



ACHIEVING HIGH-INTEGRITY VOLUNTARY CLIMATE ACTION

D2.2 - Integrity of carbon credits

WP2- Assessing integrity & impacts of
existing voluntary climate actions

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Summary Requirements

1. Changes with respect to the Description of Action (DoA)

No changes with respect to the work described in the DoA.

2. Dissemination and uptake

This report from the ACHIEVE project offers insights for a diverse range of stakeholders involved in climate governance and voluntary carbon markets.

Within the project, it serves as a useful reference for the research tool and partners, guiding future work on the quality of carbon credits and the environmental integrity of their use. Moreover, the quantitative data on carbon credit issuances and carbon credit quality may be included in the modelling work in Tasks 2.3 and 4.1. The work will furthermore be used as a long-term reference for a more quantitative assessment of the carbon market.

Outside the project, the report can assist policymaker and government agencies in evaluating the quality risks of different carbon credit portfolios and understanding how carbon credits are used. The research that fed into the report will be published (or is already partly published) in the form of journal papers. Moreover, the description of the Carbon Credit Environmental Integrity (CENVI) Model has been published as a separate document, which will be continuously updated as the model is refined.

For businesses, cities and voluntary carbon market participants, the research will be a tool to navigate the complex carbon crediting market by helping to identify high quality carbon credits and by creating an understanding of how carbon credits can be used in a manner that aligns with environmental integrity.

3. Short summary of results

This ACHIEVE project deliverable provides a comprehensive analysis of the environmental integrity of carbon credits and their use, structured in three parts: a mixed-methods analysis of the use of carbon credits in companies, cities and Corporate Climate Initiative (CCIs); the description of the methodology underlying the Carbon Credit Environmental Integrity (CENVI) Model; and an in-depth analysis of the emission quantification methodology VM00048.

First, the report presents insights from three studies on the role of carbon credits in non-state climate action, assessing the role of cities, companies and CCIs. The studies identify key predictors of carbon credit use of these actor groups and assess how these actors integrate carbon credits into their climate strategies, climate action plans and guidance documents. The analysis shows that carbon credit use is often part of climate strategies with some high integrity aspects, but persistent issues remain, including the use of low-quality carbon credits and carbon credit use for offsetting claims instead of contribution claims.

Second, the report provides a description of the CENVI model will combine data on issued (or planned to be issued) carbon credits with an assessment of the integrity of these carbon credits, enabling the evaluation of different carbon credit portfolios.

Third, the report presents a detailed assessment of the new landmark methodology of the Verified Carbon Standard for avoided deforestation (methodology VM0048). The methodology is particularly critical for the integrity of the future voluntary carbon market, as it is supposed to replace earlier VCS





methodologies that raise major integrity concerns. The assessment found that the new methodology is an improvement to the previous methodologies but could still lead to considerable overestimation of emission reductions.

4. Evidence of accomplishment

This report.

5. Disclosure statement on the use of generative artificial intelligence (AI)

Generative artificial intelligence was not used for preparing this report, but a large language model was used in the underlying analysis of corporate texts related to climate action and carbon credit use. Section 1 defines the use of this model.





Preface

In recent years an unprecedented number of voluntary climate commitments have been made by a wide array of non-state and subnational actors. These voluntary climate actions aim to reduce greenhouse gas emissions and build climate resilience and are crucial for lowering risks of exceeding warming limits. However, the full potential of voluntary climate action can only be realised when integrity-related concerns are overcome. ACHIEVE aims to identify opportunities to strengthen and scale up high-integrity voluntary climate action towards achieving net-zero emissions by mid-century. The project will generate transformative and timely scientific insights on the role, effectiveness and integrity of voluntary climate action including carbon credits; assess the integrity and impacts of such action; analyse how policies and regulations, and high-integrity voluntary climate action can strengthen each other; and use scientific findings to support the scaling up of high-integrity voluntary action. This will be achieved through a highly inter- and transdisciplinary consortium that, from the start, actively engages policymakers and other societal stakeholders in co-creating outcomes that respond to end users' needs. ACHIEVE is aligned with the Work Programme of Cluster 5, Destination 1 "Climate sciences and responses for the transformation towards climate neutrality" as the project directly contributes to advancing knowledge and providing solutions for climate change specifically on high integrity voluntary climate action. ACHIEVE will develop transition pathways to climate neutrality that integrate voluntary climate action by cities, regions and companies; it will develop novel social science insights for climate action; contribute to better understanding sustainability co-benefits and trade-offs; and increase transparency and trust in voluntary climate action by strengthening integrity and making scientific results easily accessible for different stakeholder groups.

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Executive Summary

This interim report synthesizes the intermediate results of Task 2.1 of the ACHIEVE-project, providing an overview of the work on assessing the integrity of voluntary carbon market, covering both the integrity of how carbon credits are used and an assessment of the quality of carbon credits.

Chapter 1 of the report presents insights from three studies on the **role of carbon credits in non-state climate action**. The three studies identify key predictors of carbon credit use for cities, companies, and corporate participants of cooperative climate initiatives (CCIs) through a quantitative analysis, and qualitatively analyse how these actor groups address carbon credits in their climate action plans (CAPs), climate strategies and guiding documents. The studies found that the prioritisation of emission reductions over carbon credit purchases has become a central theme as it is often discussed by cities, companies, and CCIs. In addition, they showed that both the wealth and size predict carbon credit purchases for cities and companies. Moreover, the qualitative analysis of key documents revealed that the environmental and social integrity of carbon credits does not play a major role in decisions on carbon credit use, nor are high-quality carbon credits preferred. The report shows that cities and companies with high integrity climate strategies are more likely to use carbon credits. However, offsetting claims are common practice by cities and companies, and CCIs rarely aim to avoid offsetting claims. Contribution claims are a higher integrity option to make claims based on carbon credit use, but they are not often mentioned by cities, companies, or CCIs.

Chapter 2 describes the methodology underlying the Carbon Credit Environmental Integrity (CENVI) Model that is currently being developed under ACHIEVE. The CENVI model will combine data on issued (or planned to be issued) carbon credits with an assessment of the integrity of these carbon credits, enabling the evaluation of different carbon credit portfolios. Moreover, the chapter contains the results of the environmental integrity assessment of the 13 mitigation activity types that have been assessed so far, as well as summarizing the key factors that influence the outcomes of the assessments. Results show that the majority of estimated annual emission reductions and removals likely have very high environmental integrity risks, stemming -to varying degrees- from issues regarding additionality, the quantification of emission reductions or removals, permanence, and double issuance.

Chapter 3 of the report contains a **detailed assessment of the new landmark** methodology of the Verified Carbon Standard for the mitigation activity type avoided deforestation (methodology VM0048). The methodology is particularly critical for the integrity of the future voluntary carbon market, as it is supposed to replace earlier VCS methodologies that raised major integrity concerns. The assessment has been conducted according to a methodology developed under the Carbon Credit Quality Initiative (CCQI). It examines factors that could lead to over- and underestimation of emission reductions in the VCS methodology, as well as factors that introduce significant uncertainty. The assessment found that the new methodology is an improvement to the previous methodologies but could still lead to considerable overestimation.





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1 Role of carbon credit purchasing by cities, companies and initiatives

1.1 Introduction

In response to the climate crisis, many non-state and subnational actors (NSAs) are setting emission reduction targets, increasingly including net zero and carbon neutrality targets (Green, 2024; Hale et al., 2022; NewClimate Institute & Data-Driven EnviroLab, 2020). In practice, companies are implementing net zero or carbon neutrality through compensating all emissions remaining after decarbonization measures (Fankhauser et al., 2022; NewClimate Institute & Data-Driven EnviroLab, 2020), commonly through the purchase and retirement of carbon credits. Net zero is often more stringently defined, and can require a minimum amount of internal emissions reduced (which can depend on sector and guidance) (SBTi, 2025). Nevertheless, it is often used interchangeably with carbon neutrality targets, and some NSAs already make net zero or carbon neutrality claims, despite having high remaining emissions (Fankhauser et al., 2022). Thus, the majority of NSAs, particularly in hard-to-abate sectors such as aviation and steel manufacturing, are relying on carbon credits to achieve their net zero targets (Kreibich & Hermwille, 2021; Machnik et al., 2020). Moreover, some amount of carbon removals have been recognised as important to compensate for residual emissions globally, i.e. those emissions that are uneconomical or technologically infeasible to abate by the target year (Broekhoff et al., 2019; Buck et al., 2023; Cooper et al., 2022; SBTi, 2025; Tanzer et al., 2022). Carbon credits could be used to finance carbon removals.

Carbon credits can in principle support more ambitious climate action by providing opportunities for climate action beyond actors' organisational boundaries, as long as purchasing carbon credits does not substitute other climate action (Lauer et al., 2025). They can also deliver other benefits such as increased carbon dioxide removal financing or social co-benefits in lower income regions. However, neither climate nor social benefits are necessarily generated in practice, and the carbon market faces substantial criticism: First, removed or reduced emissions are often over-estimated, resulting in over-crediting practices. Probst et al. (2024) performed a systematic review of empirical studies that measured actual emission reductions, in which they covered one-fifth of the credit volume issued until the date of the study. They found that only 16% of credited climate benefits are actually achieved. Second, as carbon credits are often solely focused on climate benefits, they can have many environmental and social trade-offs. For example, local biodiversity is often harmed during reforestation or afforestation practices (Pörtner et al., 2021; Seddon et al., 2019). Additionally, the commodification of carbon offsets can strengthen the (financial) position of the market players that are largely responsible for historical emissions, enhancing the neo-colonialist trade relations (Carton et al., 2020, 2021; Spash & Theine, 2016). Third, carbon credits, particularly those based on emission reductions or avoided emissions, and those used for offsetting claims, are infeasible on the long-term. The Paris Agreement aims to cover all emissions under its Nationally Determined Contributions (NDCs), which only gives room for non-additional carbon



credits. Double counting is another risk caused by full coverage of emissions by NDCs. Moreover, as global net zero emissions ensures that all possible emissions are reduced, only carbon removals are feasible in the long-term (Fearneough et al., 2020; Kreibich & Hermwille, 2021). Fourth, more fundamental criticism of the carbon market relates to the non-equivalence¹ of emitted greenhouse gases and compensated emissions from carbon credits (Carton et al., 2021; Kaupa, 2022; McLaren et al., 2019). This non-equivalence stems from the difference in geographical scales, leading to social injustices; temporal scales, which could lead to higher or wider atmospheric CO₂ peaks; and fossil carbon entering the active carbon cycle (Carton et al., 2021). Moreover, Kaupa (2022) argues that emissions compensated by carbon credits face higher uncertainties in their climate benefits than emitted greenhouse gases. For example, the comparison to hypothetical baselines, uncertainty in additionality, non-permanence of carbon credits, carbon leakage, and rebound effects all increase the uncertainty for carbon credits, while the measurement of internal emissions contains less uncertainty. The increased uncertainty further adds to the non-equivalence of emissions and carbon credits. Fifth, carbon credits also face fundamental criticism due to the reductionist view of climate benefits as a commodity and ethical concerns related to business-as-usual emissions while paying others to reduce their emissions (Spash & Theine, 2016).

As the supply-side of the voluntary carbon market plays an important role in the effectiveness and trade-offs of carbon credits, it has been frequently studied. On the other hand, the demand-side of the carbon market is insufficiently understood, although NSAs on the demand-side have the potential to increase the integrity of their climate action by adjusting their climate and carbon credit strategies. For example, best practice guidance specifies that NSAs should prioritise internal emission reductions, and only use carbon credits for a small amount of residual emissions (Axelsson et al., 2024). Other guidance states that they should prioritise higher quality carbon credits, which have improved effectiveness and reduced trade-offs, while transparent climate-related claims could reduce the risk of greenwashing (Trouwloon et al., 2023). In this study, we understand carbon credit use as the demand-side of the voluntary carbon market, which includes both the purchasing and retiring of carbon credits. We include both offsetting claims and contribution claims, and we also broaden the concept to include inseting and other emission compensation mechanisms. For our work on cities, we also use the term offsetting, as we do not include contribution claims by cities.

While carbon credit use decisions by NSAs (including cities, companies, and cooperative climate initiatives (CCIs)) are an important factor in analysing whether and how voluntary carbon

¹ The non-equivalence of carbon credits and greenhouse gas emissions implies that carbon credits and emissions are not equivalent in terms of their climate impact. Scholars argue that carbon credits and emissions have different uncertainties, temporal and spatial scales, and permanence. The latter is particularly relevant when compensating emissions from fossil fuels with nature-based carbon removal credits, as carbon will flow from permanent geological storage to the active carbon cycle (Carton et al., 2021; Kaupa, 2022; McLaren et al., 2019).



markets contribute to global emission reductions, research on the predictors of these decisions remains limited. The role of carbon credits in climate action strategies of NSAs is often unclear, raising questions about the integrity of non-state climate action. Therefore, in this report, we assess and discuss the role and predictors of carbon credits use for cities, companies and (participants of) CCIs.

First, with over half of the world's population living in urban areas, cities are directly or indirectly responsible for 80% of greenhouse gas emissions (Hoornweg et al., 2011; Lwasa et al., 2022; Seto et al., 2014). They are increasingly developing climate action plans (CAPs), although there is significant variation in the effectiveness of city climate action (Aboagye & Sharifi, 2024; Hsu et al., 2017; Wei et al., 2021). Many cities rely on carbon credits to reach net zero through the balancing of residual emissions (Balouktsi, 2020; Huovila et al., 2022; Lützkendorf & Balouktsi, 2019). However, research on the role of offsetting in cities' climate strategies is lacking, including what predicts carbon credit use by cities and how cities intend to use carbon credits.

Second, corporate carbon credit use is frequently scrutinised. An important concern is that it could divert attention and corporate spending away from deep decarbonisation efforts (NewClimate Institute & Data-Driven EnviroLab, 2020; Stolz & Probst, 2025). Moreover, untransparent and misleading climate-related claims could lead to an increased risk of greenwashing (Trouwloon et al., 2023), while products with climate-neutrality labels could lead to higher consumption (Günther et al., 2020). Furthermore, large scale carbon credit use might create challenges on the supply side of the carbon market (Kreibich & Hermwille, 2021). Companies that use carbon credits often choose low-quality, cheap offsets with a high risk of not providing actual climate benefits (Trencher et al., 2024). Although some research has looked into the role of carbon credits in corporate climate strategies (Engler et al., 2023; Gao & Souza, 2022; Lou et al., 2023; Stolz & Probst, 2025), little is known about the predictors of carbon credit use. Kim et al. (2024) explored predictors of carbon credit use by companies and found that companies often use carbon credits to improve their image after recent downgrades in ESG ratings or if net-zero targets are almost achieved. However, the authors did not explore in detail the links between corporate climate ambition and carbon credit use. Moreover, they did not distinguish between the likelihood of carbon credit use and the volume of carbon credit use.

Third, CCIs have gained increased importance in the transnational climate regime since voluntary climate action has been increasingly emphasized since the Paris Agreement in 2015 (Roelfsema et al., 2018). We define CCIs as transnational, multistakeholder partnerships that lead to climate action by NSAs. Previous research has shown mixed results regarding the effectiveness and impacts of CCIs, by assessing mitigation potential (Kuramochi et al., 2024; Lui et al., 2021), potential for scaling and entrenchment (e.g., Van Der Ven et al., 2017), their output effectiveness (Chan et al., 2021, 2022), or standard and norm setting practices (Bernstein & Hoffmann, 2018). CCIs are identified to have the potential to address the lack of governance on the voluntary carbon market, and increase the integrity of NSAs climate mitigation strategies and of the voluntary carbon market (Andonova & Sun, 2019; Trouwloon et al., 2023). As many NSAs are not able to judge the quality of carbon credits (Macintosh et al., 2025), standard setting CCIs can support actors to find and buy high-quality carbon credits. Especially if CCIs



promote net zero targets, thorough and detailed carbon credit guidance, or a reference to existing guidance, is necessary. Moreover, Trouwloon et al. (2023) find that cooperative governance has the potential to decrease greenwashing around the use of carbon credits, but measuring these indirect impacts is often difficult. Other studies have looked at the potential of CCIs in supporting non-state climate action (e.g., Bernstein & Hoffmann, 2018; Hsu et al., 2017), while others looked at the climate behaviour of participants in CCIs (Ruiz Manuel & Blok, 2023). However, there has been limited research on how CCIs address the carbon market and how they affect the climate behaviour of their participants.

In this report, we aim to assess the role of carbon credit use in cities', companies' and CCIs' climate strategies. First, we aim to identify the key predictors of carbon credit use for each NSA group. Second, we aim to qualitatively analyse how cities, companies and CCIs address carbon credits and how it fits in their climate strategy. The study on CCIs not only assesses CCIs' role in carbon credit use, but it broadens the scope to climate behaviour, including climate ambition and target progress. To address these aims, we present insights from three studies on the role of carbon credits in non-state climate action. Our work on cities has been finalised and published (Chappell et al., 2025). Our work on companies and CCIs is nearly done and we plan on submitting these studies to peer reviewed journals early 2026.

1.2 Methodology

We assess the role and predictors of carbon credits in climate action strategies by cities, companies and CCIs in three separate studies. For each study, we conduct a statistical analysis to identify the key predictors of carbon credit use. We utilise machine learning approaches to demonstrate non-linear and complex relations between the predictors and carbon credit use. To provide additional insights into the results of the statistical analyses, we conduct qualitative text analyses as well. To capture the integrity of carbon credit use, the variables in the statistical analyses and the topics in the text analyses are aligned with the high integrity principles developed within ACHIEVE (see upcoming deliverable D1.3). The specific approach differs for cities, companies and CCIs due to differences in data types and quality, the amount of data, the presence of timeseries data, and differences in contexts for the three NSA groups used in the studies. In the following sub-sections, we provide detailed information on each study's methods and data. We also identify the status of the work and highlight future steps.

1.2.1 Cities

We use publicly available data on the use of carbon credits by cities from the NetZero Tracker (NZZT), the CDP, and Climate Action Plans (CAPs). We use the NZZT data, which collects information on net-zero or similar pledges for every city globally with a population over 500,000, a total of 1,186 cities (J. Lang et al., 2024). Then, we use CDP and CAP data to supplement this. From the initial set of 1,186, a city is retained for analysis if it has a percentual emissions reduction target and target year reported in either NZZT or CDP. This creates a final set of 363 cities. We use a random forest model (RFM) to explore whether carbon credit use is associated with certain city characteristics or with characteristics of city CAPs. An RFM is a machine learning algorithm that generates many decision trees to predict the likelihood of classes based on



characteristics of multiple predictor variables. We include four categories of responses to the (intended) use of offsetting by cities: *Yes*, *No*, *Maybe*, and *Not Specified*. A city was classified as *Yes* or *No* if they have reported a decision, *Maybe* if they have indicated they are considering offsets, and *Not Specified* if they do not discuss offsetting. We run the RFM using the four classes of cities' use of carbon credits as dependent variable and 11 predictor variables relating to city characteristics and the ambition and integrity of their climate target. We select the variables based on a review of literature. The predictor variables include: population, population density, per capita GDP (national), final end target (% reduction), target year, interim target (yes/no), consumption emissions (yes/no), C40 city (yes/no), CAP discusses equity (yes/no), reporting frequency, predicted emission change (national).

To explore in more detail the trends that emerge from the RFM, we zoom in on cities that have decided to use offsetting and conducted a text analysis of CAPs. We analyse 44 cities that are indicated in the NZT as using offsets to meet their target. We systematically analyse the CAPs for each of the 44 cities, using a keyword search to identify relevant sections of the document. We record information about the type, role and integrity of emission compensation strategies in city CAPs. More detailed information on the approach taken for this study can be found in Chappell et al. (2025).

1.2.2 Companies

To identify the key predictors of carbon credit use by companies, we employ two extreme gradient boosting models (XGBoost), which are, similar to RFMs, machine learning algorithms that use an ensemble of decision trees to predict an output variable. The difference with RFMs is mainly that XGBoost models learn continuously from previous trees, rather than fitting each tree on a random sample of the data. Boosted regression trees, including XGBoost models, are able to showcase complex and non-linear relationships in the data (Elith et al., 2008), allowing us to analyse trends and correlations without assuming linear correlations. It can handle interactions between predictors and different types of predictor variables (Elith et al., 2008). These qualities of the model make it particularly suitable for our analysis and data.

Using these models, we identify the key predictors of carbon credit use by companies. Our first model aims to predict if a company uses carbon credits (*Yes/No*) and is thus a classification model. Our second model is a regression model, where we predict the volume of carbon credits for the companies that do use carbon credits. Using the potential for high dimensionality in a boosted regression tree, we explore a high number of variables (31) in the context of carbon credits. Initially, we incorporate variables related to corporate climate ambition and targets, climate performance of the companies, governance of climate-related issues within each company, and general company characteristics. We then determine the variable importance of the model, which gives us insights into the most important predictors of corporate carbon credit use. By iteratively employing the model, we exclude variables that did not influence the model prediction or that are co-linear with other variables. Our final models include 17 variables. Most continuous variables are log-transformed, and all variables are normalised to fit within a range of 0 to 1.



We use self-disclosed CDP data from the 2023 annual questionnaire (CDP, 2023). The data include a wide range of climate-related indicators such as emissions, targets, energy consumption and carbon credit use. We supplement the data with LSEG and ORBIS data to find revenue and asset data (Datastream International, 2024; Orbis International, 2024), and the World Development Indicators (World Bank, 2025) and Net Zero tracker (J. Lang et al., 2024) data for additional country-level variables. Our sample contains the 3,645 companies for which the data is complete for the classification model, and 499 companies that use carbon credits during the reporting year for the regression model.

To gain additional insights into how companies use or plan to use carbon credits, we perform a text analysis of the written responses in the CDP database, in which many companies explain their future plans for carbon credit use. We assess companies' intentions of using carbon credits in the future, including if they estimate or set an upper limit for the amount of carbon credits they will use. We also evaluate the planned timing of future carbon credit use and the role it plays in companies' climate strategy. Moreover, we assess the type of carbon credits companies prefer to use and if they discuss the integrity, co-benefits, and trade-offs of carbon credits. We employ the generative large language model Llama 3.1 8b Turbo to extract data from the texts based on specific questions we formulate about companies' intention of using carbon credits now and in the future. To ensure the accuracy of the large language model, we manually code and analyse texts from 100 of the 1,889 companies which we will use to refine the prompts and validate the large language model by calculating the accuracy.

1.2.3 Cooperative climate initiatives

To assess how the landscape of CCIs address the carbon market, we perform a qualitative text analysis of the guidance a broad sample of CCIs provide to improve the integrity of the demand-side voluntary carbon market. We select 42 CCIs from the CoAct Database (Chan et al., 2025) based on the following criteria: (1) the focus of the CCIs should be directly on climate mitigation, as these CCIs are relevant in the context of carbon credits; (2) the CCIs should include a high share of corporate actors as the focus of the study is to assess the effects of CCIs on corporate climate behaviour; and (3) the CCIs should have been recently active, which is defined as producing outputs such as reports, blog posts, or social media posts (Chan et al., 2025). These selection criteria provide us with a broad sample of CCIs that represent of the landscape of mitigation-, and corporate-focused CCIs. The CoAct Database aims to avoid selection biases by including CCIs that are identified through various channels.

We manually analyse documentation related to the guidance and requirements CCIs provide for NSAs, in particular for their participants. The document analysis aims to answer questions related to the guidance on the use of carbon credits, e.g., whether internal decarbonisation should be prioritised, how residual emissions are defined, and whether actors should prioritise specific project types. We also map if CCIs mention the quality of carbon credits or other environmental and social integrity aspects of carbon credit use. Moreover, to be able to assess the role of carbon credits in the broader climate strategies, we map CCIs' guidance on target setting and climate action in general.



To address the research gap of how participation in CCIs affect the climate behaviour of individual corporate actors, we perform a statistical time-series analysis, using an XGBoost model trained on panel data. We select four large-scale, pledge-based CCIs: the Science Based Targets initiatives (SBTi), the Climate Pledge, Carbon Neutral Now, and Business Ambition for 1.5°C. These four CCIs have substantial impact on the voluntary climate landscape, as their standard setting practices reach large numbers of corporate actors. Moreover, these CCIs are structured as pledges, i.e., all participants have committed to meet the requirements set by the CCIs, although enforcement remains limited. This makes them particularly interesting in an analysis of participants' climate behaviour, especially as it is often unclear if sanctioning is included in their accountability mechanisms. We analyse how the climate behaviour – consisting of carbon credit use, climate ambition, and target progress – of corporate participants have changed since joining the CCI, while distinguishing between types of guidance provided by CCIs.

Data on participation in CCIs are extracted from the CCIs' websites. Data from annual CDP questionnaires between 2018 and 2024 is used for insights on climate performance (CDP, 2018, 2019, 2020, 2021, 2022, 2023, 2024), which is supplemented with data from LSEG, Orbis, World Development Indicators, and Net Zero Tracker (Datastream International, 2024; J. Lang et al., 2024; Orbis International, 2024; World Bank, 2025). Participation data from the CCIs and CDP data is combined using a fuzzy logic name matching approach, taking not only the name, but also the headquarter country of each organisation into account (Snae, 2007). Data on characteristics and guidance of the CCIs follows from the text analysis described above and from the CoAct Database (Chan et al., 2025).

Similar to the corporate analysis, we employ an XGBoost model, which is a machine learning algorithm that uses an ensemble of decision trees to predict one or more output variables by continuously learning from previous trees. This method is able to capture complex and non-linear relations in the data, allowing us to perform the analysis without assumptions of linearity (Elith et al., 2008). Moreover, it accounts for possible interactions between variables, and it can account for different types of predictor variables (Elith et al., 2008). An XGBoost approach also allows us to build a model with multiple outputs, i.e., one model that predicts more than one dependent variable. These qualities of the model make it particularly suitable for our analysis and data.

Our model is built to predict carbon credit volume, climate ambition, and target progress. Carbon credit volume is indicated by the amount of carbon credits retired in the reporting year expressed in tonnes CO₂ equivalents. Moreover, to assess climate ambition, we use an indicator developed by Stolz & Probst (2025) that compares a company's targets to an average 1.5°C pathway (average of all 1.5°C pathways of the IPCC AR6 report (Byers et al., 2022)). Lastly, to indicate target progress, we use an indicator developed by Bolay et al. (2024) which not only takes the reduced emissions into account, but also the time left to achieve the target. The progress indicator is, therefore, an expression of the extent to which the company is 'on track' to achieve their target. We express all three output indicators in the percentual difference compared to the level prior to joining the CCI.



Our key explanatory variables include the time since joining the CCI in year, with $t=1$ being the year that the company has joined the CCI. We also include two variables related to the guidance provided by the CCI in which the company participates: (1) requirements for environmental integrity and use of carbon credits, and (2) requirements for making climate-related claims, such as net zero or carbon neutrality. Moreover, we included random effect variables to account for variations in the sample. These include (1) country-level emissions per capita, (2) if the company operates in a hard-to-abate sector, (3) emission reduction initiatives divided by scope 1 and 2 emissions, (4) if the company is regulated by a carbon pricing scheme, and (5) if the company has implemented an internal carbon price.

We have excluded other independent variables based on multicollinearity in the data. We tested all configurations where no variable had a variable inflation factor (VIF) above 5, and choose the configuration of variables that yielded the best model performance, which we indicated by mean absolute error and R^2 value. Furthermore, for machine learning approaches such as the XGBoost model, the hyperparameters play an important role in the performance and predictions of the model. Hyperparameters are parameters that determine the architecture or algorithmic behaviour of the model, such as the number of decision trees, their maximum depth, or the rate in which the model learns from previous decision trees. Therefore, we have tuned key hyperparameters using an automated Bayesian approach to find the hyperparameters that yielded the best model performance, as expressed in mean absolute error and R^2 value. We defined the most important hyperparameters and their respective possible ranges of values based on the literature.

1.3 Results

1.3.1 Cities

Of the 363 cities included in our dataset, 24% use or intend to use offsets, while 22% of cities specifically indicate they do not (plan to) use offsets, 15% indicate maybe, and 39% do not specify their use or intention. Overall, we found most (52%) cities that intend to use offsets are not currently offsetting and intend to wait until they are close to or have reached their target year (typically 2050) to begin offsetting residual or remaining emissions. Our sample covers all geographic regions, but most cities in our sample are from Europe (24.2%), Northern America (23.7%), or East Asia (22.9%).

Our random forest model (RFM) results show how 11 predictor variables influence the use of offsetting, see Figure 1. We found that larger and wealthier cities are more likely to offset, although reasons may vary across cities due to differing rationale for using offsets. We looked at insights from the text analysis to further explore possible reasons. First, the association between GDP per capita and offsetting may be interpreted as wealthy cities buying offsets in place of meaningful climate action. From the text analysis, this may be true for some cities, but we did not find this interpretation to be reflected by most cities analysed. Several cities recognise the potential downsides of offsetting in their CAPs or explicitly state that offsetting should only be used as a last resort for emissions they are not able to reduce through mitigation. Second, larger and wealthier cities likely have more funding to develop detailed



CAPs and conduct emissions modelling, thereby recognising it is difficult to reach absolute zero. For example, London, GBR conducted extensive modelling through which they found it not technologically feasible to reach zero emissions by 2030 and therefore has included offsetting in their plan. Third, larger and wealthier cities are typically high emitters of GHGs and want to do as much as possible to decrease their net emissions. Some large and wealthy cities may recognise their responsibility to quickly reach what they believe their fair share of carbon emissions to be, a component of equity. Cities that discuss equity in their plan are more likely to say *Yes* to offsets than *No*. Although using offsets is not necessarily equitable, the positive correlation between cities that discuss equity in their CAP and saying *Yes* to offsetting does suggest that some cities may use offsets as an additional measure to capture what they believe to be their fair share of carbon emissions, beyond what is possible through reductions.

