Should forest carbon credits be included in offsetting schemes such as CORSIA?

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Authors:
Thiago Chagas
Hilda Galt
Donna Lee
Till Neeff
Charlotte Streck

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1. Introduction

Companies are increasingly using carbon credits both for compliance and voluntary purposes. In particular, when using such credits to claim an offset, it is critical that the GHG unit being used has environmental integrity, i.e. that the activity generating the GHG unit is additional to business as usual and that measurement and accounting is robust. Because of this, a careful assessment is required when deciding what kinds of offsets should be eligible for a GHG mitigation Program.

Currently, a technical body of ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) is evaluating GHG Programs for eligibility under CORSIA. With this in mind, this paper seeks to fill a gap in analysis by providing an up-to-date comparison of the quality of forest-related GHG units against other types of units. The aim is to inform decision-makers on whether forest GHG units should be included in carbon markets such as CORSIA. The paper provides some initial views on the conditions under which such credits could be considered of equivalent quality to other units currently in compliance markets.

The paper focuses on several of CORSIA's Emissions Unit Criteria (EUC) as a framing for the analysis.[1] In particular, we focus on the criteria that influence the environmental integrity of GHG units: additionality, baseline setting, quantification of emission reductions (focused on uncertainty), permanence, and leakage. Other issues related to program design that are outlined in CORSIA's EUC, such as procedures for developing methodologies, verification rules, institutional learning and adjustment, abilities to file complaints, and conflict of interests among decision makers are not analyzed. The paper does not assess other social and environmental (e.g. biodiversity, soil, water) features which are commonly associated with certain forest carbon projects.

Historically, forest carbon credits have been kept out of several key carbon markets, such as the European Union's Emission Trading Scheme. However, much has been learned over the past decade with regard to generating forest carbon credits through experiences in the voluntary market. And, a new class of forest credits is also emerging: jurisdictional forest credits (see Box 1 for terminology used in this paper).

The report at times separates various forest-related activities that generate carbon credits—such as avoided deforestation, afforestation/reforestation and improved forest management. It also distinguishes projects from jurisdictional programs. It focuses on avoided deforestation given its high current volume in voluntary markets, as well as its preponderance in jurisdictional programs (as many countries currently only account for deforestation emissions). It also includes consideration of "nested" forest projects (see Box 1), given that nesting may address some project specific risks.

The report assesses several GHG Programs (see Box 1) that are applying to CORSIA for eligibility as a way to illustrate how forest GHG units compare to units from other sectors, or technologies. Two types of Programs were selected for analysis: (1) Programs that issue GHG units for multiple mitigation technologies and make up a large portion of current carbon markets (i.e. the Clean Development Mechanism (CDM), Verified Carbon Standard (VCS), and Gold Standard); and (2) Programs that are designed to generate jurisdictional forest GHG units (i.e. VCS Jurisdictional and Nested REDD+ (JNR) and the Forest Carbon Partnership Facility (FCPF) Carbon Fund (based on its Methodological Framework). The

[1] ICAO CORSIA Program Application Form, Appendix A. Supplementary Information for Assessment of Emissions Unit Programs. https://www.icao.int/environmental-protection/CORSIA/Documents/TAB/ Programme_Application_Form_Appendix_A_ Supplementary_Information_for_Assessment.pdf

Warsaw Framework for REDD (WFR) is also included, as it is the framework for REDD+ negotiated under the UN Framework Convention on Climate Change (UNFCCC) that, among others, provides guidance on how developing countries can measure, report and verify REDD+ performance. The WFR leaves space open for "results-based actions that may be eligible to appropriate market-based approaches that could be developed by the Conference of the Parties", but recognizes that such actions "may be subject to any further specific modalities for verification consistent with any relevant decision of the Conference of the Parties".[2] This suggests that further modalities for the verification of emission reductions from REDD+ activities may be needed in the context of market-based approaches. While the WFR differs from the other standards assessed in this paper in that it does not formulate a full set of carbon accounting rules, it serves as the basis for a CORSIA submission.[3]

Box 1 Terminology

Throughout the document, a "**GHG Program**" (upper case P) denotes a standard, initiative or scheme that issues GHG units that is evaluated by this study, either for projects or for programs. A "**project**" employs methodologies that have been specifically created at the scale of activities, usually implemented by private-sector players. By contrast a "**program**" (lower case P) denotes a mitigation activity at the sectoral level, such as large-scale REDD+ programs at national, subnational or jurisdictional scale. The term "**jurisdictional program**" is used to denote large-scale forest programs that are backed by specific carbon accounting rules. Throughout this paper, "**nesting**" refers to the integration of forest carbon projects into national or subnational REDD+ programs through harmonized GHG accounting rules.

The Paris Agreement has defined a framework for future carbon markets in its Article 6 (see Box 2). While the emerging guidelines for Article 6 may influence private and public carbon markets, this paper does not yet consider the impact of such guidelines or of Nationally Determined Contributions (NDCs) under the Paris Agreement for a number of reasons. First, Article 6 rules are still being negotiated and their final shape remains unclear. Second, NDCs today fall well short of the ambitious commitments needed to meet the Paris Agreement's temperature target, with national pledges not always set below conservative business as usual scenarios. When it comes to the generation and transfer of carbon credits, a weak NDC may be similar to no NDC at all. Third, there is currently no foreseen or expected centralized mechanism to evaluate the level of stringency of NDCs. Finally, most NDCs are limited in scope and/or do not adequately reflect land-use emissions.

The report is structured with Section 2 constituting the analytical core of the assessment. It is divided into five sections that assess the key elements that determine the quality of GHG units being issued. Each section starts with a brief definition of the assessed element, then a discussion of how each element relates to both forest and non-forest offset projects and programs, followed by a quick description of specific GHG Program requirements with regard to each element. In assessing GHG Programs, the report cites the criteria used by CORSIA to evaluate each element but may also include additional considerations that should be used when assessing whether a GHG Program is providing sufficient assurances that the GHG units issued have a high level of environmental integrity. Each section ends with an assessment of the specific element, including how well various programs mitigate the risks of that element. The Conclusion (Section 3) focuses on providing a cross-element analysis.

[2] Decision 14/CP.19, para 15

[3] Programs that applied to CORSIA can be found at: https://www.icao.int/environmental-protection/CORSIA/Pages/TAB.aspx The submission that is based on the Warsaw Framework is "REDD.plus".

Box 2. *Environmental integrity of carbon credits in the context of the Paris Agreement*

The Paris Agreement presents a new context in which the generation and transfer of GHG units may occur. Nearly all countries have put forward GHG mitigation pledges and the Paris Agreement envisions a periodic ratcheting-up process to make targets increasingly more ambitious and aligned with the goal of holding the increase in the global average temperature to well below 2°C above pre-industrial levels.

Article 6 of the Paris Agreement formulates a framework for cooperative approaches among countries, which can involve the transfer of "internationally transferable mitigation outcomes" or ITMOs – GHG units in the parlance of the Paris Agreement. There is currently substantial discussion on the implementation guidance of Article 6. Its rules are supposed to be finalized this year at COP 25, in Chile, and will frame how carbon markets should operate in this new context. A number of countries and experts demand that the generation of GHG units under the Paris Agreement should go beyond the business-as-usual and lead to an increased ambition in the implementation of NDCs.

Any international transfer of carbon credits (in line with Article 6.2 or issued as Article 6.4 units) will need to follow clear and robust double counting provisions in the form of corresponding adjustments, preventing two countries or entities claiming the benefit of the same emission reduction.

In absence of clear rules, weak targets and no mechanism to evaluate them, any compliance market should not rely on country NDCs to provide assurances that carbon credtis generated within the country are additional, mitigate leakage and reversals, or do not require a high level of accuracy in quantifying the emission reduction. Rather, GHG Programs should provide sufficient assurances of such characteristics to promote the integrity of carbon transactions.

2. Assessment of offsets against selected Emission Unit Criteria

a. Crediting baselines

A crediting baseline represents a benchmark level of emissions that a project or program needs to outperform in order to issue carbon credits. REDD+ national and jurisdictional programs refer to crediting baselines as reference levels or forest reference (emissions) levels. It is essential that baselines are not “inflated”, i.e. that they are set to avoid over-crediting activities and therefore compromise the environmental integrity of issued units.

Crediting baselines for different project/program types

Establishing crediting baselines is complex because it involves developing a counterfactual emissions trajectory, often understood to represent the **business as usual (BAU) scenario.** Crediting baselines for carbon projects and programs are developed using a variety of approaches, most notably:

(i) **activity-specific emissions trajectories** based on scenario analysis and modelling, which forecasts emissions based on assumptions regarding future developments;
(ii) **sectoral performance standards**, which benchmark emissions associated with a selected practice or technology; or
(iii) **historical average emissions,** as a proxy for business as usual; alternatively, trends based on historical average emissions or adjustments made to historical average emissions (e.g. taking into account planned infrastructure or land concessions).

Activity-specific emissions trajectories can be determined via different types of analysis (see Table 1). Scenario analysis helps evaluate the expected drivers of emissions and consider several plausible options of what might happen to these in absence of a mitigation intervention. Scenario analysis can be used, for instance, to determine the baseline in a landfill project. If flaring of methane from solid waste is not required by domestic regulation, a scenario in which the landfill continues without proper collection of methane can be used to set the baseline. Scenario analysis in avoided deforestation projects is often determined by assessing a reference area with similar drivers and applying the historical deforestation seen there to the project accounting area. The baseline scenario can also include the implementation of infrastructure projects such as roads or agricultural policies that lead to increased deforestation, in which case more complex modelling may be needed.[4] Other forest project types determine the baseline differently—for example, reforestation projects often consider historical land use and/or assumptions of how much planting would occur in the absence of the project.

A **sectoral performance standard** is a standardized baseline based on benchmark levels that activities are expected to outperform in order to achieve emission reductions. This approach is particularly suitable where activities and products are homogenous and robust data are available, such as for energy-intensive industries like the steel and cement sectors.[5] If performance standards rely on the ‘topmost percentile’ performing technologies in a country and are updated regularly, they are considered to be more conservative than activity-specific business-as-usual emissions trajectories. Baselines based on sectoral performance should be updated regularly, in particular in fast-changing sectors and subsectors (e.g.

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[4] There is a trade-off with the use of complex modeling approaches, which become difficult for validators to audit and therefore become an opportunity for project developers to game baselines; it may be that simpler, conservative approaches are more optimal in such cases.
[5] Partnership for Market Readiness (2017). A Guide to Greenhouse Gas Benchmarking for Climate Policy Instruments. Technical Note 14, April 2017.

efficient lighting).[6] Ranking technologies for performance standard baselines also requires gathering considerable amounts of verifiable data, which is difficult in some developing country contexts where data may be incomplete, lost or simply non-existent.

Jurisdictional REDD+ programs mostly develop crediting levels based on **historical data**. Such programs are qualitatively different from projects as they look at performance for an entire sector over very large areas, making it impossible to attribute emissions (or removals) to specific activities.[7] For this reason, some GHG Programs (e.g. the FCPF Carbon Fund) focus on historical average emissions as a proxy to predict business-as-usual, or simply as a conservative crediting level if it is a requirement of the GHG Program. Other programs (e.g. VCS JNR) may allow historical *trends,* projecting historical data into the future (e.g. using a linear projection) to determine the baseline. In other cases, "adjustments" to historical average data is permitted, such as for planned deforestation from infrastructure / concessions. Adjustments are also sometimes allowed in the case of 'high forest low deforestation' (HFLD) regions under the assumption that these regions face forest loss even though historically deforestation has been low. Data show that for most developing countries a historical average reference level tends to be conservative, as in many cases deforestation is increasing; however, where deforestation is slowing the opposite is true.[8]

Table 1 Example baseline establishment approaches for different project types

Project or program type	Approach for baseline setting	Baseline scenario	Sources of uncertainty
Fuel efficient cookstoves	Analysis of historical data	Use of charcoal or wood fuel in a three-stone fire or another inefficient stove	Amount and type of fuel used in the baseline; fraction of biomass that can be considered non-renewable
New grid-connected fossil fuel fired power plants using a less GHG intensive technology	Sectoral performance standard	New power generation technologies using the same fossil fuel category as the project activity	Characteristics of baseline fossil fuel power plants (e.g. base load, fossil fuel use, size of the facility)
Avoided deforestation project	Activity-specific emissions trajectory	Deforestation in a "reference area" similar in characteristics to the project area	How well the reference area estimates future BAU of the project accounting area.
Switching from conventional to reduced impact logging	Activity-specific emissions trajectory (using a scenario analysis and models for expected logging damages)	Forest management using conventional logging techniques and its expected damages (which are higher than for reduced impact logging)	Reliability of the scenario analysis for establishing conventional versus reduced impact logging
Afforestation / Reforestation	Activity-specific emissions trajectory	No tree planting or other activities	Reliability of the scenario analysis for establishing the BAU scenario
Jurisdictional REDD+ program accounting for deforestation emissions	Analysis of historical data (either average historical value or trend, e.g. linear extrapolation)	Current polices and measures (or lack thereof) to protect forests	Data availability, justification of upward adjustments of the reference level (baseline)

[6] One downside to regularly updating benchmarks based on top performance arises in situations where industry giants own a large number of facilities worldwide. These industrial owners may become hesitant to upgrade their facilities with very low emissions technologies if this would affect the baselines for all of their other facilities (for which they earn carbon credits).
[7] For example, Carbon Fund Emission Reduction programs range from 1.6 to 35 million hectares.
[8] Personal communication with Marieke Sandker, Food and Agriculture Organization.

Approaches to baseline setting by various GHG Programs

For CORSIA, carbon offset credits must be based on a defensible, conservative baseline estimation of emissions. CORSIA's EUC also require that GHG Programs have procedures in place for making baseline revisions to account for changing baseline conditions that were not expected at the time of registration.

GHG Programs typically, as suggested by the EUC, try to employ both conservativeness and periodic updates to promote environmental integrity of baselines (Table 2 summarizes various ways in which specific GHG Programs try to promote credible baselines). They also sometimes create prescriptive rules to avoid gaming.

Require conservativeness. This is an approach that disadvantages the project or program through requiring that lower emission reductions are claimed than would likely have occurred in reality. Conservativeness can be applied to either the baseline setting or in the estimation of GHGs. For example, as mentioned above, in countries where deforestation is rising, setting the jurisdictional baseline as the average historical level of emissions over a reference period is conservative. The FCPF Carbon Fund follows this approach, but allows certain countries the ability to adjust baseline emissions above the historical average, capped at 0.1% of carbon stocks per year.[9] Whether this cap is conservative depends entirely on the country, the magnitude of its carbon stocks and the growth in its deforestation trends. It is also conservative when VCS methodologies for tree planting projects only account for carbon gains in living biomass of trees and exclude carbon gains through accumulating carbon litter and deadwood. Equally, it is conservative when the usage duration of energy efficient lighting is set at a default level lower that the actual average utilization. Another example can be drawn from the CDM standardized baseline tool, which requires that baselines are set in line with the top 20% best performing facilities, resulting in emission reductions being credited against the lowest GHG-emitting technologies present in the country.[10]

However, choosing historical average emissions as the reference level (i.e. baseline) in jurisdictional REDD+ programs is clearly not conservative in countries where deforestation rates and associated GHG emissions are expected to fall. Because of this, the FCPF Carbon Fund includes a requirement to downwardly adjust the reference level in case of falling emission trends. The Warsaw Framework does not include any rules regarding projection approaches and to date no country has proposed a downward adjustment below historical averages. It has been debated whether in some countries deforestation rates are in reality already falling, such that the use of the historical average inflates their crediting baseline.

