The key source of overestimation is the assumed trajectory of the grid emission factor. Both methodologies allow for a fixed value for the entire crediting period rather than updating it annually. This approach fails to reflect that the grid emission factor is declining over time in most regions of the world, as the share of renewables is expanding due to their profitability and policy support (CCQI 2023k; 2023h).

Overall, we assess the integrity risk for this criterion to be medium.

Additionality: The CCQI and the Carbon Offset Guide identify the lack of additionality as a key environmental integrity risk for Grid-connected solar PV activities. They are likely financially viable without the revenues from carbon credits, as they generate revenues streams and benefit from policy support in many regions of the world. Moreover, carbon credit revenues make up only a minor share of their total project revenues (Broekhoff et al. 2025; CCQI 2023aa).

We also consider how carbon programme provisions reduce the risk of registering already viable mitigation activities. Based on CCQI analyses, we generally assume that programme provisions only lead to a slight reduction in additionality risks since they are not able to prevent registration of already viable carbon credits entirely: mitigation activities may demonstrate prior consideration aligned with the programme's requirements but still be viable without carbon credits. The analyses show that while the VCS' provisions do not prevent the registration of activities after their project start, the GS has such provisions in place and is therefore more likely to reduce the share of mitigation activities that are already viable without carbon credits (CCQI 2022a; 2024t).

Overall, we assess the integrity risk for this criterion to be very high.

Permanence: This mitigation activity type does not involve a non-permanence risk (CCQI 2023x).

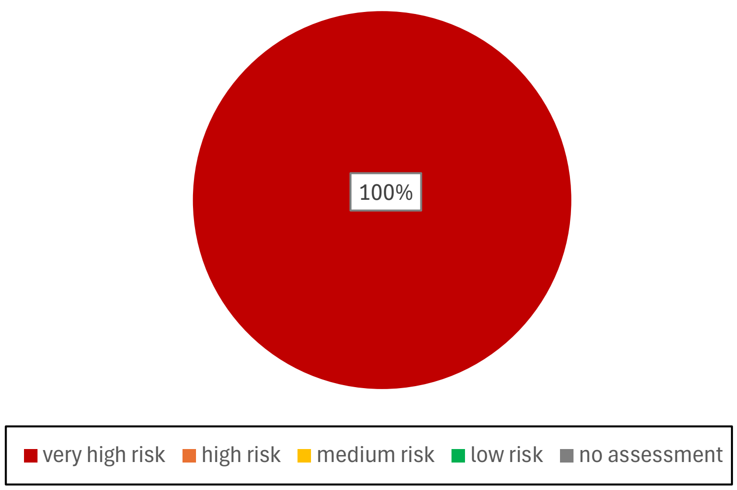
Double issuance due to overlap: There is in practice no material risk of double issuance due to overlapping mitigation activities for this mitigation activity type (CCQI 2024z).

3.5.2 Results

As of December 2025, the CENVI model contains 234 registered Grid-connected Solar PV activities with an annual emission reduction potential of more than 37 Mt CO_2e.[18] This accounts for 4.9% of estimated annual emission reductions and removals of all registered mitigation activities included in CENVI. We can assess the integrity of all of the categories belonging to this mitigation activity type.

All assessed carbon credit categories belonging to this mitigation activity type are classified as having very high environmental integrity risks (see Figure 7). This is primarily driven by very high risks of non-additionality.

Figure 7 Grid-connected Solar PV: Estimated annual emission reductions by risk grade



Source: Authors' own compilation

[18] The estimated annual emission reductions are included in the GS' and VCS' registries and stem from the mitigation activities documentation.

3.6 Household Biodigesters

Similar to the CCQI, we define this mitigation activity type as the generation of biogas by anaerobic digestion of livestock manure, and possibly other household waste such as kitchen waste, through household size or community-scale biodigesters. The biogas is used by households for cooking. The mitigation activity type may include a compost unit that utilizes the fermented sludge from the biodigester to produce organic fertilizer. The mitigation activity type reduces emissions by (i) avoiding methane emissions from the uncontrolled decomposition of livestock manure and (ii) by reducing the use of firewood or fossil fuels for cooking activities. Mitigation activities are located in rural areas in developing countries (derived from CCQI 2023ac).

We assess the environmental integrity of carbon credit categories consisting of this mitigation activity type, considering all possible combinations of the following attributes:

- **Carbon crediting programmes:** Gold Standard (GS) and Verified Carbon Standard (VCS); and
- **Quantification methodologies:** Clean Development Mechanism AMS-I.C. Thermal energy production with or without electricity (short: CDM AMS-I.C), Clean Development Mechanism AMS-I.E. Switch from non-renewable biomass for thermal applications by the user (CDM AMS-I.E), Clean Development Mechanism AMS-III.R. Methane recovery in agricultural activities at household/small farm level (CDM AMS-III.R), Gold Standard reduced emissions from cooking and heating -technologies and practices to displace decentralized thermal energy consumption (TPDDTEC) and Gold Standard Methodology for animal manure management and biogas use for thermal energy generation.

3.6.1 Key issues for each integrity criterion

Quantification: According to the CCQI, applying the analysed methodologies leads to a significant overestimation of emission reductions. The degree of overestimation may vary depending on the type of biodigester project. Biodigester activities differ, as some replace the use of fossil fuels, while others replace non-renewable biomass such as firewood or charcoal, and some do both. In addition, some mitigation activities avoid methane emissions, as the manure that is fed to the biodigesters would have generated methane in the absence of the project (CCQI 2023u).

The most important source of overestimation for mitigation activities that replace non-renewable biomass is the fraction of non-renewable biomass (f_{NRB}). The parameter represents the share of biomass that a project conserves (relative to the baseline) and that is assumed not to regrow. Therefore, the higher the share, the higher the estimated emission reductions (Gill-Wiehl et al. 2024). Methodologies often allow mitigation activity proponents to use the CDM TOOL30 to determine f_{NRB}, which offers considerable leeway for how to estimate this parameter. Studies show that most mitigation activity proponents assume f_{NRB} values of 80% or higher, which are substantially above estimates derived from independent models using satellite-based and ground data, such as the Modelling Fuelwood Savings Scenarios (MoFuss) model[19] (Bailis et al. 2015; Ghilardi and Bailis 2024). In May 2025, the CDM Executive Board withdrew TOOL30 and adopted default values for

[19] https://www.mofuss.unam.mx/

f_{NRB} based on the MoFuss model.[20] According to the CCQI, mitigation activities replacing fossil fuel cooking still face some of the same overestimation risks as mitigation activities that replace non-renewable biomass, such as the omission of key emission sources. However, overestimation through applying the analysed methodologies is likely to be lower. Regarding the avoidance of methane emissions, a CCQI analysis shows that applying the analysed methodologies likely leads to accurate results, but is associated with high uncertainty (CCQI 2023p).

Overall, we assess the integrity risk for this criterion to be high.

Additionality: According to a CCQI analysis, household biodigester activities often face barriers in their implementation, such as high up-front installation costs and no access to finance, which carbon credits can help overcome. However, the analysis states that biodigesters are already used in some households, and carbon credit revenues likely accelerate the uptake (CCQI 2023n). Correspondingly, an analysis by Calyx Global showed that most household biodigester and cookstove activities have low additionality risks (Calyx Global 2025). Thus, we assume that few carbon credits are issued for mitigation activities that were already viable without carbon credits.

We also consider how carbon programme provisions reduce the risk of registering already viable mitigation activities. Based on CCQI analyses, we generally assume that programme provisions only lead to a slight reduction in additionality risks since they are not able to prevent registration of already viable carbon credits entirely: mitigation activities may demonstrate prior consideration aligned with the programme's requirements but still be viable without carbon credits. The analyses show that while the VCS' provisions do not prevent the registration of activities after their project start, the GS has such provisions in place and is therefore more likely to reduce the share of mitigation activities that are already viable without carbon credits (CCQI 2022a; 2024t).

Moreover, according to the CCQI, there is no known case of household biodigester activities being legally required (CCQI 2024r).

Overall, we assess the integrity risk for this criterion to be medium.

Permanence: The non-permanence risk of household biodigesters depends on the processes that the biodigester replace (Schneider et al. 2023; CCQI 2023z).