Cities with interim targets and C40 member cities are more likely to make a decision on carbon offsetting, meaning they have said either *Yes* or *No* to offsetting instead of *Maybe* or *Not Specified*. These cities may be more likely to have a detailed CAP and therefore also be more likely to have made a decision about offsetting (*Yes* or *No*). Having an interim target and/or being a member of C40 may also be associated with greater accountability or integrity, suggesting high integrity may be associated with both saying *Yes* and saying *No* to offsetting. In contrast, cities with higher percent emission reduction target and a later target year are more likely to be *Not Specified*, suggesting that these cities have less detailed strategies on how to achieve their targets. Cities with a low per capita GDP are also most likely to be *Not Specified*, suggesting fewer resources available to develop a detailed CAP.

From our text analysis of 44 cities that intend to use offsetting in combination with the RFM, we identified key themes relevant for better understanding the type and role of carbon credits in city CAPs. First, results from both the RFM and the text analysis suggest many cities that intend to use offsets perceive offsetting as an extra step allowing them to achieve more ambitious targets than possible with reductions alone.

Second, the majority of cities (52%) note they will wait until they are close to, or have reached, their target year to offset remaining emissions. While this can help cities prioritise emissions reduction action over offsetting and cities might prefer to wait until the quality of carbon credits in the market has improved, it can also delay the creation of concrete plans regarding offsets. Cities often lack clear decisions or guidelines around what type of offsets they intend to use and from where, making it difficult to evaluate the environmental integrity of planned offsetting. Less than half the cities (43%) mention environmental integrity of offsetting; those that do, often mention challenges but do not clarify how they intend to address them.

The majority of cities in our text analysis intend to prioritise local or regional offsets over those from further away (Figure 2). All 44 cities are considering insetting (i.e., emissions compensation by carbon dioxide removal projects within the city limits) in addition to offsetting, and 11 of the 44 cities intend to prioritise insetting over offsetting. A further 15 cities note a preference for regional offsets (outside the city boundaries but closer than the national scale). This local/regional preference is generally due to envisioned co-benefits, and sometimes due to integrity concerns about offsets from further away. However, local offsets pose higher risks for



double counting.

Additional findings are presented in Chappell et al. (2025).

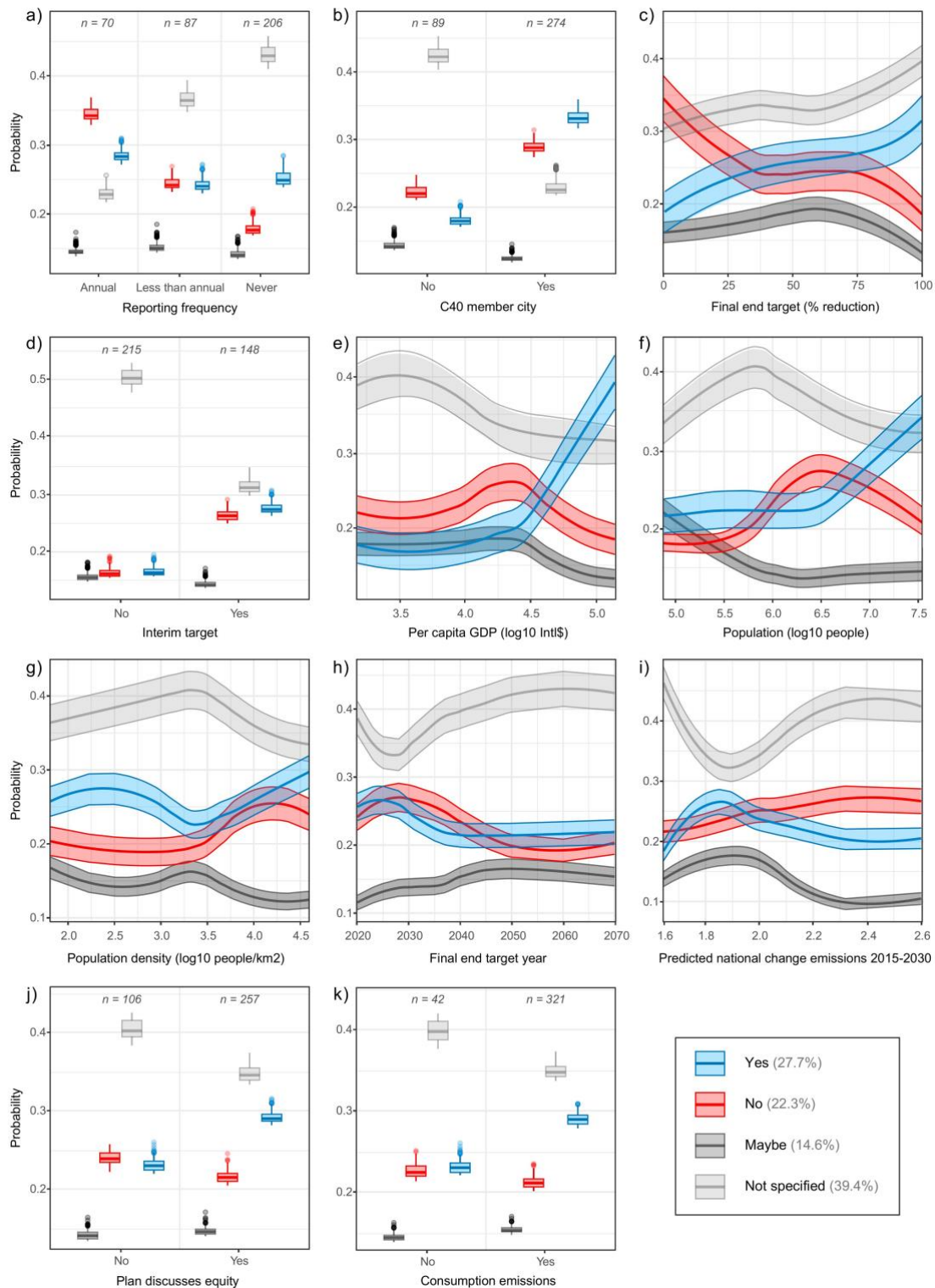


Figure 1 RFM results showing impact of 11 variables on the probability of four classes of responses to carbon credit use (Yes, No, Maybe, Not Specified) for 363 cities. For all parameter values/ categories, the probability adds up to 1. The sample size for each category is shown at the top of each panel for categorical variables. Variables are presented in order of overall importance in the RFM. Source: Chappell et al. (2025).

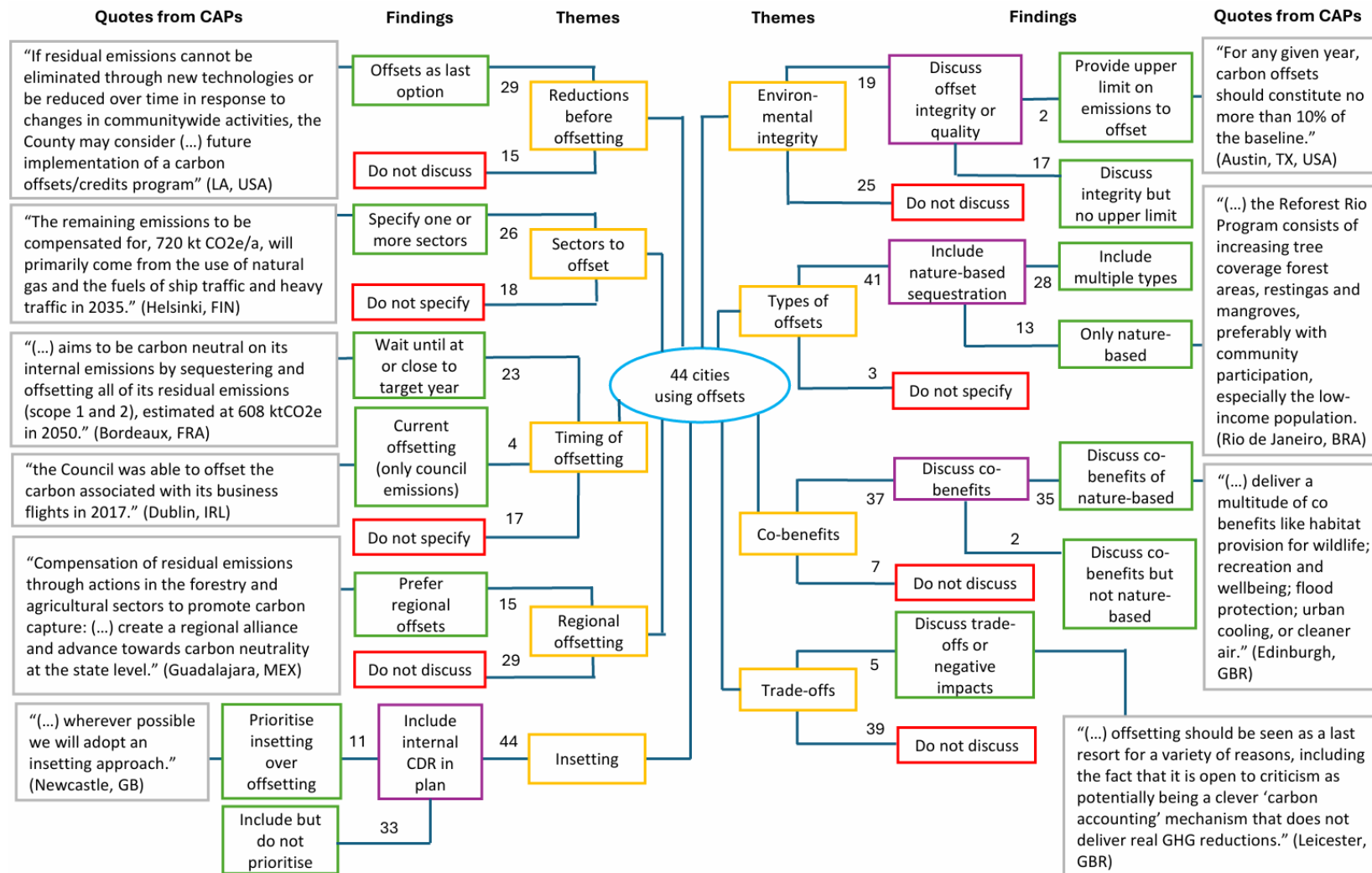


Figure 2 Themes, findings and counts of their occurrence identified using text analysis of climate action documents for 44 cities that intend to use offsetting. Example quotes from city climate action plans. Source: Chappell et al. (2025).



1.3.2 Companies

Our sample for the statistical analysis contains 3,645 companies, of which 499 (13.7%) have used carbon credits in the reporting year. The text analysis covers a further 1,889 companies, of which 587 are not included in the statistical analysis. In total, our analyses cover 4,232 companies. The majority of the companies report their climate data for the year 2022, with a few reporting for other years between 2019 and 2023. Most companies operate in the services and manufacturing sectors, 27.7% and 26.7% respectively. Other frequent sectors include materials (11.1%), retail (7.5%), infrastructure (7.2%), food, beverage and agriculture (4.7%), and biotech, health care and pharma (3.9%).

Most companies are headquartered in Japan (933), the United States of America (762), or in the United Kingdom (354). Aggregated to geographic regions, the majority of companies have headquarters in Asia (1,729), followed by Europe (1,260) and Northern America (889). In total, 83.4% of companies are headquartered in the Global North.

Variable importance and model performance

Our results show that wealth, expressed in either assets or revenue, emissions in scope 1, 2 and 3, emissions intensity, the volume of emissions reduced through emission reductions initiatives (ERIs) relative to scope 1 and 2 emissions, the presence of an internal carbon price, and climate ambition are among the key predictors of corporate carbon credit use (in both our classification model and regression model) (see Figure 3 and Figure 4). However, we do observe some differences in variable importance between our classification and regression models. For example, emissions intensity is mainly an important predictor of whether companies use carbon credits, while scope 1 emissions play a more important role in predicting the volume of carbon credits.

Evaluation of our models provide insights into the reliability of our results. First, our classification model performs well on accuracy, with a score of 85%. However, the f1-score, i.e., a combined score of recall and precision of classifying companies as carbon credit users, is 0.41. The f1-score can be relatively low without affecting the accuracy as our sample mainly contains companies that are not currently retiring carbon credits. To ensure interpretable and reliable results, we have optimised our model for the f1-score. Second, our regression model has a mean absolute error of 0.097 (the possible range of prediction is between 0 and 1), with an R^2 score of 0.15. Third, for our qualitative text analysis, we calculated the accuracy for each question. The accuracy ranged between 71% and 94%, with most questions falling somewhere in between.

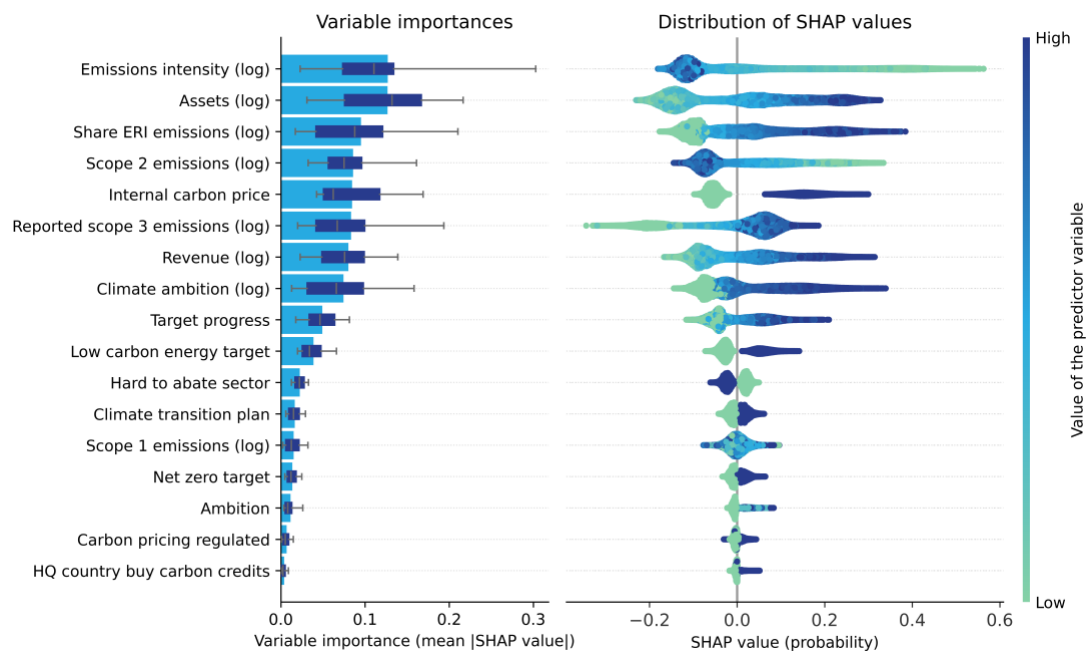


Figure 3 Overview of the results from the classification XGBoost model that aims to predict the probability of carbon credit use by companies. The data in this figure is based on SHAP values, which represent how much impact the respective variable has on the prediction of the model compared to the average prediction. Each company has one SHAP value for each variable. In the left panel, we show the variable importance of each variable (mean absolute SHAP value, which is a measure that indicates how much each variable influences the prediction of the model, independent from it being in a positive or negative direction). The box plots represent the distribution of the absolute SHAP values. In the right panel, we show the distributions of the SHAP values. Here, each dot represents one company, with its respective value of the variable indicated by colour, and its respective SHAP value indicated by its x-axis location. Bubbles represent that large numbers of companies have similar SHAP values. For example, we observe that companies with low emissions intensity (indicated in light green in the top row) often have high SHAP values, suggesting that these companies have higher predicted probability of carbon credit use.

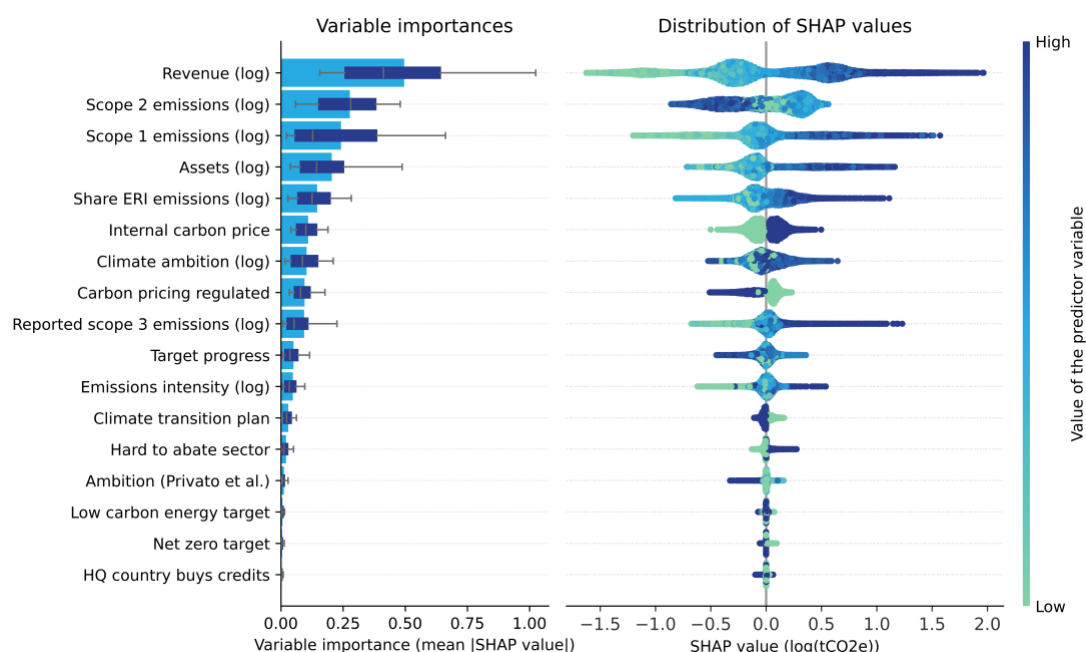


Figure 4 Overview of the results from the regression XGBoost model that aims to predict the volume of carbon credit use by companies. The data in this figure is based on SHAP values. In the left panel, we show the variable importance of each variable (mean absolute SHAP value), with the box plots representing the distributions of absolute SHAP values. In the right panel, we show the distributions of the SHAP values by value of the feature (colour). See caption of Figure 3 for detailed insights into the interpretation of the figure.

Climate ambition and target progress

Our statistical model shows that companies with higher climate target ambition – as measured by an indicator developed by Stolz and Probst (2025) that captures the targeted emissions reductions compared to a 2020 base year – are more likely to have retired carbon credits during the reporting year, but climate ambition predicts the volume of carbon credits less well. Specifically, we observe that companies with medium high ambition have highest predicted carbon credit volume, which is higher than for companies with high ambition (see Figure 3 and Figure 4). This suggests that only limited amounts of carbon credit use could be part of a highly ambitious climate strategy.

Although our statistical model only sheds light on current carbon credit use, we find in the text analysis that the majority of companies that discuss carbon credits aim to start or increase carbon credit use in the future (66%). This suggests that carbon credits will play an increasingly important role in corporate climate strategies, like for achieving targets. Although many discuss future trends, specificity is often lacking with only 19% of companies predicting a specific amount of carbon credits that they will use and 18% that set an upper limit on future carbon credit use.

Further, our findings indicate that companies generally agree that emission reductions should



be prioritised over carbon credit use, but we find limited evidence that companies explicitly act on this prioritisation. Specifically, our results show that there is a general consensus among companies that internal emission reductions should be prioritised over carbon credit use, with 1,655 out of 1,889 companies (87.6%) mentioning this in their written response. Moreover, our statistical analysis also shows that companies that implement more ERIs relative to their scope 1 and 2 emissions are also more likely (on average 34% more likely) to use carbon credits and they do so in higher volumes (see Figure 3 and Figure 4). However, if we assess how target progress predicts carbon credit use and volume, we find that companies with higher target progress are slightly more likely to use carbon credits (on average 13% more likely), but we see a slight opposite trend for the volume of carbon credits (see Figure 3 and Figure 4). Notably, these results suggest that we should be cautious with interpreting the positive correlation between the probability of carbon credit use and climate ambition, as climate ambition without target progress provides only limited insights into companies' climate performance (Bolay et al., 2024). Moreover, higher climate ambition but low target progress for heavy carbon credit users suggest that there might either be an overreliance on carbon credits or otherwise a delay in achieving climate targets.

In conclusion, we find that carbon credit use could go hand in hand with ambitious climate targets, but progress towards these targets is lower for companies that use high volumes of carbon credits. Moreover, target progress plays a very limited role in our model, suggesting that carbon credit use does not necessarily lead to, or is correlated with, internal decarbonisation. Some industry reports show different results with a positive correlation between whether companies use carbon credits and their internal decarbonisation (e.g., Ecosystem Marketplace, 2023), and one even finds that heavier users achieve more emission reductions (Trove Research & MSCI Carbon Markets, 2023). However, our results are in line with Stolz & Probst (2025), who find a negligible correlation between climate ambition and carbon credit use.

High integrity climate action

Our results indicate that aspects of high integrity (having an internal carbon price, setting a net zero or low-carbon energy target, or having a climate transition plan) are correlated with low volumes of carbon credits use, i.e. companies with high integrity aspects have higher probability of carbon credit use, but they do not have higher volume of carbon credit use. Specifically, having an internal carbon price, a low-carbon energy target, a climate transition plan, or a net zero target increases the probability for carbon credit use with 21%, 9%, 3%, and 3%, respectively. At the same time, our model to predict the volume of carbon credits gives some more mixed results, with slightly negative or unclear correlations. One exception is having any type of internal carbon price, which is correlated with higher volumes of carbon credit use. As companies with aspects of integrity are using lower amounts of carbon credits, we argue that predominantly low volumes of carbon credit use are associated with high integrity climate action.

Moreover, our text analysis highlights that many companies are planning on using carbon



credits for offsetting claims, which poses high greenwashing risks (Trouwloon et al., 2023). We find that 28% of the companies in our text analysis mention that they will explicitly use carbon credits for climate-related claims based on offsetting of emissions, which poses significant risks for greenwashing (Trouwloon et al., 2023). A common alternative way of using carbon credits discussed in the literature are contribution claims (e.g., Fearnough et al., 2020a). However, we find that companies only rarely discuss this (only 4% of companies discuss this).

Type of carbon credits

The type and quality of carbon credits used plays an important role in supporting high integrity use of carbon credits, but we find little emphasis on high-quality carbon credits. The voluntary carbon market is often criticised for its low-quality and ineffective carbon credits that have substantial social and environmental trade-offs. However, in our text analysis, we find that only 25% of companies mention that they will use high-quality carbon credits or ensure the environmental integrity of the used carbon credits. About 11% of companies also discuss social or environmental co-benefits of carbon credits, such as supporting biodiversity or reducing indoor air pollution.

The location of implementation is another important part of the type of carbon credits, but only few companies indicate they will use carbon credits from a specific location, often in the country where they are based. Carbon credit use has been criticised to promote neocolonial trade relations if implementation happens in the Global South, while the credits are used by Global North actors (Carton et al., 2020; Spash & Theine, 2016). At the same time, implementation of carbon crediting projects in the Global North faces more additionality concerns. Moreover, the provision of co-benefits on the one hand, and the exploitation of local communities on the other hand make it also important to carefully consider the location of implementation (Carton et al., 2020; S. Lang et al., 2019). We find that about 15% of companies specify a specific location that they prefer for implementing carbon crediting projects, of which two-thirds of those companies specify the country in which they are headquartered. Furthermore, we find that 28% of companies also mention insetting as a possible emission compensation mechanism, which also has a strong focus on local implementation as the emission compensation happens within the value-chain.

Characteristics of companies using carbon credits

We observe some trends in the characteristics of the companies that are using carbon credits. First, our statistical models show that wealthier companies, measured by both assets and revenue, are more likely to use carbon credits and in higher volumes. Wealthier companies might be more often scrutinized which could lead to either a reduction in carbon credit use as the carbon market faces substantial criticism, or an increase in carbon credit use as scrutiny could create additional incentives for climate action. Our results are more in line with the second explanation. Second, we find that companies in hard-to-abate sectors are less likely to use carbon credits, but if they do, they tend to use higher volumes of carbon credits. Although carbon credits are often framed as necessary for hard-to-abate sectors to achieve climate



targets, these sectors also tend to face more stringent regulations that incentivises internal decarbonisation. However, our results are in line with Kim et al. (2024). Possibly, companies in hard-to-abate sectors could experience less incentive in providing a sustainability narrative, as their emissions will still remain high after emissions reduction and emission compensation. They might focus more on future technologies, such as green hydrogen, to still engage with sustainability. Kim et al. (2024) also note that the relative quantity of carbon credit use would not align with the magnitude of emissions in high emission industries. Third, we find that scope 2 emissions are playing a more important role in predicting carbon credit use and volume than scope 1 and 3 emissions, although carbon credits are rarely used to compensate scope 2 emissions. We find a negative correlation between scope 2 emissions and the probability and volume of carbon credit use. As scope 2 emissions are market based, companies with low scope 2 emissions are likely experienced with market-based emission compensation mechanisms such as renewable energy certificates.

Further, we find that the regulatory context in which companies operate plays a very limited role in predicting carbon credit use, although companies regulated by a carbon pricing scheme, such as a carbon tax or emissions trading system, tend to use lower volumes of carbon credits. At the same time, carbon pricing regulations do not influence whether our model predicts that companies use carbon credits or not.

1.3.3 Cooperative Climate Initiatives

Our text analysis of 42 mitigation-focused CCIs showed that 26 (62%) CCIs discusses carbon credits, of which the majority promote the use of carbon credits. Only 2 of these 26 CCIs discourage the use of carbon credits. Carbon credit guidance is particularly important as a supplement to net zero guidance, or other strategies that often rely on the carbon market. However, we find that 17% of CCIs that encourage net zero targets do not discuss carbon credits at all nor do they refer to existing guidance for carbon credit use, which signals an important gap in guidance. Furthermore, we find that half of the CCIs that discuss credits set requirements for their participants, while the other half only provides voluntary guidance. Some CCIs also refer to existing guidelines to support actors in high-integrity carbon credit use (12/26), most often the SBTi (5), the Integrity Council for the Voluntary Carbon Market (ICVCM) (5), or the Voluntary Carbon Market Integrity Initiative (VCMI) (4). Overall, we find that the provided guidance generally lacks detail and specificity.

Variable importance and model performance

Our statistical model shows that country-level emissions per capita and the volume of ERIs relative to a companies scope 1 and 2 emissions play a more important role than time since joining an initiative or variables related to the CCI a company participates in. Particularly for predicting the change in carbon credit volume, time since joining plays a limited role (see Figure 5), suggesting that CCIs also have limited influence in changing corporate climate behaviour, while country, sector, and company characteristics are more strongly associated with changes in corporate climate behaviour.



Our model has a mean absolute error of 0.77, with outputs ranging from -2 to +2 (which are the percentual changes in output variables compared to before joining the CCI). Our model has a R^2 value of 0.21.