Some CDM methodologies also require adjusting baseline values to account for uncertainty and ensure conservativeness.[11] For example, the default emission factor for the amount of nitrous oxide produced per ton of nitric acid is conservative, as are the default baseline values applied in HFC-23 projects. One study estimated that only 30-40% of HFC-23 abatement is actually credited under the CDM, resulting in

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[9] The Carbon Fund Methodological Framework makes this exception for "high forest cover, low deforestation" (HFLD) countries; it does not prescribe a threshold for how a country may qualify as HFLD.

[10] CDM-EB66-A49-GUID. Quality assurance and quality control of data used in the establishment of standardized baselines. Version 2.0; CDM-EB77-A05-STAN. Determining coverage of data and validity of standardized baselines. Version 2.0

[11] For example, ACM0002 (version 19) requires that historical electricity generation from retrofitted, rehabilitated or replaced renewable energy power plants is adjusted according to its standard deviation. This is a conservative approach since power generation from renewables can vary significantly from year to year, and the use of a few historical years to establish the baseline electricity generation can therefore involve significant uncertainty. Another example is ACM0007 (version 06.1.0), which requires that the total amount of energy supplied to the grid in the baseline is adjusted by applying a discount factor to account for future energy efficiency improvements in power generation.

significant net benefit to the atmosphere from this project type.[12] Another example is the fraction of non-renewable biomass (fNRB) value applied in clean cooking projects. This value seeks to determine the portion of fuelwood that is extracted beyond the ability of a forest to regenerate itself, thereby leading to forest loss or degradation.[13] The CDM Executive Board has approved a conservative global default value of 30% fNRB, down from an average at 87% fNRB approved by host countries.[14,15]

Require periodic updates. Limiting the period over which a baseline is valid ensures that crediting of emission reductions is carried out against the current baseline emissions. For example, projects that have renewable crediting periods are required to update their baselines every seven years (under the CDM and VCS), or every five years (under the Gold Standard).[16] The CDM also requires periodic updates to standardized baselines by limiting the validity of standardized baselines to three years. VCS forest projects require a reassessment and revalidation of the baseline every 10 years, with the justification that "changes beyond a 10-year period are not likely to be realistic because rates of land-use and/or land management practices are subject to many factors that are difficult to predict over the long term".[17] Changes to the baseline must capture changes in drivers or change agents, use of the latest version of the methodology, and an updated project description.

Among the GHG Programs for jurisdictional REDD+ that we assessed, only VCS JNR has clear rules for baseline revisions (between 5 to 10 years, after which the baseline must be updated and revalidated). The FCPF Carbon Fund does not have such rules due to its short time horizon (i.e. the GHG Program is set to end in 2026, so is only crediting for a short period of time over which the initial baseline remains valid). The Warsaw Framework suggests that countries should update forest reference levels "periodically as appropriate, taking into account new knowledge, new trends and any modification of scope and methodologies", but provides no further guidance beyond this.[18]

Prescriptive rules to reduce 'gaming' of baselines. Although it is clear that baseline establishment is to draw on a combination of analyzing historical data, modeling expected trends and benchmarking against performance standards, there is considerable scope for cherry-picking data to maximize the baseline. Some GHG Programs develop default values or guidelines to minimize the risk of gaming baselines. The CDM, VCS and Gold Standard have integrated a number of conservative default values into their accounting methodologies to mitigate this risk.

Jurisdictional forest reference levels calculated as historical average emissions are sensitive to the choice of the reference period.[19] The FCPF Carbon Fund therefore requires countries to set a reference period of "about 10 years" that can only be extended with "convincing justification".[20] Similarly, VCS JNR programs set either a historical average baseline of 8 to 12 years or, if using a trend, it must be based on historical data of land use change for at least 10 years prior to the crediting period. In both cases, the start of the

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[12] Schneider, L. and Cames, M. (2014) Options for continuing GHG abatement from CDM and JI industrial gas projects. Oeko Institut, Berlin.
[13] CDM. Methodological tool 30: Calculation of the fraction of non-renewable biomass (version 02.0)
[14] Projects are still permitted to estimate project-specific values if they wish to. CDM. Methodological tool 30: Calculation of the fraction of non-renewable biomass (version 02.0)
[15] UNFCCC (no date) Default values of fraction of non-renewable biomass. Available at https://cdm.unfccc.int/DNA/fNRB/index.html
[16] Under the CDM, there is an option to also update after 10 years for one non-renewable crediting period.
[17] VCS AFOLU Requirements, para 3.1.10.
[18] UNFCCC, Decision 12/CP.17, paragraph 12.
[19] Mertz et al (2018). Uncertainty in establishing forest reference levels and predicting future forest-based carbon stocks for REDD+, Journal of Land Use Science, 13:1-2, 1-15, DOI: 10.1080/1747423X.2017.1410242
[20] FCPF Carbon Fund Methodological Framework, criterion 11.

crediting period is when new laws or policies were enacted and/or concrete GHG mitigation activities implemented and the "historical period chosen must be conservative and adequately justified".[21]

The Warsaw Framework does not provide any parameters around the reference period—and countries have submitted reference levels based on historical periods that span 8 to 22 years. For example, Brazil's forest reference level submitted to the UNFCCC, while revised every 5 years, continuously returns back to 1995 (i.e. extends the historical period with each new baseline), thereby always capturing a high deforestation period in the early 2000s.

In the case of avoided deforestation projects, the choice of a benchmark reference area for observing an assumed business-as-usual deforestation for the project accounting area may be gerrymandered by selecting high deforestation zones. Prescribing that projects "nest" within a jurisdictional reference level can reduce the ability to inflate baseline emissions. This is the case if nesting in the given jurisdiction requires that, in aggregate, project-level baseline emissions do not exceed (and take only a reasonable share of) the value of a well-constructed BAU jurisdictional reference level. In some cases, it has been shown that the aggregation of avoided deforestation project baselines within a jurisdiction is unrealistically high when compared to a jurisdictional baseline, suggesting that some projects have likely inflated their expected deforestation rate.[22] It is worth noting that the latest thinking on nesting of avoided deforestation projects involves allocating a jurisdictional crediting baseline down to project scales, while apportioning emissions according to deforestation pressure. Other options for nesting are also possible—and how to "nest" projects into jurisdictional schemes remains an emerging field.

Table 2: Examples of how GHG Programs approach baseline setting

GHG Program	Project/ program type	Approaches for baseline setting	Strategies for achieving conservative baselines	Baseline revision
CDM	Renewable energy generation and energy efficiency	Scenario analysis; sectoral standardized benchmarks	Applies conservative default values Where standardized baselines are applied, only the 20% of top-performing technologies are used to define the baseline	Required at the renewal of each crediting period every 7 years. Standardized baselines to be updated every 3 years
Gold Standard	As above	As above	As above	Required every 5 years
VCS (non-forest)	As above	As above	As above	Required at renewal of crediting period every 10 years
VCS	Avoided deforestation projects	Comparison to a reference region or modelling	Current methodologies sometimes do not lead to conservative baselines; for CORSIA, however, avoided deforestation project are expected to "nest" into jurisdictional reference levels, which should result in more conservative baselines	Reassessed and revalidated after a 10-year period
VCS JNR	Jurisdictional REDD+	Average historical baseline or historical trend	If no UNFCCC reference level submitted, the program is required to develop several baseline scenarios and select the most plausible or the more conservative option; the current provision of using an	The baseline is fixed for 5 to 10 years, after which the baseline must be updated and revalidated

[21] JNR Requirements v3.4, paragraph 3.11.12. Paragraph 3.11.13 (1) also allows programs to use a baseline "accepted and approved under the UNFCCC for the purposes of generating GHG emission reductions for market-based mechanisms"; since such baselines have not been agreed in the UNFCCC, we do not cover this instance.
[22] Authors' own observation from analyses conducted for several Latin American and Sub-Saharan African countries.

			8 to 12 years reference period will result in a conservative baseline for most countries (if using a historical average where deforestation is rising)	
FCPF Carbon Fund	National / subnational REDD+	Historical average for all programs, except "high forest cover, low deforestation" (HFLD) regions	The use of 10 year historical average baselines will be conservative for most countries (where deforestation is rising). HFLD programs can increase emissions above the historical average by up to 0.1% of carbon stocks in the forest, which may not be conservative	No guidance provided since the FCPF Carbon Fund has a limited period of operations to 2026
Warsaw Framework	National / subnational REDD+	No guidance provided on how to set the reference level	Historical data taken into account and, if adjusted from historical data, information must be provided on the "national circumstances" to justify the adjustment; these assumptions cannot be questioned during the technical assessment of the reference level.	No guidance provided; countries may decide voluntarily when they wish to revise the forest reference level

Conclusions

For many types of mitigation activities, setting reliable baselines is the most important factor in generating robust GHG units, and is also the most challenging task. It often involves assuming a counterfactual business-as-usual scenario that requires making assumptions about future trends (which can be unknown). This is true for both forest and non-forest projects and programs.

Basing emissions trajectories on scenario analysis and modelling is extremely challenging. Forecasting emissions trajectories into the future is difficult and hugely uncertain. Scenario analysis will need to answer questions such as 'how will deforestation rates develop over the next years?' Since uncertainties in such projections can be significant, there is a risk of inflated baselines and thus over crediting a project with emission reductions that perhaps did not occur.

In the case of forest project baselines, **setting avoided deforestation baselines is more challenging than setting baselines for other forest project types**. Deforestation is the result of complex socio-economic dynamics. The drivers of deforestation and pressures on forests are hard to predict and often come from outside the accounting area. Therefore, developing a counterfactual baseline scenario tends to be more challenging than for projects in other sectors. The use of a reference area to model what would occur in a project accounting area has – in some cases – led to projects selecting regions of very high deforestation that may, or may not, reflect well future deforestation risk. The "nesting" of avoided deforestation projects into a jurisdictional baseline, in particular ensuring that project baselines in aggregate are a reasonable share of the higher-level baseline, can mitigate the risks of baseline inflation.

Setting sectoral performance standards for entire sectors can reduce the risk of over-crediting. This is particularly true if sectoral baselines are set conservatively, as done in industrial gas projects or for REDD+ programs when historical averages are used in contexts of clearly rising deforestation. A centrally-determined, top-down benchmark then replaces project-level baseline establishment. The benchmark can either be used by jurisdictional / sectoral programs or to determine stand-alone project baselines.[23] Setting a sectoral performance standard, or a jurisdictional baseline under which a project must nest, can

[23] Noting that, for avoided deforestation projects, the jurisdictional baseline would not be directly applied to projects, but rather allocated based on risk.

remove the incentive by projects to overstate the baseline. This is the case for forest crediting, as well as other sectors—for example, the use of well-established grid emission factors in the energy sector.

There is a tradeoff when setting prescriptive rules for jurisdictional baselines. Determining a sectoral performance standard or jurisdictional reference level has its own complexities and much care needs to be taken to avoid overestimating the baseline emissions. More rigid calculation rules tend to restrict the ability to 'game' the baseline. It may also result in reduced accuracy, although this may be justified by the increased likelihood of baselines being conservative. For example, the FCPF Carbon Fund has more prescriptive rules compared to the Warsaw Framework, and has generally resulted in more conservative baselines.

GHG Programs that account for jurisdictional forest carbon performance vary in their stringency. The FCPF Carbon Fund's methodological framework requires using historical averages of at least 10 years even in countries with clearly rising deforestation. However, it allows countries with high forest cover and low deforestation rates to increase the baseline by up to 0.1% of carbon stock, which may not be conservative. VCS JNR suggests a reference period of 8 to 12 years, but allows the use of historical trends, even if these increase, but only if justified. And the Warsaw Framework provides little guidance to countries on how to set a crediting baseline, resulting in high variability in forest reference level submissions—from average historical approaches (to date, covering periods that range from 8 to 22 years) to a variety of projection approaches.

Most non-forest methodologies within GHG Programs meet CORSIA's requirements regarding conservative baseline estimation. CORSIA's EUC require that GHG Programs have procedures in place to ensure that methods of developing baselines use assumptions, methodologies, and values that do not over-estimate mitigation from an activity. The CDM, VCS and Gold Standard overall all integrate conservative default baseline values into non-forest project methodologies, and the CDM requires standardized baselines to be based on the top performing technologies in a country.

Most GHG Programs meet CORSIA's requirements regarding baseline revision. The CDM, VCS, VCS JNR and Gold Standard all require that baselines are revised, although differ in the allowable intervals between baseline revisions. The FCPF Carbon Fund does not require baseline revision, but this is due to the duration of the Fund as whole being limited only to 2026. The Warsaw Framework, however, does not have requirements for baseline revision instead allowing countries to decide when they wish to revise the forest reference level.

b. Additionality

The concept of additionality is a recurrent issue in discussions of international and domestic emission trading and carbon pricing schemes. Fundamentally, additionality refers to the requirement that emission reductions or removals would not have happened in the absence of a mitigation project or program. GHG units for non-additional emission reductions or removals, when used for offsetting purposes, lead to an increase in global GHG emissions. This is due to the fact that acquired offsets are used to compensate for emissions, rather than the buying entity reducing its own emissions. Because of this, over the last decades permitted approaches to demonstrating additionality of GHG reductions have grown increasingly restrictive.[24]

Additionality for various project/program types

Determining additionality is essential to safeguarding the environmental integrity of a GHG unit. Any additionality test is closely linked to the baseline setting. A conservative baseline should be able to capture non-additional emission reductions and removals. While this logic applies to jurisdictional and sectoral programs, most programs require the passing of a project-specific additionality test that confirms that the project would not have been realized in the absence of carbon finance.

Typically, demonstrating project-level (in both forestry and non-forestry sectors) additionality requires demonstrating that the activity faces barriers that would prevent it from otherwise going ahead—for example, that the project activity is not already required by law, is not financially viable without income from the offsets, or common practice. Some GHG Programs also employ positive lists, which define certain technologies that are considered automatically additional without requiring further demonstration of additionality from the project developer. Positive lists significantly simplify the demonstration of additionality. Programs also formulate negative lists when certain project classes are not any longer considered additional. The basic elements of these project-level additionality tests are as follows:

- **Prior consideration** requires projects to demonstrate that the decision to pursue carbon certification occurred within six months of the start of the project, and therefore serves to corroborate the additionality argumentation. It is not, on its own, sufficient evidence of additionality though.
- **Investment analysis** requires that project proponents demonstrate that the proposed project activity is economically less attractive than realistic alternatives or a financial benchmark. Because forest protection in many tropical countries is weak, budgets for forest protection are largely absent, and economic incentives for deforestation abound, many avoided deforestation projects are able to demonstrate investment additionality.
- **Common practice analysis** determines that if a project is common practice, it is not considered additional. For example, certain renewable energy projects in richer and middle-income countries have become common practice in the last decade.
- **Barrier analysis** requires projects to demonstrate that certain barriers prevent the project from being implemented. For example, technological barriers such as lack of natural gas transmission and distribution networks; or a high risk of technological failure in the absence of skilled local labour to operate, maintain and repair the technology. Generally, additionality requires going beyond existing legal requirements. In the land-use sector, however, lack of enforcement capacity is an

[24] A. Michaelowa (2009): Interpreting the additionality of CDM projects: Changes in additionality definitions and regulatory practices over time, in: D. Freestone, C. Streck (eds.): Legal aspects of carbon trading, Oxford University Press, Oxford, p. 248-271

implementation barrier that forest carbon investments can help to overcome, for example, by helping to safeguard protected areas.