In case that household biodigesters replace cooking with fossil fuels or avoid methane emissions from livestock, there is no non-permanence risk. However, household biodigesters displacing cooking with non-renewable biomass have a material non-permanence risk, as they aim at reducing the consumption of non-renewable biomass, thereby conserving carbon stocks in forests, croplands, or grasslands. These stocks are at risk of being destroyed or depleted later on. As household biodigester activities address the underlying drivers of deforestation or forest degradation, this risk of non-permanence is likely lower than for forestry project types, such as REDD activities (Schneider et al. 2023; CCQI 2023z). Neither the GS nor the VCS address the non-permanence risk for household biodigester activities.

[20] CDM Executive Board, report of the 125th meeting. https://cdm.unfccc.int/UserManagement/FileStorage/CTVUINODJZP8LRWAYX305SK7H9M216

Overall, we assess the integrity risk for this criterion to be medium.

Double issuance due to overlap: This mitigation activity type has a material risk of double issuance due to overlapping mitigation activities. Overlaps can occur if an activity aiming to reduce the consumption of firewood (e.g. cookstove activities) is located close to an afforestation project, and both activities claim the same emission reductions or removals from the increased forest carbon stock (CCQI 2024ad).

To estimate the average share of emission reductions and removals that is subject to double issuance due to overlap, we apply an expert judgement based on an own analysis and a report by Calyx Global (Calyx Global 2023). We estimate this risk only for those countries where cooking with biomass is common.

None of the carbon crediting programmes addresses this risk at the time of this assessment (CCQI 2024ad).

Overall, we assess the integrity risk for this criterion to be low.

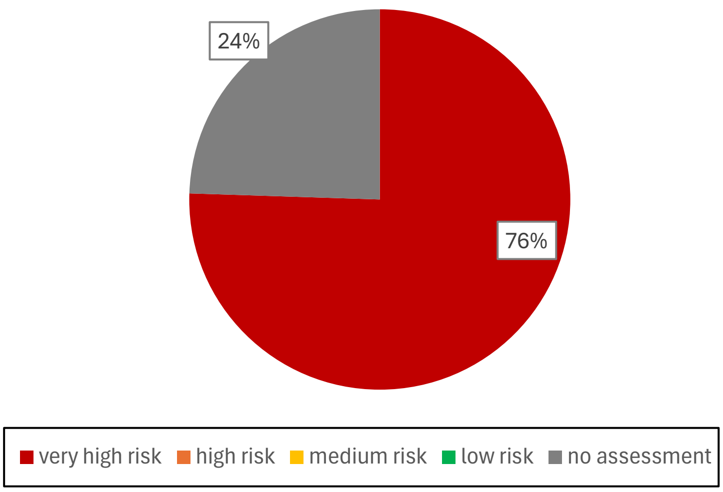
3.6.2 Results

As of December 2025, the CENVI model contains 220 registered Household Biodigester activities with an annual emission reduction potential of about 8 Mt CO_2e.[21] This accounts for 1.1% of estimated annual emission reductions or removals of all registered mitigation activities included in CENVI. We can assess the integrity of the categories encompassing 163 out of the 220 mitigation activities, corresponding to 76% of all estimated annual emission reductions belonging to this mitigation activity type.

All assessed carbon credit categories belonging to this mitigation activity type are classified as having very high environmental integrity risks (see Figure 8). This is primarily driven by high risks of overestimating emission reductions combined with medium risks of non-additionality and non-permanence.

[21] The estimated annual emission reductions are included in the GS' and VCS' registries and stem from the mitigation activities documentation.

Figure 8 **Household Biodigesters: Estimated annual emission reductions by risk grade**



Source: Authors' own compilation

3.7 Hydropower

Similar to the CCQI, we define this mitigation activity type as the installation of a new hydro power plant. We consider two types: (i) the installation of plants with no or minimal storage harvesting energy from flowing water, such as rivers or streams, and (ii) the installation of plants by building a new dam or the installation of additional power generation capacity at an existing reservoir. The electricity is fed into a national or regional electricity grid. The mitigation activity type reduces emissions by displacing more greenhouse gas intensive electricity generation (derived from CCQI 2023g).

We assess the environmental integrity of carbon credit categories consisting of this mitigation activity type, considering all possible combinations of the following attributes:

- **Carbon crediting programmes:** Gold Standard (GS) and Verified Carbon Standard (VCS);
- **Quantification methodologies:** Clean Development Mechanism ACM0002 Consolidated baseline methodology for grid-connected electricity generation from renewable sources (short: CDM ACM0002) and Clean Development Mechanism AMS-I.D. Grid connected renewable electricity generation (CDM AMS-I.D).

Another attribute by which we differentiate our assessment is:

- **Size:** We distinguish between hydropower activities with up to 15 MW capacity and hydropower activities with more than 15 MW capacity. This distinction is relevant for the assessment of additionality.

3.7.1 Key issues for each integrity criterion

Quantification: According to CCQI analyses, applying the analysed methodologies likely leads to a low to moderate degree of overestimation of emission reductions. The methodology CDM AMS-I.D is the small-scale version of methodology CDM ACM0002 and uses largely the same approaches, except for some minor simplifications.

The key source of overestimation is the assumed trajectory of the grid emission factor. Both methodologies allow for a fixed value for the entire crediting period rather than updating it annually. This approach fails to reflect that the grid emission factor is declining over time in most regions of the world, as the share of renewables is expanding due to their profitability and policy support (CCQI 2023k; 2023h).

Overall, we assess the integrity risk for this criterion to be medium.

Additionality: Carbon credits are seldom a decisive factor when deciding whether to implement a hydropower project (Broekhoff et al. 2025). This is supported by a CCQI analysis, which shows that hydropower activities are already likely to be financially viable without carbon credits, albeit small scale activities to a lesser extent. Moreover, carbon credits do not substantially influence the financial viability of hydropower activities (CCQI 2023g). In addition, large-scale hydropower activities are often integrated into national planning processes, which are primarily driven by considerations regarding energy security, environmental considerations, or irrigation demands. It is unlikely that carbon credits influence these decisions (Haya and Parekh 2011; Cames et al. 2016; IEA 2021b).

We also consider how carbon programme provisions reduce the risk of registering already viable mitigation activities. Based on CCQI analyses, we generally assume that programme provisions only lead to a slight reduction in additionality risks since they are not able to prevent registration of already viable carbon credits entirely: mitigation activities may demonstrate prior consideration aligned with the programme's requirements but still be viable without carbon credits. The analyses show that while the VCS' provisions do not prevent the registration of activities after their project start, the GS has such provisions in place and is therefore more likely to reduce the share of mitigation activities that are already viable without carbon credits (CCQI 2022a; 2024t).

Moreover, according to the CCQI, there is no known case of hydropower activities being legally required (CCQI 2024r).

Overall, we assess the integrity risk for this criterion to be high to very high.

Permanence: This mitigation activity type does not involve a non-permanence risk (CCQI 2023i).

Double issuance due to overlap: There is in practice no material risk of double issuance due to overlapping mitigation activities for this mitigation activity type (CCQI 2024a).

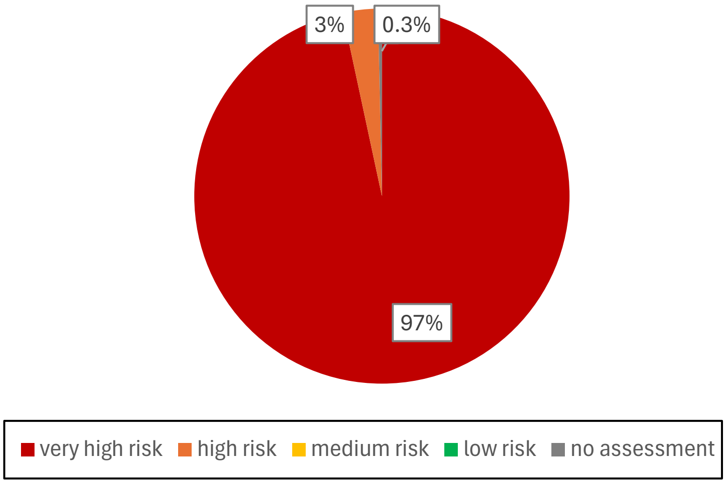
3.7.2 Results

As of December 2025, the CENVI model contains 430 registered Hydropower activities with an annual emission reduction potential of about 58 Mt CO_2e.[22] This accounts for 7.6% of estimated annual emission reductions and removals of all mitigation activities included in CENVI. We have sufficient information to assess the integrity of categories encompassing 421 of the 430 mitigation activities, corresponding to more than 99% of all estimated annual emission reductions belonging to this mitigation activity type.