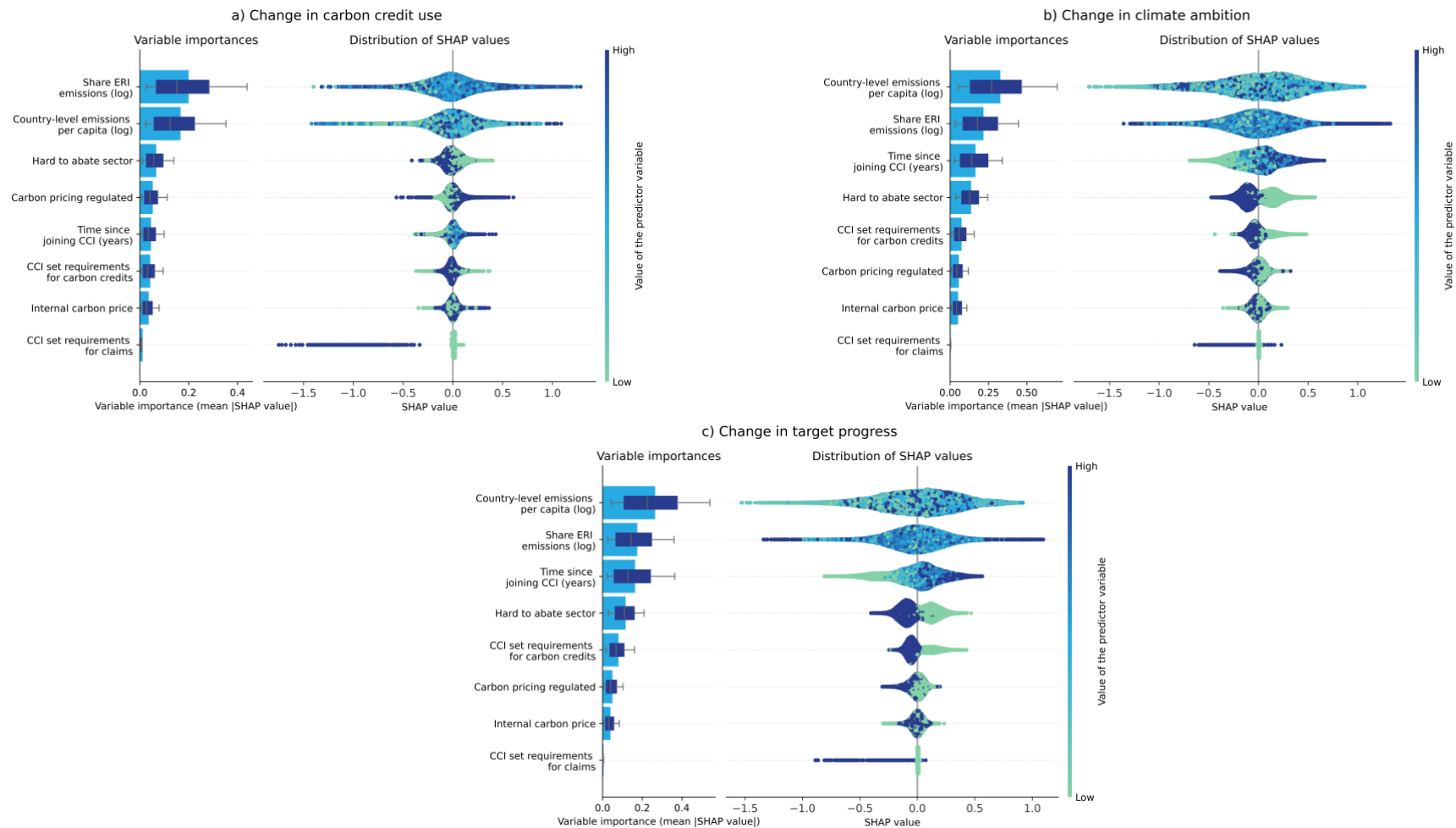


Figure 5 Overview of the results from the XGBoost model that aims to predict carbon credit use (a), climate ambition (b) and target progress (c). In the left panels, we show the variable importance of each variable (mean absolute SHAP value), with the box plots representing the distribution of the absolute SHAP values. In the right panels, we show the distributions of the SHAP values (x-axis) by value of the predictor variable (colour). See the caption of Figure 3 for detailed explanation of the interpretation of the figure.



Trends over time

Overall, our model shows an increase in carbon credit volume, climate ambition and target progress over time, see Figure 5. These results could be explained by the results of our qualitative text analysis. For example, we find that CCIs often encourage their participants to use carbon credits, as they often frame it as an essential tool for ambitious climate action, i.e., carbon credits are necessary to achieve net zero targets. This framing could normalise carbon credit use or remove hesitation among participants, thus leading to increased carbon credit use. Moreover, most CCIs require or promote setting net zero or emission reduction targets (32/42 – 76%), of which 23 specifically require net zero targets for 2050 (17), 2040 (3), or 2030 (2). If participants follow the guidelines of CCIs and set these targets in the years after joining the CCI, their climate ambition will increase. Likewise, we find that many CCIs are also able to support implementation of emission reductions to achieve the targets by setting certain target quality requirements. For example, we find that many CCIs require actors to disclose their emissions (25/42 – 60%), develop transition plans (19/24 – 45%), or set interim targets (24/42 – 57%). These practices can strengthen accountability and thus support progress towards companies' climate targets (Bäckstrand et al., 2017; Bjørn et al., 2023; Michaelowa & Michaelowa, 2017).

We do see the least increase (and even slight decrease after a few years) in carbon credit use of CCI participants. This is in line with the general consensus among CCIs that emission reductions should be prioritised over carbon credits use (23/26 – 89%). However, as we still see a general increase in current carbon credit use after joining (i.e., predicted values are always larger than 0), a question still remains about how rigorous participant take up this requirement.

The timing of carbon credit use is an important aspect of high-integrity carbon credit use, but we observe that CCIs provide little guidance on this topic. The Oxford Principles for Net Zero Aligned Carbon Offsetting state that over time, permanent carbon removal credits should be increased, while emission reduction or avoided emission credits should be reduced (Axelsson et al., 2024). As our statistical model only considers current carbon credit use (i.e., retirements in the reporting years), it is important to specifically assess how CCIs address the timing of carbon credit use. We find that 27% of CCIs (7/26) discuss the timing of carbon credits, but the guidance they provide is fragmented. Four CCIs encourage current use of carbon credits to compensate currently unabated emissions, while one CCI argues that carbon credits should only be used at the target year. Two CCIs are in line with the Oxford Principles and state that actors should increase carbon removal credits over time.

Carbon credit use as part of a high integrity climate strategy

Carbon credit use is often associated with greenwashing (Trouwloon et al., 2023), but our findings indicate that CCIs insufficiently address this issue by only providing high-level guidance that lacks specificity and detail. For example, defining net zero, including the role of carbon credits within net zero, can support clarity in achieving net zero targets. Although we find that 41% of CCIs define net zero (17/42), still 9 out of 23 CCIs that encourage actors to set net zero targets do not provide a definition. Furthermore, many net zero definitions also lack specificity,



with 6 CCIs only mentioning that carbon sources and sinks should be balanced. Moreover, guidelines rarely define how to determine the amount of residual emissions and/or what level of emissions is considered residual. Five CCIs (12%) specifically define residual emissions, but they don't provide details. For example, some define residual emissions as emissions that are technically and/or economically unfeasible or difficult to eliminate. However, technical and economical feasibility is subject to temporal dynamics and provide little guidance in the interpretation of residual emissions on a company level. Another approach is by setting an upper limit on the use of carbon credits, which 27% of CCIs do (7/26), typically around 10% of baseline emissions. Another 3 CCIs do not set a hard limit, but they do provide an approximate amount companies can aim for.

Climate claims made by companies, such as carbon neutrality or net zero, are important in relation to greenwashing and carbon credit use, but it plays a limited role in CCIs' guidance. Although CCIs have the potential to better regulate these claims (Trouwloon et al., 2023), only four CCIs (15%) set specific requirements or guidelines for climate-related claims, and five CCIs (19%) discuss contribution claims as an alternative to offsetting claims. However, they typically argue that actors can use carbon credits for both offsetting and contribution claims side by side. Transparency around to use of carbon credits can also support the integrity of climate-related claims, which is encouraged by 35% of CCIs (9/26).

Our statistical analysis provides insights into the question on how this guidance impacts actual climate behaviour of companies, but we find only limited effect. We find companies that participate in CCIs that set any requirements for the use and environmental integrity of carbon credits tend to increase their carbon credit use less quickly (see Figure 5a). Although the differences are quite small, it does suggest that discussing carbon credits and setting requirements for its use can support changes in corporate climate behaviour. Nevertheless, we also find that climate ambition and target progress tends to improve less after joining CCIs that set requirements for the use and environmental integrity of carbon credits (See Figure 5b and c). As these requirements are likely designed to encourage high-integrity carbon credit use, and thus more effective climate action, CCIs should aim to mitigate the reductions in ambition and progress improvements.

Types of carbon credits

CCIs can mitigate issues related to the use of low-quality carbon credits, but we find that they only provide limited support for actors to identify high-quality carbon credits. The use of high volumes of low-quality carbon credits is common among companies (Trencher et al., 2024) and likely to lead to greenwashing (Trouwloon et al., 2023). It can also be harmful as it can lead to increased consumption (Günther et al., 2020) and environmental and social trade-offs can occur (e.g., Lyons & Westoby, 2014). The complexity of the voluntary carbon market hinder companies in identifying high-quality carbon credits (Macintosh et al., 2025). CCIs can provide support in identifying high-quality carbon credits and guiding actors to types of carbon credits that are most likely to achieve their claimed climate impact and pose the least risks of environmental or social trade-offs. We find that over 60% of CCIs that discuss carbon credits require use of only



high-quality carbon credits, however, it remains unclear how CCIs define high-quality carbon credits and how actors can identify them. Nevertheless, some CCIs do provide guidance for aspects of high-quality carbon credits. For example, the Oxford principles require future use of permanent removals rather than carbon credits based on emission reductions or “avoided emissions” (Axelsson et al., 2024). Just under half of CCIs encourage the (future) use of permanent removals, while five CCIs (5/26 – 19%) specify project types that actors should aim for when using carbon credits. However, four of these five CCIs encourage nature-based climate action, which poses significant risks of non-permanence. Moreover, insetting is mentioned by six CCIs (6/42 – 14%), of which two encourage the use of insetting over offsetting.

The implementation of carbon crediting projects can cause substantial social harm such as carbon colonialism, adverse impacts on livelihoods of local communities, and erosion of cultural heritage (Arko, 2025; Lyons & Westoby, 2014), but most CCIs pay little attention to these issues. Although 42% of CCIs (11/26) encourage use of carbon credits that provide social or environmental co-benefits, only five CCIs (19%) explicitly require the use of carbon credits with social safeguards in place, while only three CCIs (12%) advocate for carbon credits for which communities are included in the development of the credits.

1.4 Discussion and conclusion

In this assessment of carbon credit use by cities, companies and CCIs, we found that carbon credits play an important role in their climate action or guidance. However, there is an overall lack of details and specificity in the strategy and guidance around carbon credit use. For example, CCIs tend to provide only high-level guidance for carbon credit use, while companies and cities rarely discuss their plans for carbon credit use in detail.

Moreover, we observed some reoccurring themes in the three studies. First, the prioritisation of emission reductions over carbon credit use has become a central theme in all three studies, as it is often mentioned by cities or companies and in the guidance CCIs provide. However, how this prioritisation should be implemented and enforced in practice is persistently lacking. For example, CCIs, cities, and companies rarely define residual emissions in detail, and predicted amounts or upper limits for future carbon credit use are often ignored. Similarly, the timing of carbon credit use is only rarely discussed but when it is, large differences can be observed. For example, we find that some cities aim to use carbon credits close to their target year, while others focus on current use of carbon credits. At the same time, scientific insights are fragmented on whether to wait using carbon credits until the target year to fully prioritise emissions reductions or already starting earlier to be able to prepare the carbon market for future demand (increase in demand, particularly for permanent carbon removal credits). Organisations might also prefer to currently use carbon credits to learn to work with the carbon market. Nevertheless, scientific insights show that offsetting claims are only feasible in the short to medium term if the Paris Agreement is implemented, as NDCs aim to cover all emissions in the future, thus raising concerns over double-counting and non-additionality. Contribution claims show longer future perspective (Fearnough et al., 2020), as double counting does not pose risks for contribution claims. Additionally, permanent carbon removal credits should be particularly increased, as global net zero emission result in lack of possibilities



for emission reduction or avoided emissions credits (Axelsson et al., 2024). These important elements are insufficiently addressed by carbon credit guidance of non-state actors and should thus be emphasized more.

Second, both wealthier and larger cities and companies are more likely to use carbon credits, measured as GDP per capita and population for cities and assets or revenue for companies. This observation could be caused by higher capacity for developing climate strategies and climate action, higher responsibility for (historic) emissions, or increased public scrutiny. Although climate financing through carbon credits by wealthy and large emitters can be desirable under the right circumstances to provide co-benefits, the carbon market has been criticised to promote neocolonial trade relationships (Arko, 2025; Lyons & Westoby, 2014; Spash & Theine, 2016), particularly when mainly wealthy, Global North actors participate on the demand side of the carbon market while the supply is largely generated in the Global South.

Third, the environmental and social integrity of carbon credits does not play a major role in any documents analysed for cities, companies and CCIs. For example, less than 20% of companies discuss it. While half of the cities mention environmental integrity in relation to carbon credits in the CAPs, they often only mention its importance but do not define specifics regarding an upper limit for the use of carbon credits. Although many CCIs mention high-quality carbon credits, specific aspects of high-quality carbon credits are also mostly ignored. Social integrity receives even less attention, with co-benefits of carbon credits occasionally mentioned by CCIs, cities, and companies, but only few address social trade-offs. However, we did find that cities that do discuss equity in their CAP are more likely to intend to use carbon credits, but we did not find any indication that the mention of equity is related to carbon credits.

Fourth, in the study on cities, we found that predictors related to higher integrity climate action, such as an interim targets, C40 membership, and reporting frequency, all predict higher probability that the city has made an explicit decision on future carbon credit use, including both the *yes* and *no* categories. Although we only analyse current carbon credit use for companies with different categories, we do find an increased probability of carbon credit use related to predictors that suggest higher integrity climate action, such as internal carbon price and transition plan. However, we do not find the same relation for the volume of carbon credit use by companies (except for internal carbon price), suggesting that only low amounts of carbon credit use are associated with higher integrity climate action. Moreover, we find that many CCIs aim to increase the integrity of climate action, for example by requiring interim targets, monitoring and disclosure of climate impacts, or more ambitious climate action, while at the same time encouraging the use of carbon credits. Importantly, issues around the carbon market are often raised in the literature, meaning that increased carbon credit use is not necessarily in line with high-integrity climate action, as this depends on many other factors such as claims based on carbon credits, the quality of carbon credits, or the discourse around carbon credits (Chen et al., 2021; Haya et al., 2023; Kreibich & Hermwille, 2021; Spash & Theine, 2016; Trouwloon et al., 2023).

Fifth, offsetting claims based on carbon credit use is a common practice that is often associated with greenwashing, particularly for companies (Trouwloon et al., 2023). Overall, we find that



offsetting claims based on carbon credits remain common practice among companies, with over a quarter of companies specifically using carbon credits to support offsetting claims such as carbon neutrality or net zero. Moreover, CCIs provide hardly any guidance of climate claims to avoid issues around greenwashing. An alternative approach to avoid misleading climate-related claims are contribution claims, which is gaining traction in academic literature (e.g., Kreibich & Hermwille, 2021) and civil society (Fearneough et al., 2020, 2023). However, we find that contribution claims are only rarely discussed among companies and CCIs, suggesting that the concept is mainly popular in academic and grey literature, while the uptake in practice remains low.

Finally, we find that cities and companies' often discuss insetting next to offsetting, but CCIs are hesitant to support or discuss insetting. Similarly, local or regional carbon credits are preferred by some cities and companies, while CCIs lack guidance on the geographic location of carbon credits.

In conclusion, carbon credits play an important role in the climate strategies of cities, companies and CCIs. Some persistent issues regarding the integrity of the demand-side of the voluntary carbon market are observed among all three NSA groups. Particularly the demand-side guidance and governance on the voluntary carbon market lacks behind. Although CCIs partly fill this gap, the specificity of their guidance is crucial to improve. Issues around the quality of carbon credits, their environmental and social integrity, and neocolonial trade relationships are also rarely addressed.

1.4.1 Recommendations

Based on the results, we provide key recommendations to address persistent issues in using carbon credits. First, improving transparency around the current and future planned use of carbon credits is essential for high integrity carbon credit use. For example, most actors do not discuss carbon credit purchases and retirements separately, although retirements can happen many years after the purchase of carbon credits. Moreover, only small numbers of companies and cities discuss carbon credits, even though many non-state actors rely on carbon credits to achieve their targets (Machnik et al., 2020).

Secondly, as contribution claims have clear advantages over offsetting claims and we currently find only limited uptake in practice, we advocate for contribution claims as an alternative to offsetting claims. It can not only reduce greenwashing by avoiding misleading climate claims such as carbon neutrality or net zero, it also reduces fundamental critiques of the voluntary market such as ethical concerns around allowing rich actors to continue emitting greenhouse gases while paying others to compensate for their behaviour. Additionally, contribution claims conflict less with host countries' NDCs and reduces risks for double counting.

Thirdly, we find that the demand-side of the voluntary carbon market pays little attention to the environmental and social integrity of the carbon credits that actors use. We advocate for increased focus on the quality of carbon credits, including its environmental and social integrity, as part of carbon credit strategies. Increased support to identify high-quality carbon credits is needed. The development of the CENVI model presented in Part 1 of this report is a crucial step



in facilitating this by providing an overview of the environmental integrity risks of many categories of carbon credits in the voluntary carbon market.

National governments and international bodies have an important role to play in facilitating and ensuring these key recommendations. Integrating recommendations like these in important governmental statements (e.g., Gewessler, et al., 2023) or taking them up in relevant national and EU policies related to green claims and emission and climate reporting provides guidance and clarity to cities and companies, which in turn can contribute to effective use of carbon credits with no or minimized trade-offs. Some of our recommendations have already been included to some extent in a joint statement on the demand-side of the voluntary carbon market by seven European countries (Gewessler, et al., 2023).

Cities and city networks

As we find a lack of clarity on the use and integrity of emissions compensation, there is a need for better guidance from city climate networks on how to define the use of offsets and what information to publish. Existing guidance still lacks detail on the specific types of carbon credits allowed and methods to ensure the credibility of carbon credits (Balouktsi, 2020). We highlight the need for better guidance from city climate networks to help cities develop clear plans around the use of carbon credits. This guidance should include at a minimum: outlining how cities should define residual emissions following Ulpiani et al. (2024), setting an upper limit on the per cent emissions cities are permitted to compensate, and providing guidelines to help cities ensure the integrity of offsets.

Further, we recommend that all cities intending to use offsets: define an upper limit on carbon credits; estimate how much and from what sectors they anticipate having residual emissions to compensate; discuss from where and how they plan to acquire carbon credits; and detail how they intend to ensure the environmental integrity of carbon credits. If carbon credits are purchased from another jurisdiction or the private sector, cities should also consider in their plans how they will avoid the double counting of carbon credits, which is an important aspect of environmental integrity (Kreibich & Hermwille, 2021). Increasing explicit decision making and transparency along the lines of these recommendations can safeguard maximum emissions reductions and carbon credits being used with the greatest positive impact, and thereby allow cities to more significantly contribute to net zero goals.

Companies

As most companies do not discuss carbon credit use in their written responses of CDP questions, we recommend all companies to make explicit if and how they (aim to) use carbon credits currently and in the future. Similarly to cities, it is essential that companies define an upper limit on carbon credits; estimate how much and from what processes they anticipate having residual emissions to compensate; discuss from where and how they plan to acquire carbon credits; and detail how they intend to ensure the environmental integrity of carbon credits. As greenwashing remains a risk, particularly for companies, we recommend companies



to specifically develop a strategy to avoid greenwashing when using carbon credits, for example by increasing transparency or avoiding offsetting claims at both company and products & services levels.

Furthermore, overreliance on or high volumes of carbon credit use increase risks of low-integrity climate action. Hence, we encourage companies to limit their carbon credit use and only use carbon credits if it does not compete with other climate action, and to demonstrate publicly that this is the case. Safeguards to avoid carbon credit use going hand in hand with lower climate ambition or target progress could support high integrity climate action.

CCIs

We encourage CCIs to discuss carbon credit use in more detail, as they have the power to support and influence actors' climate action strategy. Carbon credit guidance is particularly important as supplement to encouragement of net zero targets, as many NSAs remain reliant on carbon credit to achieve net zero targets (Kreibich & Hermwille, 2021; Machnik et al., 2020). Moreover, many actors do not have the knowledge and skills to identify high-quality carbon credits (Macintosh et al., 2025). CCIs can support actors in developing the required knowledge and skills by providing extensive guidance in identifying high-quality carbon credits, or referring to existing guidance to ensure that actors can find relevant resources. Furthermore, we encourage CCIs to specify their provided guidance by defining important concepts, such as net zero or residual emissions.

Although stringency in requirements or guidance often has a trade-off in the number of actors that are willing to participate in a CCI (e.g., Bäckstrand et al., 2017), we advocate for more stringent requirements set by CCIs for their participants, particularly regarding carbon credit use. As many companies are currently using low-quality, cheap carbon credits (Trencher et al., 2024) with many negative impacts, CCIs can improve the integrity of the voluntary carbon market not only through providing guidance for their participants, but also by normalising high integrity carbon credit use (Kreibich, 2024).

However, as we find that more stringent requirements for carbon credit use could result in lower climate ambition and target progress, we encourage CCIs to provide additional support for ambitious climate targets and implementation to achieve the targets. This would ensure that stringency regarding carbon credit use does not cause lower performance in other aspects.

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2 An introduction and overview to the Carbon Credit Environmental Integrity (CENVI) Model

2.1 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.

Table 1 provides an explanation for key terms relevant for the CENVI model.

Table 1 Relevant terms for the CENVI Model

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. 2022a).
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. 2022a).
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.

2.2 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 Project², 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 DTU⁶.

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.

2.3 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

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/>



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 ICVCM⁷ and the CCQI⁸, assessments from rating agencies that assess the integrity of specific mitigation activities⁹, the Carbon Offset Guide¹⁰, documents issued by carbon crediting programmes and scientific literature. Table 2 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 2 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	Detailed information on programme provisions publicly	Deriving integrity issues from programme



and quantification methodologies	available	documents is time-consuming and requires in-depth knowledge
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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.

3 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 3.1). We then describe our assessment methodology for each integrity criterion: quantification (section 3.2), additionality (section 3.3), permanence (section 3.4), double issuance (section 3.5) and the limitations of the model (section 3.6).

3.1 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 6.

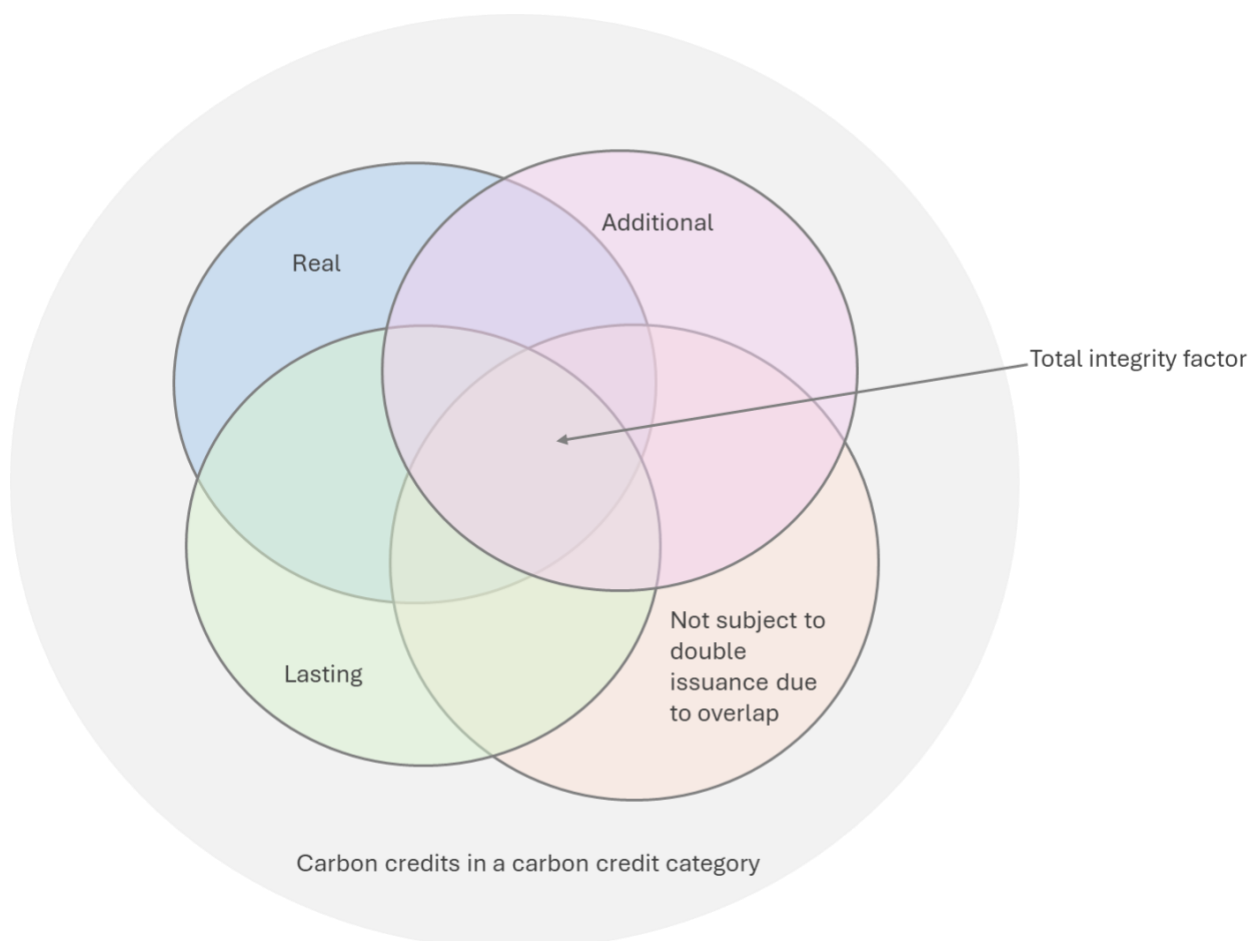


Figure 6 Conceptual visualisation of the total integrity factor

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</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>i</i> representing <i>actual</i> 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>i</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>i</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>i</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

3). We base these categories on the likelihood ranges of the IPCC (Mastrandrea et al. 2010).

Table 3 (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.

3.2 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. 2022b; Integrity Council for the Voluntary Carbon Market (ICVCM) 2025; 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 CO₂e)

$Q_{issued,ME,i}$ = 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 CO₂e 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 4). 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 4 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 $\pm 10\%$)'	$\frac{100}{100}$	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., $\pm 10\text{-}50\%$) 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 $\pm 10\%$)'	$\frac{100}{105}$	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 $\pm 50\%$) 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 ($\pm 10\text{-}30\%$)'	$\frac{100}{120}$	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 $\pm 30\%$)'	Estimation derived from specific information in the CCQI assessment
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Source: Schneider et al. 2022b

3.3 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 $IF_{\text{Additionality},i}$). 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

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

Where:

$IF_{\text{Additionality},i}$	=	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
$A_{\text{viability},P,MA,i}$	=	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
$A_{\text{legalrisk},MA}$	= 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)
$A_{\text{legalprogramme},P,MA,i}$	= 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 ($A_{\text{legalrisk},MA}$) 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 ($A_{\text{viability},P,MA,i}$). 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, $IF_{\text{Additionality},i}$ 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 ($A_{\text{viability},P,MA,i} = 20\%$) and 60% of emission reductions and removals are generated by mitigation activities that are legally required ($A_{\text{legalrisk},MA} = 60\%$). However, the carbon crediting programme restricts the registration of mitigation activities that are legally required and therefore reduces the share of $A_{\text{legalrisk}}$ by 85% ($A_{\text{legalprogramme},P,MA,i} = 85\%$). In this example, the integrity factor would be determined as follows:

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

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

3.3.1 Viability of mitigation activities ($A_{\text{viability},P,MA,i}$)

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 N₂O from nitric acid production) (Schneider et al. 2022a). 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 $A_{\text{viability},P,MA,i}$. 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 und 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.

3.3.2 Regulatory surplus ($A_{\text{legalrisk},MA}$ and $A_{\text{legalprogramme},P}$)

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 $A_{\text{legalrisk},MA}$. 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 $A_{\text{Legalprogramme},P,i}$.

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.

3.4 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 $IF_{\text{Permanence},i}$, 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

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



Where:

$IF_{\text{Permanence},i}$	=	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
$P_{\text{reversal},MA}$	=	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)
$P_{\text{programme},P,MA,i}$	=	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 ($P_{\text{reversal},MA,i}$) 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 ($A_{\text{reversal},MA}$). This share may be reduced due to programme provisions reducing reversal risk and addressing reversals ($P_{\text{programme},P,MA,i}$). Thus, $IF_{\text{Permanence},i}$ 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 ($P_{\text{reversal},MA} = 60\%$). Furthermore, programme provisions reduce this share by 40% ($P_{\text{programme},P,MA,i} = 40\%$), 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:

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

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

3.4.1 Reversal risk of mitigation activities ($P_{\text{reversal},MA}$)

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 $P_{\text{reversal},MA}$). 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-CO₂ 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. 2022a). 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, $P_{\text{reversal,MA}}$ 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 $P_{\text{reversal,MA}}$. For mitigation activities with a material reversal risk, the parameter $P_{\text{reversal,MA}}$ 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 $P_{\text{reversal,MA}}$, 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 (California Air Resources Board (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.

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

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

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.

3.5 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; The Integrity Council for the Voluntary Carbon Market (ICVCM) 2024; Schneider et al. 2022b). 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. 2022a).

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 7 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).

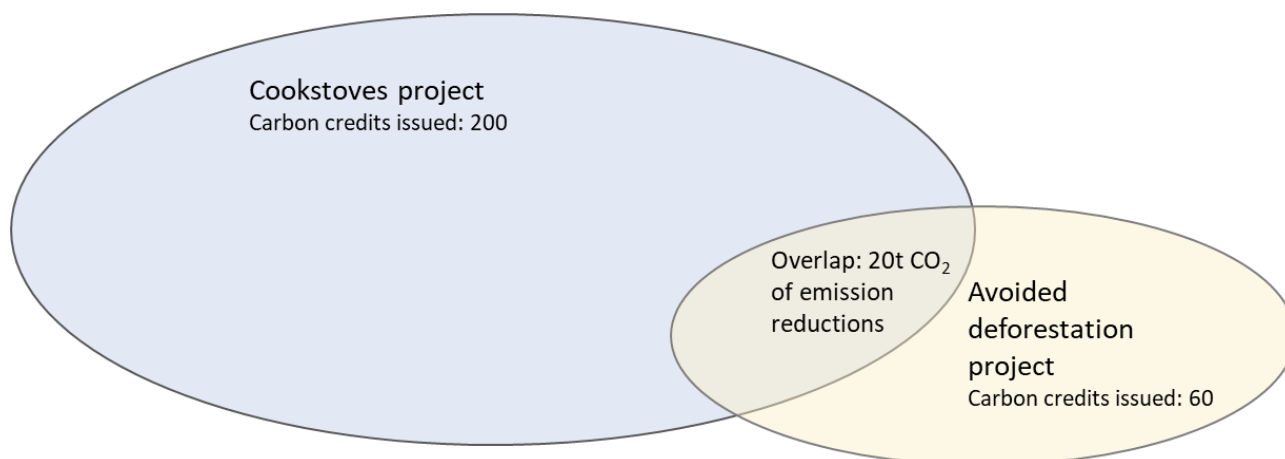


Figure 7 Example illustration of an overlap between a cookstove and an avoided deforestation project. Source: Authors' own illustration

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. 2022a). Thus, our assessment considers how these provisions reduce the risk of double issuance due to overlap.