- **Positive lists** superceed the above requirements (i.e. if the project's technology is on the 'positive list', the project does not need to demonstrate additionality via the above options). The technologies that are included in the positive lists are deteremined by the GHG Program, and tend to define not only specific technologies but also their required scale or geographical location to be considered automatically additional.

Conversely, sectoral or jurisdictional (REDD+) programs are considered additional simply if they **outperform the reference emission level** (i.e., the baseline) – although some GHG Programs also require jurisdictional programs to show deliberate policies, measures or action were taken. When generating GHG units at the jurisdictional level, it would not make sense to propose project-style additionality testing since such programs often include a multitude of specific actions across a landscape that includes public policy interventions, private sector engagement, and community-scale interventions. Linking the additionality tests to existing legal or policy requirements would also create perverse incentives for governments, which risk losing eligibility to generate GHG units if they adopt strict mitigation policies. However, it can also be problematic to simply consider any outperformance of a crediting baseline additional because emissions also respond to market trends, to climate patterns, to demography and many other factors that are not linked to deliberate climate policies. Because of this, some REDD+ Programs include requirements that strengthen confidence that emission reductions are the result of new policies or actions rather than merely incidental.

Furthermore, if the jurisdictional reference level is stringent, the risk of non-additionality is lessened for "nested"[25] projects or programs that issue carbon credits (see previous section on baselines). Conversely, where confidence in jurisdictional baselines is lacking, the additionality of nested projects or programs may also be questionable without applying tests to assess additionality. Similarly, under Article 6 of the Paris Agreement, discussions are on-going on whether additionality could potentially also be implied for Article 6 activities if and when these are are covered by an ambitious and stringent NDC (see Box 3).

Box 3: Additionality under the Paris Agreement [26]

Discussions on possible new nuances of additionality are currently taking place in the context of cooperative approaches under Article 6 of the Paris Agreement. According to some experts and negotiators, additional mitigation action may need to go beyond unconditional NDC pledges of the host country, rather than simply being beyond business-as-usual. Where NDCs (and national baselines) are deemed stringent enough, project-specific additionality tests could be waived as the host country has an intrinsic incentive to ensure that only real and additional emission reductions are exported or used domestically as offsets.

Conversely, where NDCs are not ambitious (or where activities are outside the scope of the NDC), additionality testing is necessary to prevent international transfer of hot-air or non-quality offsets.[27] However, there is currently no (foreseen or expected) centralized review system to evaluate the

[25] In this instance, "nesting" refers to the case where project baselines in aggregate comprise a reasonable share of the jurisdictional reference level.
[26] For detailed discussions, see A. Michaelowa et al (2019): Additionality revisited: guarding the integrity of market mechanisms under the Paris Agreement, in: Climate Policy, DOI: 10.1080/14693062.2019.1628695.
[27] R. Spalding-Fecher et al. (2017) Environmental integrity and additionality in the new context of the Paris Agreement crediting mechanisms. Carbon Limits AS, Stockholm Environment Institute-US Center and INRAS

stringency of NDCs proposed by countries. In the absence of such centralized system, a dedicated additionality determination would probably still be required for all activities and emission reductions.[28]

To the extent that REDD+ is eventually allowed under Article 6, the same analysis could be used for REDD+ activities covered by the NDC of the host country. Where the NDC, Land Use, Land-use Change and Forestry (LULUCF) and REDD+ reference levels (baselines) are stringent and aligned, forest projects and programs that are embedded ("nested") into national scale accounting would not require a specific additionality test to ensure environmental integrity. Conversely, where these are not aligned and/or are not deemed stringent enough, the absence of an additionality determination of the program or activity could risk allowing the transfer of low-quality offsets.

Table 3 provides a number of mitigation project types and describes considerations influencing the assessment of their additionality.

Table 3: Examples for mitigation project additionality

Project type	Baseline	Type of activities	Additionality risks
Renewable energy power generation	Fossil-fuel based power generation	Hydro, wind, geothermal, wave, tidal	In many countries, financial, technological and political barriers for certain renewable energy sources have disappeared or been reduced significantly. Demonstrating additionality will be challenging in these circumstances.
Energy efficiency (efficient lighting)	The use of incandescent bulbs would remain widespread	Programmatic activities replacing incandescent bulbs with more efficient lighting alternatives	Some countries already have policies in place to promote efficient lighting, putting the automatic additionality of efficient lighting in question in these contexts[29]
Improved forest management project	Conventional logging	Reduced impact logging as part of sustainable forest management	Practices may be financially attractive and/or common practice in the region.
Reforestation project	Low intensity farmland	Establishment of fast-growing species to supply a close-by paper mill	Establishing feedstock for a paper mill may be financially attractive compared to low intensity agriculture.
Avoided deforestation program	A variety of deforestation drivers	Strengthening law enforcement, alternative livelihood options, others	Whether observed deforestation reduction is actually due to the government intervention or whether it simply reflects other trends or impacts from external factors (e.g. commodity prices).

Treatment of additionality by GHG Programs

CORSIA requires GHG Programs to have in place analyses or tests to demonstrate that credited mitigation is additional, on the basis of one or more methods, such as barrier or investment analyses, common practice, performance standards or benchmarks, or legal or regulatory analyses. If GHG Programs use other procedures, CORSIA requires additional evaluation by an expert body to make a recommendation regarding the sufficiency of the approach prior to any final determination of the program's additionality.[30]

With regards to GHG Programs that generate offsets at the project level (whether forestry or non-forestry), all such Programs essentially follow or build-on the step-wise additionality tool used by the

[28] A. Michaelowa et al. (2019) Additionality revisited: guarding the integrity of market mechanisms under the Paris Agreement. Climate Policy.
[29] See M. Cames et al (2016) How additional is the Clean Development Mechanism? Öko-Institut, SEI and Carbon Limits.
[30] Additional evaluation may be done by ICAO's Global Market-based Mechanism Technical Task Force (GMTF) or another expert body.

CDM. The *Tool for the demonstration and assessment of additionality* was first published in 2004 and refined several times over the years.[31] It requires that projects demonstrate additionality through a combination of: prior consideration; investment analysis; common practice analysis; and/or barrier analysis. A process for developing standardized baselines has also been established under the CDM as a means to streamline baseline development and additionality assessment; and a separate tool to demonstrate additionality in the case of first-of-its-kind technologies has also been approved.[32]

More nuanced additionality tools exist for CDM afforestation and reforestation activities and for VCS agriculture, forestry and other land-use (AFOLU) activities.[33] For instance, for VCS Improved Forest Management projects on State land subject to indigenous rights and title, extra steps are added to the additionality tool.

Demonstrating additionality via investment analysis can be problematic, especially for those project types that generate revenues from sources other than selling carbon credits. First, there is a considerable degree of judgment and subjectivity in assessing the financial returns of a project. Also, under the CDM, projects and programs did not have to consider new mitigation policies that provide financial support in their investment test for additionality.[34] The issue was widely discussed in 2009 when the CDM Executive Board assessed Chinese wind farm projects and their profitability vis-a-vis China's national wind-power tariff rates.[35] But public subsidies are not the only difficulty in proving additionality. Carbon projects in sectors that are able to attract private finance are also challenged to demonstrate additionality. For example, where tree plantations are established as part of well-established and profitable value chains (e.g., for production of pig-iron or pulp), proving additionality can be hard.

Where projects generate no revenues other than through selling carbon credits, the investment analysis will generate clear results. This is the case for industrial gas projects where industrial processes need modification, for example in phasing out HFC-23 generation in adipic and nitric acid production. Such modifications have a moderate cost and would not be undertaken in absence of carbon finance. Similarly, obtaining finance for forest conservation remains difficult and therefore carbon finance is essential. Equally, tree planting for protective purposes and without a strong linkage into timber markets will not usually generate revenues and may therefore often be seen as additional.[36]

The analysis of common practice can also be problematic if technologies become common practice faster than originally envisaged. For instance, the additionality of small-scale solar photovoltaic projects, which are considered automatically additional through the CDM’s positive list, can be questioned due to the rapid cost reduction of the technology in some regions. A project may be additional at the time of registration, but due to rapid technological growth and national policy change may have trouble demonstrating that it is still additional in subsequent years. Projects are not, however, required to re-

[31] CDM, Tool for the demonstration and assessment of additionality (version 7.0.0) EB 70, Annex 08

[32] CDM, Combined tool to identify the baseline scenario and demonstrate additionality (version 7.0), EB 96, Annex 03; CDM, Additionality of first-of-its-kind project activities (version 3), EB 84 Annex 6

[33] See A/R Methodological tool “Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities” (Version 01); and VT0001 Tool for the demonstration and assessment of additionality in VCS agriculture, forestry and other land use (AFOLU) project activities version 3.0. February 2012.

[34] A. Michaelowa et al (2019): Additionality revisited: guarding the integrity of market mechanisms under the Paris Agreement, in: Climate Policy, DOI: 10.1080/14693062.2019.1628695

[35] C. Tang & A. Wood, (2009). *Chinese Wind Farm Projects Rejected by UN.* Retrieved August 1, 2019, from https://bit.ly/334hFMH

[36] M. Purdon & R. Lokina (2014) Ex-post evaluation of the additionality of Clean Development Mechanism Afforestation Projects in Tanzania, Uganda and Moldova. Available at https://www.oecd.org/env/cc/2956438.pdf / https://www.cccep.ac.uk/wp-content/uploads/2015/10/WP149-Ex-post-evaluation-of-Clean-Development-Mechanism-Afforestation-projects.pdf

demonstrate additionality after registration as this would be prohibitively expensive and complex. Instead, GHG Programs limit the time period over which carbon credits can be issued to fixed crediting periods, or require that baselines are reassessed periodically.

The CDM was also the first GHG Program to employ positive lists in an effort to reduce transaction costs and obstacles to participation for certain groups of countries and types of projects. The concept of automatic additionality through positive lists emerged to ease approval of micro-scale renewable energy and energy efficiency activities (e.g. household-level technologies) in least developed and special under-developed zones of countries.[37] The positive list was later expanded to small-scale project categories, including renewable energy projects below a certain size, agricultural irrigation, landfill gas recovery and methane recovery in wastewater treatment.[38] Positive lists have since also been published by the VCS and Gold Standard.[39] The CDM, VCS and Gold Standard also all define ineligible project types. The VCS, for example, now excludes all renewable energy projects that are not located in Least Developed Countries in a 'negative list'; with the Gold Standard considering a similar arrangement.[40] This means that these projects are considered a priori as non-additional.

With regard to GHG Programs that generate jurisdictional forest carbon offsets, most suggest that the baseline setting justifies additionality, i.e. any action that outperforms a historical reference level is automatically deemed additional. As explained above, this is the case because a barriers analysis in the style of the CDM additionality tool would not be helpful to understand public policy choices. However, a couple of GHG Programs require providing further assurances that there is additionality. Notably, the FCPF Carbon Fund requires forest programs to demonstrate "new or enhanced" measures have taken place. VCS JNR requires that crediting can only start after new laws, policies, regulations or concrete implementation of mitigation activities have taken plase. Table 4 provides examples for additionality tests of selected GHG Programs and project categories.

Table 4 Example of GHG Programs address additionality

GHG Program	Examples	Additionality tests
CDM	Renewable energy generation and energy efficiency	Additionality tests combine: (i) Demonstration whether the proposed project activity is the first-of-its-kind (optional); (ii) identification of alternatives to the project activity; (ii) investment analysis; (iii) common practice analysis; (iv) barrier analysis. Positive lists for selected project activities below certain size thresholds that are deemed additional.
Gold Standard	Renewable energy generation and energy efficiency	Requires using either: (i) the CDM tools, (ii) Gold Standard approved additionality tools or (iii) a self-developed additionality tool, as long as it is approved by the Gold Standard. Relies substantially on the CDM Executive Board guidance from the Validation Verification Manual (VVM) for the evaluation of additionality.

[37] CDM, Demonstration of additionality for micro-scale project activities (version 9), EB 101, Annex 15

[38] CDM, Demonstration of additionality for small-scale project activities (version 12), EB 99, Annex 3. CDM, Positive list of technologies (version 01.0), EB 101, Annex 06

[39] VCS (no date) *Standardized Methods* [online] Available at https://verra.org/project/vcs-program/methodologies/standardized-methods/; Gold Standard (no date) *CDM Tool 32 – Positive list of technologies for additionality* [online] Available at https://globalgoals.goldstandard.org/cdm-tool-32-positive-list-of-technologies-for-additionality/

[40] Gold Standard (2018) Renewable energy eligibility. Second consultation [online] Available at https://www.goldstandard.org/our-work/innovations-consultations/renewable-energy-eligibility-second-consultation

VCS	Renewable energy generation and energy efficiency	Defines two standardized methods to determine additionality and/or the crediting baseline: (i) Performance methods establish performance benchmark metrics for determining additionality and/or the crediting baseline; (ii) Activity methods pre-determine additionality for given classes of project activities using a positive list.
VCS	Projects in forestry and land use	Requires additionality tests combining: (i) prior consideration; (ii) investment analysis; (iii) common practice analysis; (iv) barrier analysis.
VCS JNR	Jurisdictional REDD+	Additionality is mostly assumed through baseline setting. However, JNR also requires that "the program start date shall be justified based on the establishment of relevant GHG laws, policies or regulations that target GHG mitigation, and/or concrete implementation of GHG mitigation activities".
FCPF Carbon Fund	National / subnational REDD+	Additionality is mostly assumed through baseline setting. However, emission reduction programs must also provide information on measures that address a significant portion of emissions, and demonstrate that the program is ambitious, takes a programmatic approach, and reflects a variety of interventions from the national REDD+ strategy in a coordinated manner. It also must demonstrate "new or enhanced" measures to reduce emissions.
Warsaw Framework	National / subnational REDD+	Additionality is (entirely) assumed through baseline setting and there is no requirement to assess policies and measures taken.

Conclusions

Most GHG Programs provide reasonable assurances of additionality through their testing requirements. In principle, nearly all of the GHG Programs assessed have procedures in place to assess the additionality of GHG units. Major GHG Programs have also worked towards closing loopholes for non-additional projects over time, mostly by excluding project classes through negative lists. GHG Programs like the CDM, the VCS, and the Gold Standard tend to require projects (both forest and non-forest) to apply a multiple-step approach to establish their additionality. The core of additionality testing is the investment analysis that establishes that the project would not have happened without carbon finance.

Additionality testing delivers clearer results where projects have little or no financial incentive other than the revenues stemming from offset credits. This is the case, for example, with industrial gas projects that include modifications to industrial processes that would not be undertaken without revenues from carbon credit sales.[41] This is also the case for protective tree planting where wood use is not a principal objective, or for forest protection that generates no or few revenues. But even with standardized tools, establishing additionality is challenging for those activities that generate substantial revenues, receive national support, or where the cost of technologies are rapidly dropping.

The additionality case for projects in the forest sector can in many instances be stronger than for other sectors. At project level—in particular for avoided deforestation and protective reforestation—there is generally a clear case for arguing that the project activity would not have been developed (and maintained for a period of time) if not for the incentive created through crediting and payment. This is not the case, for instance, for certain renewable energy projects, such as large solar and wind power plants in emerging economies, where plummeting capital costs over the past years made these investments largely attractive on their own.