The majority of annual emission reductions belonging to this mitigation activity type are generated by categories with very high environmental integrity risks. The remaining annual emission reductions are generated by categories with high risks (see Figure 9). This is primarily driven by high to very high risks of non-additionality combined with medium risks of overestimating emission reductions.

[22] The estimated annual emission reductions are included in the GS' and VCS' registries and stem from the mitigation activities documentation.

Figure 9 **Hydropower: Estimated annual emission reductions by risk grade**



Source: Authors‘ own compilation

3.8 Improved Forest Management

According to the CCQI, we define this mitigation activity type as ‘forest management practices that aim to increase carbon stocks of forests and/or avoid their loss.’ (CCQI 2024ae). Improved Forest Management activities may implement one or several different activities, which may include extended rotation, production to conservation, increasing productivity, reduced impact logging and avoiding degradation.

We assess the environmental integrity of carbon credit categories consisting of this mitigation activity type, considering all possible combinations of the following attributes:

- **Carbon crediting programmes:** Verified Carbon Standard (VCS);
- **Quantification methodologies:** VCS VM0003 Methodology for Improved Forest Management through Extension of Rotation Age (short: VM0003), VCS VM0005 Methodology for Conversion of Low-Productive Forest to High-Productive Forest (VM0005), VCS VM0010 Methodology for Improved Forest Management: Conversion from Logged to Protected Forest (VM0010) and VCS VM0012 Methodology for Improved Forest Management in Temperate and Boreal Forests (LtPF) (VM0012).

Another attribute by which we differentiate our assessment is:

- **Location:** We differentiate our assessment between countries in which cooking with biomass is common and countries in which it is not. This distinction is relevant for the criterion double issuance due to overlap.

3.8.1 Key issues for each integrity criterion

Quantification: CCQI analyses found that applying the analysed methodologies likely leads to a very high overestimation of emission reductions, due to various issues. First, the methodologies provide considerable leeway in establishing baseline emissions. This is likely to lead to picking baselines that overestimate emission reductions. Moreover, the large uncertainty of how forests will be managed in the future in the light of changing circumstances, such as timber prices, policies and regulations, is not accounted for. Secondly, the analysed methodologies offer substantial leeway regarding the quantification of carbon stocks which may lead to picking factors or methods that lead to overestimation of emission reductions. Lastly, the leakage is likely not sufficiently accounted for. Leakage in the context of IFM activities means that the project leads to an increase in timber harvesting elsewhere or an increase in the production of substitute materials to compensate for the reduction of the supply of wood products. The CCQI found leakage deductions required by the methodologies are often not sufficient to account for leakage (CCQI 2024j; 2024n; 2024o; 2024i).

Overall, we assess the integrity risk for this criterion to be very high.

Additionality: According to CCQI analyses, the additionality risks of IFM activities range between medium and very high, as they depend on the implemented activities.

Mitigation activities that stop an ongoing logging operation to conserve the forest are likely not viable without carbon credits, as the forest owners are foregoing revenues (CCQI 2024d). In contrast, mitigation activities that increase the productivity of the forest are very likely already viable without carbon credits, as these activities are already widespread and increase the profitability of forests (CCQI 2024h). Similarly, mitigation activities that avoid the start of or increase in harvesting compared to the baseline scenario or target harvesting towards higher quality timber might still receive revenues from harvesting, making it likely that mitigation activities were viable without carbon credit revenues (CCQI 2024g).

Mitigation activities implementing reduced impact logging are more likely to be already viable without carbon credits, as they can increase the profit of a timber operation in the long term. However, they are sometimes not implemented due to barriers such as high upfront costs or the lack of expertise, which carbon credits may help overcome (CCQI 2024e). Mitigation activities that extend the time before harvesting might also be already viable without carbon credits, depending on how much the rotation is extended. Short delays are common in forest management, as the harvesting time decisions depend on a variety of economic and ecological factors, which may influence the harvesting time independent of carbon credit revenues. However, longer delays likely imply that revenues are foregone (CCQI 2024b).

In addition, if conservation easements are in place, they increase additionality risks for IFM activities substantially. Conservation easements are an incentive mechanism in the US that promotes specific conservation objectives. They are voluntary agreements between private landowners and a conservation entity, such as a trustee or government agency, whereby the landowner provides certain land-use rights to a conservation entity in exchange for substantial tax benefits. If the conservation easement requires the specific activity that is implemented by the IFM project, it is very unlikely that this project is additional. The VCS does not address the issue of conservation easements (CCQI 2024b). We also consider how carbon programme provisions reduce the risk of registering already viable mitigation activities. Based on CCQI analyses, we generally assume that programme provisions only lead to a slight reduction in additionality risks since they are not able to prevent registration of already viable carbon credits entirely: mitigation activities may demonstrate prior consideration aligned with the programme's requirements but still be viable without carbon credits. The analyses show that while the VCS' provisions do not prevent the registration of activities after their project start, the GS has such provisions in place and is therefore more likely to reduce the share of mitigation activities that are already viable without carbon credits (CCQI 2022a; 2024t).

According to the CCQI, many countries have federal, state or local laws and regulations that contain requirements regarding forest management. Thus, we assume that there is a risk of IFM being triggered by forest-related regulation (CCQI 2024s). Regarding programme provisions to address legal requirements, CCQI analyses show that both GS provisions and VCS provisions lead to an exclusion of mitigation activities that are mandated by legal requirements but allow for exceptions in the case of non-enforcement of laws and regulations (CCQI 2024s; 2024r). We assume that these and other provisions lead to a substantial reduction of registered mitigation activities that are legally required.

Overall, we assess the integrity risk for this criterion to be high.

Permanence: This mitigation activity type has a material non-permanence risks, as forests may be destroyed through anthropogenic forces, such as land conversion, or natural disturbances, such as wildfires (Schneider et al. 2024; CCQI 2024p). We used an expert judgement to estimate the share of credited removals that will likely be reversed over a 100-year period in the absence of carbon crediting provisions.

The risk of non-permanence may be addressed through various programme provisions, whose effectiveness we evaluate based on CCQI assessments. These show that the VCS and the GS have several provisions in place to address non-permanence, notably including provisions regarding monitoring and compensation of reversals. However, the required monitoring periods are substantially shorter than 100 years: 40 years under the VCS and 30 to 50 years under the GS (CCQI 2024w; 2024x; 2024q; 2024y). Thus, we assume that the programme provisions address reversals only to some extent.

Overall, we assess the integrity risk for this criterion to be high.

Double issuance: This mitigation activity type has a material risk of double issuance due to overlapping mitigation activities. Overlaps can occur if an activity aiming to reduce the consumption of firewood (e.g. cookstove activities) is located close to an IFM project, and both activities claim the same emission reductions or removals from the increased forest carbon stock (CCQI 2024ad).

To estimate the average share of emission reductions or removals that is subject to double issuance due to overlap, we apply an expert judgement based on internal data and a report by Calyx Global (Calyx Global 2023). We consider this risk only for those countries where cooking with biomass is common. Moreover, we assess the risk of double issuance to be lower for IFM activities than for other forest-related mitigation activity types. First, only about half of annual emission reductions of this mitigation activity type are issued from mitigation activities in countries where cooking with biomass is common. In addition, IFM activities are on managed lands and therefore likely have an incentive to implement measures against firewood collection.

None of the carbon crediting programmes addresses this risk at the time of this assessment (CCQI 2024ad).

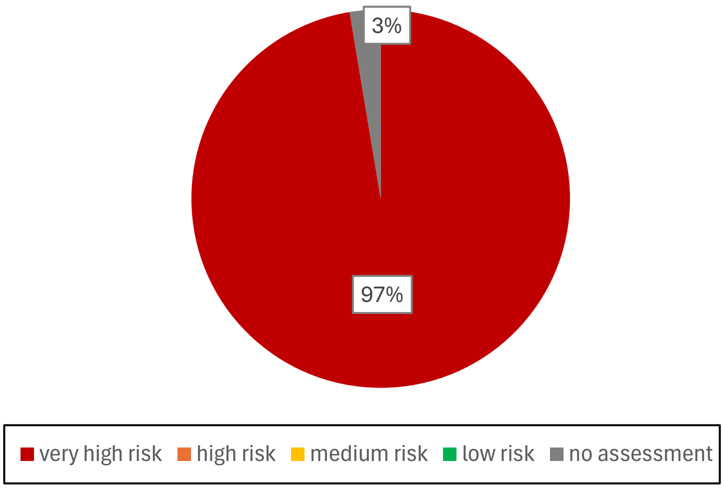
Overall, we assess the integrity risk for this criterion to be low.