3.6 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 reliably 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. 2022b; The Integrity Council for the Voluntary Carbon Market (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.

4 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 3.1).



4.1 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 CO₂e.

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 CO₂e, i.e. 55% of total expected annual emission reductions or removals from ART, GS and the VCS.

Figure 8 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.

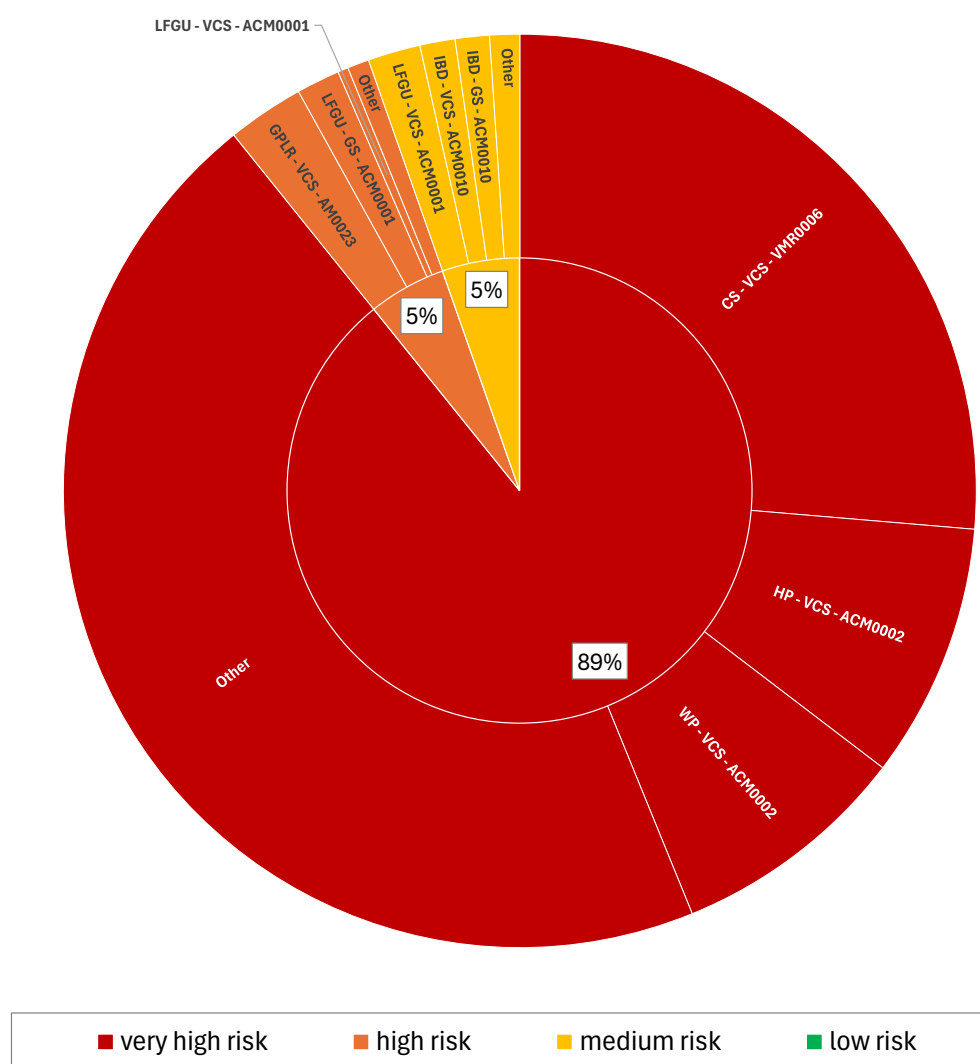


Figure 8 All assessed categories of carbon credits: Estimated annual emission reductions or removals by risk grade. Source: Authors' own compilation. Notes: The figure illustrates for each risk grade the three largest carbon credit categories. Categories consist of combinations of the mitigation activity 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, LFGU = 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.

4.2 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.

4.2.1 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, 2023d).

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 2024o). 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).

4.2.2 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 CO₂e.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 9Error! Reference source not found.). This is primarily driven by high risks of non-additionality combined with medium to high risks of non-permanence.

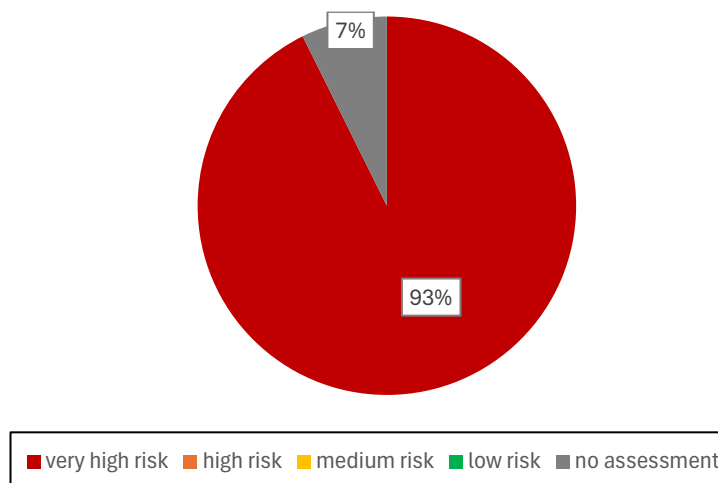


Figure 9 Commercial Afforestation for Timber Harvesting: Estimated annual removals by risk grade.

Source: Authors' own compilation

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



4.3 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 Carbon Credit Quality Initiative (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.

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

4.3.1 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

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).



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) model¹⁴. 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 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

¹⁴ <https://www.mofuss.unam.mx/>

¹⁵ CDM Executive Board, report of the 125th meeting.

<https://cdm.unfccc.int/UserManagement/FileStorage/CTVUINODJZP8LRWAYX305SK7H9M216>



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.

4.3.2 Results

As of December 2025, the CENVI model contains 1,180 registered cookstove activities with an annual emission reduction potential of about 225 Mt CO₂e.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 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 Carbon Credit Quality Initiative (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 10). 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.

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

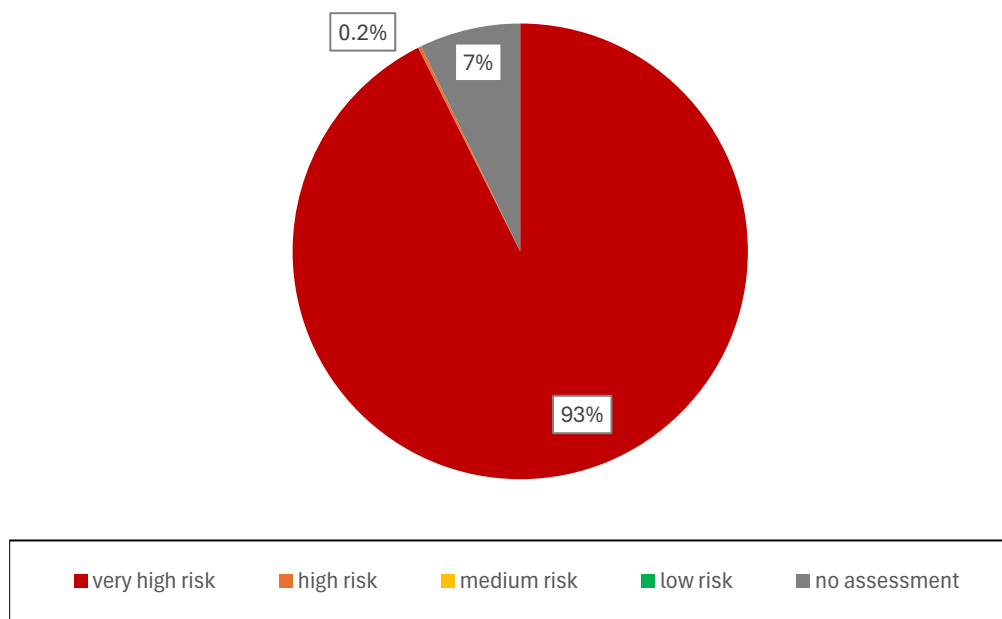


Figure 10 Efficient Cookstoves: Estimated annual emission reductions by risk grade. Source: Authors' own compilation.



4.4 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.' (Carbon Credit Quality Initiative (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.

4.4.1 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, 2023d).

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 2024o). 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.

4.4.2 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 CO₂e.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

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



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 reductions are generated by categories with high risks (see Figure 11). This is due to a combination of low to medium risks for all integrity criteria, which lead to medium risks overall.

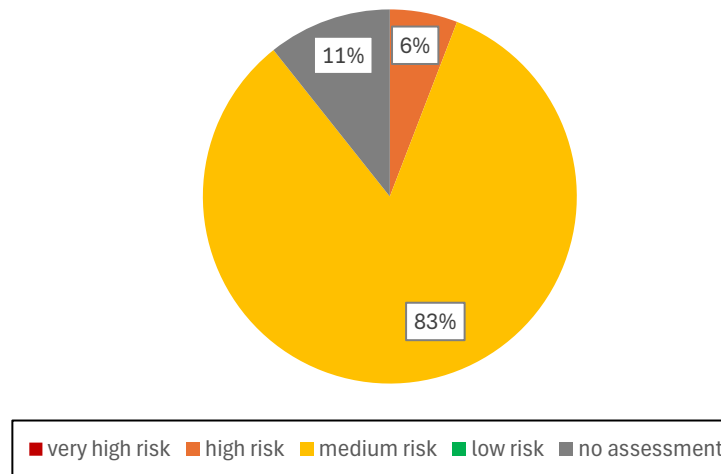


Figure 11 Establishment of Natural Forest: Estimated annual removals by risk grade. Source: Authors' own compilation.



4.5 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 Carbon Credit Quality Initiative (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).

4.5.1 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 2023e, 2023c).

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 2023u).

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 2023r).

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).

4.5.2 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 CO₂e.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 12). This is primarily driven by very high risks of non-additionality.

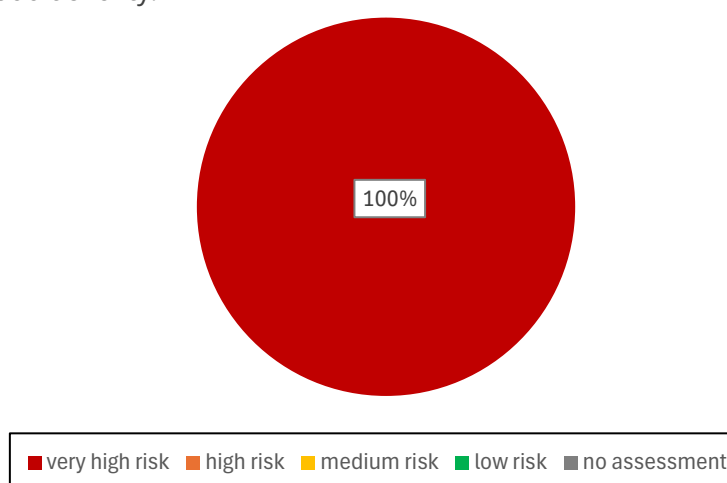


Figure 12 Establishment of Natural Forest: Estimated annual removals by risk grade. Source: Authors' own compilation.

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



4.6 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 2023w).

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.

4.6.1 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 2023o).

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) model¹⁹ (Bailis et al. 2015; Ghilardi und Bailis 2024). In May 2025, the CDM Executive Board withdrew TOOL30 and adopted default values for 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 2023j).

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 2023h). 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 2023t).

¹⁹ <https://www.mofuss.unam.mx/>

²⁰ CDM Executive Board, report of the 125th meeting.

<https://cdm.unfccc.int/UserManagement/FileStorage/CTVUINODJZP8LRWAYX305SK7H9M216>



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 2023t). Neither the GS nor the VCS address the non-permanence risk for household biodigester activities.

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.

4.6.2 Results

As of December 2025, the CENVI model contains 220 registered Household Biodigester activities with an annual emission reduction potential of about 8 Mt CO₂e.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 13**Error! Reference source not found.**). 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.

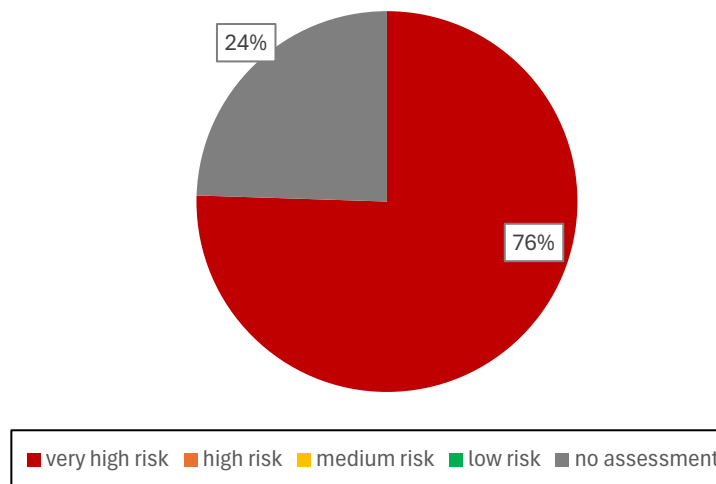


Figure 13 Household Biodigesters: Estimated annual emission reductions by risk grade. Source: Authors' own compilation



4.7 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 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 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.

4.7.1 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 2023e, 2023c).

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 2023a). 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 und



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 2023b).

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).

4.7.2 Results

As of December 2025, the CENVI model contains 430 registered Hydropower activities with an annual emission reduction potential of about 58 Mt CO₂e.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 14). 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.

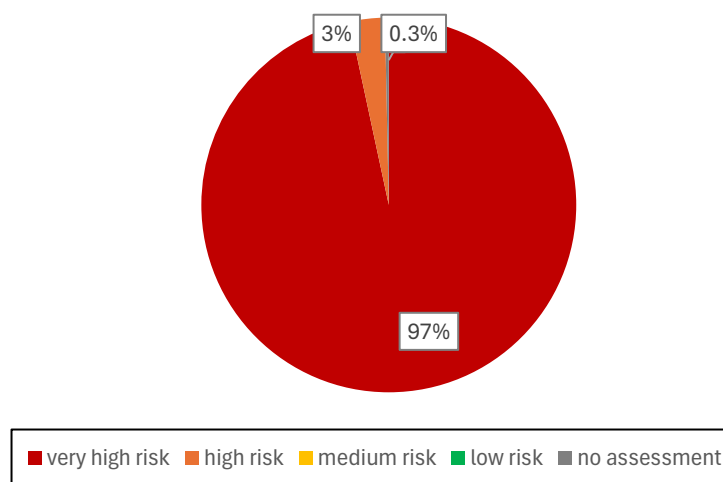


Figure 14 Hydropower: Estimated annual emission reductions by risk grade. Source: Authors' own compilation.



4.8 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.

4.8.1 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, 2024k, 2024n, 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 2024c). 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 2024o). 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.

4.8.2 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 CO₂e.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

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



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 15). 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.

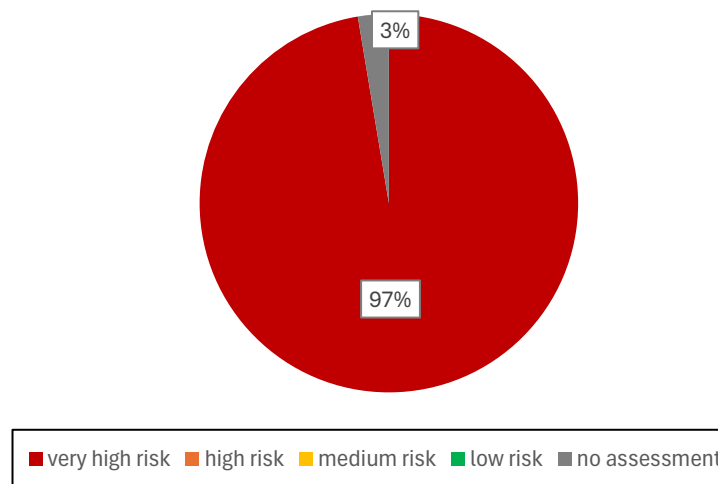


Figure 15 Improved Forest Management: Estimated annual emission reductions or removals by risk grade. Source: Authors' own compilation.



4.9 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.' (Carbon Credit Quality Initiative (CCQI) 2023b).

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.

4.9.1 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 3.2) (CCQI 2023l).

The methodology GS GHG emission reductions from manure management systems and municipal solid waste is largely based on version 7 of the ACM0010, with only minor differences. Therefore, the same factors leading to overestimation are also relevant for this methodology (CCQI 2023m).

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 2023k). 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 (Carbon Credit Quality Initiative (CCQI) 2023b).



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 2023p).

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

4.9.2 Results

As of December 2025, the CENVI model contains 160 registered Industrial Biodigesters activities with an annual emission reduction potential of about 22 Mt CO₂e.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 16). This is primarily driven by a medium risk of non-additionality combined with low to medium risks of overestimating emission reductions.

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

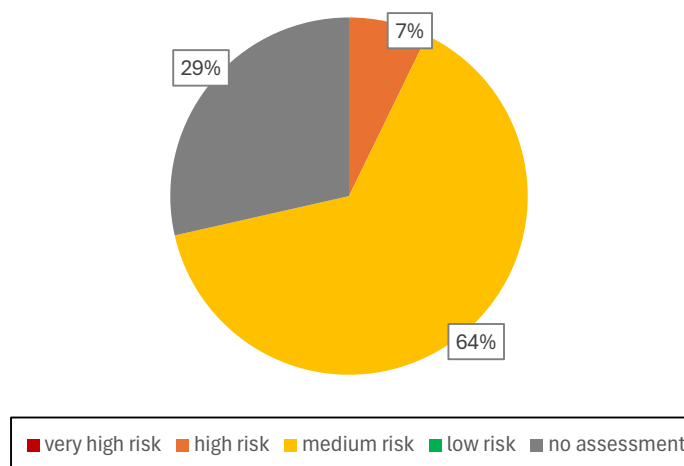


Figure 16 Industrial Biodigesters: Estimated annual emission reductions by risk grade. Source: Authors' own compilation.



4.10 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 The Nature Conservancy (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);

4.10.1 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 und 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.



4.10.2 Results

As of December 2025, the CENVI model contains one JREDD-HFLD mitigation activity with an annual emission reduction potential of about 8 Mt CO₂e.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 17). This is primarily driven by a high risk of overestimating emission reductions combined with a high risk of non-additionality.

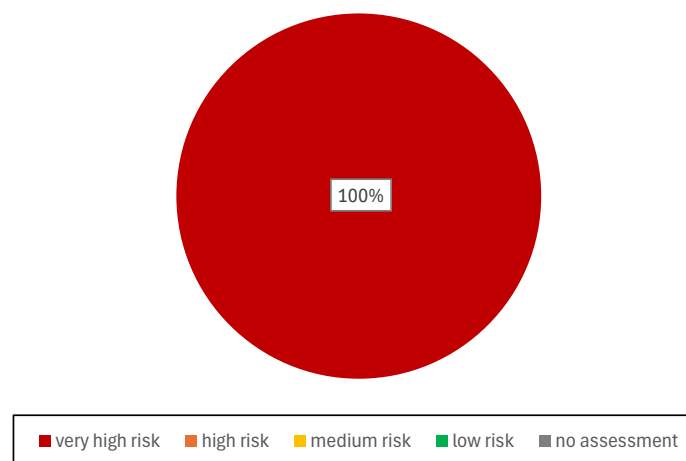


Figure 17 JREDD – HFLD: Estimated annual emission reductions by risk grade. Source: Authors' own compilation.

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



4.11 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 2023v).

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).

4.11.1 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 2023v).

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 (Carbon Credit Quality Initiative (CCQI) 2023a; 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).

4.11.2 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 CO₂e.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 18). 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.

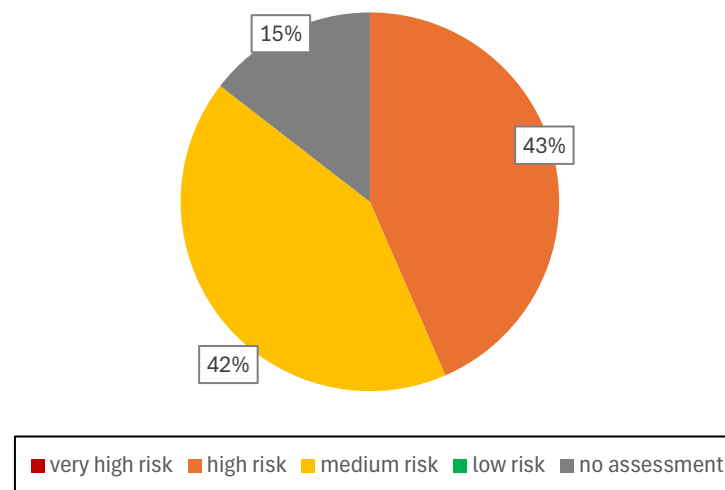


Figure 18 Landfill Gas Utilisation: Estimated annual emission reductions by risk grade. Source: Authors' own compilation.



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

4.12.1 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 3.2).

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 2023n).

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 2023i).

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 2023q).

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

4.12.2 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 CO₂e.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 19). 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.

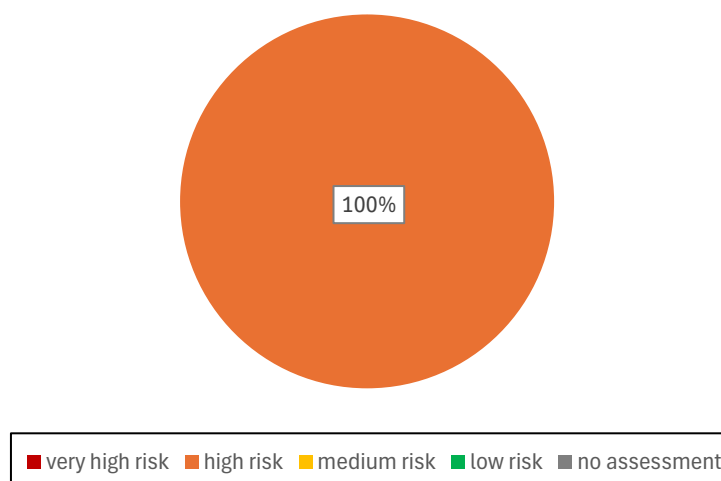


Figure 19 Leak Repair in Natura Gas Transmission and Distribution Systems: Estimated annual emission reductions by risk grade. Source: Authors' own compilation.



4.13 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 (VM0015), VCS VM0048 Reducing Emissions from Deforestation and Forest Degradation (VM0048). Note: While all methodologies apply to avoided unplanned activities, VM0007 and VM0009 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.

4.13.1 Key issues for each integrity criterion

Quantification: 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 2024p, 2024m, 2024l, 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, 2024l, 2024p).

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 2024d). 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 2024o). 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.

4.13.2 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 CO₂e.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

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



having very high environmental integrity risks (see Figure 20). This is primarily driven by very high risks of overestimating emission reductions and high risks of non-additionality and non-permanence.

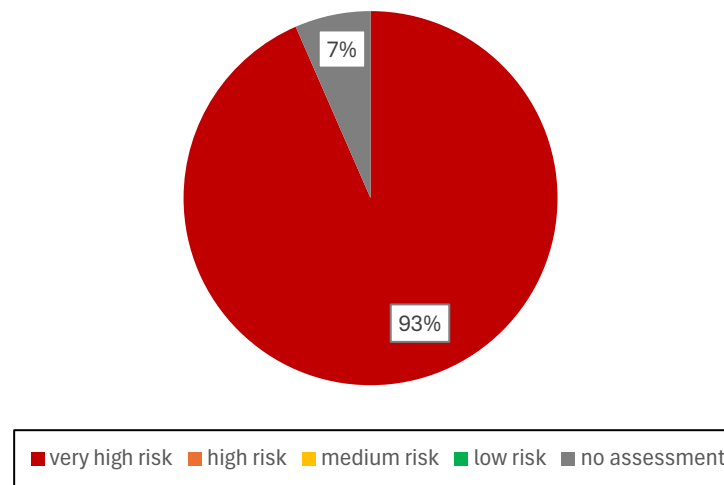


Figure 20 Project-based REDD – Terrestrial: Estimated annual emission reductions by risk grade.

Source: Authors' own compilation.



4.14 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 Carbon Credit Quality Initiative (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).

4.14.1 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 2023e, 2023c).

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 2023f; 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 2023s).

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).

4.14.2 Results

As of December 2025, the CENVI model contains 883 registered Wind Power activities with an annual emission reduction potential of about 94 Mt CO₂e.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 21). This is primarily driven by high to very high risks of non-additionality combined with medium risks of overestimating emission reductions.

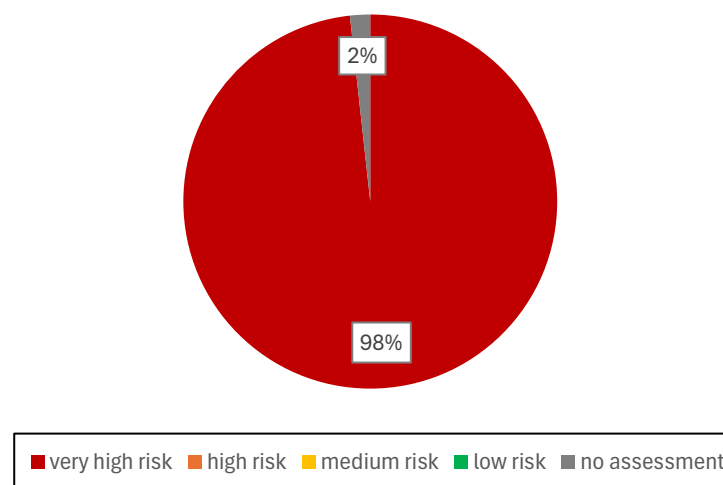


Figure 21 Wind Power: Estimated annual emission reductions by risk grade. Source: Authors' own compilation.

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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3.1 Significance of non-permanence risks, Commercial afforestation. Online verfügbar unter <https://www.carboncreditquality.org/download/Assessments/3.1%20Commercial%20afforestation%20%2821%20February%202024%29.pdf>.

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1.3.2: Robustness of the quantification methodologies applied to determine emission reductions or removals, Avoided unplanned deforestation, VCS Methodology VM0015, Version 1.2 Methodology for Avoided Unplanned Deforestation. Online verfügbar unter <https://carboncreditquality.org/download/Assessments/1.3.2%20VM0015%20%2802%20July%202024%29.pdf>.

CCQI (2024q): Application of the CCQI methodology for assessing the quality of carbon credits,

3.2.2 Approaches for avoiding or reducing non-permanence risks, VCS, Avoided Planned Deforestation, Avoided Unplanned Deforestation, Commercial afforestation, Establishment of natural forest, Improved forest management. Online verfügbar unter <https://carboncreditquality.org/download/Assessments/3.2.2%20VCS%20Forest%20activities%20%2802%20July%202024%29.pdf>.

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CCQI (2024s): Application of the CCQI methodology for assessing the quality of carbon credits.

1.1.1: Eligibility of mitigation activities that are triggered by legal requirements, VCS. Online verfügbar unter <https://carboncreditquality.org/download/Assessments/1.1.1%20VCS%20%2802%20July%202024%29.pdf>.

CCQI (2024t): Application of the CCQI methodology for assessing the quality of carbon credits.

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<https://carboncreditquality.org/download/Assessments/1.1.2%20VCS%20%2802%20July%2024%29.pdf>.

CCQI (2024u): Application of the CCQI methodology for assessing the quality of carbon credits.
1.1.3 Financial attractiveness, Commercial afforestation. Online verfügbar unter
<https://carboncreditquality.org/download/Assessments/1.1.3%20Commercial%20Afforestation%20%2821%20February%202024%29.pdf>.

CCQI (2024v): Application of the CCQI methodology for assessing the quality of carbon credits.
1.3.2 Robustness of the quantification methodologies applied to determine emission reductions or removals. Commercial afforestation/Establishment of natural forests, CDM AR-ACM0003 Version 2.0. Online verfügbar unter
<https://carboncreditquality.org/download/Assessments/1.3.2%20CDM%20AR-ACM0003%20for%20Reforestation%20%2821%20February%202024%29.pdf>.

CCQI (2024w): Application of the CCQI methodology for assessing the quality of carbon credits.
3.2.1 Approaches for accounting and compensating for reversals (Approach 1), GS, Commercial Afforestation/Establishment of natural forest. Online verfügbar unter
<https://carboncreditquality.org/download/Assessments/3.2.1%20GS%20Forest%20activities%20%2821%20February%202024%29.pdf>.