At jurisdictional level, GHG Programs that require evidence of new policies or actions provide a higher level of confidence that GHG units issued are additional. Jurisdictional programs often rely on baseline setting to capture additionality. However, capturing the socio-economic developments of a whole sector or, in

[41] Today these projects are excluded from all major carbon standard programs after they created enormous windfall profits and perverse incentives in the early days of the CDM.

the case of REDD+, of the full set of direct and indirect drivers influencing the dynamics of forest cover, is challenging. Large-scale programs have inherent risks that emission reductions issued against a national or jurisdictional baseline—with no additional requirements—could reflect larger economic trends or political dynamics rather than specific efforts to reduce deforestation. To encourage new actions, GHG Programs like the FCPF and the VCS JNR include requirements that jurisdictional programs must demonstrate new (or enhanced) laws, policies, or actions that tackle the key drivers of emissions to demonstrate that action has been taken to reduce emissions. By contrast, the Warsaw Framework does not have such requirements but exclusively relies on outperforming the crediting baseline for establishing additionality.

c. Quantification, monitoring, reporting and verification

Quantification, monitoring, reporting and verification is needed to measure the emission reductions that a program has achieved and to determine the GHG units to be issued. The quantification should be based on accurate and precise measurements and may require, for example, estimating the amount of power generated, water filters distributed, or – in the case of forest carbon crediting – carbon stock in forests and the area of deforestation. Monitoring is the collection and archiving of data necessary for determining the baseline and measuring GHG emissions (or removals) thereafter. Where every installation cannot be monitored, sampling needs to be carried out to estimate a program's overall performance. How the monitoring was carried out, the results obtained, and eventual emission reduction calculations are documented in a monitoring report. Typically, an independent third party, duly accredited by the GHG Program, then scrutinizes how the quantification, monitoring and reporting was carried out to ensure adherence to the GHG Program's requirements.

Error in estimating emissions can occur during monitoring, but is also sensitive to assumptions made in setting the baseline (see Section 2a). For some technologies the baseline is more prone to error – for example grid emission factors are much more uncertain than emissions quantification in off-grid renewable energy plants. Similarly, for jurisdictional forest programs, emissions quantification may have higher uncertainties (see below), while the baseline setting (e.g. use of an historical average emissions level) is often clearly conservative.

Quantification of performance for various project or program types

Quantifying the GHGs used to calculate emission reductions requires identifying potential sources of error and estimating uncertainty. While measuring GHGs from projects differs from measuring at national or jurisdictional scale, looking at national GHG inventories can provide insight into the magnitude of error for land use and other sectors (Table 5). Data from within the European Union illustrates that emissions estimates tend to be more accurate for the fuel combustion and industrial processes sectors. Assessing emissions from the waste, fugitive emissions, agriculture and land use and forestry sectors could be more challenging, as reflected in their higher levels of uncertainty.

Table 5 Uncertainty of GHG emission estimates at the EU level[42]

Sector	Level of uncertainty (%)
Fuel combustion (including transport)	0.9
Industrial processes	11.8
Fugitive emissions	27.9
Land use and forestry	34.3
Agriculture	47.0
Waste	51.5

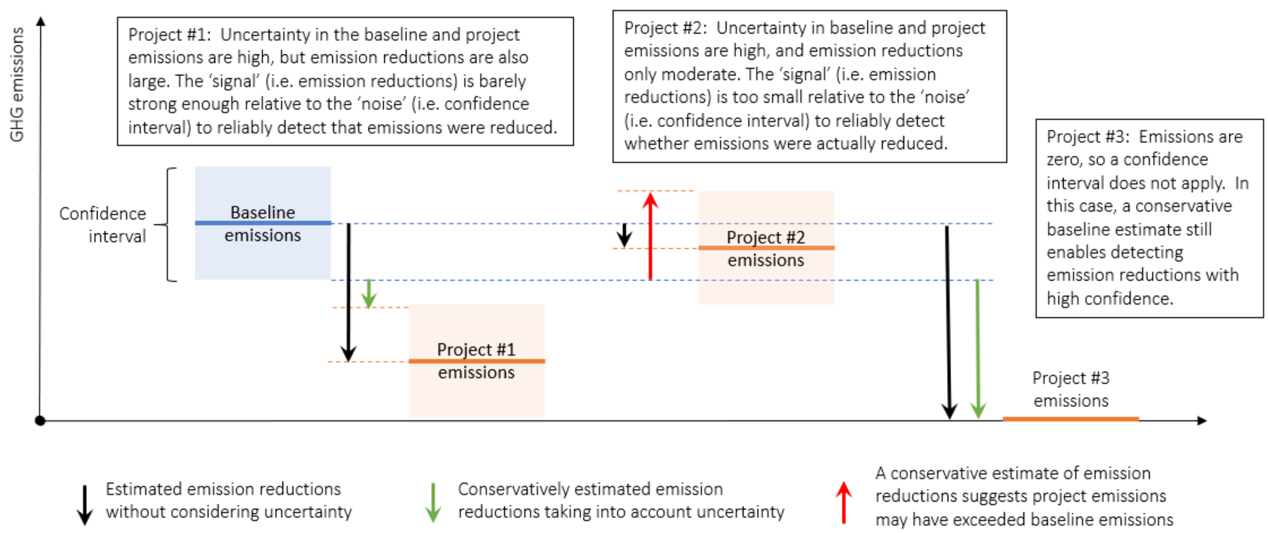
The forest sector is among those sectors where uncertainty is higher in quantifying emissions. This is due to the relative complexity of estimating GHGs from forests—from analyzing satellite data to multiple (and repeated) field measurement across a broad landscape—which can lead to substantial measurement errors. In addition, certain types of forest (for example dry forest) and certain types of forest-related emissions (for example GHGs from forest degradation) have substantial underlying variability, further challenging the ability to generate accurate estimates.

[42] European Commission (2012) Annual European Union greenhouse-gas inventory 1990-2017 and inventory report 2019. Available at https://www.eea.europa.eu/publications/european-union-greenhouse-gas-inventory-2019.

Improving the accuracy of measurements in the case of forest-related GHGs may be achieved through a range of improvements in measurement, such as increasing the number of samples measured in the forest inventory (that measure carbon stock and change) or used in determining forest area and its changes (if using a sample-based method), through improvements in the algorithms that classify land cover and change, or through using higher-quality satellite data and related methods of analysis. In general, making such improvements and bringing down the uncertainty of GHG estimates is easier for projects where the underlying variability of ecosystems is typically smaller than that of large-scale jurisdictions.

For estimating emission reductions, understanding the 'signal-to-noise ratio' is important*;* i.e. the uncertainty of the baseline emissions in relation to the magnitude of the emission reductions. For example, if a project's baseline emissions could range anywhere between 50 and 150 ktCO_2e, and monitoring detects emission reductions of only 30 ktCO_2e, i.e., smaller than the uncertainty in estimating baseline emissions, then there is a risk that the monitoring results do not actually indicate emission reductions that truly occurred. For sectoral activities or jurisdictional programs, the uncertainty of emission reductions tends to be much less favourable than for projects. Uncertainties are substantial to begin with (see above) and activities at the scale of entire sectors or jurisdictions will not typically aim to eliminate emission altogether, but only reduce emissions by a certain relative amount. Therefore, the 'signal' (i.e. the emission reduction) may be buried in 'noise' (the potential error in the baseline and crediting period). This is illustrated in Figure 1 below.

Figure 1. Illustration of the signal-to-noise ratio in estimating emission reductions[43]



Uncertainty management by various GHG Programs

CORSIA's specific guidelines for interpretation of this EUC focus on aspects that are not directly related to the quantification, monitoring, reporting and verification, but rather on procedural aspects (e.g. requiring auditor conflict of interest provisions). Since this report is mostly concerned with aspects related to the

[43] The figure is a simplification. A more detailed trend analysis would also consider covariances between emission estimates at varying time points.

quality of the GHG units generated, the CORSIA EUC guidelines to characterize the requirement for quantification, monitoring, reporting and verification, are unpacked as follows:

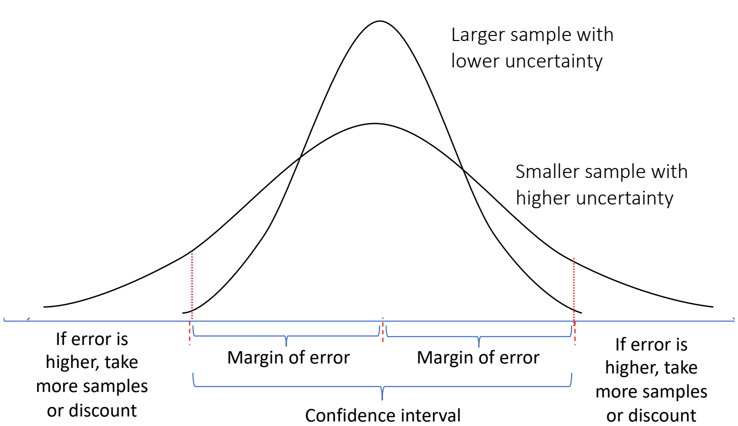
- **Conservativeness:** Emission reductions should be calculated in a manner that is conservative.
- **Uncertainties:** Offset credits should be based on measurement and quantification methods/protocols that lead to low uncertainties.
- **Validation and verification audits:** GHG Programs need to undergo third-party validation and verification before being issued carbon credits. These accredited third-parties must assess and publicly document the likely emission reductions. Verification of the issued GHG units is required.

There are two complementary approaches adopted by GHG Programs to manage uncertainty: by defining the level of uncertainty that is acceptable **per monitored parameter,** undertaken by projects when collecting data, and **in aggregate for the overall emission reductions**, usually built into methodologies.

First, efforts for **limiting uncertainty for monitored parameters** is undertaken by projects when these collect data. For example, the VCS limits allowable uncertainty estimated *per monitored parameter*, and requires that discounts be applied on the parameter in question once projects find uncertainties that exceed an acceptable range. Table 6 provides information related to the EUC assessment criteria (see top of this section). It does not include the requirements around data transparency, as this is not directly related to the quality of the emission reduction estimate.

Specifically, the VCS requires estimating parameters that are no more than 20-30% uncertain at a 90-95% confidence level (see Figure below) and discounting otherwise.[44] Where an uncertainty value is not known, a project may neglect uncertainty for indisputably conservative parameters. The CDM requires the use of conservative approaches throughout. With regards to sampling, it requires uncertainties to be lower than 5-10% at a 90-95% confidence level when using sampling. If these minimum requirements are not met, the CDM requires either that more samples are taken until the error threshold is met (Figure 2); or – as long as the error level of the parameter in question does not exceed 15% – discounting is permitted.[45] The Gold Standard also manages uncertainty of individual monitored parameters, but with different uncertainty thresholds depending on the methodology applied.

Figure 2: Illustrating how minimum levels of confidence and margins of error are applied to sample results to determine minimum sample size. If the margin of error is larger than the specified minimum threshold, more samples will need to be taken, or the parameter discounted.



[44] VCS (2017) VCS Standard (version 3) Available at https://verra.org/wp-content/uploads/2018/03/VCS_Standard_v3.7.pdf
[45] CDM Standard for sampling and surveys for CDM project activities and programmes of activities (version 07.0).

Second, to avoid high uncertainties in the overall emission reductions, the CDM and VCS **require that methodologies use conservative estimation approaches**.[46] Methodologies that are not able to sufficiently demonstrate how they mitigate any risk of overestimation in key parameters, including for setting the crediting baseline, are not approved under these GHG Programs. Since a detailed assessment of expected uncertainties is undertaken at the time of assessing the methodology, it is assumed that uncertainties no longer need to be assessed when individual projects apply the methodology to estimate emission reductions. For example, the VCS standard refers to a recommendation of the CDM Methodologies Panel[47] (which was not directly translated into CDM guidance), which suggests that methodologies need to make arrangements for discounting the number of issued GHG units in case uncertainty above 15% is expected, and that the methodology should address any uncertainty exceeding 100%.

Clearly, building conservativeness into methodologies can only effectively avoid overcrediting if the methodology approval process is sound. A careful checking for expected uncertainties needs to be undertaken at the time of methodology approval. Only then is it credible for projects to avoid undertaking a comprehensive uncertainty assessment. However, fully understanding expected uncertainties for project methodologies is extremely complex because it requires detailed technical knowledge in a range of fields, as well as making a solid assumption on project design. Shortcomings could easily occur in this. For example, some VCS forest project methodologies require reporting the sampling error of carbon stock measurements but neglect the potentially significant uncertainties involved in estimating deforestation area.

For such GHG Programs that manage large portfolios of hundreds of projects, the allowance of error up to 15% per monitored parameter with no discount is justified by the “law of large numbers”; i.e. the assumption that there will be a large number of projects that both over and underestimate credited emission reductions (since this only considers random error) and therefore over the portfolio, in aggregate, the uncertainty in estimating total achieved emission reductions is significantly reduced.[48]

The approach chosen in the different methodologies is often a function of the costs related to reducing uncertainty for the different sectors, scale and project types, as there exists a trade-off between reducing error and the costs of data gathering.[49] For example, getting perfect data on the portion of water filters in use would require re-visiting every household that owns a device; a time-consuming and logistically complex task for a project that might distribute thousands of filters. Similarly, increasing the number of plots sampled in an afforestation or reforestation project can lead to greater monitoring precision, but also becomes economically prohibitive.[50]

Jurisdictional forest standards take different approaches compared to project standards. VCS JNR, for example, appears more flexible in its allowances for uncertainty. In its uncertainty requirements, it currently only states that a program should estimate the accuracy of the “forest versus non-forest classification” with a 75% accuracy (i.e., forest area and non-forest-area at a given time), but does not appear to include estimates on the land use *change* (i.e. area changed from forest to non-forest), which is most critical for the emissions estimate in the case of avoided deforestation. Similar to what was discussed above for the VCS project standard, uncertainty in emission and removal factors is restricted

[46] Guideline: Completing the proposed new baseline and monitoring methodology form (version 02.0)
[47] CDM Meth Panel 32, Annex 14.
[48] CDM Meth Panel 32, Annex 14.
[49] See I. Shishlov and V. Bellassen (2014). Review of monitoring uncertainty requirements in the CDM. CDC Climat Research.
[50] See Igor Shishlov and Valentin Bellassen (2014). Review of monitoring uncertainty requirements in the CDM. CDC Climat Research.

(30% uncertainty at a 95% confidence level). The current guidance does not clearly require programs to estimate the aggregate uncertainty of the GHGs for the baseline, or for the claimed emission reduction.[51]

By contrast, the FCPF Carbon Fund's Methodological Framework clearly states that the uncertainty of the emission reduction must be quantified. The FCPF Carbon Fund also requires all uncertainty estimates to be quantified following a specific statistical approach to ensure quality (i.e. Monte Carlo methods[52]). While guidance on calculating uncertainties of the aggregate emission reductions is the most detailed (of any of the GHG Programs we assessed) under the FCPF Carbon Fund, it takes a more lenient approach with regard to allowing high statistical uncertainty, i.e. if uncertainty is higher than 100% at 90% confidence level, the emission reductions are only discounted by a 15% conservativeness factor. Because current "buyers" of emission reductions from the FCPF Carbon Fund are purchasing a portfolio of programs, this may reduce the risk of high uncertainty (similar to the justification provided in the CDM guidance on why there is an allowable 15% uncertainty with no deductions).[53] However, this would be a less effective way of reducing uncertainties if the portfolio has only a few programs in it.