3.8.2 Results

As of December 2025, the CENVI model contains 34 registered Improved Forest Management activities with an annual potential of reducing emissions or enhancing removals of about 5 Mt CO_2e.[23] This accounts for 0.6% of estimated annual emission reductions and removals of all mitigation activities included in CENVI. We have sufficient information to assess the integrity of categories encompassing 33 of the 34 mitigation activities, corresponding to 97% of all estimated annual emission reductions or removals belonging to this mitigation activity type.

All assessed carbon credit categories belonging to this mitigation activity type are classified as having very high environmental integrity risks (see Figure 10). This is primarily driven by a high risk of non-additionality combined with a high risk of non-permanence and a very high risk of overestimating emission reductions or removals.

Figure 10 Improved Forest Management: Estimated annual emission reductions or removals by risk grade



Source: Authors' own compilation

23 The estimated annual emission reductions are included in the GS' and VCS' registries and stem from the mitigation activities documentation.

3.9 Industrial Biodigesters

According to the CCQI, we define this mitigation activity type as the '[g]eneration of biogas by anaerobic digestion of livestock manure. The biogas is combusted for the generation of power and/or heat, which can be fed into the grid or used on-site. A smaller fraction of the gas may be flared. The mitigation activity type reduces emissions by (i) avoiding methane emissions from the uncontrolled decomposition of livestock manure and (ii) by displacing more greenhouse gas intensive energy generation based on fossil fuels.' (CCQI 2023a).

We assess the environmental integrity of carbon credit categories consisting of this mitigation activity type, considering all possible combinations of the following attributes:

- **Carbon crediting programmes:** Gold Standard (GS) and Verified Carbon Standard (VCS);
- **Quantification methodologies:** Clean Development Mechanism ACM0010 Consolidated methodology for GHG emission reductions from manure management systems (short: CDM ACM0010), Clean Development Mechanism AMS-III.D. Methane recovery in animal manure management systems (CDM AMS III.D) and GS GHG emission reductions from manure management systems and municipal solid waste.

3.9.1 Key issues for each integrity criterion

Quantification: CCQI analyses show that applying the analysed methodologies likely leads to a low to moderate degree of overestimation of emission reductions.

The CDM methodology ACM0010 covers all major emission sources but relies heavily on default parameters and simplified modelling, which leads to significant uncertainty. We assume that this uncertainty likely results in an overestimation of emission reductions or removals (for an explanation, see section 2.2) (CCQI 2023r).

The methodology GS GHG emission reductions from manure management systems and municipal solid waste is largely based on version 7 of the ACM00010, with only minor differences. Therefore, the same factors leading to overestimation are also relevant for this methodology (CCQI 2023s).

The methodology AMS-III.D is based on the methodology ACM0010 but applies to small-scale activities. It contains some simplifications regarding the considered emission sources, as it does not include emissions from nitrous oxide and leakage emissions due to the disposal of treated manure (CCQI 2023q). Due to these simplifications, we assume that it leads to a higher overestimation than the ACM0010.

Overall, we assess the integrity risk for this criterion to be low to medium.

Additionality: According to a CCQI analysis based on a sample of CDM activities, many industrial biodigester activities are not financially viable without carbon credit revenues and carbon credit revenues substantially impacted their viability (CCQI 2023a).

However, there is a moderate risk that industrial biodigesters are legally required, as manure use is regulated in many countries. A 2014 assessment of manure policy frameworks in 34 developing countries found that 30 had policies addressing manure management, while 18 had policies specifically related to digestion (Teenstra et al. 2014). Regarding programme provisions to address legal requirements, CCQI analyses show that both GS provisions and VCS provisions lead to an exclusion of mitigation activities that are mandated by legal requirements but allow for exceptions in the case of non-enforcement of laws and regulations (CCQI 2024s; 2024r). We assume that these and other provisions likely lead to a substantial reduction of registered mitigation activities that are legally required.

Overall, we assess the integrity risk for this criterion to be medium.

Permanence: This mitigation activity type does not involve a non-permanence risk (CCQI 2023v).

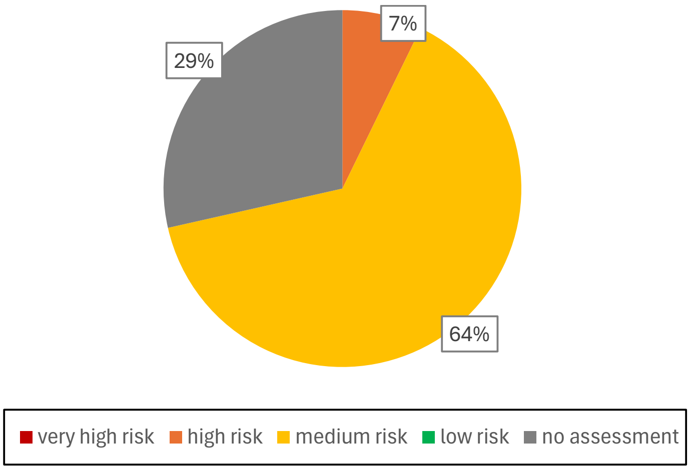
Double issuance due to overlap: There is no risk of double issuance due to overlapping mitigation activities for this mitigation activity type (CCQI 2024z).

3.9.2 Results

As of December 2025, the CENVI model contains 160 registered Industrial Biodigesters activities with an annual emission reduction potential of about 22 Mt CO_2e.[24] This accounts for 2.9% of estimated annual emission reductions and removals of all mitigation activities included in CENVI. We have sufficient information to assess the integrity of categories encompassing 99 of the 160 mitigation activities, corresponding to 71% of all estimated annual emission reductions belonging to this mitigation activity type.

The majority of annual emission reductions belonging to this mitigation activity type are generated by categories with medium environmental integrity risks. The remaining annual emission reductions are generated by categories with high risks (see Figure 11). This is primarily driven by a medium risk of non-additionality combined with low to medium risks of overestimating emission reductions.

Figure 11 Industrial Biodigesters: Estimated annual emission reductions by risk grade



Source: Authors' own compilation

[24] The estimated annual emission reductions are included in the GS' and VCS' registries and stem from the mitigation activities documentation.

3.10 Jurisdictional Deforestation and Forest Degradation activities (JREDD) in high forest, low deforestation (HFLD) jurisdictions

We define the mitigation activity type JREDD as reducing emissions from deforestation and forest degradation on a jurisdictional scale, implemented with government involvement. The accounting area encompasses an entire country, one or several subnational jurisdictions, or an area whose boundary is defined by other factors, such as an ecozone or concentration of economic activity located in one or stretching across several subnational jurisdictions. JREDD typically includes the adoption or strengthening of governmental policies and regulations as well as other measures that aim to reduce deforestation and forest degradation. Examples are land tenure reforms, formalising land zoning, enforcement of existing laws, designing development plans and establishing benefit sharing arrangements. We distinguish between JREDD mitigation activities with the attribute 'HFLD' and 'non-HFLD', where HFLD refers specifically to jurisdictions with high forest and low deforestation (HFLD), see for instance TNC (2023). The distinction between HFLD and non-HFLD is particularly relevant with regards to the integrity criteria quantification and additionality.