CCQI (2024x): Application of the CCQI methodology for assessing the quality of carbon credits.
3.2.1 Approaches for accounting and compensating for reversals (Approach 1), VCS, Avoided Planned Deforestation, Avoided Unplanned Deforestation, Commercial afforestation, Establishment of natural forest, Improved forest management. Online verfügbar unter
<https://carboncreditquality.org/download/Assessments/3.2.1%20VCS%20Forest%20activities%20%2802%20July%202024%29.pdf>.

CCQI (2024y): Application of the CCQI methodology for assessing the quality of carbon credits.
3.2.2 Approaches for avoiding or reducing non-permanence risks, GS, Commercial afforestation/Establishment of natural forest. Online verfügbar unter
<https://carboncreditquality.org/download/Assessments/3.2.2%20GS%20Forest%20activities%20%2821%20February%202024%29.pdf>.

CCQI (2024z): Application of the CCQI methodology for assessing the quality of carbon credits.
Sub-criterion 2.2.2: Avoiding indirect overlaps between projects, VCS. Online verfügbar unter
<https://carboncreditquality.org/download/Assessments/2.2.2%20VCS%20%2802%20July%2024%29.pdf>, zuletzt geprüft am 25.02.2025.

CCQI (2024aa): Application of the CCQI methodology for assessing the quality of carbon credits: VCS methodology VM0048, Version 1.0. 1.3.2 Robustness of the quantification methodologies applied to determine emission reductions and removals. Online verfügbar unter
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5 Analysis methodology VM0048

5.1 CCQI Methodology provisions

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

Table 5 CCQI Scoring for quantification methodologies

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



5.1.1 Carbon crediting program documents considered

This assessment is based on an evaluation of the most important VCS documents applied under this methodology. It does not consider all VCS documents that may be applied in using the methodology. The following documents were considered:

- 1 Verra (2023): VCS Methodology VM0048. Reducing Emissions from Deforestation and Forest Degradation. Version 1.0, 27 November 2023. <https://verra.org/methodologies/vm0048-reducing-emissions-from-deforestation-and-forest-degradation-v1-0/>
- 2 Verra (2023): VCS Module VMD0001. Estimation of carbon stocks in the above- and belowground biomass in live tree and non-tree pools (CP-AB). Version 1.2, 27 November 2023. <https://verra.org/wp-content/uploads/2023/11/VMD0001-Estimation-of-Carbon-Stocks-in-Above-and-Belowground-Biomass-in-Live-Tree-and-Non-tree-Pools-CP-AB-v1.2.pdf>
- 3 Verra (2024): VCS Tool VT0007. Unplanned Deforestation Allocation (UDEF-A). Version 1.0, 21 February 2024. <https://verra.org/wp-content/uploads/2024/02/VT0007-Unplanned-Deforestation-Allocation-v1.0.pdf>
- 4 Verra (2023): VCS Module VMD0013. Estimation of greenhouse gas emissions from biomass and peat burning (E-BPB). Version 1.3, 27 November 2023. <https://verra.org/wp-content/uploads/2023/11/VMD0013-Estimation-of-Greenhouse-Gas-Emissions-from-Biomass-and-Peat-Burning-E%E2%80%93BPB-v1.3.pdf>
- 5 Verra (2024): VCS Module VMD0055. Estimation of Emission Reductions from Avoiding Unplanned Deforestation, Version 1.0, 20 February 2024. <https://verra.org/wp-content/uploads/2024/02/VMD0055-Estimation-of-Emission-Reductions-from-Avoiding-Unplanned-Deforestation-v1.0-2024.02.20-update.pdf>
- 6 Verra (2023): VCS Program Definitions. Version 4.4, 29 August 2023. <https://verra.org/wp-content/uploads/2023/08/VCS-Program-Definitions-v4.4.pdf>
- 7 Verra (2023): VCS Methodology Requirements. Version 4.4, 4 October 2023. <https://verra.org/wp-content/uploads/2023/08/VCS-Methodology-Requirements-v4.4-updated-4-Oct-2023.pdf>
- 8 Verra (2023): VCS Registration and Issuance Process. Version 4.4, 4 October 2023. <https://verra.org/wp-content/uploads/2023/08/Registration-and-Issuance-Process-v4.4-last-updated-4-Oct-2023-watermark.pdf>
- 9 Verra (2023): VCS Module VMD0011. Estimation of emissions from market-effects (LK-ME). Version 1.2, 27 November 2023. <https://verra.org/wp-content/uploads/2023/11/VMD0011-Estimation-of-Emissions-from-Market-effects-LK-ME-v1.2.pdf>

Verra also announced that it plans to update several methodologies, modules and tools applicable to avoided deforestation projects, as part of its forest strategy.³⁰

5.2 Assessment

The quantification methodology is assigned a score of 1 according to the CCQI methodology.

Note that in contrast to other methodologies assessed by CCQI, the methodology VM0048 has not yet been applied to any projects as of 1 April 2024. Therefore, this assessment is only based on an analysis of the methodology, without practical experience and literature on how it is applied in practice. The findings are therefore preliminary and may need to be updated once more experience with the implementation of the methodology becomes available.

Further note that all avoided unplanned deforestation registered under Verra using older methodologies (VM0006, VM0007, VM0009 and VM0015) are required to transition to this new methodology. When all projects have completed the transition, these older methodologies will be inactivated by Verra.

5.2.1 Justification of assessment

5.2.1.1 Project type

This assessment refers to the following CCQI project type:

“Activities to avoid deforestation that is driven by multiple, mostly local agents. The deforestation occurs as a result of socioeconomic forces, such as subsistence agriculture of local communities, encroaching roads, or illegal logging. In addition, forest degradation may be reduced. Projects usually combine different activities to reduce deforestation, such as improving agricultural practices of local communities, providing alternative livelihoods, instituting patrols or assisting with land tenure reform. The activities are implemented on a dedicated project-level geographical area (not at jurisdictional level). The project type reduces emissions by avoiding the loss of forest carbon stocks.”

The CCQI project type, as described above, is applicable to the methodology.

The methodology VM0048 is a framework that is to be used together with several modules and tools. As of 1 April 2024, the methodology VM0048 is only applicable to avoided unplanned deforestation, for which module VMD0055 must be applied. A module for Avoiding Planned Deforestation and requirements for Avoiding Unplanned Forest Degradation are under development (with associated leakage adjustments). In the future, the methodology will thus also become applicable to these activities.

This assessment does not apply to projects that are nested under a jurisdictional carbon crediting program or where a government provides a jurisdictional baseline. In these instances,

³⁰ See, for example: <https://verra.org/wp-content/uploads/2024/02/Forest-Carbon-Strategy-15-Feb-2023.pdf>



the conservativeness of the emission reductions strongly hinges on the conservativeness of this jurisdictional baseline, which is not evaluated as part of this assessment.

The methodology VM0048 and the module VMD0055 define unplanned deforestation as "deforestation of degraded to mature forests not legally authorized and documented for conversion". Planned deforestation is respectively defined as "deforestation on forest lands that are legally authorized and documented for conversion". In the VCS program definitions, "deforestation" is defined as "direct human-induced conversion of forest land to non-forest land" and forest is defined as "land with woody vegetation that meets an internationally accepted definition (e.g., UNFCCC, FAO, or IPCC) of what constitutes a forest, which includes threshold parameters, such as minimum forest area, tree height, and level of crown cover, and may include mature, secondary, degraded, and wetland forests". The VCS module VMD0055 further specifies that forest "must include woody vegetation with a canopy cover of between 10 and 30 percent, as used in the relevant country's international reporting to the UNFCCC, or as otherwise officially elected as an applicable definition for use by climate change mitigation projects and programs." Moreover, the project boundary section of the VCS module VMD0055 specifies that the project area may only include "land qualifying as forest for a minimum of 10 years before the project start date". The module further specifies in its applicability conditions that "agents of deforestation in the baseline scenario clear the land for tree harvesting, settlements, roads, unsanctioned expansion of roads or other infrastructure, agricultural crop production, ranching or aquaculture" and that projects that "harvests trees to generate income, fiber or fuel" are not eligible. Several further provisions in the module VMD0055 indicate that drivers of deforestation can be "commercial" or "subsistence" and that drivers may include "prices of agricultural, timber, mineral or other commodities".

Un1 **Lack of clarity of definitions:** The definitions in the methodology and the documents referred to above lack some clarity. The methodology VM0048 and the module VMD0055 lists in various places different drivers of deforestation that may be considered but the descriptions of possible drivers are not fully consistent. While the definition includes "mature, secondary, degraded, and wetland forests, the methodology VM0048 further specifies that forest "must include woody vegetation with a canopy cover of between 10 and 30 percent". A 30 percent canopy cover is far too low for mature, non-degraded forests. The 30 percent reads as a maximum canopy cover; the definition thus seems to exclude mature, non-degraded forests – which may not be intended but should be clarified. In our assessment, the lack of clarity of creates some uncertainty how the methodology would be interpreted. This applies to **all** projects. The level of uncertainty and the variability among projects are **unknown**.

5.2.1.2 Selection of carbon pools and emission sources for calculating emission reductions or removals

The methodology VM0048 describes in sections 5.2 and 5.3 various carbon pools and emission sources that must be included in the boundary of projects implementing VM0048 as well as pools and sources that are optional to include, sometimes specifying conditions under which they must or may be included or excluded. In addition, the methodology requires assessing the significance of emission sources and carbon pools, following the approach set out in Appendix 1 to the methodology. According to this procedure, project and leakage emission sources (including emissions from carbon pools) are ranked according to their significance. The sources or pools contributing the last 5% of total emissions may be excluded.



The combination of these provisions does not provide clarity to resolve which emission sources and carbon pools must be accounted for. The methodology is not clear on the following points: (a) whether the analysis in Appendix 1 must be carried out for all emission sources and carbon pools (including those that are mandatory to be included) or only for those that are optional to include; (b) whether emission sources and carbon pools that are mandatory for inclusion according to section 5.2 and 5.3 may be excluded if procedure in Appendix 1 concludes that they are negligible; and (c) whether carbon pools and emission sources labelled as “optional” in sections 5.2 and 5.3 of the methodology may be excluded if the procedure in Appendix 1 leads to the conclusion that they are not negligible. Based on information provided by Verra to CCQI, in the following we interpret the methodology to mean that optional pools and sources can be excluded only if determined to be negligible.

The drivers of deforestation considered by this methodology seem to include a broad spectrum, including conversion for agriculture, encroaching roads, and illegal logging. The implications of including or excluding carbon pools and emission sources depend on the post-deforestation land uses predicted to occur in the baseline. If agriculture is the driver of deforestation, the land use following deforestation is likely to be agriculture. The patterns of agricultural use may differ by region. The land may be continuously used for agriculture, such as when palm oil plantations are established (e.g., in Indonesia) or if pastures are established following a period of crop cultivation (e.g., in Brazil). The land use may also be cyclical where a period of agricultural use is followed by a fallow period in which secondary forest may grow back (e.g., in the Democratic Republic of Congo). Following the fallow period, the area is often again cleared of its forest cover and cultivated, at the landscape level, which creates a mosaic of fallow, secondary forest of different ages, and agricultural fields. How much carbon is stored in the landscape (i.e., in trees, other vegetation and soils) depends on the length of the fallow period. If illegal logging is the initial driver of deforestation, trees would be harvested and removed, and non-tree biomass may be damaged but would not be targeted for removal. The initial effect of illegal logging is a degradation of the forest carbon stock, since usually the largest and more valuable trees are removed first. However, agriculture is often a secondary driver of deforestation, since the infrastructure created for logging increases access to forests. For these reasons, we here assume for our analysis that ultimately the dominant post-deforestation land use is agriculture. We thus assume deforestation in the baseline scenario would in the long-term result in agriculture on these lands.

Table 6 Assessment of sources, sinks, reservoirs

Source, sink, or reservoir	Included? How?	Relevant for this assessment?
Carbon pools		
Aboveground tree biomass	Included for baseline and project	Major carbon pool affected by projects.
Aboveground non-tree biomass	Post-deforestation carbon stocks must be included in the baseline; May be conservatively excluded from the “forest carbon stocks”	In the baseline scenario (post-deforestation land-use for agriculture), non-tree biomass such as shrubs are likely to be removed. Therefore, inclusion of this pool in the baseline scenario and exclusion in the project scenario is likely to be conservative.



Belowground tree biomass	Included for baseline and project	Major carbon pool affected by projects.
Belowground non-tree biomass	Optional, methodology states the potential emissions are negligible	Belowground non-tree biomass there could be affected in different ways in the baseline scenario, depending on the agricultural practices. Non-tree biomass is likely to be removed and belowground biomass will be removed or disrupted to prepare the soil, resulting in a release of the stored carbon. However, while non-tree biomass may be initially disturbed and removed, it could also recover and potentially increase beyond the project scenario. Therefore, exclusion of this pool in the baseline and project scenario would lead to uncertainty. In most cases, however, we deem these effects to be negligible.
Deadwood	Optional, methodology states it is conservative to exclude	In the baseline scenario, slash deadwood would result from harvesting (which does not occur in the project) but when the land use shifts to agriculture then deadwood would be burned or removed. The projects are likely to result in more naturally occurring deadwood (which would not occur in the baseline). Exclusion of deadwood in the project and baseline scenario is therefore conservative.
Litter	Optional, methodology states it is conservative to exclude	In the baseline scenario, litter is likely to decrease due to removal of living biomass and deadwood for the purpose of site preparation for agriculture (e.g., biomass burning). Exclusion of this pool from the baseline and project scenario is therefore conservative.
Soil organic carbon (SOC)	Required when project activities take place in wetlands (currently not allowed under VMD0055), otherwise optional. Methodology states that it is conservative to exclude this pool if projects are implemented on non-wetland areas.	In the baseline scenario, soil disturbance can be expected, leading to the release of SOC. In tropical regions, post-deforestation land use for agriculture is unlikely to increase SOC stocks. Therefore, exclusion of this pool from the baseline and project scenario is conservative.



Harvested Wood Products (HWP)	Optional if timber harvest is determined to be negligible in the baseline. Based on determinations from appendix 1.	Timber harvest/logging may occur as a first stage of land transition to agriculture in the baseline scenario. In the project scenario, forest protection would likely result in reduced logging levels relative to baseline and thus a decrease in the HWP pool. Therefore, exclusion of this carbon pool in the project and baseline scenario may not be conservative. The methodology only allows exclusion if timber harvest is deemed negligible in the baseline. This is appropriate.
Emission sources		
Emissions from biomass burning	CO ₂ included. However, the module VMD0013 (which is referenced in the methodology used to calculate emissions from biomass burning) states that inclusion of fire in the baseline "is always optional".	Could be an important emission source in the baseline and project scenario. If project proponents opt not to include the emission source in the baseline (as indicated by VMD0013) this would be conservative.
	CH ₄ and N ₂ O are optional in baseline and included in the project scenario.	Conservative to exclude in the baseline scenario, but can be an important emissions source in project scenario.
Combustion of fossil fuels	CO ₂ may be excluded when determined to be negligible in the baseline. CO ₂ from combustion of fossil fuels related to leakage prevention activities are "always considered insignificant", but CO ₂ from other activities (e.g., monitoring, patrolling) must be demonstrated to be negligible to be omitted.	Exclusion may lead to uncertainty because emissions from combustion may increase or decrease as result of project activities relative to baseline. Under the baseline scenario, emissions from combustion of fuel in harvesting equipment and fuel crop production equipment fuel occurs. In project scenarios emissions may increase or decrease from equipment used in monitoring or patrolling the project area.
	CH ₄ and N ₂ O are excluded, considered negligible.	Exclusion may lead to uncertainty because emissions from combustion may increase or decrease as a result of project activities. However, this source is likely to be small.
N ₂ O emissions from application of fertilizer	Optional in baseline, must be included if fertilizer use increases due to the project. May be excluded from the baseline if	In the baseline scenario, fertilizer use may increase or decrease over time. Where fertilizer use in the baseline is excluded, this is conservative.



	determined to be negligible. If excluded from the baseline and fertilizer use does not increase due to the project, then it may be excluded.	Exclusion in the project where fertilizer does not increase compared to the baseline is appropriate and conservative.
Livestock emissions	Excluded (not addressed)	If deforestation for livestock operations occurs in the baseline, then it is likely that livestock production will decrease due to the project or shift to other areas through activity shifting or market leakage (and remain at the same level as the baseline or decrease). Therefore, it is conservative to exclude this source from the baseline and project.

- OE1 **Lack of clarity regarding which emissions sources and carbon pools must be considered:** The lack of clarity of the methodology on which emission sources and carbon pools must be considered, as described in the second paragraph of this section above, creates some room for interpretation. We see a risk that project developers and validation and verification bodies may interpret the methodology in ways that could lead to higher credited emission reductions. The number of projects affected is **unknown**. For those projects where this issue materializes, the impact on total credited emission reductions is estimated to be **low** (less than 10%). The variability in the degree of overestimation among projects is **unknown**.
- OE2 **Determination of significance of emission sources allows project developers to choose among multiple methods:** The methodology in Appendix 1 of VM0048 provides a procedure to determine the significance of project and leakage emission sources and to allow project developers to exclude those sources that amount to as much as 5% of total project and leakage emissions. The approach provides leeway to project developers regarding how the significance is estimated. Provision 2)a) in the Appendix states that “estimation must be based on site/project-specific data, scientific peer-reviewed literature and/or the most recent default emission factors provided by IPCC.” Project developer could pick from these methods for each source in such a way that more significant project or leakage sources are excluded (using a method that tends to underestimate them) and conversely minor sources are included (using a method that tends to overestimate them). For example, the determination of whether harvested wood products are significant depends on many assumptions, including the potential uses of wood products in the baseline scenario. As project developers have incentives to make favorable assumptions, this could cause overestimation of total credited emission reductions. The number of projects affected by this is **unknown**. For those projects where this issue materializes, the impact on total credited emissions



reductions is estimated to be **low**³¹ (less than 10%). The variability in the degree of overestimation among projects is **unknown**.

- UE1 **Soil carbon is identified as an optional source**, except when project activities are implemented in wetlands (which are not eligible to apply the methodology at this time). Soil carbon is anticipated to decrease in the baseline scenario, resulting from soil disturbance caused by deforestation, and may not be significantly impacted under the project scenario. Exclusion of this carbon pool therefore likely leads to underestimation of total credited emission reductions. This issue applies to projects that opt to exclude soil carbon. The number of projects affected is **unknown**. For those projects where this issue materializes, the impact on total credited emission reductions is estimated to be **low** (less than 10%). The variability in the degree of underestimation is **unknown**.
- UE2 **Litter is identified as an optional source**: Litter is anticipated to decrease in the baseline scenario resulting from deforestation. Given that measuring litter would increase the emission reductions that could be quantified as project impact it is conservative to exclude litter. This issue applies to projects that opt to exclude litter. The number of projects affected is **unknown**. For those projects where this issue materializes, the impact on total credited emission reductions is estimated to be **low** (less than 10%). The variability in the degree of underestimation is **unknown**.
- UE3 **Emissions from biomass burning is identified as an optional source in the baseline**: Emissions of CO₂ from biomass burning are identified in VMD0013 as “always optional” despite it being “included” in the VM0048 methodology. If these emissions occur in the baseline scenario, their exclusion lowers the baseline emissions, and therefore leads to underestimation. This issue applies to projects that opt to exclude CH₄, N₂O, and potentially CO₂ emissions from biomass burning. The number of projects affected is **unknown**. For those projects where this issue materializes, the impact on total credited emission reductions is estimated to be **low** (less than 10%). The variability in the degree of underestimation is **unknown**.
- UE4 **Above ground non-tree biomass is optional to include in the project’s forest carbon stocks**: In the baseline, deforestation would result in a lower amount of non-tree biomass than in the project with exclusion leading to underestimation. This issue applies to projects that opt to exclude above ground non-tree biomass. The number of projects affected is **unknown**. For those projects where this issue materializes, the impact on total credited emission reductions is estimated to be **low** (less than 10%). The variability in the degree of underestimation is **unknown**.

³¹ The potential harm of this provision is somewhat limited by the methodology in Appendix 1 which requires all pools and sources of emissions to be accounted for, up to 95% of the total emissions impact of the project. While the flexibility in methods may allow the exclusion of pools and sources representing more than 5% of the actual project impact, this provision is determined to reduce the risk of gaming.



- UE5 **Deadwood is an optional pool:** Naturally occurring deadwood (both standing and lying) is likely to be lower in the baseline scenario than in the project scenario. Therefore, exclusion of this carbon pool is likely to lead to underestimation of emission reductions. This issue applies to projects that opt to exclude deadwood. The number of projects affected is **unknown**. For those projects where this issue materializes, the impact on total credited emission reductions is estimated to be **low** (less than 10%). The variability in the degree of underestimation is **unknown**.
- UE6 **Methodology does not consider emissions from livestock:** Livestock emissions within the project boundary are likely to decrease compared to a baseline scenario where deforestation occurs to enable livestock production. Excluding livestock emissions from baseline and project is therefore likely to result in underestimation of emission reductions. The number of projects affected is **unknown**. For those projects where this issue materializes, the impact on total credited emission reductions is estimated to be **low** (less than 10%). The variability in the degree of underestimation is **unknown**.
- UE7 **N₂O emissions from the application of fertilizer are optional unless fertilizer use increases due to the project:** The use of fertilizer in the baseline and project scenario is highly dependent on local conditions and common fertilizer use. If fertilizer use increases due to the project as a result of the implementation of leakage prevention measures, it must be included and accounted for. If fertilizer use does not increase due to leakage prevention measures, we expect fertilizer use to decrease in the project scenario relative to baseline levels because more land did not shift to agricultural use (in which case fertilizer may have been used). Therefore, the exclusion of this source is conservative. The number of projects affected by this is **unknown**. For those projects where this issue materializes, the impact on total credited emission reductions is estimated to be **low** (less than 10%). The variability in the degree of underestimation is **unknown**.
- Un2 **Methodology does not require CO₂ from the combustion of fossil fuels to be included:** Given that CO₂ emissions from the combustion of fossil fuels may occur in the baseline related to harvesting and agriculture, or in the project related to monitoring and patrolling, it is uncertain – and likely variable among projects – whether the under- or over-estimation effect is greater. The number of projects impacted by this issue is **unknown**. For those projects where this issue materializes, this issue introduces a **low** (less than 10%) degree of uncertainty to the estimation of total credited emission reductions. The variability in the degree of uncertainty is **unknown**.

5.2.1.3 Determination of baseline deforestation levels

In the following, we first provide an overview of general challenges regarding the determination of baseline deforestation levels. We then turn to a detailed assessment of VM0048.

General challenges in establishing baselines for avoided deforestation projects

Establishing baselines for avoided deforestation projects is associated with very large uncertainty. Establishing baseline is always associated with uncertainty, as it is not directly observable what would have happened in the absence of a project. For avoided deforestation



projects, uncertainty in establishing baselines is particularly high. The rate of future deforestation in a particular forest area depends on many unknown factors, such as changes in political, economic and social conditions. The literature suggests that changes in such “confounding” or “exogenous” factors can have a large impact on avoided deforestation (see, for example Miranda et al. 2024). Uncertainty in the underlying (historical) data used to establish baseline deforestation rates is another important source of uncertainty.

The divergence in estimates of baseline deforestation rates for the same projects is an indicator of the large uncertainty associated with predicting future deforestation rates for a specific project. For example, Guizar-Coutiño et al. (2022) and West et al. (2023) arrived at the different baseline deforestation estimates for the same projects. Similarly, some rating agencies built their own models to assess the quality of baselines and arrived at different deforestation baselines as the underlying projects. Aggregated estimates between rating agencies also differ (Calyx Global 2023; Sylvera 2023). Another indicator for the uncertainty is that even at jurisdictional level deforestation rates can vary considerably over time.

Large uncertainties raise challenges for ensuring attributability of the emission reductions to the project intervention. As the uncertainty in future deforestation scenarios is very high, this poses the risk that the calculated emission reductions could only partially be attributable to the project intervention and partially be an artefact of wrongly set baselines. This is illustrated in Figure 22 through two hypothetical projects. Project A reduces deforestation to some extent, by about one third. In this case, a large overestimation of the baseline would lead to significant over-crediting. A large underestimation of the baseline may lead to no carbon credit issuance at all, although the project reduces deforestation. This challenge is lessened for project B. Here the project reduces deforestation close to zero. In this case, an overestimation of the baseline leads to a lower degree of over-crediting relative to the actual reductions. Moreover, the project would still receive carbon credits if the baseline were significantly underestimated.

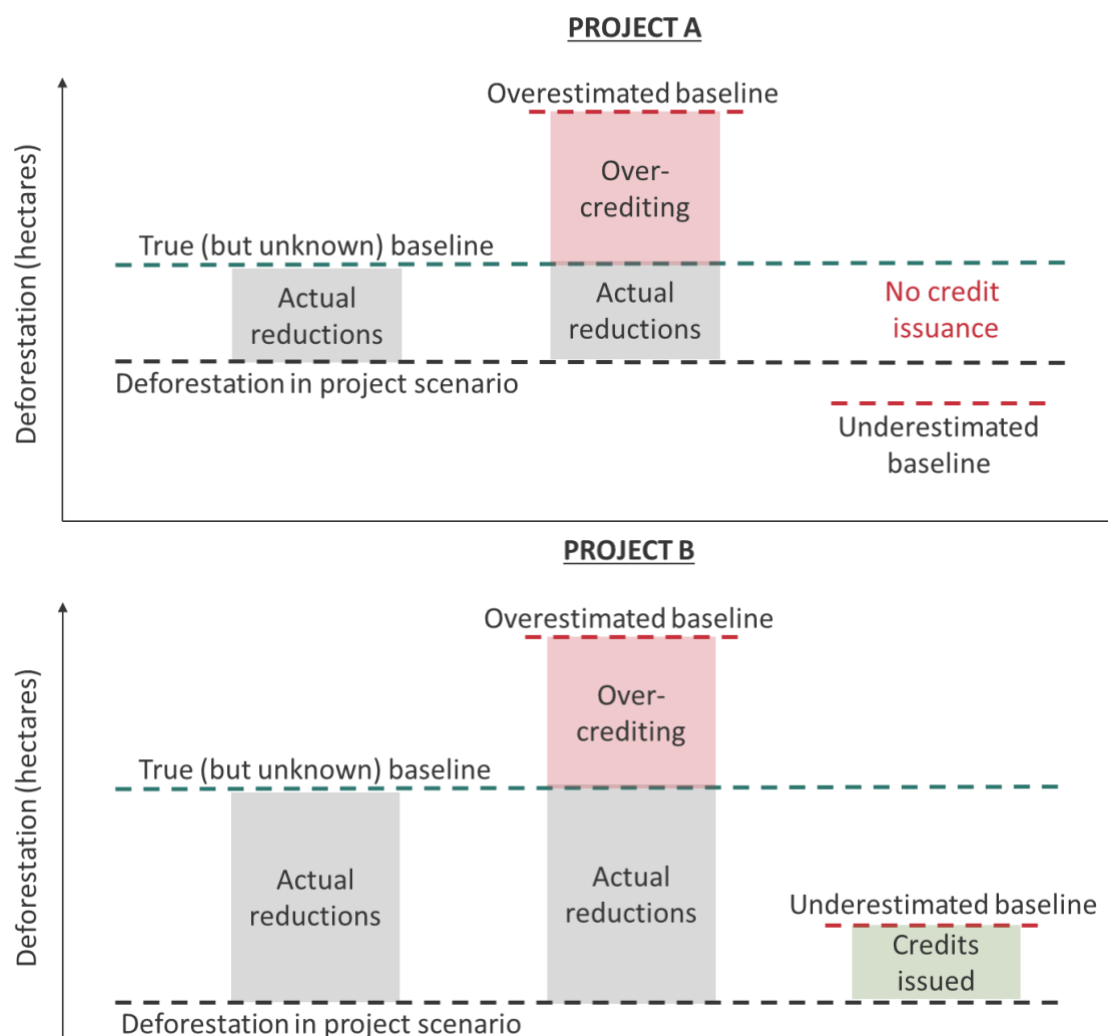


Figure 22 Implications of uncertainty in baseline deforestation levels

Two issues arise from this challenge:

1. **It is important to address the large uncertainty in predictions about future deforestation levels, by choosing a scenario that is conservative in the light of the uncertainty.** In theory, one could argue that over-crediting in one project may be compensated by under-crediting in other projects. However, projects with overestimated baselines have a competitive advantage over other projects. They receive more carbon credits than their actual emission reductions and can thus offer carbon credits at lower prices. By contrast, projects with underestimated baseline may not receive any carbon credits at all (as illustrated in Figure 1 above) or may only receive fewer carbon credits. Some of these projects may thus not succeed, or may fail later on, as they cannot generate sufficient revenues from carbon credits. This would lead to more carbon credits being generated from projects with overestimated baselines. Therefore, in a competitive market, unaccounted baseline uncertainty can undermine integrity across a portfolio of projects. Underestimation in some projects does therefore not compensate for overestimation in other projects. This is why many standard setting organizations, such as the Integrity Council for the Voluntary Carbon Market, require that uncertainty is addressed at the level of each individual mitigation activity and not only across a portfolio of projects and that all



sources of uncertainty are considered. To address this issue, baselines need to be set at a sufficiently conservative level where the degree of conservativeness takes into account the level of uncertainty.