The Warsaw Framework also focuses on action at the national or subnational scale, and encourages countries to reduce and report uncertainties. Although generally emissions reporting is to follow IPCC guidance, which includes much detail on the analysis of uncertainties, the adherence of country reports to these guidance is uneven at best. The technical assessments tend to commend countries for mere efforts to analyze uncertainties, but do not usually assess the quality of such analysis. The Warsaw Framework for REDD+ also does not have caps or discounts for managing uncertainty (discounts have been introduced by the Green Climate Fund, but are minimal).[54,55]

The nature of **validation and verification** also differs among different standards, largely beween project standards and jurisdictional standards. For projects, it is common practice to have an accredited and independent verifier scrutinize how the quantification and monitoring was conducted, methods for analyzing the monitored data and how these data are used to calculate the emission reductions. The role of the independent verifier is to ensure that the emission reductions issued adhere to the GHG Program's rules and requirements. Most GHG Programs for projects, including CDM, VCS, Gold Standard and others, follow the ISO standard for validation and verification of GHG assertions.[56] There are cases where more leniency is introduced, for example, the Gold Standard permits an observer-based assessment by third-parties that are not accredited as auditors for particularly small projects.[57] In the case of forest carbon projects, there is also variability in the stringency and/or depth of the validations or verifications, in part due to the complexity of GHG estimation and baseline setting.

[51] According to Verra, JNR will be revised to clarify and improve the requirements around uncertainty.
[52] A simulation technique to aggregate uncertainties between different variables and sources of error.
[53] EB 32, Proposed guidance on addressing bias uncertainty, Annex 14.
[54] See Decision 4/CP.15. Methodological guidance for activities relating to reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries.
[55] See the GCF scorecard for REDD+ results-based payments. Available at: https://www.greenclimate.fund/documents/20182/820027/GCF_B.18_06_-_Request_for_proposals_for_the_pilot_programme_for_REDD-plus_results-based_payments.pdf/0691c547-110a-4bee-886b-084664326fe1
[56] ISO 14064-3 Greenhouse gases – Part 3: Specification with guidance for the validation and verification of GHG assertions.
[57] Microscale project requirements (version 1.1) allow for audits to take place via 'objective observers'. The project developer suggests three 'independent experts' that could audit their project, with the Gold Standard then selecting one of these for the validation/verification.

Jurisdictional forest standards, however, vary in the approaches taken to verify emission reduction units.[58] Only VCS JNR follows the ISO standard for validation and verification. The FCPF Carbon Fund uses an 'expert review' process, where quality management is hard, for validation of forest programs (including for reference level setting) but is moving towards a more market-ready approach that follows the ISO standard for verification.[59] The Warsaw Framework relies on an expert review that diverges from the verification process typically undertaken by GHG Programs intending to issue market-ready GHG units. For example, the technical assessment of forest reference levels under the UNFCCC (similar to a validation under most standards), was designed with the objective to be a "facilitative, non-intrusive technical exchange of information… with a view to supporting the capacity of developing country Parties".[60] The technical analysis of submitted "results" is then only focused on an assessment of GHGs measured in the crediting period against the reference level, even if the latter is flawed.

Table 6 provides information related to the EUC assessment criteria (see top of this section). It does not include the requirements around data transparency, as this is not *directly* related to the quality of the emission reduction estimate.

Table 6 Examples of how GHG programs ensure accurate and precise measurements and quantification methods

GHG Program	Conservativeness	Uncertainties	Validation and verification audits
CDM	Requires use of conservative assumptions and measurements throughout.[61] This obviates the need for estimating uncertainties of individual parameters	Aggregate uncertainties of emission reductions not estimated In the case of sampling, discounting required for monitored parameters if error is >10% and <15%, and issuance not permitted for uncertainty >15%[62]	By accredited entity following ISO standard
Gold Standard	Requires conservative assumptions in baseline establishment[63] Discounting sometimes required in case of higher uncertainties	Aggregate uncertainties of emission reductions not estimated For parameters monitored via sampling, the permissible uncertainty differs per methodology. Usually a 90 – 95% confidence level per parameter; accuracy is not always defined	By accredited entity following ISO standard[64]
VCS (forest and non-forest projects)	Requires conservative assumptions throughout.[65] This obviates the need for estimating uncertainties of individual parameters	Aggregate uncertainties of emission reductions not usually estimated. Additional guidance for some approaches in methodologies, e.g., regarding allowable error in land-use change maps Requires methodologies to use discounts where aggregate uncertainties in emission reductions >15% are expected (according to CDM Meth	By accredited entity following ISO standard

[58] Till Neeff and Donna Lee (2018). Applying lessons learned from GHG evaluations to the Carbon Fund TAP and ER verification. GFOI.
[59] See FCFP Verification Process. Sixteenth Meeting of the Carbon Fund (CF16) Paris, France June 19-22, 2017, available at https://www.forestcarbonpartnership.org/system/files/documents/CF16%204c%20Verification%20process_Final_Rev01.pdf
[60] UNFCCC, Decision 13/CP.19 Annex.
[61] CDM Project standard for project activities (version 02.0), Section 5
[62] CDM Standard for sampling and surveys for CDM project activities and programmes of activities (version 07.0)
[63] Gold Standard for the Global Goals Principles & Requirements (version 1.1), Section 3.1.2
[64] For microscale activities a simplified procedure is permitted, whereby the third party does not need to be accredited and can be put forward by the project developer.
[65] VCS Program Criteria for GHG Projects and Programs (version 3), Chapter 3

		Panel guidance), but consistent application is not obvious For parameters monitored via sampling, discounting of the individual parameter required where uncertainties >20 – 30%[66]	
VCS JNR	Conservative estimation methods and discounts where uncertainty >30 - 50% (at 95% confidence)	No clear requirement to estimate aggregate uncertainty in emission reductions Additional guidance for some approaches, e.g., regarding allowable error in land-use change maps	By accredited entity following ISO standard
Warsaw Framework	Not an objective	Uneven application of IPCC guidance on uncertainty analysis	Technical expert assessment and consultative exchange under the UNFCCC
FCPF Carbon Fund	Conservative estimation methods and discounts where uncertainty of emission reductions >15% (at 90% confidence)	Clear requirement to estimate aggregate uncertainties of emission reduction estimates	Validation: Through technical expert assessment. Verification: following audit approach

Conclusions

Most GHG Programs set limits to permissible uncertainty, but vary in how such rules are applied. GHG Programs that generate and issue GHG units typically set allowable uncertainties after which conservativeness deductions must be taken, which apply equally across sectors. However, only the FCPF Carbon Fund requires an analysis of *aggregate uncertainties in estimated emission reductions.* To avoid high uncertainties in the overall emission reductions, the CDM and VCS take a different approach by requiring that methodologies demonstrate and justify the conservativeness of default values. Methodologies that fail to demonstrate conservativeness are not approved for use the GHG Program. The CDM, Gold Standard and VCS all have additional guidance for limiting the uncertainty, notably for sampling, discounting is required if the uncertainty exceeds the permissible uncertainty level(s).

The CDM sets the most stringent requirements regarding the conservativeness of uncertainty for key parameters used to estimate emissions. Conservativeness is to be applied throughout. This also includes the CDM requiring that all parameters monitored via sampling are within 10% error, at a 90-95% confidence level. Discounting of the parameter in question is permitted if the sampling error exceeds 10%, and issuance is not permitted if error exceeds 15%. The VCS also requires conservative approaches throughout but allows higher error levels per monitored parameter – at 20-30%. The Gold Standard's guidance differs per methodology, with some defining an error level in line with the CDM's requirements and others not defining a permissable error level at all. The VCS JNR and FCPF Carbon Fund both allow higher uncertainties still; and the Warsaw Framework takes a different approach altogether, not referring to conservativeness but rather to IPCC guidance on managing uncertainties in estimating emission reductions, but without evaluating programs against these criteria consistently.

Forestry is among those sectors where uncertainty in estimating emission reductions is generally larger and therefore the analysis of uncertainties is crucial. This is due to the relative complexity of estimating GHGs from forests and to a large underlying variability in forest ecosystems. There are cases where

[66] VCS (2017) VCS Standard (version 3). Available at https://verra.org/wp-content/uploads/2018/03/VCS_Standard_v3.7.pdf

methodologies have technical shortcomings, which could obscure whether the GHG Program boundaries are, in fact, being met. In addition, the signal-to-noise ratio in estimating emission reductions can be high – especially in large-scale programs. In other words, jurisdictional forest program have baseline emission estimates that often have uncertainties that exceed relative emission reduction. For example, a jurisdictional program may reduce emissions by 20%, but its emission measurements may be 30% uncertain. For most project level activities, including both forest and non-forest projects, the signal-to-noise ratio will be much more favourable.

GHG Programs that issue jurisdictional forest GHG units vary widely in their requirements around quantification and MRV. The FCPF Carbon Fund has the strongest requirements around quantification but is lenient on applicable discounts in case of high uncertainty. VCS JNR requires conservativeness in estimating emission reductions, but is less stringent than the Carbon Fund on quantification of emission reductions. The Warsaw Framework has no requirements on conservativeness and applicable country reporting is not usually strong in the quantification of uncertainty.

GHG Programs do not have equally strong validation and verification requirements. The CDM, VCS, VCS JNR and most of the activities covered by the Gold Standard[67] meet the EUC requirements, while other GHG Programs may require strengthening. The Warsaw Framework uses a 'technical expert' assessment process that differs significantly from market-based GHG Programs. The FCPF Carbon Fund has a flexible validation process (using technical experts) but considers a more market-ready verification process.

In summary, to meet the CORSIA requirements GHG Programs will need to provide detailed guidance on how uncertainty should be accounted for, and ensure robust independent third-party review. This may rely on requiring conservative methods and approaches throughout, while carefully scrutinizing methodologies to ensure they follow GHG Program requirements. Else, it could rely on specifying a maximum level of uncertainty up to which no deductions are taken, and requiring discounting above that level to achieve conservative emission reduction estimates. Or it could rely on a combination of both approaches. The CDM, the VCS and – to a certain extent – the Gold Standard have taken this approach. Other GHG Programs have some, but not all, elements incorporated into their standard.

[67] The Gold Standard permits less stringent approaches for micro-scale activities and projects located in conflict zones, such as allowing verification site visits to take place in some years by third parties that are not accredited as auditors.

d. Permanence

The requirement for GHG reductions to be "permanent" reflects the need for an emission reduction to represent a long-term mitigation benefit, optimally forever. The opposite term, "non-permanence", is used to represent situations where a credited emission reduction or carbon removal is reversed, i.e. credited avoided GHG emission or carbon stored in a system is emitted back into the atmosphere.[68]

Permanence for various projects and program types

In storing carbon through enhanced carbon sinks – whether in trees or in geological formations – there is a non-permanence risk that could materialize during reversal events. Such events can be natural or man-made. For example, a forest restoration project can be reversed if the land owner decides it is more profitable to grow soy crops. Carbon stored in planted forests could be re-emitted due to natural disturbances (i.e. fire, floods, pests and diseases, landslides and even climate change) or carbon stored underground in geological carbon-capture and storage (CCS) activities could be released after an earthquake. The risk of non-permanence may increase in regions affected by climate change, for example, areas that become hotter and drier and therefore more vulnerable to forest fire. Table 7 lists a number of project types and associated considerations on non-permanence.

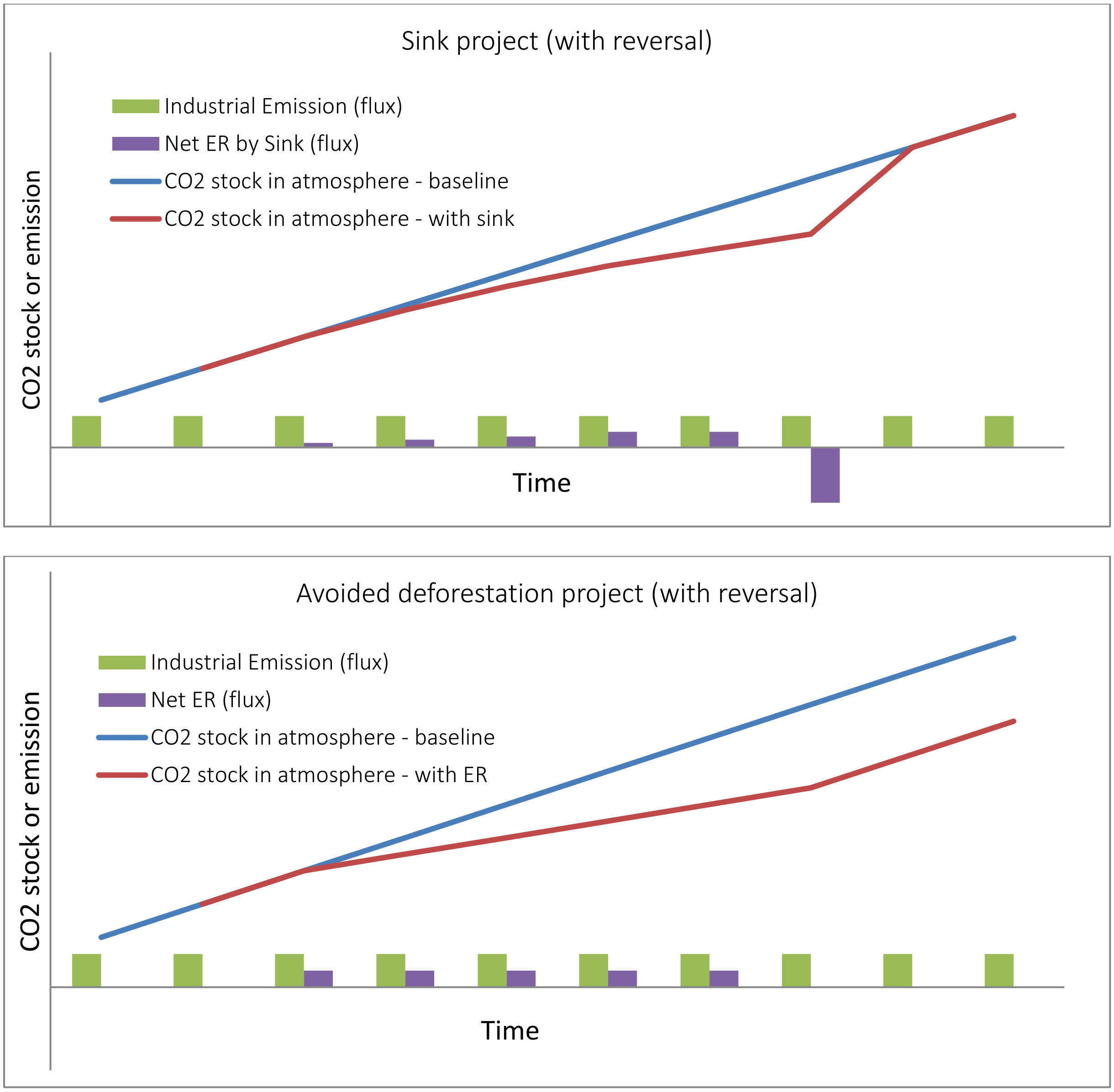
The scale of activities also matters for permanence risks. Large-scale forest programs are more difficult to control and predict given the size of territories, political priority shifts, oscillation in prices of agricultural commodities, and variations in government budgetary spending for forest protection. On the other hand, where large programs cover many types of forest activities located in different areas, the failure of some activities due to reversals might be compensated by the success of others.

The nature and degree of reversal risk also differs among forest activities. In a sink project (e.g. afforestation), CO_2 is removed from the atmosphere and stored in wood biomass and CO_2 concentration in the atmosphere is reduced. If the forest is cut after the end of the project (and the wood is not used for durable products), the stored carbon is released as CO_2 again and the atmospheric CO_2 concentration is the same as in the baseline scenario. By contrast, in an avoided emissions project, if deforestation occurs after the project ends and emissions return to the original (baseline) level, the atmospheric CO_2 concentration nevertheless remains lower in comparison to the baseline scenario (see Figure 3).[69]

While forests are generally seen as more prone to reversal events, many experts highlight that GHG reductions occurring in the energy sector are not entirely different, to the extent that their 'true' permanence is conditioned on fossil fuels remaining unused underground. This is the case for mitigation activities that avoid GHG emissions, such as reduced use of fossil fuels and reduced deforestation. In both cases, the generation of emission reductions can still cease in the future – e.g. if the renewable power plant stops operating or deforestation increases again – and GHG emissions spike back to original levels or even worse.