As of today, there is only one registered JREDD mitigation activity in CENVI. This mitigation activity is registered under the Architecture for REDD+ Transactions and qualifies as HFLD. Therefore, for this mitigation activity type, we assess the environmental integrity of only one category of carbon credits with the following attributes:

- **Carbon crediting programme:** Architecture for REDD+ Transactions (ART);
- **Quantification methodology:** The REDD+ Environmental Excellence Standard (TREES);

3.10.1 Key issues for each integrity criterion

Quantification: Applying the analysed methodology likely leads to high overestimation. The most critical factor leading to overestimation in JREDD mitigation activities is the approach for determining the baseline scenario. It is common practice among carbon crediting programmes to determine the baseline scenario based on average rates of deforestation and forest degradation over a historical reference period. On the project level, this approach has been found to be the most important source of overestimation (Seyller et al. 2016; West et al. 2020; West et al. 2023; West et al. 2024). Our own analysis suggests that this approach also leads to overestimation if applied at the jurisdictional level. This is due to short-term variations in deforestation, e.g. due to changes in commodity prices, infrastructure development, climate conditions etc. This variation can lead to significant over- or underestimation, depending on the development of the drivers of deforestation. However, overestimation in one jurisdiction may not be counterbalanced by under-estimation in another. This is because jurisdictions with overestimated emission reductions would face a competitive advantage due to lower unit costs of generating carbon credits. In addition, jurisdictions with underestimated emission reductions might be less likely to register in the first place in light of retroactive crediting as allowed under ART TREES. These aspects may lead to a bias towards over-crediting.

Moreover, under-credited jurisdictions or those that do not generate any carbon credits might not be willing to renew their crediting period. This increases the bias towards over-crediting. While ART TREES imposes some degree of conservativeness by prohibiting an increase in the baseline emissions in subsequent crediting periods, this only affects jurisdictions that renew their crediting period, which over-credited jurisdictions might be more inclined to do. Yet, to be eligible under

CORSIA, jurisdictions registered under ART TREES are required to renew their crediting period at least three times, which may significantly reduce the risk of overestimation.

Another aspect which may lead to overestimation is the HFLD add-on granted to the baseline in HFLD jurisdictions. The rationale behind the add-on is the projected increasing pressure on forests in HFLD jurisdictions along with limited incentives to protect such (Teo et al. 2024). While our own analysis confirms that using average rates of historical deforestation to determine the baseline scenario tends to lead to lower degrees of overestimation in HFLD countries than in non-HFLD countries, the suggested size of the HFLD add-on of 0.05% of total carbon stocks under ART TREES is arbitrarily chosen.

Another aspect which may cause overestimation is leakage. Since JREDD covers land-use change in an entire jurisdiction, it fully accounts for leakage within this jurisdiction. However, the risk of leakage across national borders is well established in literature (Gan and McCarl 2007; Pan et al. 2020; Daigneault et al. 2023) and is not taken into account by ART TREES, which may lead to overestimation of emission reductions. For sub-national jurisdictions, ART TREES imposes deductions to account for leakage. Yet, these deductions are relatively small compared to the leakage risks from forest conversation activities identified in the literature (see for example Pan et al. (2020)).

Overall, we assess the integrity risk for this criterion to be high.

Additionality: In order for a JREDD mitigation activity to generate additional emission reductions, it must implement mitigation actions. However, ART TREES does not require demonstrating that the planned mitigation actions have been implemented. This implies a risk that observed changes in emissions may not be attributable to the JREDD mitigation activity. Further, there is a risk that implemented mitigation actions are not additional since involved governments might have implemented the mitigation actions regardless of the incentive provided by carbon credits. However, ART TREES considers JREDD mitigation activities in HFLD jurisdictions to be additional per a positive list. This means that participants are not required to demonstrate that the mitigation actions would not have been viable without carbon credits or that they had been considered prior to the implementation of the mitigation activity. On the contrary, participants are allowed to register the mitigation activity retroactively for up to four years prior to the acceptance of the TREES concept.

Overall, we assess the integrity risk for this criterion to be high.

Permanence: JREDD mitigation activities have a non-permanence risk, as they aim to increase or avoid the loss of carbon stored in biogenic reservoir. Accordingly, there are material reversal risks, e.g. due to natural disturbances such as wildfires or anthropogenic forces such as land mismanagement or intentional depletion. At jurisdictional scale, natural disturbances are less likely to fully reverse the achieved mitigation impact (Böttcher et al. 2022; Schwartzman et al. 2021). ART TREES does not define a time horizon over which reversals must be monitored and compensated for beyond the end of a crediting period or the exit of a participant. If participants fail to submit a monitoring report, this may be interpreted as a breach of the operative documents according to the terms of use of ART's registry. If ART follows this interpretation, it may terminate access to the registry for the participant and cancel TREES credits. Yet, this is not explicitly prescribed by the rules included in the terms of use; neither is any amount of credits specified that should be cancelled in case no monitoring report has been submitted. ART TREES requires contributing 5% to 25% percent of carbon credits to a buffer pool, depending on the results of a reversal risk assessment. This contribution may not be sufficient to cover potential reversals. Firstly, ART TREES does not specify over which time horizon potential reversal risks should be assessed. Secondly, intensifying impacts of climate change over time are not taken into account (Schneider et al. 2024). Thirdly, the mitigating factors that would lower the risk assessment are only vaguely defined and evidence from the risk assessment in the case of Guyana suggests that a mitigating factor may in practice be claimed on unsubstantiated grounds (ART 2022). Furthermore, countries can terminate their participation in ART TREES when a reversal occurs so that the obligation to contribute additional credits to the buffer pool subsequent to a reversal may not be enforceable.

Overall, we assess the integrity risk for this criterion to be medium.

Double issuance due to overlap: JREDD mitigation activities have a material risk of both overlapping claims with other forestry-related mitigation activities and non-forestry mitigation activities (e.g. cookstove mitigation activities). ART TREES has provisions in place to address double issuance between forestry activities and jurisdictional mitigation activities, thus significantly reducing this risk. It requires the disclosure of any verified or issued emission reductions of forestry mitigation activities in the accounting area by the mitigation activity proponent. Furthermore, ART TREES also addresses the overlap of JREDD mitigation activities with other mitigation activities: the terms of use of ART's registry prohibit participants from claiming credits for mitigation activities that have already been listed or registered under ART TREES or other carbon crediting programmes, including in instances where the accounting boundaries overlap. The provisions can be understood to imply that participants must identify potential overlaps with non-forestry activities. However, if no such overlaps are reported, it depends on the validation process whether additional checks are implemented and potential overlaps are identified. The provisions thus bear the risk that instances of double issuance may not be reported or identified. Additionally, ART TREES provides an exemption if credits from mitigation activities located in a participating jurisdiction are only allowed for use in a domestic compliance market within the participating jurisdiction. In this case, such credits may also be claimed under ART TREES.

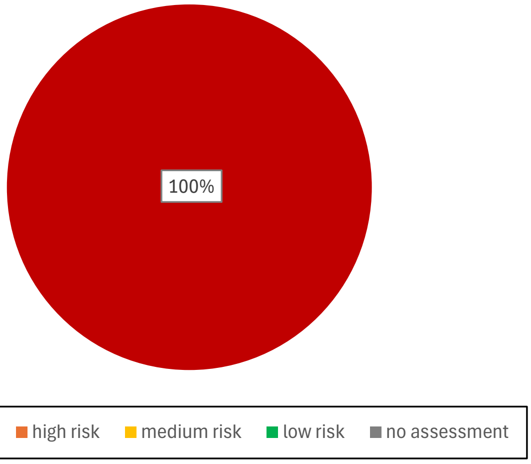
Overall, we assess the integrity risk for this criterion to be low.

3.10.2 Results

As of December 2025, the CENVI model contains one JREDD-HFLD mitigation activity with an annual emission reduction potential of about 8 Mt CO_2e.[25] This accounts for 1% of estimated annual emission reductions and removals of all mitigation activities included in CENVI. The assessed JREDD-HFLD mitigation activity is classified as having very high environmental integrity risks (see Figure 12). This is primarily driven by a high risk of overestimating emission reductions combined with a high risk of non-additionality.

25 The estimated annual emission reductions are based on the average annual issuances in 2021 and 2022.

Figure 12 JREDD – HFLD: Estimated annual emission reductions by risk grade



Source: Authors' own compilation

3.11 Landfill Gas Utilisation

Similar to the CCQI, we define the mitigation activity type landfill gas utilisation as the capture and utilisation 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. This mitigation activity type includes mitigation activities where a fraction of the gas may be flared. The mitigation activity excludes mitigation activities that merely enhance the efficiency of plants that already utilise gas from an existing solid waste disposal site. The mitigation activity type reduces emissions by destroying methane and displacing more greenhouse gas intensive energy generation (derived from CCQI 2023ab).