2. **It is important that projects have a significant impact on deforestation levels.** The larger the impact of project interventions on deforestation drivers relative to the impact of confounding or exogenous factors is, the more likely it is that the emission reductions are attributable to the project interventions. As shown in Figure 1 above, the implications of baseline uncertainty are mitigated if projects strongly and effectively reduce deforestation drivers. The available literature indicates that this may not always be the case for avoided unplanned deforestation projects. Projects often aim to create alternative sources of income for local communities, through improving existing agricultural techniques on existing farmland, developing agroforestry systems or establishing fisheries and aquaculture. However, in some cases, projects only reached certain groups and failed to address those communities which are most dependent on the forest as a source of income (Haya et al. 2023; Kapos et al. 2022). Another driver of deforestation are unclear land tenure structures, which some projects address through supporting land tenure reforms. However, research showed that improving land tenure is immensely difficult, as the local context and the individual interests of affected groups needs to be appropriately considered to ensure that the relevant groups receive tenure rights and to avoid that new tenure arrangements create conflict (Sunderlin et al. 2018; Alusiola et al. 2021). Lastly, projects oftentimes implement measures to prevent illegal logging, such as forest patrols, monitoring posts or marking forest boundaries. While these measures might reduce deforestation, they are not always implemented stringently enough (Nathan and Pasgaard 2017). To ensure that project activities are effective – and thereby mitigate the impact of baseline uncertainty – methodologies could require monitoring of the implementation of the project interventions or that projects must reduce deforestation to levels close to zero in order to receive carbon credits.

Assessment of VM0048

The newer methodology VM0048 was introduced by Verra in November 2023 and will replace the older VCS methodologies (VM0006, VM0007, VM0009 and VM0015). The new methodology VM0048 is a major evolution compared to the previous methodologies and addresses some of the issues identified with them, as summarized above. A key change is that the new methodology determines baseline deforestation rates for an entire jurisdiction and allocates the jurisdictional deforestation data across the jurisdiction based on deforestation risk. This approach allows for consistency with jurisdictional targets (e.g., NDCs) or crediting levels (e.g., jurisdictional crediting approaches). A second important change is that VM0048 strongly reduces the flexibility for project developers in establishing baseline deforestation rates. For a given project area, the baseline deforestation rate will be determined by Verra and provided to the project developers.

Under the methodology VM0048, the module VMD0055 and tool VT0007, the determination of baseline emissions involves the following main steps:

1. **Estimation of baseline deforestation levels at jurisdictional level:** Module VMD0055 requires determining a “jurisdictional average annual rate of unplanned deforestation” for an entire jurisdiction, referred to as 'activity data' in the methodology. This deforestation



rate is determined based on the average rate of deforestation observed in the jurisdiction in a historical reference period of about ten years (images from within ± 365 days from the start and end date of the historical reference period may be used for the analysis depending on availability of remote sensing images (see VMD0055, p. 111)).³² The methodology thus implicitly assumes that the average historical deforestation rate in the jurisdiction will continue at the same rate in the future. The jurisdictional baseline activity data is provided by Verra and developed by data service providers for Verra. The work carried out by independent service providers will be assessed by independent experts. The total area of deforestation in the historical reference period is determined using high-resolution remote sensing imagery interpreted by humans. Starting from a wall-to-wall map of the jurisdiction, a representative sample of plots is taken. The land cover assessment is then done for the representative sample. The statistical uncertainty must not be greater than 20%. The estimated area of unplanned deforestation is adjusted downwards to account for statistical uncertainty if the uncertainty lies between 10% and 20%. No uncertainty deduction is applied if the sampling uncertainty is smaller than 10%. As a final step, the total historical deforestation over the historical reference period is then annualized.

2. **Construction of a map of future deforestation risk (risk map):** The tool VT0007 is used to build a deforestation risk map for the jurisdiction. This includes the development of “benchmark risk map”, which uses a simplified approach and considers only two parameters to identify deforestation risk: historical deforestation and distance to forest edge. In addition, at least two alternative approaches towards the risk map must be implemented, which may consider other parameters, such as existence of roads or the slope of the area. The median absolute error between modelled deforestation density and actual deforestation is used to assess and compare the accuracy of the alternative risk maps with the benchmark risk map. Alternative risk maps are candidates for use as the final risk map if

³² The duration of the historical reference period of ten years is not explicitly mentioned in VM0048, VMD0055 or VT0007. We assume it to be 10 years ($\pm$ a specific number of days depending on imagery used for the analysis of historic activity data) under consideration of the following sources:

- The definitions section in VMD0055 states that the historical reference period is “a fixed period of time (...), the duration of which is set out in the VCS Methodology Requirements”.
- The VCS Methodology Requirements (version 4.4 from 4 October 2023, p.32) state that the analysis of “past patterns” of deforestation “shall be based on historical factors over **at least** the previous 10 years” (emphasis added). Note that VMD0055 specifies that images within a period of ± 365 days from the start and end date of the historical reference period may be used. Thus, the reference period could also be shorter than ten years, which would not be in line with the Verra Methodological Requirements.
- The Verra website and introductory webinars to the methodology mention a ten-year historical reference period (<https://verra.org/methodologies-main/technical-background-note-new-redd-methodology/>, <https://www.youtube.com/watch?v=YhXg9zOX3As>, <https://www.youtube.com/watch?v=1nIEiBgYJtc>)



they exhibit lower median absolute error than the benchmark map. This approach includes the following sub-steps:

- a. In a first sub-step, a “forest cover benchmark map” (FCBM) is developed. This benchmark map is a raster map of the jurisdiction, developed based on imagery with a minimum resolution of 30m x 30m. Images from three points in time during the historical reference period are analyzed, namely the beginning, the middle, and the end. Each map contains binary information where land is classified as forest or non-forest. This allows determining changes from forest to non-forest land between these points. This results in 8 forest transitions (see Appendix 1.4.3 step 1), which are then further grouped into four “simplified classes” (stable forest, stable non-forest, deforested in the first half of the historical reference period, deforested in the second half of the historical reference period). The information from the forest benchmark map is used to calibrate and test the prediction of future deforestation. Observations at the start and the middle of the reference period are used for calibration, and observations at the middle and the end of the reference period are used for testing the quality of the prediction.
- b. In a second sub-step, the forest cover benchmark map is used to assign “vulnerability classes” to the forest land within the jurisdiction, representing different degrees of vulnerability to deforestation. Distance to forest edge is the only covariate used for determining vulnerability in the benchmark risk map. The forest cover benchmark map is used to identify the distance to forests edge at which 99.5% of deforestation in the historical reference period has occurred. This distance is referred to as the negligible risk threshold. All relevant forest areas within the jurisdiction are assigned vulnerability classes, depending on their distance to the forest edge. Vulnerability is defined on an ordinal scale of 30 classes. Areas close to an edge get assigned the highest vulnerability (30). The lowest class (1) is assigned to land areas that lie beyond the negligible risk threshold and are still within the jurisdiction. Areas that are not considered forest in the analysis are assigned 0. In addition to the benchmark method based on distance to forest edge, at least two alternative vulnerability maps that incorporate jurisdiction-specific risk factors must be developed. Like the benchmark approach, alternative vulnerability maps should also be scaled from 1 to 30. Any classification scheme is acceptable as long as vulnerability is scaled from 1 to 30, with 1 denoting the lowest risk class and 30 the highest.
- c. In a third sub-step, the benchmark and alternative maps of vulnerability classes are each combined with a map of administrative divisions, to create so-called “modelling regions”. Each modelling region is a unique combination of vulnerability class and an administrative division.
- d. The fourth step is to calculate the relative frequency of deforestation. A relative frequency is calculated by counting how many times an event of interest occurs and dividing it by the total number of possible events. In this methodology, the event of interest is whether deforestation occurred in a pixel. The total number of possible events are the pixels within a modeling region. The forest cover benchmark contains information on possible forest transitions, including deforestation, during the calibration and testing periods. The relative frequency of deforestation during the



calibration period in each modeling region is applied to the corresponding modeling region in the period to be predicted, yielding a map of probabilities of deforestation in the prediction period. To determine an area of deforestation, the relative frequency is multiplied by the area of a pixel, resulting in the deforestation density (ha/pixel).

Sub-steps a to d are carried out two times for each candidate risk map (the benchmark and at least two alternatives). The first time is for model fitting to the calibration period data. The second time is for creating predictions on a test set, which are ultimately used for assessing risk map quality and map selection among the candidates.

A coarse grid, with a resolution equal to the median size of REDD projects within the jurisdiction, is established for both the calibration and testing periods to compare benchmark and alternative models. The amount of deforestation (in hectares) observed in both periods is tabulated. For both periods, median absolute error (MedAE) is calculated as the median of the absolute differences between actual and fitted deforestation across these grid cells, providing a summary measure of the error in hectares. The candidate that exhibits the lowest MedAE in both periods is selected as the final model.

After a risk map is selected from among the candidates, the sub-steps are carried out a final time to predict deforestation risk during the baseline validity period. When predicting for the baseline validity period, the model used to create the vulnerability map referenced in step b is fit using the same parameters as the selected candidate model. However, data spanning the entire historical reference period is used to fit this model. As a final step the total predicted deforestation is adjusted to not exceed the total deforestation assumed for the entire jurisdiction as determined in step 1 above. The resulting benchmark risk map will be publicly available.

3. **Allocation of deforestation activity data to projects based on the risk map:** The result of all previous steps is a predicted deforestation density for one year of the baseline validity period (ha/pixel/year) for all pixels within a jurisdiction. The methodology refers to the predicted deforestation density as the allocated risk. The portion of that risk corresponding to a project equals all pixels that fall within the project area polygon. A sum of values of all pixels is the baseline activity data of a project. Project proponents receive an allocation from Verra upon request and will have to pay a yet to be determined fee for this.
4. **Calculation of the project specific baseline emissions:** For calculating the project-specific baseline emissions, project proponents must stratify their project area and determine emission factors for each stratum. Then the pixels that fall within a specific stratum and allocated risk are determined. Overlaying the map with the information on stratification and the map with the allocated risk allows multiplying the allocated risk with the emission factors of each stratum and calculating baseline emissions in tCO₂/year.

A baseline is valid for six years (e.g., from 1 January 2021 until 31 December 2026). Thereafter, new activity data, forest benchmark maps and risk allocations for the next “baseline validity period” will be provided by Verra and the data service providers.

Project developers are also required to determine a baseline scenario. This is done using an additionality analysis, which starts by identifying alternative land use scenarios that are consistent with existing laws and regulations. If there are none, the baseline scenarios to be



considered include the continuation of pre-project land use, the project activity without financing from the voluntary market and similar activities to the project. Additionally, an investment analysis or a barrier analysis must be carried out to determine the baseline scenario. The project must analyze and describe the agents and drivers of deforestation of its baseline scenario.

The methodology VM0048, and the module VMD0055 and tool VT0007, aims to address several of the significant shortcomings identified with the previous VCS methodologies assessed by CCQI (VM005, VM0007, VM0009, VM0015). The most important improvement is that baseline data on avoided deforestation areas is provided by Verra. This considerably reduces the flexibility for project developers to make unrealistic assumptions about baseline deforestation rates. This flexibility is considered as the main cause of significant overestimation of emission reductions under the existing methodologies (Haya 2023, other references). A further improvement is the use of a shorter baseline validity period and thus more frequent updates of baselines. A third improvement is that uncertainty in the data used to establish baseline, including historical deforestation rates and emission factors (carbon per hectare) is considered and accounted for.

In the following, we assess potential sources of overestimation, underestimation or uncertainty with the methodology and its modules and tools. With regard to the establishment of the jurisdictional average annual rate of unplanned deforestation, we identify the following elements of possible overestimation, underestimation or uncertainty:

OE3 Establishment of the jurisdictional baseline scenario: For each six-year baseline validity period, the methodology establishes the jurisdictional baseline scenario as the average deforestation rates observed in a historical reference period of about 10 years. The methodology thus assumes that the average historical deforestation rates will continue for a period of six years. During this period, the methodology does not account for confounding or exogenous factors that may impact deforestation levels over time, which could result in higher or lower true (but unknown) baseline levels than observed historically. Any changes in confounding or exogenous factors would, however, be captured over time when establishing an updated baseline for a subsequent baseline validity period. The level of the calculated baseline also hinges on the which 10-year period is selected (i.e., what the start and end date of this period is), as there are often large interannual variations in the level of deforestation.

In assessing the conservativeness of this approach, we discuss four issues:

1. Uncertainty in short-term variations in deforestation levels;
2. Potential underestimation of baseline levels due to the impact of carbon crediting projects on deforestation in the historical reference period;
3. Impact of longer-term trends in deforestation levels;
4. Potential overestimation of baseline levels due to continued crediting even if no forest would be available anymore.

Uncertainty in short-term variations in deforestation levels

The available data suggests that deforestation levels are decreasing in some jurisdictions and decreasing in others. Often trends change over time. These short-

term changes in individual jurisdictions introduce uncertainty in establishing the jurisdictional baseline.

Figure 23 illustrates the implications of such short-term variations in deforestation levels for 54 countries with tropical moist forests. In the figure, we use historical deforestation data from the Joint Research Centre (JRC) to compare for each country the actual deforestation levels observed in a hypothetical six-year baseline validity period from 2017 to 2022 (the latest available data) with the calculated baseline for the jurisdiction based on the average deforestation observed in the period 2007 to 2016. The figure shows that the baseline would be accurate ($\pm 5\%$) for five jurisdictions. For 12 jurisdictions, the baseline would be underestimated and for 37 jurisdictions it would be overestimated. The figure also shows that the deviation is significant for many jurisdictions. In the most extreme scenarios, the baseline could be 435% higher (Uganda) or 53% lower (Cameroon) than actually observed deforestation in the hypothetical baseline validity period. While there is uncertainty in these numbers, this illustrative example suggests that assuming historical deforestation data could lead in significant over- or underestimation of jurisdictional baseline deforestation levels for a given baseline validity period.

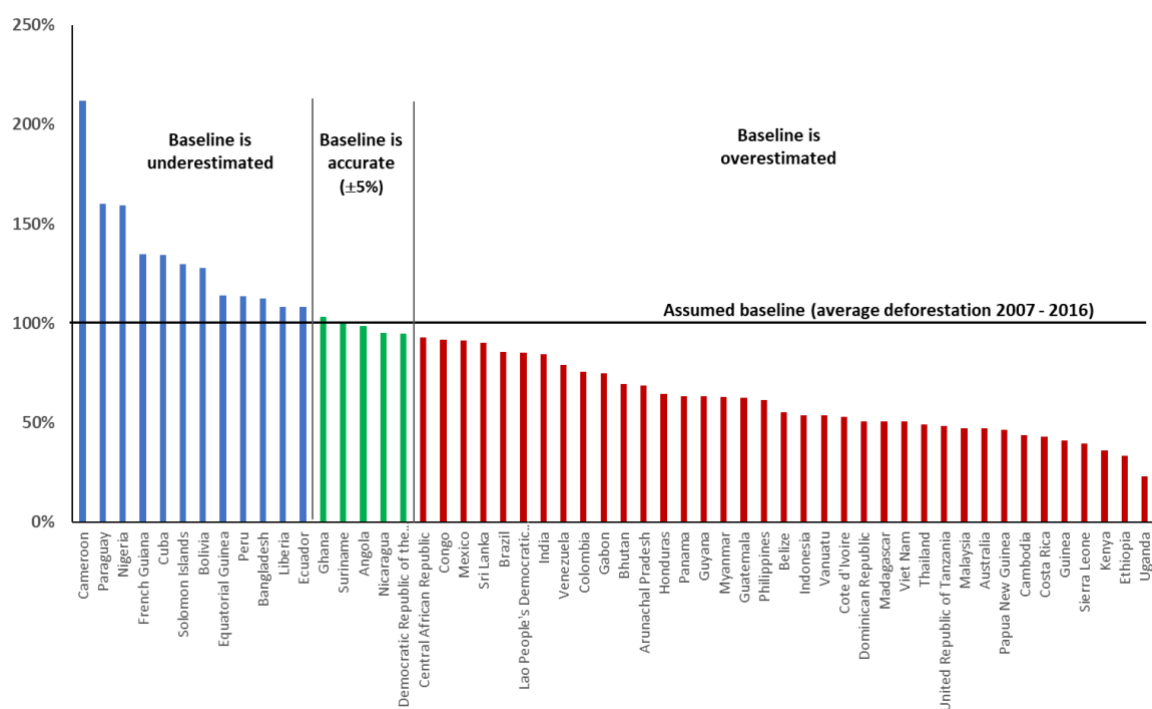


Figure 23 Deforestation in 54 jurisdictions in a hypothetical baseline validity period from 2017 to 2022 compared to the assumed baseline based on deforestation in the period 2007 to 2016. Source: Own illustrated based on data on direct and indirect deforestation from EU Joint Research Centre (<https://forobs.jrc.ec.europa.eu/TMF/data#stats>)

The risk of large uncertainty in a given baseline validity period may be mitigated by the fact that baselines are updated every six years. For example, a jurisdiction that has an overestimated baseline in the first baseline validity period might have an underestimated baseline in the subsequent period, depending on the deforestation



trends in the jurisdictions. The deviations between the calculated baseline and the actual jurisdictional deforestation levels could thus be small when aggregating several baseline validity periods.

The uncertainty in establishing the jurisdictional baseline deforestation rates poses the risk that projects in those jurisdictions where the true (but unknown) baseline is lower than the calculated baseline have a competitive advantage over projects in regions where the true baseline is higher than the calculated baseline. As discussed above, large unaccounted uncertainty in baselines can undermine the overall portfolio of projects. This is because projects in jurisdictions with overestimated baselines will receive more carbon credits than their actual emission reductions and can thus offer these at relatively lower prices, whereas projects in jurisdictions with underestimated baselines receive fewer carbon credits and may not find buyers or may even fail, or not succeed, as they cannot generate sufficient revenues from carbon credits. This could lead to more carbon credits being generated from regions where the jurisdictional baseline is overestimated, and fewer carbon credits generated from regions with underestimated jurisdictional baselines. On the other hand, the location and success of projects may only partially be influenced by carbon credit revenues. Some projects may succeed even if they receive much fewer credits than their actual emission reductions. At this stage, it is difficult to assess how large this risk will be for VM0048, given that the location of projects and the jurisdictional baselines are not yet known.

Underestimation of baseline levels due to the impact of carbon crediting projects on deforestation in the historical reference period

The methodology uses the average historical deforestation levels in a reference period of 10 years to establish the baseline deforestation levels for the subsequent six years. If carbon crediting projects are implemented in the historical reference period, their emission reductions are reflected in the historical data. In the absence of these carbon crediting projects, deforestation levels would be higher. This contributes to an underestimation of baseline deforestation levels. The degree of underestimation strongly depends on the impact of carbon crediting projects on overall deforestation levels in the jurisdiction. The larger their impact is, the larger is the underestimation of baseline deforestation levels (see discussion further below).

Impact of longer-term trends in deforestation levels

While deforestation rates are subject to short-term changes, as discussed above, an important question is how well the methodology captures any longer-term deforestation trends. In principle, the methodology captures longer-term trends, as the baseline is updated every six years. The trends are, however, only captured with a delay, due to the use of historical data from the past ten years to establish the baseline scenario.

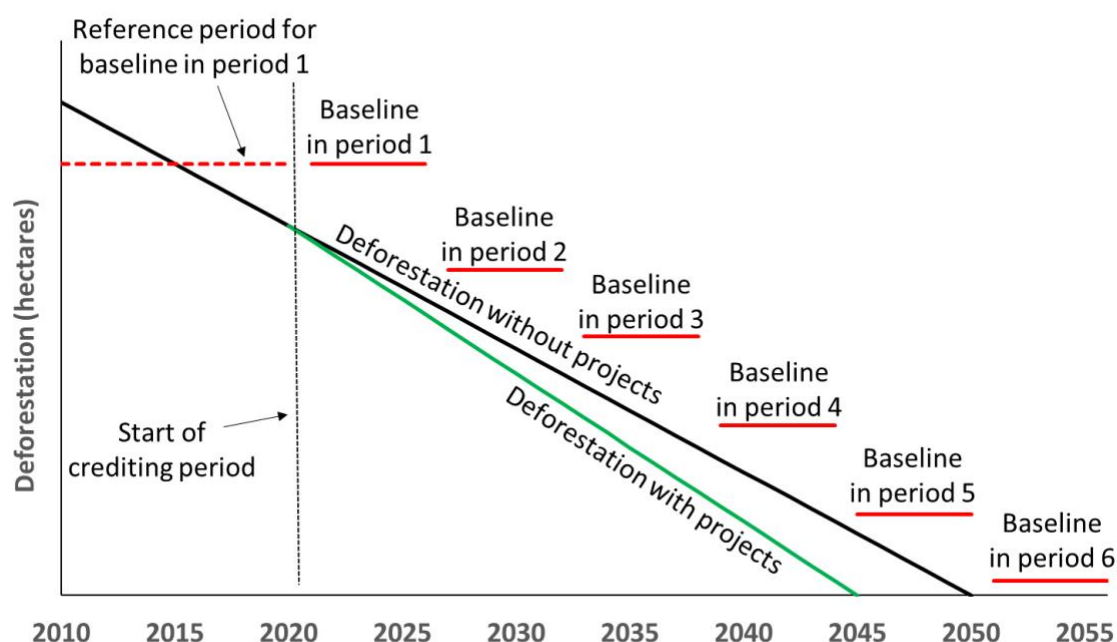


Figure 24 Implications of using historical data to establish the jurisdictional baseline deforestation rates if deforestation is declining over time. Source: Own illustration.

Figure 24 illustrates this for a simplified example of a jurisdiction where deforestation rates are declining. In this example, we assume that without carbon crediting projects deforestation in the jurisdiction would decrease linearly and would be halted by 2050 (black line). We further assume that the implementation of carbon crediting projects brings this decline forward by five years (green line). The baseline for the first baseline validity period from 2021 to 2026 (red line) is determined based on the average deforestation observed in the period 2011 to 2020 (red dotted line). Due to the decline in deforestation levels, the baseline is significantly higher than the true – but unknown – deforestation levels without the projects (black line). This also holds for subsequent baseline periods. Under a trend of declining deforestation rates, the use of historical data could thus lead to a systematic overestimation of baseline emissions. By contrast, if deforestation increases over time, the baseline could be systematically underestimated, as the increase in jurisdictional emissions would also only be captured with a time delay.

The implications do not only depend on whether and how strongly deforestation levels increase or decrease over time but also on the impact of carbon crediting projects on deforestation levels. As highlighted above, the baseline could also be systematically underestimated as the historical data includes the impacts from carbon crediting projects. Without carbon crediting, the historical deforestation levels would be higher. Figure 3 shows the combined effect from overestimation of the baseline if deforestation levels were to decline and potential underestimation of the baseline due to the impact of carbon crediting projects on deforestation in the historical reference period.



The impact of this effect can be large. In the example of the figure, the baseline would be overestimated by 43% over the entire period (i.e., the red line is on average 43% higher than the black line over the period 2021 to 2056 when the last baseline validity period ends). The impact on overestimation of emission reductions from carbon crediting projects depends on how the projects within the jurisdiction reduce deforestation. In the example of the figure, it could range between 43% and 252% (assuming no error from the risk allocation model). If the reduction in deforestation would be only achieved through projects that manage to reduce deforestation to zero over the entire period, then the overestimation of emission reductions would be equal to the overestimation of the baseline and thus amount to 43%. The largest possible overestimation would occur if projects would cover the entire jurisdictional area. In this case, the credited emission reductions (the area between the red line and the green line) would be 252% larger than the actual emission reductions (the area between the black line and the green line). The impact on overestimation of credited emission reductions thus depends on how the reduction in deforestation is achieved by projects.

A variation of these underlying parameters shows that the impacts could strongly vary. For example:

- If deforestation would be halted by 2040 without carbon crediting projects and if carbon crediting projects have only a smaller impact and bring the halting of deforestation forward by two years, to 2038, then baseline emissions would be overestimated by 86% on average over the period. The emission reductions could then be overestimated between 86% and 820%, depending on how the projects are implemented.
- If deforestation would only be halted by 2070 without carbon crediting projects and if carbon crediting projects have a major impact and bring this forward to 2050, then the baseline would be underestimated by 6%. In this case, the effect of underestimating the baseline due to impact of carbon crediting projects on the historical data in the reference period prevails over the effect of underestimation of the baseline due to declining trends in deforestation.

This analysis shows that two parameters are critical to assess the risk of potential overestimation of the jurisdictional baseline rate: (a) whether deforestation will increase or decrease over a longer period and how strong any such trend is, and (b) how large the impact of carbon crediting projects on deforestation levels is. Both parameters are associated with considerable uncertainty.

The available data suggests that deforestation is increasing in some jurisdictions and decreasing in others. The jurisdictional baseline under VM0048 would be conservative if deforestation would continue to increase and not be halted at some point in time. However, at some point in the future, deforestation may always decline and be halted – at the latest when all forests are lost. The literature also suggests that countries undergo different forest transition phases that ultimately halt deforestation (see, for example, Hosonuma et al. 2012).

Another consideration is how policies affecting deforestation rates may evolve over time. Many governments and non-governmental actors have committed to slowing



and ultimately halting deforestation, such as in the New York Forest Declaration and the Glasgow Leaders' Declaration on Forest and Land Use. Many countries have also pledged ambitious NDC targets and long-term low emission development strategies (LEDS). This could support the implementation of national policies that slow deforestation. On the other hand, developing countries are lacking finance to implement such policies and current efforts would need to be considerably enhanced to reach the goal of halting and reversing deforestation by 2030. In addition, other drivers, such as prices for agricultural commodities, increased use of biomass and land competition could increase pressure on forests.

Over a longer horizon, with the enhanced policies to slow and halt deforestation, we consider it plausible that deforestation could, in aggregate across jurisdictions, slow over time and ultimately be halted at some point in the future, though this unlikely to be achieved by 2030. If this assumption holds, then the approach in VM0048 could, in aggregate across jurisdictions, lead to a systematic bias towards overestimating baseline emissions.

To address this matter, the methodology could, for example, assume a jurisdictional baseline that uses historical data as a starting point but declines over time and reaches zero deforestation at some point in the future, choosing a conservative trajectory in the light of the uncertainty. Another approach could be alignment of the baseline with the NDC and LEDS of the host country, and the long-term goals of the Paris Agreement, as required under the carbon crediting mechanism established under Article 6.4 of the Paris Agreement.

Potential overestimation of baseline levels due to continued crediting even if no forest would be available anymore

The methodology does not consider whether forest land would in the baseline scenario still be available for deforestation. If deforestation stops in the baseline scenario at a future point because all forests have been deforested, the methodology still allows claiming carbon credits after that point in time although no such emission reductions would be physically possible. For example, if baseline deforestation in a jurisdiction would be constant in the period from 2010 to 2050 and all forest area would have been deforested by 2050, then the methodology would still allow projects to claim emission reductions thereafter, for up to 12 years. In the baseline validity period from 2051 to 2056, the baseline would be based on the constant deforestation rate observed in the period from 2041 to 2050. Even in the next baseline validity period from 2057 to 2063, project developers could still claim some emission reductions, because the average deforestation rate in the period 2047 to 2056 would be used, which still includes four years in which deforestation occurred (2047 to 2050). The methodology thus allows assuming aggregated total baseline deforestation levels to exceed the forest land available for deforestation. In practice, however, this issue is unlikely to materialize. In most countries, there are still large amounts of forests. And if efforts to reduce and stop deforestation are successful, then this issue may also not materialize.

*Overall assessment*

In summary, in our assessment, assuming average historical deforestation rates as the jurisdictional baseline scenario could lead to significant overestimation. Most importantly, there is large uncertainty in short-term changes in jurisdictional deforestation rates at the level of individual jurisdictions. This could result to large over- or underestimation of the jurisdictional baseline. This could result in more carbon credits coming from jurisdictions with overestimated baselines, thereby undermining the integrity of the portfolio of projects. Second, while assuming average historical deforestation rates to continue in the future is a well-established practice in jurisdictional approaches, this may not be a likely scenario over a longer time horizon. And third, the impact of carbon crediting project on deforestation levels in the historical reference period could lead to some underestimation. However, this effect could, under a broad range of circumstances, be much smaller than the effect of potentially declining trends in deforestation.

Overestimation of baseline emissions, or large uncertainty in baselines, could also have a large effect on overestimation of emission reductions, as projects may not be able to entirely address deforestation drivers and may only moderately reduce deforestation. Next to addressing uncertainty in baselines, it is therefore important that projects are effective and strongly reduce deforestation levels. This would alleviate the implications of baseline uncertainty.

We assess that these issues affect a **high** fraction of projects. The degree of overestimation of total credited emission reductions is **unknown**. The variability among projects in the degree of overestimation is also assessed to be **high**.