[68] C. Galik et al. (2014). Alternative approaches for addressing non-permanence in carbon projects: an application to afforestation and reforestation under the Clean Development Mechanism. Nicholas Institute for Environmental Policy Solutions. Mitig. Adapt. Strateg. Glob. Change. DOI 10.1007/s11027-014-9573-4.
[69] See differences e.g. between reforestation and rewetting activities with to exposure to permanence risks in H. Joosten et al. Peatlands, Forests and the Climate Architecture: Setting Incentives through Markets and Enhanced Accounting. Climate Change 14/2016.

Figure 3: Differences in permanence between removal and avoidance of emissions in the event of a reversal.[70]



[70] H. Joosten, M. von Unger, I. Emmer, Peatlands, Forests and the Climate Architecture: Setting Incentives through Markets and Enhanced Accounting, Umweltbundesamt (2016).

Table 7: Example mitigation activities and associated non-permanence risks

Project type	Type of greenhouse gas reduction	Carbon reservoir	Non-permanence risks	Options to manage non-permanence risks
Displacement of fossil fuel-based electricity through renewable energy generation	Emission reduction (source)	-	Not addressed or considered	Not addressed or considered
Geological carbon capture and storage	Sequestration / carbon removal (non-forest sink)	Geological formation (injected into subterranean reservoirs)	Carbon could percolate out and reach the ocean or atmosphere	Reserve account; liability for cancellation if amount still outstanding; secure carbon storage design and monitoring
Emission reduction through avoided deforestation or forest degradation	Emission reduction (source)	Forest	Poor management or encroachment by outside actors (human-induced); drought, fire or insects (natural disturbance)	Address rather than suppress deforestation drivers; embed forest protection into national laws and policies; develop sustainable resources for protection
Enhancement of carbon sinks through reforestation	Carbon removal (sink)	Forest	Poor management or encroachment by outside actors (human-induced); drought, fire or insects (natural disturbance)	Establish legal and financial commitments; use of native species

Reversal management by various GHG Programs

The CORSIA guidelines require mitigation measures to be in place to monitor, mitigate and compensate for non-permanence. Specifically, the EUC require that GHG Programs have in place:

- Risk assessment provisions for potential causes, relative scale and relative likelihood of reversals
- Reversal risk monitoring
- Reversal risk mitigation
- Full compensation for mitigation reversals with replacement units that are fully eligible under CORSIA
- Procedures and obligations placed on project developers to notify reversal events and assume liability for such reversals

Where there is a risk of non-permanence within the project boundary, issuing permanent carbon credits requires GHG Programs to insure against it. With the exception of the CDM, which uses a temporary-credit approach, all GHG Programs assessed deal with non-permanence risks by making use of buffer accounts. Projects and programs contribute a share of their carbon credits to this buffer system and, should reversals occur, an equivalent number of buffer credits are cancelled to secure the permanence of the achieved emission reductions. As with any insurance, risk events are unlikely to occur in all projects at once and hence units can be deemed overall permanent.

But variations of the buffer approach exist. Verra's VCS requires forest projects or programs seeking to obtain Verified Carbon Units from GHG removals through carbon sinks or avoided emissions to deposit a certain quantity of units into a pooled buffer account to be used to offset any reversal. The number of units required to be placed in reserve is based on an analysis of the likelihood of a reversal of each project or program considering different risk factors ("non-permanence risk rating"), including the effect of risk mitigation efforts. Projects or programs with risk-rating percentages deemed unacceptably high (i.e. above 60%) are not eligible for crediting.[71] For land use-related projects, risk assessment covers a period of 100 years and is based on the information available at the time of the risk analysis. Projects with longevity[72] lower than 30 years automatically fail the risk analysis.[73]

Verra's global buffer pool has currently 36.5 million credits from more than 120 projects located in 34 countries. Recently, in light of the increased forest fires taking place in the Brazilian Amazon, Verra stated publicly that diversification of projects from different countries ensures that the buffer is resilient enough and "is not put at risk even by disastrous events such as the fires in the Brazilian Amazon". Verra's estimates that, in the worst-case scenario, between 4.7 and 6 million buffer credits would need to be cancelled to cover reversals from recent forest fires in Brazil (although actual impact may in fact be much lower, depending on the severity of the fires in the project areas).[74]

The Gold Standard applies a standardized process to assess the project-design risks for each project. Projects are required to develop mitigation measures at the design phase to counteract identified risks. Projects have to contribute a fixed 20% of all credits issued to a compliance reserve, which is meant to insure against non-permanence risks, as well as any other risks of non-compliance with the Gold Standard requirements.[75] The carbon stock of project must be frequently monitored, but there is no specific time-period requirement. If, in spite of the undertaking of the safeguards planned at design stage, a reversal occurs (or any other non-compliance with requirements), an appropriate number of compliance reserve credits is put on hold to cover the gap and ensure the integrity of credits issued (until the project developer takes the necessary reparation measures). If appropriate reparation measures are not taken, reserve credits are ultimately cancelled to compensate for the shortfall.[76]

It is worth noting that the Gold Standard issues GHG units not only for already achieved, but also for future expected emission reductions or carbon removals. For any type of project (both in the forest and the non-forest sectors), there are so-called Pending Issuance Units (PIUs) that can facilitate forward selling. Such forward units should be not be understood to represent already achieved emission reductions or carbon removals. For tree planting projects, there are in addition so-called Planned Emission Reductions (PERs) that represent not only the removals that could be verified but also expected removals for up to five years into the future.

The FCPF Carbon Fund also requires non-permanence risks to be assessed and reversal mitigation measures included during the program design. To deal with reversals that occur during the period of the Emission Reductions Payment Agreement (ERPA) – which is relatively short, not longer than five years – the FCPF requires programs to deposit emission reductions into a buffer account, either a central account

[71] VCS (2013) Jurisdictional and Nested REDD+ (JNR) Non-Permanence Risk Tool (version 3). Available at http://verra.org/wp-content/uploads/2018/03/JNR_Non-Permanence_Risk_Tool_v3.0.pdf; VCS (2016) AFOLU Non-Permanence Risk Tool (version 3.3) Available at http://verra.org/wp-content/uploads/2018/03/AFOLU_Non-Permanence_Risk_Tool_v3.3.pdf

[72] Longevity refers to the number of years beginning from the project start date that project activities will be maintained. See Verra's VCS AFOLU Non-Permanence Risk Tool. Version 3.3 of 19 October 2016.

[73] See Verra's VCS AFOLU Non-Permanence Risk Tool. Version 3.3 of 19 October 2016.

[74] See Verra, "Fires in the Brazilian Amazon – A case in point for Forest Carbon Projects" 3 September 2019, available at https://verra.org/fires-in-the-brazilian-amazon-a-case-in-point-for-forest-carbon-projects/.

[75] See GHG Emission Reduction & Sequestration Product Requirements – Land-Use and Forests Specific Requirements. Version 1.1, March 2018, available at https://globalgoals.goldstandard.org/500-gs4gg-ghg-emissions-reductions-sequestration-product-requirements/#post-1372-_Toc507583597

[76] See GHG Emission Reduction & Sequestration Product Requirements – Land-Use and Forests Specific Requirements. Version 1.1, March 2018, available at https://globalgoals.goldstandard.org/500-gs4gg-ghg-emissions-reductions-sequestration-product-requirements/#post-1372-_Toc507583597

set up by the FCPF Carbon Fund or a comparable buffer account proposed and established by the REDD+ country itself.[77] The amount of emission reductions set aside will be defined in accordance with the level of risk of the relevant program and may vary from 10 to 40%.[78] To deal with reversals in the post-contracting period, the FCPF Carbon Fund requires program developers to establish a domestic reversal management system (either a buffer or an insurance mechanism) to address reversals beyond the term of the ERPA. Such reversal management mechanism needs to be set up before the end of the ERPA in a manner acceptable to the FCFP Carbon Fund, following dedicated buffer guidelines. If no reversal management mechanism is established, credits retained in the buffer are cancelled.[79]

The Warsaw Framework, in turn, states that REDD+ should "promote and support actions to address the risks of reversals"[80], but provides no further guidance beyond this.

Under the CDM, Kyoto countries agreed to modalities and procedures governing the registration of CCS projects and issuance of CCS Certified Emission Reductions (CERs) in 2011. But rather than using the temporary-credit model applied to afforestation and reforestation activities (see below), in this case of CCS, the CDM applies a combination of buffer pool, liability provisions, and actions to manage the risk of reversals in the design and operation of projects. The CDM risk buffer requires all CCS projects to forward 5% of issued CERs into a common reserve account managed by the Secretariat. These CERs are returned to project developers once the complete crediting period (7 years, renewable twice) and the geological monitoring period (minimum of 21 years after the end of the last crediting period or after issuance of CERs ceases) have lapsed. In addition, verification continues beyond the end of the crediting period and only ceases after the monitoring of the geological storage site has ended (pursuant to the conditions for the termination of monitoring).[81]

Also, in 2003, the UNFCCC devised a system of temporary credits to address permanence risks in CDM afforestation and reforestation activities. This model is based on periodic monitoring, with re-issuance or re-verification of the credits. There is no requirement for assessing the risk of reversals and credits will necessarily expire within certain specified timeframes, varying between so-called temporary and long-term Certified Emission Reductions ("CERs"). While technically as or even more robust than some buffer systems, this approach has become unpopular in the market place given the uncertainty associated with the temporary nature of units issued and the shifting of liability to buyers with little control over project risks.[82] For this reason, in 2013, the Subsidiary Body on Scientific and Technological Advice (SBSTA) of the UNFCCC asked countries and stakeholders inputs on the modalities and procedures for alternative approaches to addressing the risk of non-permanence under the CDM, but no conclusions have yet been reached.[83]

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[77] The Carbon Fund is also currently developing a centralised transaction registry and the expectation is that all participating REDD+ countries will be required to apply the buffer guidelines for all emission reductions generated and buffer accounts will be all managed in a centralised registry.

[78] FCPF (2013) FCPF Carbon Fund Methodological Framework, Indicator 19.1.

[79] FCPF Carbon Fund Methodological Framework (2013), Indicator 20.1; Section 11.03 ERPA General Terms and Conditions: www.forestcarbonpartnership.org/system/files/documents/FCPF%20ERPA_General%20Conditions_November%201%202014_0.pdf

[80] UNFCCC Decision 1/CP.16, Appendix paragraph 2(f), Decision 10/CMP.7 Modalities and procedures for carbon dioxide capture and storage in geological formations as clean development mechanism project activities. FCCC/KP/CMP/2011/10/Add.2.

[81] See Decision 10/CMP.7. Modalities and procedures for carbon dioxide capture and storage in geological formations as clean development mechanism project activities. FCCC/KP/CMP/2011/10/Add.2.

[82] Should REDD+ be Included in the CDM? Analysis of issues and options. Prepared for the CDM Policy Dialogue. http://www.cdmpolicydialogue.org/research/1030_Redd.pdf

[83] See SBSTA 39, the agenda item 12(b), available at: https://unfccc.int/resource/docs/2013/sbsta/eng/04.pdf

The table below provides information on how various GHG Programs address the CORSIA criteria for permanence: reversal assessment, monitoring, mitigation and compensation.

Table 8: Examples of how GHG Programs address non-permanence risks

GHG Program	Definition	Risk assessment	Reversal monitoring	Reversal mitigation	Reversal compensation
CDM Carbon Capture and Storage in geological storage sites	A net reversal of storage e.g. through the release of carbon dioxide from beneath the ground surface or seabed to the atmosphere or ocean	A risk and safety assessment is carried out and confirmed by a Designated Operational Entity. A reserve account is established for the CCS project activity with 5% of the CERs issued for such project.	A net reversal of storage through a seepage event leads to an equivalent cancelling in CERs	Geological storage sites can only be used to store carbon if there is no significant risk of seepage, no significant environmental or health risks exist.	Cancellation of CERs from, as follows: (i) the project's reserve account; (ii) the pending account; (iii) holding account of project participations; (iv) obligation to cancel other types of units (if amount is still outstanding).
Gold Standard Afforestation, Reforestation and agriculture projects	A situation where net carbon stocks are negative as a result of a loss in carbon stocks[84]	Standardized tool to assess the particular risk profile of each LUF project. A flat 20% of carbon credits goes into a non-compliance reserve.[85]	Reversal event triggers reparation measures. In addition, an equivalent number of credits are put on hold by the GS Secretariat.[86]	Frequent monitoring of carbon stocks provides an incentive to maintain carbon stocks.	Compensation shall follow the following preferential order: (a) Use an equivalent number of buffer credits; (b) Use GS credits not affected by the reversal event; (c) Purchase of GS credits from another project; (d) All active credits get locked and purchase of GS credits from another project.
VCS Forest projects, jurisdictional and nested REDD+	Emissions of "loss events" that emit more than five percent of ERs (unless planned for) and negative net GHG benefit	Detailed tool to establish a risk of 10-60 percent (beyond that fail) as a basis for a pooled buffer for all programs. Risk assessment for AFOLU projects are performed for a period of 100 years.	Loss events trigger a dedicated monitoring and assessment process	Risk assessment includes mitigation factors that provide incentive for reversal mitigation. Risk assessment covers a period of 100 years and is based on the information available at the time of the risk analysis.	Through retiring buffer credits up to a maximum of total issued credits – no liability for programs

[84] See Gold Standard Performance Shortfall Guidelines, available at https://globalgoals.goldstandard.org/performance-shortfall-guidelines/

[85] See GHG Emission Reduction & Sequestration Product Requirements – Land-Use and Forests Specific Requirements. Version 1.1, March 2018, available at https://globalgoals.goldstandard.org/500-gs4gg-ghg-emissions-reductions-sequestration-product-requirements/#post-1372-_Toc507583597

[86] See Gold Standard Performance Shortfall Guidelines, available at https://globalgoals.goldstandard.org/performance-shortfall-guidelines/

FCPF Carbon Fund National / subnational REDD+	Emissions of "reversal events" that lead to a decrease in ERs between reporting periods	Simple tool to establish a risk of 10-40 percent as basis for establishing both a program buffer – and a pooled buffer for all programs	Ongoing monitoring to detect decrease in ERs – and additional monitoring for "reversal events"	Risk is mitigated by identifying strategies to reduce reversals, pooling buffers across programs, accounting for any reversals during contract term and putting in place a reversal management mechanism for post-contracting period	Through retiring program buffer credits and pooled buffer credits up to a maximum of total buffer amount – no liability for programs
Warsaw Framework National / subnational REDD+	Not defined	Not required	Not specified, but may be covered within national accounting	Cancun safeguards encourage actions to address risk of reversals	Not specified, but may be accounted by country's Nationally Determined Contribution

Conclusions

Identifying and addressing non-permanence risks is important for the credibility of, in particular, GHG units used as offsets. Non-permanence risks are particularly important for mitigation actions that store carbon – whether in underground geological layers as happens in CCS or in the biomass of trees when avoiding deforestation or planting trees.