We assess the environmental integrity of carbon credit categories consisting of this mitigation activity type, considering all possible combinations of the following attributes:

- **Carbon crediting programmes:** Gold Standard (GS) and Verified Carbon Standard (VCS);
- **Quantification methodologies:** Clean Development Mechanism ACM0001 Flaring or use of landfill gas (short: CDM ACM0001), Clean Development Mechanism ACM0001 Flaring or use of landfill gas (CDM AMS-III.G).

3.11.1 Key issues of each integrity criteria

Quantification: CCQI analyses show that applying the analysed methodologies likely leads to a low to moderate overestimation of emission reductions. A key parameter driving the overestimation is the fraction of methane that oxidises in the baseline scenario. Methane oxidises due to methanotrophic micro-organisms when passing through the topsoil layer of a landfill. A low oxidation factor implies that more methane is emitted by the landfill, and, consequently, the estimated emissions in the baseline are higher. All methodologies use default values for the oxidation factor, which are often 10 to 20 percentage points lower than what is suggested by literature, likely leading to an overestimation (CCQI 2023ab).

Overall, we assess the integrity risk for this criterion to be medium.

Additionality: In the absence of relevant policy incentives, the mitigation activities are often not financially viable without carbon credit revenues. This is underpinned by a CCQI analysis, which assessed the financial viability of landfill gas activities registered under the Clean Development Mechanism (CDM) and how their viability was impacted by carbon credit revenues. The assessment found low additionality risks (CCQI, 2022a).

We also consider how carbon programme provisions reduce the risk of registering already viable mitigation activities. Based on CCQI analyses, we generally assume that programme provisions only lead to a slight reduction in additionality risks since they are not able to prevent registration of already viable carbon credits entirely: mitigation activities may demonstrate prior consideration aligned with the programme's requirements but still be viable without carbon credits. The analyses show that while the VCS' provisions do not prevent the registration of activities after their project start, the GS has such provisions in place and is therefore more likely to reduce the share of mitigation activities that are already viable without carbon credits (CCQI 2022a; 2024t).

Legal requirements are particularly relevant for this mitigation activity type, as some countries already require or incentivise processing or destroying landfill gas. This risk is substantially higher for mitigation activities implemented in high income countries than for those implemented in non-high income countries (Broekhoff et al. 2025; Calyx Global 2025). Correspondingly, we determine the integrity factor for additionality based on the cited literature and differentiate between mitigation activities implemented in high income and non-high income countries.

Regarding programme provisions to address legal requirements, CCQI analyses show that both GS provisions and VCS provisions lead to an exclusion of mitigation activities that are mandated by legal requirements but allow for exceptions in the case of non-enforcement of laws and regulations (CCQI 2024s; 2024r). We assume that these and other provisions lead to a substantial reduction of registered mitigation activities that are legally required.

Overall, we assess the integrity risk for this criterion to be medium to high.

Permanence: This mitigation activity type does not involve a non-permanence risk (CCQI 2023b; Calyx Global 2024).

Double issuance due to overlap: There is no risk of double issuance due to overlapping mitigation activities for this mitigation activity type (CCQI 2024z).

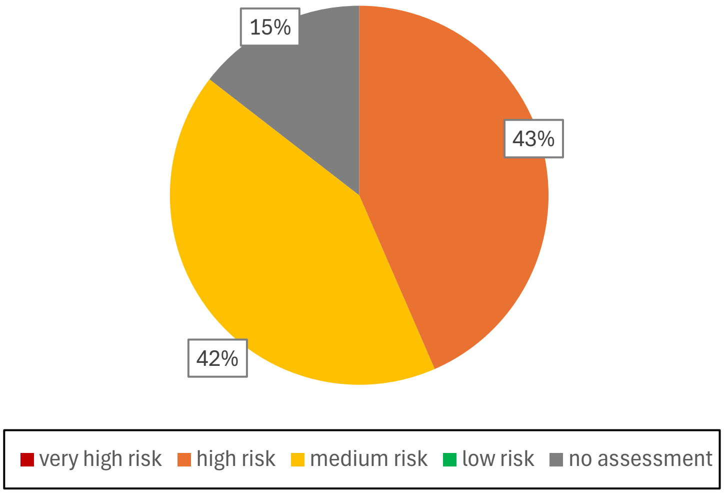
3.11.2 Results

As of December 2025, the CENVI model contains 157 registered Landfill Gas Utilisation activities with an annual emission reduction potential of about 25 Mt CO_2e.[26] This accounts for 3.3% of estimated annual emission reductions and removals of all mitigation activities included in CENVI. We have sufficient information to assess the integrity of categories encompassing 114 of the 157 mitigation activities, corresponding to 85% of annual emission reductions belonging to this mitigation activity type.

The annual emission reductions belonging to this mitigation activity type are generated by categories with high (43%) and medium (42%) environmental integrity risks (see Figure 13). This is primarily driven by a low to medium risk of overestimating emission reductions combined with a medium to high risk of non-additionality.

[26] The estimated annual emission reductions are included in the GS‘ and VCS‘ registries and stem from the mitigation activities documentation.

Figure 13 **Landfill Gas Utilisation: Estimated annual emission reductions by risk grade**



Source: Authors' own compilation

3.12 Leak Repair in Natural Gas Transmission and Distribution Systems

Similar to the CCQI, we define this mitigation activity type as the implementation of a system to inspect, measure and repair leaks of above ground components of natural gas production, processing, transmission, storage and distribution systems and refinery facilities. The mitigation activity type reduces emissions by reducing the amount of methane leaking into the atmosphere (derived from CCQI 2023m).

We assess the environmental integrity of carbon credit categories consisting of this mitigation activity type, considering all possible combinations of the following attributes:

- **Carbon crediting programmes:** Verified Carbon Standard (VCS);
- **Quantification methodology:** Clean Development Mechanism AM0023 Leak reduction from natural gas pipeline compressor or gate stations (short: CDM AM0023).

3.12.1 Key issues for each integrity criterion

Quantification: A CCQI analysis shows that applying the analysed methodology likely leads to an accurate estimation of emission reductions but is associated with high uncertainty. We assume that this uncertainty likely results in a low to moderate overestimation of emission reductions (for an explanation, see section 2.2).

Two major sources of uncertainty in the methodology CDM AM0023 are: 1) the option to measure leak rates with flow measurement technologies that likely involve significant uncertainty, and 2) the lack of requirements to measure the line pressure throughout the monitoring period which can fluctuate substantially and greatly influence the leak rate (CCQI 2023t).

Overall, we assess the integrity risk for this criterion to be medium.

Additionality: According to the Offset Guide, Leak Repair in Natural Gas Transmission and Distribution System carry high additionality risks, as they are often cost-effective without carbon revenues due to the additional income from the reduction in gas losses (Broekhoff et al. 2025). However, a CCQI analysis found that several barriers may prevent the implementation of these mitigation activities. Most importantly, firms operating the transmission and distribution systems do not necessarily own the gas and thus do not profit from gas savings. Other barriers include high upfront investment costs, lack of knowledge regarding leak detection technologies and diminishing returns from repeated leak detection surveys. The revenues of carbon credits can help overcome some of these barriers (CCQI 2023o).

We also consider how carbon programme provisions reduce the risk of registering already viable mitigation activities. Based on CCQI analyses, we generally assume that the programme provisions only lead to a slight reduction in additionality risks since they are not able to prevent registration of already viable carbon credits entirely: mitigation activities may demonstrate prior consideration aligned with the programme’s requirements but still be viable without carbon credits. Specifically, the CCQI analysis of VCS provisions show that they do not prevent the registration of activities after their project start and are therefore not likely to reduce the registration of already viable mitigation activities substantially (CCQI 2022a; 2024t).

We assume that only a small share of Leak Repair in Natural Gas Transmission and Distribution Systems are implemented as a result of legal requirements, as an analysis from the International Energy Agency shows that, in 2014, only the US and Canada had legal requirements regarding leak repair (IEA 2021a). None of the Leak Repair in Natural Gas Transmission and Distribution Systems in CENVI are located in the US or Canada. Nonetheless, there remains a risk that some countries have introduced such requirements since 2014. Regarding programme provisions to address legal requirements, CCQI analyses show that VCS provisions lead to an exclusion of mitigation activities that are mandated by legal requirements but allow for exceptions in the case of non-enforcement of laws and regulations (CCQI 2024s; 2024r). . We assume that these and other provisions likely lead to a substantial reduction of registered mitigation activities that are legally required.