- UE8 **Discounting for uncertainty in historical deforestation data.** The methodology requires estimating the uncertainty in the estimated total area of unplanned deforestation in the jurisdiction in the historical reference period. A discount to the estimate is applied if the uncertainty is above 10% and below 20%. This could potentially lead to underestimation of total credited emission reductions. It is, however, unclear for how many jurisdictions the uncertainty will be determined to be within the range where a discount applies. Therefore, the fraction of projects affected is **unknown**. Where this issue materializes (i.e., the uncertainty is larger than 10% and an uncertainty deduction is applied), the applied discount is between 10% and 20%, and the degree of underestimation thus **medium**. The variability in the degree of underestimation among projects is **unknown**.
- OE4 **Exclusion of areas with planned deforestation and natural disturbances:** To improve accuracy of the activity data estimates, areas of planned deforestation and natural disturbance can be excluded from sampling. Excluding such areas is a requirement for areas above 1000 ha and optional for smaller areas. The methodology does not clarify whether the threshold is applied to one year or over the ten-year historical reference period. In principle, exclusion of these areas is appropriate; including them would lead to inflated estimates of unplanned deforestation levels in the jurisdiction. However, the inclusion of areas below the 1000 ha threshold in the calculation would lead to overestimation of the jurisdictional unplanned deforestation levels and thus overestimation of the baseline. This risk is assessed to apply to a **high** fraction of projects, as some degree of inclusion of areas with planned deforestation or



natural disturbances is likely to occur in most jurisdictions. Where this issue materializes, we estimate that the degree of overestimation of total credited emission reductions is however rather **low**. The variability among projects in the degree of overestimation is **unknown**.

With regard to the establishment of the risk map, we identify the following elements of possible overestimation, underestimation or uncertainty:

- Un3 **Uncertainty in the forest cover benchmark map:** Accuracy of the forest cover benchmark map is assessed against the sample-based observations made to determine the activity data. Two measures to enhance accuracy are used. The first looks at how much of the area mapped to a specific class corresponds to the sampled land cover. The second looks at how much of the area with a specific land cover is assigned the correct corresponding class. The methodology requires assessing the accuracy of the estimate of deforested area (change of forest cover between the start and the end date of the historical reference period) and the accuracy of the estimate of forest area at the end of the historical reference period. This is done by estimating for each class (forest/non-forest) the proportion of pixels correctly assigned to the actual land cover or land use on the ground (user's accuracy) and by estimating the proportion of areas on the ground that are assigned to the correct corresponding class on the map (producer's accuracy). For the deforestation estimate, 70% or more of the area must be correctly assigned, for forest at the end of the historical reference period, 90% or more of the area must be correctly assigned. Lower thresholds apply for forests with a canopy cover of 50% or below (60% for deforestation and 80% for forest cover and the end of the historical reference period). These accuracy provisions means that total deforestation in the reference period can be over- or underestimated to a large degree. The issue applies to **all** projects and is estimated introduces a **high** degree of uncertainty to the estimation of total credited emission reductions. The variability in the uncertainty among projects is **unknown**.
- Un4 **Uncertainty in the models used to establish the risk map:** Allocating the jurisdictional average annual rate of unplanned deforestation to specific areas is associated with considerable uncertainty. The goodness of fit (accuracy) of the models used strongly hinges on how well different effects and drivers for deforestation can be reflected in the model. While distance to forest edge may be more easily incorporated into models, other important factors driving deforestation, such as the current land-use in non-forest land areas, distance to roads and slope can affect where deforestation will take place. Such data is however more difficult to obtain and incorporate into models. The methodology takes this into account and aims to reduce uncertainty but does not account for the model uncertainty in preparing the risk map). The benchmark model will only include distance to forest edge as a factor. The two alternative models that must be considered may also consider other factors. The model with the lowest median absolute error in the relevant historical period is used. This reduces uncertainty to some degree. However, the methodology does not pursue a conservative approach to address uncertainty (e.g., for example by comparing the results for each pixel from different models and choosing the most conservative outcome for each pixel or by adjusting all pixels by a factor to account for model uncertainty). This issue applies to **all** projects. The degree of uncertainty and the variability among projects is **unknown**.



- Un5 **Potential overestimation of deforestation risk on the edge of natural disturbance:** Sampling of historical deforestation includes a step where areas of natural disturbances larger than 1000 ha and commercial plantations and deforestation by large scale infrastructure are excluded from the sampling frame. The same exclusions apply to the forest cover benchmark map. VMD0055 states that this approach is pursued to ensure “that these forest clearings are not used to inform risk modelling of unplanned deforestation”. In VT0007 all areas that are not forested at the beginning of the historical reference period are treated as stable non-forest and used to calculate the distance from forest edge. From this, we understand that areas affected by natural disturbances and classified as non-forest will be considered as a forest edge for the purpose of risk mapping. Areas close to this edge will be assigned the corresponding risk class. If deforestation in this area occurred due to natural disturbances and human drivers are largely absent, the assigned risk around these areas will be overestimated. In remote areas, this could even overestimate the deforestation risk in these land pixels by 100%. From the description in VT0007, it is further not clear how the risk close to permanent water bodies is treated. If they were treated as forest edge, the same risk of overestimation would apply. The issue is most relevant for the benchmark risk map and may be addressed in alternative risk maps, where additional factors are considered. The number of projects affected by this issue is **unknown**. Where the issue materializes it introduces a **low** degree of uncertainty. The variability in the uncertainty among projects is **unknown**.
- OE5 **Possibility of gaming baseline validity periods:** The baseline deforestation rates provided by Verra are valid for six years. Verra will determine the start and end date of a baseline validity period and provide an updated baseline for the following period. A project may start at any time within a baseline validity period. For example, the first baseline validity period could start on 1 January 2025 and may end on 31 December 2030. The subsequent baseline validity period with updated baseline data would then start on 1 January 2031 and end on 31 December 2036. Projects that start within the first baseline validity period (e.g., in 2028) can choose between transitioning to the updated baseline right away or applying the 2025-2030 baseline for a maximum of two years and then transition to the next baseline. In the former case, this project could use a baseline for a period of eight instead of six years. If jurisdictional baselines and risk maps are publicly available or projects are informed about their updated baseline upon request, project proponents would have the possibility to choose the baseline that is higher. Even if they could not formally inquire about the new baseline data applicable to their project, it seems likely that they could derive from other information (e.g., other projects, public data on deforestation rates in the region) whether the updated jurisdictional baseline is higher or lower than the previous baseline. If all projects choose the higher baseline among two plausible options, this will in aggregate across projects lead to overestimation of total credited emission reductions. It is unclear to how many projects this risk will apply. If all projects transitioning from the existing methodologies must apply the VM0048 methodology as of 1 January 2025 and thus use the updated baseline as of 1 January 2031, this risk would not apply to currently registered projects but only to new projects. This issue is only relevant for the transition from the first baseline validity period to the second. We therefore assume here that this issue only applies to a **low** fraction of projects, though their share may increase over time. Where this issue materializes, we estimate that the degree of



overestimation of total credited emission reductions could be **low to medium** (up to 30%), given that historical deforestation levels can vary considerably. The variability in the degree of overestimation among projects is assessed to be **high**, given that the degree of changes in updating baselines could vary considerably among jurisdictions.

- OE6 **The allocated baseline may be higher than a government baseline:** Where governments establish a jurisdictional deforestation baseline and that baseline is lower than the deforestation baseline determined by Verra, project developers are not required to use the lower governmental baseline, unless this is mandated by regulation. It is plausible that most project developers would in such instances choose the higher baseline provided by Verra. This provision only contributes to overestimation, or prevents more conservative estimates, where the baseline provided by Verra is overestimated. The fraction of projects affected by this issue, the degree of overestimation and the variability in the degree of overestimation among projects are all considered to be **unknown**.

Potential elements of overestimation, underestimation or uncertainty with regard to the determine of baseline emission factors (carbon stocks lost per hectare of deforested land) are discussed further below in the section "Quantification of carbon stocks in the project and the baseline scenario".

5.2.1.4 Determination of the geographic boundaries of the project

The methodology VM0048 has provisions to clearly define and delineate the project area, including through maps and geographic coordinates. The project area may encompass more than one discrete area of land. Moreover, each discrete forest area "must be continuous without arbitrary exclusions of forests in the same geography (e.g., without excluding forests next to villages around which deforestation is likely to occur)".

The project boundary section of module VMD0055 further specifies that geographical boundary of the project area remains fixed for the duration of the project crediting period, regardless of any land cover change after the start of the project. However, it provides for an exception where a "project activity instance (or equivalent) leaves the project (e.g., a landowner decides to leave a project) before the end of the crediting period". In this case, the project "must conservatively assume a loss of all previously verified emission reductions associated with the excluded area", exclude the respective area, and recalculate baseline emission respectively.

We identify the following sources of overestimation, underestimation or uncertainty with this approach:

- OE7 **Selection of favorable project areas:** The allocation of baseline deforestation data to projects by Verra considerably reduces the flexibility by project developers compared to the previous methodologies by Verra. A key question is whether there is a risk that project developers could select those areas in which the risk map overestimates deforestation risk. This risk may arise from two factors: first, the preparation of the risk map is associated with considerable uncertainties (see Un4 to Un6), making it likely that deforestation risk is overestimated in some areas and underestimated in other areas. Second, the risk map can only incorporate a limited number of factors. Projects developers may have access to local knowledge that cannot be considered in building the risk maps. For example, project developers may be aware of plans to build roads



and select regions that are further away from these planned roads. If these plans were not considered in developing the risk map, the deforestation risk may be under-allocated in the areas where the roads are planned and accordingly overallocated in all other areas of the jurisdiction. Another example could be that a forest has a value to local communities due to reasons that cannot be picked up by risk modes (e.g., generation of forest-related products and services or a certain area being sanctuary to local communities).

This risk also depends on the degree to which project developers can shape the area. The methodology states that “the forested project area (within each discrete area of project activity) must be continuous without arbitrary exclusions of forests in the same geography (e.g., without excluding forests next to villages around which deforestation is likely to occur)”. While the intent of the methodology is that areas with higher deforestation risk are not systematically excluded, it is unclear how well this can be prevented in practice, given that the methodology allows that the project area may consist of several discrete land areas that may not be connected. This provides some flexibility to project developers to construct the project areas around areas with overestimated deforestation risks. A further challenge is the information asymmetry between project developers and third-party auditors or the carbon crediting program in assessing whether “arbitrary exclusions” have been made.

At this stage, without data on the practical implementation of projects, it is difficult to judge to what extent this risk will materialize. Whether and to what extent this risk materializes depends on several factors. One factor is the level of information that Verra makes available in the risk maps. According to information provided by Verra to CCQI, the risk maps will be made publicly available, although it is not clear at which spatial resolution. The risk also depends on the fit and uncertainty of the models used to prepare the risk map. If the fit is good and the uncertainty is low, the risk that project developers identify areas where modelled deforestation rates are likely overestimated may be lower. Moreover, this risk applies only to new projects developed under the methodology but not to projects that were originally registered under the previous methodologies by Verra (except if the project area of existing projects could be changed when transitioning to the VM0048 methodology). We here assume that existing projects cannot alter their project areas when transitioning to VM0048 and that the risk therefore only applies to new projects. This means that in the next years the fraction of projects affected by this risk is **low** but could substantially increase in the future. We estimate that where this issue materializes the degree of overestimation of total credited emission reductions is likely to be **low to medium** (up to 30%). The variability in the degree of overestimation among projects is likely to be **high**.

- OE8 **Ex-post determination of the project area:** The VCS programs allows projects to retroactively claim credits for time periods before the project registration is finalized. Avoided deforestation projects must complete validation only five years after the project start (VCS Standard, Version 4.6, paragraph 3.8.4). At the same time, the exact shape of the project area only needs to be finalized when starting the validation of the project. This enables project developers to ex-post adjust the project area at validation stage, for example by including areas where actual deforestation observed in the first years of the project was lower than predicted in the risk map and excluding areas



where observed deforestation was higher than predicted in the risk map. This would lead to a systematic overestimation of the project's emission reduction impact. At this stage, without data on the practical implementation of projects, it is difficult to judge to what extent this risk will materialize. The number of projects affected is therefore **unknown**. Where this issue materializes, we estimate that the risk of overestimation is **medium**. The variability in the degree of overestimation is likely to be **high**. Note that Verra informed CCQI that it is planning to change its project start date rules. A consultation on this matter is planned to go out in summer 2024.

- OE9 **Ex-post exclusion of project areas:** The methodology assumes that the provisions for ex-post exclusion of project areas are conservative, given that all previous emission reductions are assumed to be reversed in such cases. This may be conservative where the area that leaves the project is not further deforested thereafter. However, it may also be plausible that a landowner wishes to leave the project because of its intent to engage in larger deforestation. If an area is excluded where little or no deforestation has occurred in the past, and the area is more strongly deforested following the exclusion, then the exclusion would lead to an overestimation of the projects impact. In our assessment, this latter scenario is more plausible. Another scenario of how this provision could lead to overestimation is if project proponents exclude areas with currently low deforestation, but where they know that an increase is very likely, for example because they know that in some areas their project interventions are failing or that new roads will be constructed. Under both scenarios, overestimation would occur if the area is excluded from monitoring and if the impact of future deforestation in the area is larger than the previously calculated emission reductions for that area. At this stage, without data on the practical implementation of projects, it is difficult to judge to what extent this risk will materialize. The fraction of projects affected by this issue and the degree of overestimation where this issue materializes are **unknown**. The variability in the degree of overestimation among projects is likely to be **high**.
- OE10 **Reshaping of project area at renewal of the crediting period:** The VCS module VMD0055 requires that the project area is unchanged during a crediting period (with the exception of the provisions for exclusion discussed above). There are no provisions in the methodology that prevent project developers from reshaping the project area at the renewal of the crediting period. Due to the risks highlighted above with regard to selection of favorable project areas, project developers could reshape the area with the view to excluding areas where deforestation risk may be underestimated in the risk maps provided by Verra and including areas where deforestation risk may be overestimated. In aggregate across projects, this could lead to overestimation of total credited emission reductions. At this stage, without data on the practical implementation of projects, it is difficult to judge to what extent this risk will materialize. The fraction of projects affected by this issue and the degree of overestimation where this issue materializes are **unknown**. The variability in the degree of overestimation among projects is likely to be **high**.

5.2.1.5 Quantification of carbon stocks in the project and the baseline scenario and determination of deforestation rates under the project

Under the VM0048 methodology, the calculation of emission reductions is based on the difference in deforestation rates between the baseline and the project (referred to as activity



data) and the difference in carbon stocks per hectare of land between forest area and post-deforestation land (referred to as the emission factor). While the baseline deforestation rates (baseline activity data) are provided by Verra to projects, the deforestation in the project area observed after the implementation of the project (project activity data) and the carbon stocks per hectare of land (emission factors) are determined by each project. This section focuses on the determination of this project-specific data.

In the four older VCS methodologies (VM0006, VM0007, VM0009 and VM0015), carbon stocks are mainly determined through sampling or by using existing values from previous inventories. In VM0048, carbon stocks are determined in the project area through sampling. All methodologies encourage to stratify the relevant forest area to reduce uncertainty of carbon stock estimates.

As an overarching issue, we observe that the methodology does not address uncertainty in determining carbon stocks in a systematic and appropriate manner. Accuracy requirements and uncertainty deductions are applied for some parameters (e.g., land use classifications) but not for other parameters that are associated with considerable uncertainty (e.g., allometric equations). The methodology does not define an overall minimum level of accuracy for the determination of carbon stocks in the baseline and project scenario and lacks a systematic approach to account for uncertainty. This could be implemented by calculating error propagations and applying an uncertainty deduction based on the total error or by ensuring that uncertainty is addressed for all relevant parameters (e.g., by choosing a conservative value that reflects the uncertainty). In our assessment, the lack of provisions to address uncertainty in an appropriate manner, combined with outdated approaches and flexibility for project developers to choose between different approaches, results in a very high uncertainty in the quantification of carbon stocks, with results that may significantly differ from actual carbon stocks existing in the projects.

We identify the following elements of possible overestimation, underestimation or uncertainty with the approach in the methodology:

OE11 Overestimation of emission factors due to limited consideration of degradation:

Next to deforestation, it is possible that significant levels of forest degradation occur in the project area. This holds in particular where forest is defined based on a relatively low canopy cover, as is usually the case with national forest definitions that are allowed to be used under the methodology. In this case, a significant amount of forest carbon stocks may be lost without qualifying as deforestation.

The methodology does not provide guidance on how forest, deforestation and forest degradation should be defined in the context of the jurisdiction and specific project types. Guidance on the choice of these definitions would be necessary for different forest types, biomes or ecosystems, taking into account the specific features of the ecosystems and landscape units and the monitoring methods. Verra informed CCQI that for each jurisdiction these definitions will be determined by Verra in consultation with the government, local stakeholders and Verra's data providers. The relevant definitions are communicated to project proponents with their data allocation.

Projects are required to estimate the emission factor (i.e., the difference in carbon stocks per hectare in forest strata and in post-deforestation land-use) once at the start of the six-year baseline validity period. The module VMD0055 requires the



consideration of degradation under defined conditions, namely in the presence of new roads or in areas where the canopy cover decreases by 50% or more (section 5.3.3.2).

This implies that degradation occurring during the six-year period would in most cases not be captured in the estimate of the emission factors. As it is plausible that forests in the project area degrade over time, in particular where forest definitions with a low canopy cover are used, emission factors estimated ex-ante may not be representative for the six-year period, but rather reflect the level of degradation at the start of the period and are thus overestimated. The use of biomass stocks based on intact forests may significantly overestimate the emission reductions from deforestation. This is because the project may avoid deforestation in areas where the forest has already been severely degraded. This may lead to an overestimation of total credited emission reductions. In our assessment, this is likely to affect a **high** fraction of projects. The degree of potential overestimation is **unknown** as it is difficult to predict how much degradation would occur within a six-year period. The variability in the degree of overestimation among projects is likely to be **high**.

- Un6 **Uncertainty due to lack of accounting for forest degradation:** Next to the issue of overestimating emission factors (OE11), not accounting for degradation introduces uncertainty in the overall estimate of emission reductions. The implementation of the project could not only influence deforestation levels but also the degree of forest degradation. This could have different effects: Some projects may reduce both deforestation and forest degradation. In this case, the reduction in degradation would not be accounted for, as the project only accounts for changes in deforestation. This would lead to an underestimation of total credited emission reductions. Some projects may take actions that lead to deforestation but result in an increase in degradation. This could, for example, occur where the measures implemented through the project would shift drivers of deforestation or forest degradation from areas that are at the edge of deforestation to areas where the forest is still more intact. This would lead to an overestimation of total credited emission reductions. Not accounting for forest degradation could thus lead to under- or overestimation, and thus introduces uncertainty in the estimate of overall emission reductions. This issue applies to **all** projects under the currently available version of the methodology and modules. The level of uncertainty and the variability among projects are **unknown**.
- Un7 **No minimum mapping unit:** The methodology does not refer to a minimum mapping unit for remote sensing classification and therefore implicitly allows large minimum mapping units and high resolution. This introduces further uncertainty, in particular in the context of 'mosaic' landscapes. This applies to **all** projects. The level of uncertainty and the variability among projects are **unknown**.
- UE9 **Application of a discount for uncertainty in the carbon stock change estimates:** A discount factor to account for uncertainty is applied. The factor is determined based on the uncertainty of the weighted average carbon stock change estimated during the historical reference period. The weighted averages are calculated according to the area of each forest stratum and for each carbon pool. If the uncertainty is below or equal 10%, the discount factor is 0. For uncertainty above 10% and below 100% the discount factor is applied for all pools together, although soil carbon and wood products pools are kept separately. Only if uncertainty is above 100%, additional



sampling is required. The application of the discount factor results in an underestimation of total credited emission reductions. This uncertainty estimation in VM0048 is an improvement compared with previous methodologies.

Where carbon stock estimates are derived from sampling, the uncertainty estimates are also derived from the sampling. Where literature sources (including IPCC guidance) are used for carbon stock estimates, the uncertainty associated with these data must also be estimated. Data ranges may be used as proxies of confidence intervals. This provision lacks clarity for how project developers should estimate uncertainties from data ranges. Data ranges provided in IPCC guidelines are neither confidence intervals nor uncertainties. They indicate the range in which the values may be found, but uncertainties can be much larger. Thus, while pragmatic, the approach is scientifically incorrect. Moreover, some sources of uncertainty, such as uncertainties from allometric equations and root-to-shoot ratios, are not considered. Thus, the uncertainty estimation may also be incomplete, depending on the specific approach and parameters chosen. This will likely reduce the degree of conservativeness in applying the discount factors.

This issue applies to **all** projects since uncertainty is inherent to estimations of carbon stock changes. We expect that project proponents have an incentive to keep uncertainty low, but high levels of uncertainty are also allowed. As the methodology is new, it could not yet be checked how this uncertainty estimation is applied in practice and to what extent it results in resampling to reduce high uncertainties. We estimate that the degree of underestimation due to uncertainty discounts is likely to be **low** (up to 10%) because additional sampling in cases where uncertainty is above 100% is likely to be conducted and because of the limitations how overall uncertainty is derived, as described above. The variability in the degree of underestimation among projects is **unknown**.

- OE12 **Flexibility in choosing allometric equations:** Allometric equations are used to estimate the volume or biomass of trees based on parameters that are more easily to measure (e.g., height and trunk diameter at breast height). Allometric relationships can be determined based on destructive sampling of trees. Given the costs of destructive sampling, carbon crediting projects usually use literature sources of allometric equations. The quality of allometric relationships is best if the determination is site- and species-specific and from the same or a similar location. The determination of aboveground biomass through allometric equations is associated with considerable uncertainty, in particular in the case of tropical forests where the choice of allometric equations has been identified as a main source of error. Three important shortcomings have been identified: equations are constructed from limited samples; they are sometimes applied beyond their valid diameter range; and they rarely take into account the wood's specific density (Martínez-Sánchez et al. 2020; Chave et al. 2004; van Breugel et al. 2011).

The VCS module VMD0001 provides a 'priority' list for the type of equations that may be used. The sources provided are all based on older publications. More recent developments to achieve improved data on allometric equations are not taken into account. For example, the [GlobAllomeTree](#) platform was created in 2013 to share and provide access to tree allometric equations. Since then, wood densities, biomass



expansion factors, and raw data have been added to the platform. The FAO, CIRAD, and University of Tuscia, and many other organizations all over the world have contributed both their data and expertise.

While the module aims to prioritize the use of equations that are more specific to the project context, in practice, the provisions still leave room for project developers to select among different equations and to choose rather general pan-tropical equations. The module also provides a specific approach to validate the sources used by project developers. However, the validation approach uses generic, biomass expansion factors for which the data sources or their scope are not indicated. In our assessment, drawing on values provided by the IPCC, the use of these biomass expansion factors could tolerate an overestimation of at least 20%. Given that the uncertainty and variability in results from allometric equations is large and given that the limitations with the prioritization and validation approach, there is a risk that project developers can pick equations that lead to the determination of larger biomass carbon stocks.

This was observed with the methodologies VM0006, VM0009, VM0007 and VM0015. Haya et al. (2023) analysed a sample of avoided deforestation projects using these methodologies and found that the allometric equations chosen by the project developers resulted in aboveground carbon estimates that were 15.4% higher than the average of their set of best-fit equations. This result suggests that project developers have likely taken advantage of the methodologies' flexibility to choose allometric equations that lead to higher estimates of forest carbon and more emission reductions.

The methodology and module VMD0001 also do not account for the uncertainty of allometric equations; they do not require project developers to make any deductions for the uncertainty range or to select those equations that would lead to more conservative estimates. The flexibility in choosing between different equations and the lack of accounting for the uncertainty is therefore likely to lead to project developers choosing equations that result in higher carbon stocks, leading to overestimation of total credited emission reductions. Given that VMD0001 provides for a clearer prioritization of data sources, we deem this risk to be lower than for the methodologies VM0006, VM0009 and VM0015. The fraction of projects affected by this issue is **unknown**. Where this issue materializes, the degree of overestimation is estimated to be **low to medium** (up to 30%). The variability in the degree of overestimation among projects is likely to be **high**.

OE13 Flexibility in determining belowground biomass: Belowground biomass is usually estimated using root-to-shoot ratios for trees as a relationship between aboveground biomass and roots. Direct measurement is very time-consuming; therefore, methodologies usually apply values from literature and IPCC Guidelines. Root-to-shoot ratios vary with tree species, age, tree size and climate. Therefore, it is important to select a scientific source that is as specific as possible for the forests and trees in the project region.

The module VMD0001 requires to choose root-to-shoot ratios with the following order of 'priority': "detailed data collected using common practices for root sampling in the area; globally forest type-specific or eco-region-specific (e.g., IPCC GPG-LULUCF); or root to shoot ratios for tropical and subtropical forests modified from Table 4.4. in



IPCC GL AFOLU". The guidance further specifies that mean values from relevant sources are considered to be 'conservative'; however, IPCC and literature values commonly provide the best estimate and are not conservative (i.e., they do not err towards underestimating these values).

As with other parameters in this assessment, the flexibility to choose from different sources, including picking between the 2006 IPCC Guidelines and the outdated IPCC GPG, with limited guidance on prioritization of data sources and no requirement to use conservative values, poses the risk that project developers pick favorable root-to-shoot ratios that overestimate belowground biomass.

This was observed with the methodologies VM0006, VM0009, VM0007 and VM0015. Haya et al. (2023) compared the choice of root-to-shoot ratios for randomly selected VCS avoided deforestation projects with alternative peer-reviewed methods. On average, the projects' choice of root-to-shoot ratio was 37% higher than the mean of alternatives. They also found ratios applied in projects from literature that were not conservative, but much higher than alternative estimates. This suggests that project developers and verifiers did not conduct a careful comparison with literature sources. Similar to the estimation of aboveground biomass, this result shows that the flexibility provided by the methodologies was used by project developers to determine higher emission reductions.

This issue is likely to affect a **high** fraction of projects. Where this issue materializes, the impact on total credited emission reductions is estimated to be **low** (up to 10%), given that below-ground biomass usually is a smaller part of the overall emission reductions. The variability in the degree of overestimation among projects is likely to be **high**.

- OE14 **Overestimation of the carbon fraction in biomass:** The carbon fraction in biomass is the percentage of total dry aboveground biomass that is carbon and is applied to the estimates of aboveground biomass derived from the allometric equations. For tropical trees, Martin et al. (2018) derived a best estimate of 0.456 based on a global synthesis of over 2,000 wood carbon concentration measurements. For tropical woodland trees Ryan et al. (2011) determined 0.47 as the most appropriate value. This value is also used as a global default value in the 2006 IPCC Guidelines (Volume 4, Chapter 4, Table 4.3). The module VMD0001 states that values from the literature (e.g. IPCC 2006 INV GLs AFOLU Chapter 4 Table 4.3) shall be used if available, otherwise a default value of 0.47 can be used. This provision leaves room for project developers to select values that lead to higher estimates. For example, the provision would allow project developers to pick the value of 0.49 for wood in tropical forests from Table 4.3 in Volume 4 of the 2006 IPCC Guidelines. This value is based on a single study – rather than more recent and comprehensive information that has become available since – and would, in most instances, lead to an overestimation of emission reductions (e.g., by 7.5% compared to the best estimate for tropical trees determined by Martin et al. 2018). This issue is likely to apply to a **high** fraction of projects. For those projects where this issue materializes, the impact on total credited removals or emission reductions is estimated to be **low** (less than 10%). The variability in the degree of overestimation among projects is estimated to be **high**.



UE10 **Application of a discount for uncertainty in the project deforestation rates:** A discount factor to account for sampling uncertainty in determining project deforestation rates is applied where the sampling uncertainty is larger than 10%. The application of the discount factor results in an underestimation of total credited emission reductions. This uncertainty estimation in VM0048 is an improvement compared with previous methodologies. The fraction of projects affects is estimated to be **low**, as we assume that most projects are likely to pursue measures to reduce the sampling uncertainty below 10%. Where a deduction is applied, the degree of underestimation is likely to be **low** (up to 10%). The variability in the degree of overestimation among projects is **unknown**.

5.2.1.6 Determination of leakage emissions

In the following, we first provide an overview of general challenges regarding the determination of leakage emissions. As the VCS methodologies use partially similar approaches to quantify leakage emissions, we then provide an overview of commonalities and differences among the five VCS methodologies assessed by CCQI (VM0006, VM0007, VM0009, VM0015 and VM0048). We then turn to a detailed assessment of VM0048.

General challenges in establishing baselines for avoided deforestation projects

The main leakage risk for avoided deforestation projects arises from potential increases in deforestation elsewhere. This may occur due to “activity shifting” or “market leakage”. Activity-shifting leakage arises when a deforestation driver is displaced from the project area and leads to deforestation elsewhere. For instance, if timber production is the primary driver, activity leakage occurs if the deforestation agents relocate harvesting from the project area to surrounding areas. Market leakage occurs when avoiding deforestation alters market conditions by reducing the production of a traded commodity relative to the baseline, thereby creating incentives for others to intensify deforestation outside the project area (Streck 2021).

Leakage emissions are methodologically difficult to estimate. Depending on the type of leakage, different ways exist to estimate leakage effects. Activity shifting is often estimated by observing changes in deforestation in areas surrounding the project, which Verra refers to as leakage areas or leakage belts. Measurement tools to quantify such leakage effects can encompass onsite measurement or remote sensing to estimate changes in forest area and carbon stocks, along with interviews conducted within the local community (Henders and Ostwald 2012).