Overall, when compared to other unit types, forest GHG units carry a higher potential risk of non-permanence, which has triggered the development of risk mitigation approaches. In particular, credited emission reductions through carbon sinks can be released back in to the atmosphere and thus require a dedicated system capable of guaranteeing its permanence in the long-term.

Over the last decade GHG Programs have converged the use of buffer systems to manage non-permanence risks. Although the same basic approach is used, there are differences regarding the magnitude of risks and consequently amounts of units that endow the buffer (for example the Gold Standard usually only applies a flat 20% default risk, regardless of the actual context), as well as the way in which GHG Programs deal with reversals once the crediting period has lapsed. Risk analysis may also draw on different types of criteria, giving greater or more reduced weight to mitigation strategies.

Buffers to manage the reversal risk of forest carbon projects have so far been successful. Forest carbon crediting has resulted in buffers that are oversubscribed. With the exception of recent Amazon fires (for which Verra has publicly stated that existing buffer systems have been resilient enough for local projects affected), there have been few reversals and therefore there is a glut of reserve units in buffer pools. There is no experience yet, on the other hand, on the effectiveness of buffer reserves for jurisdictional crediting. The necessarily smaller number of jurisdictional programs (than projects) may constrain effective risk-balancing.

Other approaches (outside the use of buffer pools) are also used, with varying impacts. For example, the CDM use of temporary CERs can be as or even more robust than buffer systems, but presents barriers for uptake. The Gold Standard's approach to not only issue carbon credits for removals that have already occurred (and are verified), but also credits for expected removals several years into the future—even though an increased risk buffer applies—may be questioned[87]. While this helps raising funds early on, forward carbon credits may not actually represent GHG reductions at the time of issuance. Finally, the Warsaw Framework does not include an assessment of permanence risks, nor does it set aside credits to manage reversal risks.

[87] Note that Gold Standard's Pending Issuance Units (PIUs) cannot be cancelled unless verified every 5 years. Also, PIUs are not eligible under CORSIA, so Gold Standard did not include them in their application for CORSIA eligibility.

e. Leakage

Leakage is the increase of GHG emissions outside of the boundaries of a project or program that can nonetheless be attributed to the project or program itself.[88] In other words, leakage occurs when a reduction in emissions within the boundary leads to higher emissions elsewhere. Almost every mitigation activity carries with it a risk of leakage. How this is managed, quantified and accounted for, however, depends on the type of activity and the GHG Program under which the activity is registered.

Leakage risks for various project/program types

Significant leakage is primarily a problem of project or program design. Therefore, only projects or programs designed to mitigate leakage risks should be eligible for issuing carbon credits. However, every project or program may have still have residual leakage risk. Therefore, leakage emissions need to be accounted for in order to capture the true emissions reductions resulting from a project or program. The three most common types of leakage are *activity-shifting* leakage, *market leakage* and *lifecycle leakage*.

Activity-shifting leakage occurs when activities that cause emissions are relocated to an area not monitored by the project or program, e.g., when baseline technologies are transferred out of the project boundary. Activity-shifting leakage has been documented in several carbon project types such as adipic acid production, where production shifted to countries where the sector is not regulated under a carbon pricing system.[89,90] Activity-shifting leakage can also occur in, for example, the transport sector if a bus-rapid- transit project reduces occupancy rates in other modes of transportation (e.g. buses and taxis), possibly increasing emissions. [91]

Activity-shifting leakage has also been extensively discussed in the case of forest carbon projects and programs. Where baseline deforestation agents are highly mobile, such as multinational agribusinesses, there is a likelihood that they move their activities even to other countries when access to farmlands is restricted. Activity-shifting leakage would also occur if a plantation was established on high-productivity cropland or grazing land, leading farmers to move their operations and clear an adjacent forest.

Market leakage occurs when a project or a program changes the supply or demand of an emissions-intensive product, creating an upsurge in emissions elsewhere. For this type of leakage, the agents causing the leakage are not the baseline agents. For example, a large amount of projects reducing the use of fossil fuels may eventually lead to a depression in oil prices; thus, incentivizing more use of oil outside of the project.[92] In the transport sector, rebound effects are also possible. For instance, reduced transportation costs can lead to increased demand for travel.[93]

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[88] Project boundaries are not only spatially defined, i.e. they are conceptual and define what is measured and monitored.

[89] Schneider, L.; Lazarus, M. and Kollmuss, A. (2010) Industrial N20 Projects under the CDM: Adipic Acid – a Case of Carbon Leakage? Stockholm Environment Institute

[90] Erickson, P.; Lazarus, M. and Chandler, Chelsea (2011) The potential for CDM induced leakage in energy intensive sectors. Stockholm Environment Institute, Centre for European Policy Studies and CO_2logic.

[91] See GTZ and BMU (2007). The CDM in the Transport Sector - Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities. See also P. Zegras, Y. Chen, and J. Grütter (2009). Potentials and Challenges for Using the Clean Development Mechanism for Transport Efficient Development: A Case Study of Nanchang, China; and Asian Development Bank (2013). The Clean Development Mechanism A Field Guide for Transport Projects. Working Paper Series No 1.

[92] Rosendahl, K. E. and Strand, J. (2011) Carbon Leakage from the Clean Development Mechanism, *The Energy Journal*, Vol 32 (4)

[93] P. Zegras, Y. Chen, and J. Grütter (2009). Potentials and Challenges for Using the Clean Development Mechanism for Transport Efficient Development: A Case Study of Nanchang, China; and Asian Development Bank (2013). The Clean Development Mechanism A Field Guide for Transport Projects. Working Paper Series No 1.

In the forest context, reduced supply of timber or agricultural commodities can generate price effects that change emission trends.[94] This may occur, for example, in projects that avoid conversion of forests to agricultural production areas such as for production of palm oil or soy. In already highly mechanized soy production, leakage to areas outside of the covered jurisdiction is more likely than with systems or technologies that can spare land through intensification.[95] Examples from Australia show that conservation of natural forests has not resulted in the degree of leakage previously predicted, as timber plantations have led to a substitution away from wood produced from natural forests.[96]

Lifecycle leakage considers the emissions arising from the input of resources for the project or program and disposal of products, wastes and other losses outside of the project boundary. This type of leakage occurs where emissions are embedded in the upstream production or downstream stages of a product. For example, a transport project can lead to upstream emissions associated e.g. with cement and asphalt used for trunk road construction.[97] Further examples include the emissions associated with the production and transport of additives used in cement manufacturing; or emissions arising from the land application of treated manure in biogas projects. Notably, carbon projects do not consider emissions from international aviation or maritime shipping in lifecycle leakage. In the case of forestry, lifecycle leakage could apply to the mechanization that is necessary to allow for agricultural intensification that removes pressure from primary forests.

The scale of projects or programs impacts the relevance of such leakage types. Where project or program monitoring covers an entire country, as in some jurisdictional or sectoral programs, it may be harder for baseline agents to shift their activities outside its boundaries. Accounting for market-leakage in project-based accounting is difficult since projects *in aggregate* cause market leakage, especially in the fossil fuel and timber sectors.[98] Because of this, leakage risks have often been considered easier to manage for larger-scale programs that cover entire sectors or countries since emissions that would otherwise be considered as leakage (from projects) are accounted for within the larger program boundary.

However, while accounting at larger scales may capture smaller-scale leakage, it does not automatically eliminate the risk of overcrediting due to leakage. In particular, international leakage may still occur, especially when internationally operating firms are involved. Energy-intensive industries may also relocate to countries without emission limits, or agribusiness may open up production areas in other countries. Following a precedent established with the Kyoto Protocol, projects registered under the CDM, the VCS or the Gold Standard do not require treatment of international leakage, whether in forestry or other sectors. For jurisdictional REDD+ programs, their large areas may increase the risk of displacement through global commodity markets, and VCS JNR includes provisions to account for and deduct this type of leakage. Similarly, the FCPF Carbon Fund requires REDD+ programs to assess the risk of international leakage and design programs to mitigate it. The Warsaw Framework refers only to displacement at the national level.

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[94] There are few studies on carbon leakage through policies and projects. Delacote et al. review the potential leakage effects among two payment-for-ecosystem services programs. Delacote, P., Robinson, E. J. Z. and Roussel, S. (2016) Deforestation, leakage and avoided deforestation policies: a spatial analysis. Resource and Energy Economics, 45. pp.; BC Murray (2008) Leakage from an avoided deforestation compensation policy: Concepts, empirical evidence, and corrective policy options- Nicholas Institute for Environmental Policy.

[95] But intensification is also not without pitfalls, and precaution has to be taken to avoid leakage through 'rebound effects', i.e. increasing the economic attractiveness and hence land appetite through intensification.

[96] R. Warmann, RA Nelson (2016) Forest conservation, wood production intensification and leakage: An Australian case, Land Use Policy, Volume 52, March 2016, Pages 353-362.

[97] See GTZ and BMU (2007). The CDM in the Transport Sector - Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities.

[98] Ibid.

Projects and programs can be designed to mitigate leakage risk (Table 9). For example, well-designed activities to address deforestation from encroachment of smallholders would not only prevent such encroachment (through activities such as patrolling forest areas), but also offer alternative livelihood options to replace (rather than simply ban) activities that cause baseline emissions.[99] However, even in such cases, residual leakage risks still need to be accounted for in order to capture the true emissions reductions resulting from a project or program.

Table 9 Leakage risk and risk mitigation

Project / program type	Examples of leakage sources	Example options to mitigate leakage risk
Cement manufacture	Freight transport Solid waste disposal Upstream fossil fuel use Market shifting to other manufacture locations	Support to prevent market leakage e.g. EU's free allocation of permits to sectors with high risk of market leakage;[100] quantify and deduct leakage emissions from freight transport, waste disposal and fossil fuel use from overall emissions
Bus rapid transit (BRT)[101]	Displacement of older, inefficient vehicles More space on roads lead to 'replacement' vehicles and change in speed of driving Upstream fossil fuel emissions Change of load factors in buses and taxis	Ensure disposal of old, inefficient vehicles, visual surveys to determine change in ridership; measurements of change in vehicle speed; accounting for emissions associated with fossil fuel extraction, processing
Fossil fuel switching[102]	Shifts in supply-demand balance of fossil fuel leading to lower prices and thus increased demand Upstream fossil fuel emissions	Support to prevent market leakage e.g. EU's free allocation of permits to sectors with high risk of market leakage[103] Accounting for emissions associated with fossil fuel extraction, processing
Avoided deforestation	Displacement of agricultural commodities (e.g. soy) Market demand for commodities unchanged	Exclusion of leakage-prone project types;[104] address rather than suppress deforestation drivers; involve deforestation agents into the project design, e.g. through agricultural intensification or community forestry management; responsible land and/or concession management
Avoided degradation	Displacement of logging concessionaires Demand for timber unchanged	Introduce reduced impact logging, rather than stopping production
Afforestation	Displacement of agricultural production to other areas Demand for agricultural produce unchanged	Intensify agricultural production on other sites; strengthen law enforcement; integrate farmers into plantation management

Leakage management by various GHG Programs

CORSIA's EUC require GHG Programs to monitor, quantify and take deductions for leakage risks; but do not require the implementation of risk mitigation measures. Rather, the EUC require high leakage risk mitigation activities to be implemented at a larger scale (i.e., sectoral or jurisdictional or national scale) in order to be able to account for leakage. Similar to other carbon GHG Programs, CORSIA requires **leakage prevention, leakage monitoring and leakage compensation**.

[99] Schwarze, R.; Niles, J.O. and Olander, J. (2002) Understanding and managing leakage in forest-based greenhouse-gas mitigation projects. Philos Transact Ser A Meth Phys Eng Sci 360 (1797):1685-703
[100] EU Commission (no date) Carbon Leakage. Available at https://ec.europa.eu/clima/policies/ets/allowances/leakage_en
[101] Based on the methodology AM0031 (version 7.0) Bus rapid transit projects
[102] Based on the methodology AMS-III.B (version 18) Switching fossil fuels
[103] EU Commission (no date) Carbon Leakage.
[104] Experience shows that activities with highest leakage risk, i.e. involving highly mobile deforestation agents, are not usually proposed as carbon projects.

Managing leakage is complex since it requires making assumptions about the behavior of actors within and outside the project boundary. Ideally, the approach to managing leakage would include (1) identifying and mitigating leakage; (2) monitoring and quantifying leakage during the project lifetime; and (3) deducting this from estimated emissions reductions.

Mitigation activities at the project scale (forestry or non-forestry), whether under the CDM or the VCS or similar GHG Programs, typically focus on monitoring leakage and deducting it from emission reduction claims (steps 2 and 3). The CDM publishes a number of tools on accounting for leakage from particular project types, which are also referred to by other carbon standards. Some small- and micro- scale project methodologies allow a project to either calculate leakage (following the prescribed methodology), or to apply a default factor by discounting overall emission reductions achieved by 5%.[105] Providing a default value circumvents the complex process of calculating leakage in small projects. Large-scale project activities do not allow such an approach and require leakage to be calculated and subtracted from overall emission reductions. The source(s) of leakage accounted for depend on the project type, but can include emissions arising during construction, freight transport by rail, anaerobic decay of waste material outside the project boundary or the upstream emissions associated with fossil fuel production, among others.

Forest project methodologies often require application of tools to quantify leakage and deducting emission reduction claims accordingly. In the case of VCS, the *AFOLU Project Market Leakage Module*[106] can be used by any AFOLU project type to quantify a market leakage value that can be applied as a component of an applicable methodology. Market leakage associated with the production of agricultural, livestock and forest commodities linked to markets are assessed by the module. Gold standard provides guidance on leakage accounting at the methodology level, recognizing project activity types experience different leakage risk. Some project methodologies include monitoring for leakage in a prescribed area around the project accounting area, i.e. the most probable place where activity-shifting leakage may occur, and then account for such leakage.

GHG Programs focused on jurisdictional forest carbon crediting take a different approach, focused more on program design that mitigates leakage risks. This may be because program-scale activities typically face a large number of baseline agents that could be harder to monitor than in a carbon project, but also cover a larger area, reducing some types of activity-shifting leakage. Jurisdictional forest GHG Programs differ on whether or not they require quantification and deductions from emission reduction calculations.

Implementing activities at a larger scale helps to monitor and account for leakage. Some types of activity-shifting leakage may be a lower risk than at the project level. Those causing baseline emissions may be able to move outside of a project area, but only have a limited ability to shift activities outside a larger program region. Jurisdictional programs that cover very large areas or entire countries, may also reduce leakage through market effects because supply-demand dynamics still occur within the same jurisdictions. However, simply accounting over a larger area does not prevent leakage per se, because emissions could always shift even beyond a larger boundary – even international leakage can occur when commodity markets readjust in response to mitigation measures, and for example the VCS has developed a tool that quantifies (and then deducts) international market leakage in forestry projects.[107]

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[105] See for example AMS-II.G *Energy efficiency measures in thermal applications of non-renewable biomass* (Version 10.0), paragraph 34. Small and micro scale projects are defined as those below 15 MW for renewable energy, 60 GWh per year in energy efficiency improvements or projects with GHG emission reduction not exceeding 60 kt CO_2e per year.

[106] https://verra.org/methodology/afolu-project-market-leakage/

[107] VCS VMC0036

With regard to leakage prevention, the CORSIA evaluation metric indicates this is achieved through requiring GHG Programs to account for activity-types with high leakage risks at the national level (or subnational on an interim basis). This paper suggests that leakage is not "prevented" by such an accounting rule but rather addressed through program design. Therefore, in Table 10 below, we include a summary of both the scale of accounting as well as requirements related to ensuring the activities undertaken are designed to reduce leakage risks for each GHG Program.