As there are both risks of mitigation activities being already viable without carbon credits and mitigation activities being legally required, we assess that overall, the integrity risks for this criterion to be high.

Permanence: This mitigation activity type does not involve a non-permanence risk (CCQI 2023w).

Double issuance due to overlap: There is no risk of double issuance due to overlapping mitigation activities for this mitigation activity type (CCQI 2024z).

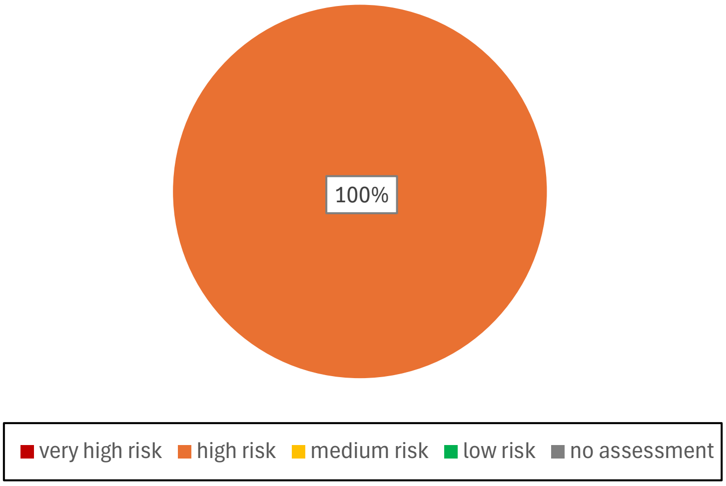
3.12.2 Results

As of December 2025, the CENVI model contains only 8 registered Leak Repair in Natural Gas Transmission and Distribution System activities with an annual emission reduction potential of about 15 Mt CO_2e.[27] This accounts for 2% of estimated annual emission reductions and removals of all mitigation activities included in CENVI. We have sufficient information to assess the integrity of all categories belonging to this mitigation activity type.

All assessed carbon credit categories belonging to this mitigation activity type are classified as having high environmental integrity risks (see Figure 14). This is primarily driven by a high risk of non-additionality combined with a medium risk of overestimating emission reductions.

[27] The estimated annual emission reductions are included in the GS‘ and VCS‘ registries and stem from the mitigation activities documentation.

Figure 14 **Leak Repair in Natura Gas Transmission and Distribution Systems: Estimated annual emission reductions by risk grade**



Source: Authors' own compilation

3.13 Project-based Avoided Deforestation and Forest Degradation – Terrestrial Forests (REDD-TF)

Similar to the CCQI, we define this mitigation activity type as activities to avoid deforestation and forest degradation at a project level, not at jurisdictional level (derived from CCQI 2024ab; 2024ac). This may include the avoidance of both planned and unplanned deforestation. While planned deforestation activities refer to those legally authorised and planned by an identifiable, commercial agent, unplanned deforestation occurs as a result of socioeconomic forces, such as subsistence agriculture of local communities, encroaching roads, or illegal logging. The mitigation activity type reduces emissions by avoiding the loss of forest carbon stocks.

We assess the environmental integrity of carbon credit categories consisting of this mitigation activity type, considering all possible combinations of the following attributes:

- **Carbon crediting programmes:** Verified Carbon Standard (VCS); and
- **Quantification methodologies:** VCS VM0006 Methodology for Carbon Accounting for Mosaic and Landscape-scale REDD Projects (short: VM0006), VCS VM0007 REDD+ Methodology Framework (REDD-MF) (VM0007), VCS VM0009 Methodology for Avoided Ecosystem Conversion (VM0009), VCS VM0015 Methodology for Avoided Unplanned Deforestation (VM00015), VCS VM0048 Reducing Emissions from Deforestation and Forest Degradation (VM0048). Note: While all methodologies apply to avoided unplanned activities, VM007 and VM009 allow for both avoided planned activities and avoided unplanned activities.

Another attribute by which we differentiate our assessment is:

- **Location:** We differentiate our assessment between countries in which cooking with biomass is common and countries in which it is not. This distinction is relevant for the criterion double issuance due to overlap.

3.13.1 Key issues for each integrity criterion

<u>**Quantification:**</u> CCQI analyses show that applying the analysed methodologies likely leads to a very high overestimation, whereby the degree of overestimation is likely to be significantly lower under VM0048 than the other assessed methodologies (CCQI 2024l; 2024m; 2024k; 2024aa).

All analysed methodologies have issues that are very likely to lead to overestimation. The CCQI found that inflated baselines are the largest risk of overestimation. Baseline setting is inherently challenging for REDD-TF activities, as the deforestation rate in a forest area is influenced by a variety of unknown factors, such as changes in policies, economic development and social dynamics. The methodologies VM0006, VM0007, VM0009 and VM0015 use historical deforestation rates in a reference area to estimate future deforestation. However, the methodologies provide substantial leeway for selecting these reference regions. According to several academic publications, this leads to a very high overestimation for the majority of REDD-TF activities (West et al. 2023; Tang et al. 2025). These findings have been echoed by an analysis of Calyx Global (Calyx Global 2023). However, an analysis of the CCQI deemed that the baseline setting requirements of the VM0048 are more stringent than those of the other methodologies, but still likely lead to overestimation (CCQI 2024aa).

In addition, leakage is not adequately considered in the analysed methodologies. Leakage in the context of REDD-TF activities means that the project leads to an increase in deforestation elsewhere. Studies have shown that methodologies offer substantial leeway when accounting for leakage, and in practice, 60% of mitigation activities do not apply any leakage deductions (Haya et al. 2023).

Lastly, the CCQI identifies outdated data and flexibility when quantifying carbon stocks as another key source of overestimation, such as the requirements regarding the value for the fraction of carbon that is stored in forest biomass (CCQI 2024aa; 2024ab; 2024ac; 2024k; 2024l).

Overall, we assess the integrity risk for this criterion to be high to very high.

Additionality: An analysis of Calyx Global of REDD+ activities found that most mitigation activities are not financially viable without carbon credit revenues (Calyx Global 2023). However, the CCQI determined that the viability of mitigation activities greatly depends on the implemented activities. For avoided unplanned deforestation activities, the financial viability depends on the extent to which economic activities generate benefits for the mitigation activity proponent. Mitigation activities may generate no economic benefits, still implement small-scale economic activities, or still conduct commercial timber production. Particularly in the latter case, mitigation activities are likely already economically viable without carbon credit revenues (CCQI 2024c). Regarding avoided planned deforestation activities, the CCQI finds that opportunity costs are primarily driven by the accessibility of the project area. This is because remote areas are more costly to access, making it less likely that the mitigation activity proponent would have deforested these areas in the absence of the carbon crediting activity (CCQI 2024f).

We also consider how carbon programme provisions reduce the risk of registering already viable mitigation activities. Based on CCQI analyses, we generally assume that programme provisions only lead to a slight reduction in additionality risks since they are not able to prevent registration of already viable carbon credits entirely: mitigation activities may demonstrate prior consideration aligned with the programme's requirements but still be viable without carbon credits. Specifically, the CCQI analysis of VCS provisions show that they do not prevent the registration of activities after their project start and are therefore not likely to reduce the registration of already viable mitigation activities substantially (CCQI 2022a; 2024t).

The CCQI also found that mitigation activities might be implemented in response to legal requirements, as many governments have adopted legal requirements to reduce deforestation (CCQI 2024ad).. Regarding programme provisions to address legal requirements, CCQI analyses show that VCS provisions lead to an exclusion of mitigation activities that are mandated by legal requirements but allow for exceptions in the case of non-enforcement of laws and regulations (CCQI 2024s; 2024r). We assume that these and other provisions lead to a substantial reduction of registered mitigation activities that are legally required.

Overall, we assess the integrity risk for this criterion to be high to very high.

Permanence: This mitigation activity type has a material non-permanence risks, as forests may be destroyed through anthropogenic forces, such as land conversion, or natural disturbances, such as wildfires (Schneider et al. 2024; CCQI 2024p). We used an expert judgement to estimate the share of credited removals that are reversed over a 100-year period in the absence of carbon crediting provisions.