Market leakage is usually estimated with economic models used to determine shifts in the market equilibrium and the subsequent impacts of these changes on leakage (Henders and Ostwald 2012). The assessment of market leakage presents a distinctive set of difficulties, as it involves evaluating the impact of market forces and the adaptability of regional forest production rates in response to these influences. This undertaking is intricate, time consuming, expensive and it possesses challenges in estimation (Guizar-Coutiño et al. 2022; Kuik 2013; Man-Keun et al. 2014). Moreover, models heavily rely on input data and are exceptionally responsive to alterations in the parameters chosen by researchers, introducing a degree of uncertainty (Filewod and McCarney 2023).

Assessing market leakage is also challenging as size of leakage effects can vary significantly. A meta-analysis by (Pan et al. 2020) highlights this complexity, revealing an average leakage rate



of 39.6% for forestry projects but with significant variation (from 0 to 75%). This indicates that market leakage effects can be influenced by specific factors like the project location and economic factors integration. Given that leakage can manifest at local, national, or international levels, determining the suitable geographic parameters for its estimation is difficult (Henders & Ostwald 2012).

Market leakage can be very large for avoided deforestation projects. Conservation activities restricting land availability have a high risk of increasing prices for commodities such as timber which can lead to deforestation outside the project's boundary. Filewod and McCarney (2023) summarize that leakage estimates for developed nations are typically at least 70% of reduced output measured in terms of either forestry production or carbon stocks and that lower values (50% or less) have been found in developing country context. The meta-analysis by Pan et al. (2020) reveals an average leakage rate of 39.6% for forestry projects but with significant variation. Research by Atmadja et al. (2022) revealed, 28 out of 62 projects showed leakage effect with rates varying from 1% to 33%. These low leakage rate have been identified as being specific for small countries with rather limited access to timber and capital markets. Filewod and McCarney (2023) and Haya et al. (2023) further emphasize how the global market for wood products and a country's levels of integration into the market can be a significant factor in determining leakage rates.

By contrast, activity leakage may not exhibit higher deforestation rates. A study by Guizar-Coutiño et al. (2022) analyzed activity leakage across 40 VCS-REDD+ projects and found minimal leakage with only 3 projects indicating increased deforestation rates while two actually demonstrated a decrease. Furthermore, Alix-Garcia et al. (2012) reported a 50% reduction in deforestation rates in Mexico with low activity leakage of 4%. These findings suggest that the risk of activity leakage may much smaller than the risk of market leakage.

Summary of commonalities and differences among VCS avoided deforestation methodologies and issues identified in the literature

Quantification methodologies use a variety of approaches to account for leakage. All assessed VCS methodologies account for leakage from activity shifting and market effects, except for VM0015 which only considers leakage from activity shifting. To estimate activity shifting, satellite image analysis is used to detect any increase in deforestation rates in designated leakage zones around the project, often referred to as “leakage belts”. An increase in deforestation rates in these leakage areas must be accounted for through leakage deductions. The methodologies differ in how projects need to establish the geographical boundaries of these leakage areas and how “baseline” deforestation rates in these leakage areas are estimated.

To account for market leakage, the methodologies use default leakage rates. These default leakage rates were specified in the VCS AFOLU requirements which were later integrated in the VCS Methodology Requirements. The rates are 20%, 40%, and 70%, depending on the ratio of the project's merchantable biomass to total biomass, in comparison to the area to which the displacement occurs. The methodologies differ in how they account for leakage (Haya et al. 2023):

- **Relevant deforestation drivers:** The methodologies differ in which drivers of deforestation are considered relevant for market leakage: VM0006 requires accounting for market leakage only when illegal logging that supplies national or international markets is



identified as a deforestation driver. VM0007 requires market leakage deductions when timber, fuelwood, or charcoal production are identified as drivers. VM0009 requires market leakage deductions when any commodity accounted for in the baseline scenario is displaced. VM0015 does not explicitly account for market leakage. VM0048 requires accounting for market leakage when timber, fuelwood, or charcoal are identified as drivers.

- **Application of default values:** The methodologies also differ in how the default values are applied in the quantification of emission reductions. VM0006 applies the leakage deduction to total emissions reductions, whereas VM0007 applies it just to the emissions associated with the displaced timber harvest, and VM0009 applies it to the portion of emissions reductions from aboveground merchantable trees. VM0048 applies the leakage deduction for market leakage to the carbon emissions associated with the timber harvesting in the baseline.
- **Alternative approaches:** VM0009 allows project developers to pursue alternative approaches to quantify leakage emissions with due justification whereas the other methodologies do not allow for such approaches.

Altogether, this suggests that the general VCS requirements for accounting for market leakage have been applied in different ways across methodologies.

Leakage deduction applied by projects appear overall too low. The available evaluations of individual projects using the methodologies VM0006, VM0007, VM0009 and VM0015 suggest that most projects do not apply any leakage deductions. Calyx Global (2023) assessed 70 projects covering 94% of the avoided deforestation credits that have been verified as of December 2022 and found that about 60% of the project claims zero leakage. Similarly, Haya et al. (2023) found that 59% of projects did not take any leakage deductions. Case studies suggest that projects which are at risk of activity or market leakage avoided leakage deductions by using various arguments for exceptions, questionable justifications, and made use of lax requirements in the methodologies).

Where projects apply leakage deductions, these are relatively low. An analysis of 73 projects using the methodologies VM0006, VM0007, VM0009 and VM0015 reveals that the median leakage deduction applied by all projects (including those claiming zero leakage) are 2.6% for activity shifting and 4.4% for market leakage. Zero or low leakage claims are quite prevalent: 55 out of the 73 projects claimed zero leakage from activity shifting and 54 claimed zero market leakage. For those that apply the deduction, total leakage rates are under 25% (Haya et al. 2023). This implies that the projects are likely to underestimate market leakage effects.

Methodologies do not account for international leakage. Any project activities that displace commodities which are linked to the global market can lead to international leakage (Haya et al. 2023). None of the VCS methodologies account for international leakage. However, several studies indicate that a decrease in harvesting of timber or other commodities within project boundary often can induce more harvesting or deforestation in other countries (Gan and McCarl 2007; Murray et al. 2004; Sohngen 2009).

Assessment of VM0048

The VM0048 methodology estimates leakage emissions by considering four types of leakage:



1. **Activity shifting by geographically constrained agents:** This refers to agents that may displace deforestation drivers (e.g., timber harvesting) to surrounding areas the project, potentially resulting in increased deforestation in these areas. Changes in deforestation must be monitored within an area where unplanned deforestation by geographically constrained agents may be displaced to. The area is referred to as 'Unplanned Deforestation Leakage Belt' (referred to as UDef LB).
2. **Activity shifting by geographically mobile agents:** This refers to migration of agents to the project area which may drive deforestation in the baseline scenario. Due to the implementation of the project, these agents may shift to other areas, potentially causing land-use changes in these areas.
3. **Market leakage:** Consideration of market leakage is confined to any decrease in timber, fuel wood, or charcoal production relative to the baseline. Market leakage must be assessed using the module 'Estimation of emissions from market effects' (LK-ME).
4. **Emissions from leakage prevention measures:** This relates to emissions caused by measures to prevent leakage. It includes emission from any carbon stock losses and non-CO₂ emissions from biomass burning or fertilizer use. These emissions are determined following the provisions in VMD0055 unless deemed de minimis.

The significance of leakage emissions is determined using Appendix 1 of the methodology (see description in the project boundary section above and OE1).

Emissions from activity shifting due to the displacement of geographically constrained activities are calculated based on the difference in carbon stocks between the baseline scenario and the monitoring period within the Unplanned Deforestation Leakage Belt (UDef LB). Additionally, significant non-CO₂ GHG emissions from fossil fuels or burning of biomass resulting from an increase in deforestation are considered. These emissions are assumed to have the same intensity (emissions per unit of land) as in the project area in the baseline period.

Emissions from activity shifting by geographically mobile agents are determined based on several parameters. A survey is conducted to determine the proportion of households in the project area that both (a) recently migrated into the project area and (b) engaged in land-use activities identified as a deforestation driver. This is referred to as the 'Proportion of Migrated Land Cover Transition Agents' (PROMIG). The methodology assumes that the land conversion due to activity shifting outside the project area corresponds to the product of this proportion and the land area prevented from deforestation. In other words, if 3% of the population has recently migrated to the project area and engaged in activities leading to deforestation and the project prevents 100 ha from being deforested, it is assumed that 3 ha of land would be deforested outside the project area. Moreover, Verra determines a total maximum area available for deforestation outside the project area. If the area of land conversion outside the project area due to activity shifting by geographically mobile agents is larger than the available area, then no further increase in deforestation outside the project activity is assumed.

The available area for activity shifting outside the project area and the emission factor (the emission per hectare from land conversion outside the project area) are provided by Verra as part of the baseline allocation report (which determines the project's avoided deforestation baseline data). The available area for activity shifting is determined by spatially delineating areas of forest and non-forest land available for leakage by considering factors like suitability



for agriculture, physical accessibility, and lack of legal protection. Jurisdictional maps of each of these three factors are combined into a single map that is considered as area of “available land”.

The emission factor is calculated based on the average amount of carbon released per hectare of forest converted to agriculture in the “available” land areas and level of carbon stored above and below ground. Carbon stratification maps are used to estimate the extent of each jurisdictional carbon stratum that falls under the available category. The map, sourced from peer-reviewed forest carbon stock maps, are overlaid on maps of “available” arable lands to calculate the average stock.

Emissions from market leakage are determined using the module ‘Estimation of emissions from market effects’ (LK-ME). Market leakage only needs to be considered when the baseline scenario involves wood harvesting for commercial markets (timber, fuel wood, or charcoal).

For quantifying market leakage through decreased timber harvest, the leakage deduction depends on where harvesting is likely to be displaced to. If harvesting moves to a forest with a lower proportion of merchantable biomass compared to the project area, then more trees need to be cut, resulting in higher emissions. However, if the displaced area has a higher proportion of merchantable species, fewer trees will need to be harvested, leading to lower emissions. The leakage deduction thus depends on a comparison in the proportion of total biomass that is merchantable in the project area and in other areas (see Table 7). The module does not specify which other areas should be used for comparison. Projects that demonstrate that market leakage occurs only outside the country can set leakage to zero. If leakage management activities are carried out to minimize displacement of land use activities or if the leakage management area produces usable biomass, the market leakage deductions are further adjusted by a ‘leakage management adjustment factor’.

Table 7 Market leakage deduction factors

Deduction Factors for LFME	
PMLFT is equal ($\pm 15\%$) to PMP	LFME = 0.4
PMLFT is > 15% less than PMP	LFME = 0.7
PMLFT is > 15% greater than PMP	LFME = 0.2

Note: PML_{FT} corresponds to the mean merchantable biomass as a proportion of total aboveground tree biomass for each forest type. PMP corresponds to the merchantable biomass as a proportion of total aboveground tree biomass for the respective stratum within the project boundary.

Leakage effects from reduced fuelwood or charcoal production are determined in a similar way. In this case, a survey of households and assumptions on population growth are used to predict fuelwood and charcoal use in the baseline. A leakage factor of 0.4 is applied.

The methodology also includes a procedure to determine leakage emissions from any peatland drainage that may occur on lands which may be converted due to market leakage. Relevant areas are identified through remote sensing. The leakage emission factor is estimated based on of carbon contained in the peat.



Emissions from leakage prevention measures must be accounted for and included as emissions caused by project implementation if they result in substantial increases in emissions from carbon stock changes, biomass burning, and/or increased fertilizer usage. The project description should include detailed planned leakage mitigation measures, specify their location (demarcate leakage management zone), and identify areas where such measures affect carbon stocks. In these specific zones, the net carbon stock changes in above- and below-ground tree biomass expected to occur due to the implementation of planned leakage mitigation must be estimated using conservation growth projects. If the sum of carbon stock changes within the leakage management zones over the monitoring period is expected to be greater than zero, then the total increase can be ignored in the estimation of net GHG emission reduction. However, if the sum of carbon stocks is negative, the significance of GHG emissions must be tested using Appendix 1 of VM00048. The significance test must also be applied to biomass burning and fertilizer usage.

When emissions are determined to be significant, they must be monitored. However, the methodology specifically excludes any increase in emissions due to the combustion of fossil fuels from leakage prevention activities. The methodology states that CDM TOOL07 must be employed to estimate any significant increases in fertilizer use due to leakage prevention.

We identify the following potential sources of overestimation, underestimation or uncertainty with this approach:

- Un8 **Uncertainty in determining leakage emissions from geographically constraint agents:** The calculation of this leakage source involves many assumptions that are subject to large uncertainties. The possibly largest source of uncertainty is the estimate of baseline deforestation rates in the leakage belt. This data is determined and provided by Verra, following the same methodological approach as for the project area. As highlighted further above, there is large uncertainty in baseline deforestation rates that is not accounted for. This creates particularly large uncertainty for the quantification of leakage emissions from activity shifting of geographically constraint agents because the actual (unknown) changes in deforestation rates due to leakage from activity shifting are likely to be small in comparison to the baseline uncertainty, creating a signal-to-noise issue. Depending on the accuracy of the baseline deforestation estimates, leakage emissions could be very significantly over- or underestimated. This issue affects **all** projects. The impact on the overall uncertainty of emission reductions is, however, more limited because leakage from activity shifting is usually relatively small compared to overall emission reductions (see discussion of literature above). We estimate that this issue introduces a **low to medium** degree of uncertainty to the estimation of total credited emission reductions. The variability in the uncertainty among projects is estimated to be **high**.
- Un9 **Uncertainty in determining leakage emissions from activity shifting by geographically mobile agents:** The calculation of this leakage source also involves many assumptions that are subject to large uncertainties. Overall, in our assessment the resulting calculation may not well reflect the likely actual leakage rates, for various reasons. It is not clear why the proportion of land that is subject to conversion is based on the proportion of migration that is observed under the project (where deforestation is halted and migration into the project area may be strongly reduced), rather than the migration expected to occur in the baseline scenario. This assumption may contribute



to underestimating leakage effects. The methodology also seems to assume lands that are currently used for agriculture, such as grasslands, are available for conversion. However, conversion of lands used for cattle grazing to other agricultural use could cause a chain of other land management practices and conversions, ultimately leading to deforestation. This assumption may also contribute to underestimating leakage effects. We also note that this source of leakage may partially overlap with market leakage, depending on the type of deforestation agents. There is also considerable uncertainty in quantifying the emission factors from any land version as a result of activity shifting. This issue applies to **all** projects. The level of uncertainty and the variability among projects are **unknown**.

- OE15 **No accounting for market leakage due to agricultural activities.** The methodology requires market leakage deductions to be applied only when timber, fuelwood, or charcoal production are identified as deforestation drivers. This approach fails to consider other important market-driven deforestation drivers. Though large-scale commercial agriculture is not relevant for avoided unplanned deforestation activities, but rather planned avoided deforestation projects, illegal conversion of forest land by small-holders for agriculture is an important driver for deforestation in many areas. If such activities would occur in the baseline scenario but are prevented under the project, this could induce higher levels of agricultural production elsewhere and thus lead to deforestation. Limiting the consideration of market leakage to timber, fuelwood or charcoal production could thus lead to underestimation of the actual impact of market leakage and overestimation of total credited emission reductions. As it is not known for how many projects these other drivers such as agriculture are relevant, the number of projects affected by this issue is **unknown**. The degree of overestimation is difficult to estimate and therefore also considered **unknown**. The variability in the degree of overestimation among projects is deemed to be **high**, as the materiality of such leakage may strongly vary between projects.
- OE16 **Use of historical records and flexibility in determining baseline timber, charcoal and fuelwood production in market leakage calculations:** The quantification of market leakage strongly hinges on predictions on how much timber, charcoal and fuelwood would be produced in the baseline. The methodology allows project developers to use “timber harvest records and/or estimates derived from field measurements and/or assessments with aerial photography or satellite imagery”. The methodology thus allows using historical records to predict the future production of timber in the baseline scenario. For many avoided deforestation projects, however, historical deforestation rates prior to the implementation of the project are likely to be lower than deforestation rates assumed to occur in the baseline scenario after project start. This is because the methodology requires that the project area must “include only land qualifying as forest for a minimum of 10 years before the project start date” (section 5.1 of VM0048) and as the deforestation front is, in the baseline scenario, likely to encroach into the project area over time, increasing deforestation levels. Historical records of timber generation may thus underestimate future levels that would occur in the baseline scenario. Similar considerations hold for the determination of baseline quantities of fuelwood and charcoal. Here surveys among households and projections about population growth may be used. However, this data may not align with a baseline scenario where deforestation could be driven by production of fuelwood and



charcoal for other neighboring regions (and just for subsistence within the project area).

The assumptions in the methodology used for determining baseline deforestation (derived by Verra using jurisdictional activity data and risk maps) are thus inconsistent with the assumptions used for quantifying market leakage (derived by project developers based on historical records or surveys assuming only subsistence use of fuelwood or charcoal). Moreover, the methodology provides considerable flexibility to project developers in quantifying such levels. They may use several different data sources and the exact geographical area or period over which historical records are used is not defined. Moreover, satellite imagery may provide information on historical deforestation rates but does not provide information on the purposes for which wood may be used and over which distances it is transported. The approach thus provides considerably leeway to project developers to pick approaches that underestimate the baseline volume of timber, charcoal or fuelwood production for commercial purposes. This issue is likely to affect a **high** fraction of projects. Where this issue materializes, we estimate that it leads to a **low to medium** overestimation of total credited emission reductions (up to 30%). The variability in the degree of overestimation among projects is estimated to be **high**.

OE17 **Flexibility in choosing key parameters to determine market leakage:** The module VMD0011 offers project developers considerable flexibility to choose between different data sources for key data to determine leakage effects. For example, a key parameter affecting overall leakage deductions is the 'mean merchantable biomass as a proportion of total aboveground tree biomass for each forest type' (PML_{FT}). For this parameter, the module does not specify which region should be considered, potentially allowing project developers to select a geographical delineation that results in a higher factor (e.g., choosing between the country or a sub-national jurisdiction). Likewise, the methodology offers project developers multiple choices which data they may use, including peer-reviewed published sources, official government data and statistics or original field managements. Similar flexibility is provided to several other data in the calculation. This is likely to lead to an underestimation of leakage effects and overestimation of total credited emission reductions. This issue is estimated to apply to a **high** fraction of projects. The degree of overestimation is estimated to be **low to medium** (up to 30%). The variability in the degree of overestimation is estimated to be **high**.

Un10 **Uncertainty in market leakage deduction discount factors:** The deductions used to account for market leakage (20% to 70%) broadly correspond to the range of market leakage expected to occur according to the literature (see discussion further above). The degree of market leakage is however associated with considerable uncertainty. This uncertainty is not accounted for by the methodology choosing a conservative approach (e.g., by using default values that are on the side of overestimating leakage). This issue affects **all** projects. As the uncertainty of leakage emissions is high and as they can make up a significant share of the emission reductions, we estimate that this introduces **medium to high** uncertainty to the total credited emission reductions. The variability among projects is estimated to be **high**.



- OE18 **No accounting for international leakage:** The methodology does not account for any international leakage but limits the consideration of leakage to national boundaries. International leakage may, however, occur if projects are implemented nearby the borders of a country or if projects reduce the supply of commodities with globally interconnected markets (e.g., timber products). Even if these commodities are used within national boundaries, they could impact the level of imports or exports and thereby lead to international leakage. This risk is likely to be lower for avoided unplanned deforestation as compared to avoided planned deforestation. The number of projects affected by this issue is **unknown**. The degree of overestimation is **unknown**. The variability in the degree of overestimation among projects is estimated to be **high**.
- UE11 **No accounting of any negative leakage:** In principle, it is conceivable that avoided deforestation projects could also reduce deforestation outside the project area. This could occur if the measures taken to address deforestation drivers not only affect the project area but also surrounding areas. The methodology does not account for any such “negative” leakage effects; any decrease in deforestation observed in the leakage zone is not accounted for as a negative leakage term. This could potentially lead to underestimation of total credited emission reductions. The fraction of projects affected and the degree of underestimation are estimated to be **low**. The variability in the degree of underestimation among projects is likely to be **high**.

5.2.1.7 Summary and conclusion

Table 8 summarizes this assessment of the VCS Methodology VM0048. For each of the elements discussed above it summarizes the potential impact on the quantification of emission reductions or removals.



Table 8 Relevant elements of assessment and qualitative ratings

Element	Fraction of projects affected by this element ³³	Average degree of under- or overestimation where element materializes ³⁴	Variability among projects where element materializes ³⁵
Elements potentially overestimating emission reductions or removals			
OE1: Lack of clarity regarding which emissions sources and carbon pools must be considered	Unknown	Low	High
OE2: Determination of significance of emission sources allows project developers to choose among multiple methods	Unknown	Low	Unknown
OE3: Establishment of the jurisdictional baseline scenario	High	Unknown	High
OE4: Exclusion of areas with planned deforestation and	High	Low	Unknown

³³ This parameter refers to the likely fraction of individual projects (applying the same methodology) that are affected by this element, considering the potential portfolio of projects. “Low” indicates that the element is estimated to be relevant for less than one third of the projects, “Medium” for one to two thirds of the projects, “High” for more than two third of the projects, and “All” for all of the projects. “Unknown” indicates that no information on the likely fraction of projects affected is available.

³⁴ This parameter refers to the likely average degree / magnitude to which the element contributes to an over- or underestimation of the total emission reductions or removals for those projects for which this element materializes (i.e., the assessment shall not refer to average over- or underestimation resulting from all projects). “Low” indicates an estimated deviation of the calculated emission reductions or removals by less than 10% from the actual (unknown) emission reductions or removals, “Medium” refers to an estimated deviation of 10 to 30%, and high refers to an estimated deviation larger than 30%. “Unknown” indicates that it is likely that the element contributes to an over- or underestimation (e. g. overestimation of emission reductions in case of an omitted project emission source) but that no information is available on the degree / magnitude of over- or underestimation. Where relevant information is available, the degree of over- or underestimation resulting from the element may be expressed through a percentage range.

³⁵ This refers to the variability with respect to the element among those projects for which the element materializes. “Low” means that the variability of the relevant element among the projects is at most $\pm 10\%$ based on a 95% confidence interval. For example, an emission factor may be estimated to vary between values from 18 and 22 among projects, with 20 being the mean value. “Medium” refers to a variability of at most $\pm 30\%$, and “High” of more than $\pm 30\%$.



natural disturbances			
OE5: Possibility of gaming baseline validity periods	Low	Low to medium	High
OE6: The allocated baseline may be higher than a government baseline	Unknown	Unknown	Unknown
OE7: Selection of favourable project areas	Low	Low to medium	High
OE8: Ex-post determination of the project area	Unknown	Medium	High
OE9: Ex-post exclusion of project areas	Unknown	Unknown	High
OE10: Reshaping of project area at renewal of the crediting period	Unknown	Unknown	High
OE11: Overestimation of emission factors due to limited consideration of degradation	High	Unknown	High
OE12: Flexibility in choosing allometric equations	Unknown	Low to medium	High
OE13: Flexibility in determining belowground biomass	High	Low	High
OE14: Overestimation of the carbon fraction in biomass	High	Low	High
OE15: No accounting for market leakage due to agricultural activities	Unknown	Unknown	High
OE16: Use of historical records and flexibility in determining baseline timber, charcoal and fuelwood production in market leakage calculations	High	Low to Medium	High
OE17: Flexibility in choosing key parameters to determine market leakage	High	Low to medium	High
OE18: No accounting for	Unknown	Unknown	High



international leakage			
Elements potentially underestimating emission reductions or removals			
UE1: Soil carbon is identified as an optional source	Unknown	Low	Unknown
UE2: Litter is identified as an optional source	Unknown	Low	Unknown
UE3: Emissions of from biomass burning is identified as an optional source in the baseline	Unknown	Low	Unknown
UE4: Above ground non-tree biomass is optional to include in the project's forest carbon stocks	Unknown	Low	Unknown
UE5: Deadwood is an optional pool	Unknown	Low	Unknown
UE6: Methodology does not consider emissions from livestock	Unknown	Low	Unknown
UE7: N ₂ O emissions from the application of fertilizer are optional unless fertilizer use increases due to the project	Unknown	Low	Unknown
UE8: Discounting for uncertainty in historical deforestation data	Unknown	Medium	Unknown
UE9: Application of a discount for uncertainty in the carbon stock change estimates	All	Low	Unknown
UE10: Application of a discount for uncertainty in the project deforestation rates	Low	Low	Unknown
UE11: No accounting of any negative leakage	Low	Low	High
Elements with unknown impact			
Un1: Lack of clarity of definitions	All	Unknown	Unknown
Un2: Methodology does not require CO ₂ from the combustion of fossil	Unknown	Low	Unknown



fuels to be included			
Un3: Uncertainty in the forest cover benchmark map	All	High	Unknown
Un4: Uncertainty in the models used to establish the risk map	All	Unknown	Unknown
Un5: Potential overestimation of deforestation risk on the edge of natural disturbance	Unknown	Low	Unknown
Un6: Uncertainty due to lack of accounting for forest degradation	All	Unknown	Unknown
Un7: No minimum mapping unit	All	Unknown	Unknown
Un8: Uncertainty in determining leakage emissions from geographically constraint agents	All	Low to medium	High
Un9: Uncertainty in determining leakage emissions from activity shifting by geographically mobile agents	All	Unknown	Unknown
Un10: Uncertainty in market leakage deduction discount factors	All	Medium to high	High

The table shows that there are many potential sources of overestimation, underestimation, and uncertainty. Based on our assessment of the elements in the table, we conclude that the methodology is likely to lead to overestimation of emission reductions or removals and that the degree of overestimation is likely to be large (i.e., larger than 30%). This corresponds to a score of 1 according to the CCQI methodology (see page 2).

In our assessment, the new methodology VM0048 is a major improvement to the previous Verra methodologies but could still lead to significant overestimation of emission reductions. The most important improvement of VM0048 compared to the older VCS methodologies assessed by CCQI (VM0006, VM0007, VM0009, VM0015) is that baseline deforestation data is determined by Verra and allocated to projects. This eliminates the considerable flexibility that the older methodologies provided to project developers in establishing baseline deforestation rates. In this regard, VM0048 can be expected to considerably reduce the large overestimation of emission reductions that is likely to occur under the older methodologies. A further important



improvement is that the establishment of a jurisdictional baseline allows aligning project baselines with jurisdictional targets or crediting approaches.

Despite these significant improvements, we identify several integrity risks that could potentially have a significant impact:

- **Estimation of the jurisdictional baseline scenario:** While the use of average historical deforestation rates to establish the baseline scenario is common practice in jurisdictional approaches, this approach does not account for the large uncertainty in the jurisdictional baseline scenario and for potentially declining deforestation trends in a longer-time horizon. It could lead to large overestimation or underestimation of baseline emissions in individual jurisdictions and thereby undermine the integrity across a portfolio of projects (OE3).
- **Accounting for baseline uncertainty:** The methodology accounts for uncertainty more comprehensively than the older Verra methodologies. Nevertheless, some sources of baseline uncertainty are not accounted for, such as short-term changes in jurisdictional deforestation levels (OE3) or the uncertainty in the model to allocate deforestation risk within the jurisdiction (Un5). Unaccounted baseline uncertainty poses the risk that the calculated emission reductions could only be partially attributable to the project intervention and could partially be an artefact of wrongly set baselines. This risk can only be addressed if all sources of uncertainty in establishing the baseline scenario are accounted for and if projects have a strong and lasting impact on deforestation.
- **Risk of adverse selection:** Large baseline uncertainties paired with information asymmetry might also lead to adverse selection. There could be a risk that project proponents select project areas for which baselines are overestimated as they may have knowledge about the area, such as road or mining expansion plans, that is not graspable by the models used by Verra to predict deforestation risk (OE7). The methodology also allows projects to retroactively register areas in which past deforestation has been lower than estimated by Verra (OE8), or to exclude certain project areas after registration (OE9 and OE10). The extent to which these issues will lead to an overestimation of emission reductions is difficult to judge as the methodology has not yet been applied by projects.
- **Leakage accounting:** We identify several overestimation risks in the approach to account for leakage emissions. Data used to calculate market leakage is inconsistent with the data used to estimate baseline deforestation rates and the use of project-specific historical records or other data to establish market leakage rates raises the same type of issues that led to overestimation in baselines in the older Verra methodologies (OE16). International leakage is not accounted for though it could be a source of leakage in some contexts (OE18).
- **Quantification of carbon stocks:** We identify that outdated data (OE14) and flexibility for project developers to pick favourable values (OE12 and OE13) could lead to significant overestimation. Another source of potential overestimation is that the methodology determines carbon stocks at the start of each six-year baseline period and does not account for degradation that may occur during this period (OE11).

We recommend that the methodology improves clarity in various places, in particular by providing more guidance on forest definitions.



The methodology also has several elements that lead to underestimation. Most notably, the omission of some emission sources and carbon pools can lead to underestimation of emission reductions (UE1 to UE8). However, in most instances, such exclusions are optional and have a relatively low impact. Uncertainty discounts may also contribute to underestimation (UE9 to UE11). However, these are only applied in some instances. Therefore, in our assessment the risks for overestimation considerably exceed the potential sources of underestimation. In addition, some risks of overestimation have the potential to have a large impact. We note, however, that the degree of overestimation is likely to be considerably lower than with the older Verra methodologies. Future research on the application of the methodology will provide more clarity on the degree and frequency of the identified overestimation risks.

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