The risk of non-permanence may be addressed through various programme provisions, whose effectiveness we evaluate based on CCQI assessments. These show that the VCS has several provisions in place to address non-permanence, notably including provisions regarding monitoring and compensation of reversals. However, under the VCS, the monitoring period is only 40 years (CCQI 2024w; 2024x; 2024q; 2024y). Thus, we assume that the programme provisions address reversals only to some extent.

Overall, we assess the integrity risk for this criterion to be high.

Double issuance: This mitigation activity type has a material risk of double issuance due to overlapping mitigation activities. Overlaps can occur if an activity aiming to reduce the consumption of firewood (e.g. cookstove activities) is located close to a REDD-TF project, and both activities claim the same emission reductions or removals from the increased forest carbon stock (CCQI 2024ad).

To estimate the average share of emission reductions and removals that is subject to double issuance due to overlap, we apply an expert judgement based on an own analysis and a report by Calyx Global (Calyx Global 2023). We estimate this risk only for countries where cooking with biomass is common. Thus, overall, this risk is very relevant for REDD-TF activities, as more than 90% of annual emission reductions of this mitigation activity type are issued from mitigation activities in countries where cooking with biomass is common. None of the carbon crediting programmes addresses this risk at the time of this assessment (CCQI 2024ad).

Overall, we assess the integrity risk for this criterion to be low.

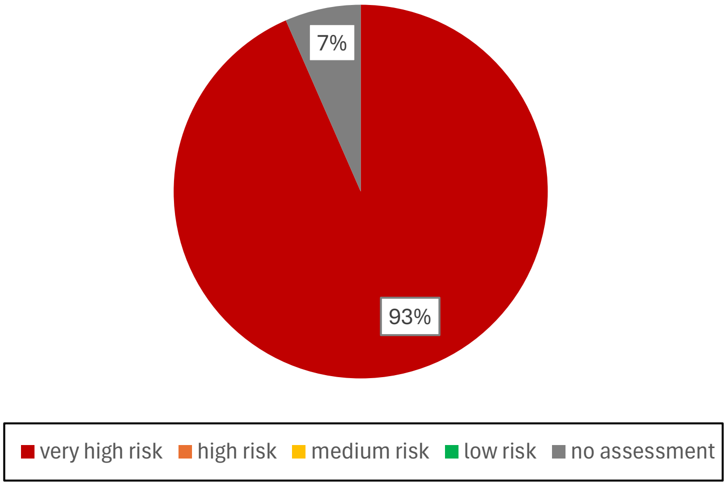
3.13.2 Results

As of December 2025, the CENVI model contains 96 registered REDD-Terrestrial Forest activities with an annual emission reduction potential of about 83 Mt CO_2e.[28] This accounts for 10.8% of estimated annual emission reductions and removals of all mitigation activities included in CENVI. We have sufficient information to assess the integrity of categories encompassing 92 of the 96 mitigation activities, corresponding to 93% of all estimated annual emission reductions belonging to this mitigation activity type.

All assessed carbon credit categories belonging to this mitigation activity type are classified as having very high environmental integrity risks (see Figure 15). This is primarily driven by very high risks of overestimating emission reductions and high risks of non-additionality and non-permanence.

[28] The estimated annual emission reductions are included in the GS‘ and VCS‘ registries and stem from the mitigation activities documentation.

Figure 15 **Project-based REDD – Terrestrial: Estimated annual emission reductions by risk grade**



Source: Authors' own compilation

3.14 Wind Power

Similar to the CCQI, we define this mitigation activity type as the installation of a new wind power plant. The electricity is fed into a national or regional electricity grid. The mitigation activity type reduces emissions by displacing more greenhouse gas intensive electricity generation (derived from CCQI 2023f).

We assess the environmental integrity of carbon credit categories consisting of this mitigation activity type, considering all possible combinations of the following attributes:

- **Carbon crediting programmes:** Gold Standard (GS) and Verified Carbon Standard (VCS); and
- **Quantification methodologies:** Clean Development Mechanism ACM0002 Consolidated baseline methodology for grid-connected electricity generation from renewable sources (short: CDM ACM0002), Clean Development Mechanism AMS-I.D. Grid connected renewable electricity generation (CDM AMS-I.D).

3.14.1 Key issues for each integrity criterion

Quantification: According to CCQI analyses, applying the analysed methodologies likely leads to a low to moderate overestimation of emission reductions. The methodology CDM AMS-I.D. is the small-scale version of methodology CDM ACM0002 and uses largely the same approaches, except for some minor simplifications. Therefore, the same factors of overestimation apply.

The key source of overestimation is the assumed trajectory of the grid emission factor. Both methodologies allow for a fixed value for the entire crediting period rather than updating it annually. This approach fails to reflect that the grid emission factor is declining over time in most regions of the world, as the share of renewables is expanding due to their profitability and policy support (CCQI 2023k; 2023h).

Overall, we assess the integrity risk for this criterion to be medium.

Additionality: The CCQI and the Carbon Offset Guide identify the lack of additionality as a key environmental integrity risk for Wind Power activities, as they are likely financially viable without the revenues from carbon credits, albeit less so than Grid-connected Solar PV activities. They often benefit from other income streams beyond carbon credits, as they generate revenues and receive from policy support in many regions of the world. Moreover, carbon credit revenues make up only a minor share of their total project revenues (CCQI 2023l; Broekhoff et al. 2025),

We also consider how carbon programme provisions reduce the risk of registering already viable mitigation activities. Based on CCQI analyses, we generally assume that programme provisions only lead to a slight reduction in additionality risks since they are not able to prevent registration of already viable carbon credits entirely: mitigation activities may demonstrate prior consideration aligned with the programme's requirements but still be viable without carbon credits. The analyses show that while the VCS' provisions do not prevent the registration of activities after their project start, the GS has such provisions in place and is therefore more likely to reduce the share of mitigation activities that are already viable without carbon credits (CCQI 2022a; 2024t).

Moreover, according to the CCQI there is no known case of cookstove activities being legally required (CCQI 2024r).

Overall, we assess the integrity risk for this criterion to be very high.

Permanence: This mitigation activity type does not involve a non-permanence risk (CCQI 2023y).

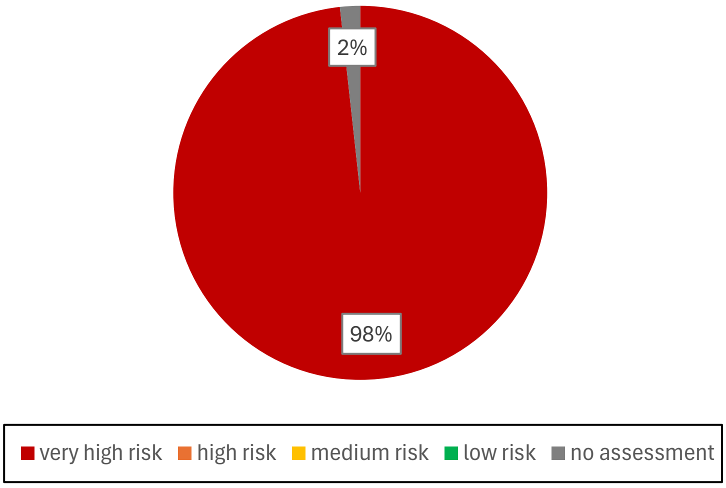
Double issuance due to overlap: There is in practice no material risk of double issuance due to overlapping mitigation activities for this mitigation activity type (CCQI 2024z).

3.14.2 Results

As of December 2025, the CENVI model contains 883 registered Wind Power activities with an annual emission reduction potential of about 94 Mt CO_2e.[29] This accounts for 12.2% of estimated annual emission reductions and removals of all mitigation activities included in CENVI. We have sufficient information to assess the integrity of categories encompassing 875 of the 883 mitigation activities, corresponding to 98% of all estimated annual emission reductions belonging to this mitigation activity type.

All assessed carbon credit categories belonging to this mitigation activity type are classified as having very high environmental integrity risks (see Figure 16). This is primarily driven by high to very high risks of non-additionality combined with medium risks of overestimating emission reductions.

Figure 16 Wind Power: Estimated annual emission reductions by risk grade



Source: Authors' own compilation

[29] The estimated annual emission reductions are included in the GS' and VCS' registries and stem from the mitigation activities documentation.

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