Table 10: Examples of how GHG Programs address leakge risks

GHG Program	Example	Leakage prevention		Leakage monitoring	Leakage compensation
		Scale of accounting	Program/project design		
CDM and VCS	Bus rapid transit transport	Project	Ensuring disposal of old, inefficient vehicles	Required	Required if monitored leakage is above a certain threshold; published tools to calculate leakage from specific project types
CDM and VCS	Fossil fuel switching	Project	Not a focus of methodologies	Not required[108], unless the project is a PoA	Not required, unless the project is a PoA
Gold Standard	Fuel efficient cookstoves	Project	Ensuring discontinued use of old, inefficient technologies	Required for large/small scale activities[109]; not required for microscale[110]	Required for large, small and microscale activities; allows application of CDM's tool(s) to account for leakage
VCS	Forest projects	Project, for CORSIA nesting required if leakage risk	Leakage mitigation measures reduce leakage discounts	Required in some methodologies, others use periodic risk assessments	Required
VCS	Jurisdictional and Nested REDD+	Jurisdiction	Risk mitigation options, e.g., through new laws or policy, which reduce discounts	Periodic risk assessment, leakage monitoring and deduction for subnational programs	Required (based on risk assessment tool) through discount factors
FCPF Carbon Fund	REDD+	National / subnational	Require mitigation strategy, assessed by verifiers	Not required[111]	Not required
Warsaw Framework	REDD+	National / subnational	Countries need "actions to reduce displacement of emissions"[112] but no verification	For subnational programs, suggests monitoring at the national level if ppropriate[113], but no specific rules or verification	Not required

[108] The methodological tool "Upstream leakage emissions associated with fossil fuel use" does not require monitoring
[109] Based on the Gold Standard Technologies and Practices to Displace Decentralized Thermal Energy Consumption (version 3.1)
[110] Based on the Gold Standard Simplified Methodology for Efficient Cookstoves (version 1.0)
[111] Carbon Fund Methodological Framework, Section 3.5, criterion 17
[112] Decision 1/CP.16, Appendix I on safeguards (para 2g).
[113] Decision 1/CP.16 in the paragraph on national forest monitoring systems, where it mentions monitoring at a subnational level there is a footnote that states, "including monitoring and reporting of emissions displacement at the national level, if appropriate, and reporting on how displacement of emissions is being addressed. Decision 11/CP.19 also alludes to this in paragraph 5 stating that "Parties' national forest monitoring systems may provide, as appropriate, relevant information for national systems for the provision of information on how safeguards in decision 1/CP.16, appendix I, are addressed and respected". There is no further guidance on this in COP decisions.

Conclusions

Leakage is an inherent risk of carbon projects and programs. The level of leakage risk depends on what drives baseline emissions and on the design of the project or program, i.e. how well it mitigates the risks. Remaining unmitigated risks should be compensated through deductions for such risks. All reviewed GHG Programs have leakage monitoring and management systems in place. However, methodologies take different approaches to account for leakage, with some requiring monitoring and compensation for leakage and others not (Table 10). This study has not been able to go through the hundreds of methodologies applicable under the GHG Programs at such a granular level.

The assessed GHG Programs are more consistent in addressing activity-shifting leakage than in addressing market leakage. For non-forest projects, few examples could be found where methodologies require quantifying market leakage, while activity-shifting leakage is more consistently addressed. For some project types, arguments have been made that indirect market leakage could, in fact, be significant. For example, supply-demand dynamics in energy markets may very well shift in response to mitigation measures, but the CDM methodologies, which the VCS and Gold Standard also rely on, ignore this issue. By contrast, for forestry and land-use projects, the VCS addresses both types of leakage.

Forest project activities have variable risks of leakage. Some projects have inherently low leakage risk—for example, some reforestation projects, reduced impact logging projects, or projects that change energy usage by communities away from fuel wood collection. Community projects that improve forest management rather than eliminate forest harvest altogether also are far less vulnerable to activity-shifting leakage than projects with highly-mobile deforestation agents. By contrast, avoided deforestation projects that have highly mobile agents causing forest loss can have high risks of leakage, and therefore in such project types, leakage should be quantified and deductions taken (i.e. compensated) in the final credits issued. The VCS, the most pertinent GHG Program assessed with regard to such projects (given its high volume of issued units), has guidance to quantify and compensate for leakage risk. Alternatively, leakage risks could be potentially managed through nesting—for example, through monitoring of national performance that either sets boundaries on the issuance of project-scale offsets or informs the quantification of the leakage deduction.

Increasing the accounting area to a national or jurisdictional scale accounts for leakage but does not eliminate it. Larger-scale programs sometimes carry significant risk of market and international leakage, which is inherently hard to manage. In the forest sector, there may be financially strong deforestation agents that operate, for example, intensified agriculture (e.g. soy operations) or large-scale forestry activities that compete with crop and pasture land. Such situations are prone to leakage risks. There may also be programs where such risks are low due to local circumstances or drivers that can be tackled within the program.

For forestry programs at a jurisdictional scale, only the VCS requires quantifying and deducting for leakage. The FCPF focuses on assessing and reducing leakage risks, while the Warsaw Framework suggests countries should reduce the risk of leakage, but there is no assessment of such risks. Neither GHG Program quantifies (or takes deductions for) leakage risks. Excluding leakage risks with a reference to the national scale of accounting in large-scale REDD+ programs implies a willingness to ignore internationally occurring leakage (following what is being done in the context of the CDM). Otherwise, quantifying and compensating for leakage risks seems prudent even for jurisdictional programs.

3. Conclusions

Regulation for carbon markets and offsetting should aim to facilitate long-term emission reductions by promoting activities that lead to the decarbonization of our economies. This may include the recognition of GHG units from forest activities, as terrestrial ecosystems will have to contribute more than a third to meeting the Paris Agreement's temperature goals, but receives only a fraction (less than two percent) of international climate finance.[114] To date, however, carbon markets have restricted the participation of forest GHG units due to a number of concerns including fear that such credits could not ensure permanence, or that they carry high uncertainties. The past decade has provided useful experience with forest GHG units, particularly in the voluntary markets. We have taken the forthcoming decision on the eligibility of GHG Programs under CORSIA as occasion to review and compare the quality of various GHG units with the goal to inform decision makers on **whether forest GHG units should be included in carbon markets such as CORSIA.** Our findings suggest that:

Forest GHG units have significant benefits, but also in some aspects higher risks than GHG units generated from other sectors. Forest carbon projects and programs tend to involve many actors and dispersed agents that drive land use and land-use change, which can make setting baselines (especially for avoided deforestation projects) challenging and also increases the risk of displacing activities and creating leakage. They measure the protection or restoration of living systems which creates a heightened risk of reversals of GHG benefits. Due to a lack of finance for forest protection, however, forest protection-related activities are also often unambiguously additional. By contrast, other types of GHG units are more clearly permanent, less prone to leakage and may have lower uncertainty in GHG estimation, but some project types may have a harder time to demonstrate additionality.

National and sectoral programs favor systemic change, but often come with larger accounting risk and error. National REDD+ programs seek to create incentives for the reform of land use policies that can impact actions across a larger landscape; this increases the chance of transformational and long-term change. They also have the advantage of capturing activity-shifting leakage within their much larger accounting area and tend to prescribe conservative reference levels. However, national programs may be prone to large-scale reversals under new governments or in light of weak governance. Larger-scale programs also tend to have higher GHG quantification error. By contrast, projects are able to measure emission reductions with greater precision and accuracy, manage reversal risks, measure, quantify and account for leakage risk, and more easily prove additionality through a closer attribution of project activities to achieved emission reductions.

The nesting of projects in jurisdictional programs can help to overcome risks associated with project and jurisdictional accounting. Ensuring that project baselines, in aggregate, sum up to a reasonable share of the higher-level baseline can mitigate the risk of project baseline inflation, particularly for avoided deforestation projects. In addition, monitoring for leakage at the jurisdictional (ideally national) scale, and implementing a mechanism to account for leakage, can also reduce the risk of over-crediting of projects that have high leakage risk. At the same time, the integration of private-led projects in national programs may help to limit the effects of weak governance or a change in political will to protect forests.

In sum, the conditions under which forest carbon credits compare well with high-quality GHG units currently generated from other sectors, is when GHG Programs include the provisions in Table 11 below.

[114] Ref: NYDF Assessment Partners (2019): A story of large commitments and limited progress, NYDF 5th anniversary progress assessment, www.forestdeclaration.org.

Table 11: Overview over program elements and comparability of forest-GHG units with non-forest GHG units

	For forest carbon projects	For jurisdictional forest programs	For reference: carbon projects in other sectors
Additionality	Avoided deforestation and protective reforestation tend to be additional due to low levels of financial return. For other types of forest carbon projects, the application of additionality tests similar to non-forest requirements should capture non-additional projects.	Additionality can be demonstrated through a combination of a conservative reference level and evidence that actions, laws, policies or measures were taken to protect forests.	Proving additionality can be extremely challenging for many types of projects, especially where they have sound levels of financial return, such as in renewable energy and energy efficiency projects.
Crediting baselines	Avoided deforestation projects have the risk of inflated baselines. 'Nesting' projects in national or subnational programs mitigates this risk, i.e. project baselines in aggregate within a jurisdiction should not exceed (and only take a reasonable share of) the jurisdictional reference level.	The use of average historical emissions for jurisdictional programs (focused on avoided deforestation and/or degradation) tends to be conservative, but evidence should be provided that the historical level is justified (i.e. that emissions are expected to stay constant or rise).	Most project types require the use of conservative baseline estimates to compensate for uncertainty. Where projects set baselines through anticipate future emission trends, robustness is hard to ensure and risk of overcrediting hard to exclude without requiring conservative approaches in estimating baseline values.
Quantification and MRV	Although this is not common practice for methodologies in other sectors, for forestry, methodologies should be more carefully scrutinized to ensure they require estimation of the full uncertainty of GHG performance claimed (some currently do not) and to ensure they effectively safeguard against high error.	Similar provisions to those required for project-level offsets should be imposed on jurisdictional crediting to ensure that they be 'fungible'. Currently, most GHG Programs allow higher uncertainties to occur.	For most project types, emissions can be quantified with reasonable accuracy. Even where uncertainties are higher, emission reductions can still be quantified with a favorable signal-to-noise ratio.
Permanence	Buffer approaches currently employed have been successful and seem to provide an adequate risk mitigation strategy.	In principle, buffer approaches should be applied, but risk-balancing may be less effective with only few jurisdictional programs, potentially requiring larger contributions to a buffer reserve.	With the exception of CCS, there is only a remote risk of non-permanence of achieved emission reductions.
Leakage	Leakage is a high risk for those projects where drivers are highly mobile and/or displace demand for agricultural commodities. Risks can also be mitigated through monitoring and quantification of leakage, and discounting of issued credits.	Jurisdictional forest programs can mitigate activity-shifting leakage (if drivers are not particularly mobile); however, they do not prevent leakage which could still occur beyond the jurisdictional boundary. If there are leakage risks, leakage should be quantified, and deductions taken.	Methodologies have much diversity in their ability to account for leakage and market leakage is not usually considered.

In Table 12, we provide an assessment of several GHG Programs that generate and issue forest carbon credits. The assessment is based on a comparison to GHG units from other sectors, i.e. how do forest-related GHG units compare to the expected risks, broadly, from non-forest GHG units? From this, one can see that on the issue of additionality, forests generally are strong in comparison to other types of units. On the others, such as baseline setting, quantification, permance and leakage, the ability of forests to be 'fungible' with other types of GHG units depends on the GHG Program and the requirements within them.

In sum, we conclude that **forest carbon credits, under certain circumstances, may be included in carbon markets,** including CORSIA.The protection and restoration of forests are critical to achieving our shared climate change goals. However, if forest GHG units are included in carbon markets, and particularly where used as offsets, a ton from forests must be as good as a ton from any other sector. It is our conclusion that this can be achieved, but only with sufficient rules in place. Forest GHG units should be assessed fairly vis-à-vis carbon credits in other sectors. This report highlights the risks in generating credits in all sectors, including those inherent to forest GHG units. It suggests how GHG Programs can mitigate these risks and, in some cases, points towards additional elements that may be needed in specific GHG Programs to provide sufficient assurance that forest credits come with the environmental integrity equivalent to GHG units generated in other sectors.

Table 12 Summary of how GHG Programs perform relative to selected CORSIA EUCs

	GHG Programs for projects			GHG Programs for jurisdictional forest programs		
	CDM, VCS, Gold Standard for non-forest projects	VCS forest projects	VCS nested forest projects	VCS JNR	FCPF Carbon Fund	Warsaw Framework
Additionality	GHG Programs have procedures in place to test additionality. But demonstrating additionality remains challenging for some project types. The risk of non-additional projects increases as some project classes, such as renewable energy projects, become economically mainstream and less dependent on carbon revenues. There is also a trend to make greater use of positive (and negative) lists.	For most project types, with the exception of commercial reforestation projects, additionality is straightforward to demonstrate.	The additionality test for nested projects is not different than for regular VCS projects.	Assumed to be reflected in a conservative baseline. Additionally, there is the requirement to implement new policies or actions.	Assumed to be reflected in a conservative baseline; there is also a requirement to implement new (or enhanced) policies or actions.	Assumed to be reflected in a conservative baseline; however, there is no additional requirement to demonstrate mitigation action.
Crediting baselines	GHG Programs tend to require conservative baseline estimation and include conservative default values in their baseline methodologies. In general, where uncertainty of emission reductions in baselines is too high, projects are deemed ineligible (no similar requirement exists for jurisdictional programs). But there are project types where the risk of over-crediting is substantial (resulting e.g. from underestimated technology improvements). Sectoral performance standards work well for homogenous sectors where good data is already available. GHG Programs require periodic revisions of the baseline, although the frequency of doing so differs per Program and type of baseline.	There is strong evidence of baseline inflation in some avoided deforestation projects. For other types of projects, such as reforestation, baseline setting is more straightforward because the counterfactual case is clearer.	Nesting can reduce the risk of baseline inflation. This is particularly true for avoided deforestation where nested projects are provided a risk-adjusted, 'fair share' of the jurisdictional reference level.	Too early to tell (as no experience yet with the JNR standard)… jurisdictions are expected to develop both an historical average and trend baseline and justify the selection.	Includes rigid rules avoid risk of gaming the baseline. Average historical reference emissions are likely conservative where deforestation is rising. High forest cover-low deforestation countries may set a reference level that exceeds historical average emissions up to a prescribed cap that may not always be conservative.	Provides only minimal guidance on how to set a crediting baseline, leading to high variability in baseline setting (from conservative to overly generous).

Quantification and MRV	Projects take conservative approaches throughout in calculating emission reductions. Requirements to account for uncertainty differ considerably per GHG Program. For methodology approval, VCS defines a maximum permissible error beyond which discounting is required; the CDM requires justifiably conservative default values. GHG Programs also provide additional and quantified guidance for limiting the uncertainty during monitoring, notably for sampling.	Some methodologies appear incomplete in their estimation of error combined with expected high uncertainties.	Expected to be similar to stand alone projects, i.e. potentially incomplete unless VCS adds additional requirements.	Current guidance appears incomplete in the estimation of error combined with expected high uncertainties.	Strong for the reporting of aggregate error of the emission reduction, but lenient on allowable uncertainty.	Does not require conservativeness or reporting of uncertainty calculations. Adherence to IPCC guidance on uncertainties is uneven.
	All projects undergo independent third-party validation and verification (as per ISO standard).	All projects undergo independent 3rd validation and verification.	An independent 3rd validation and verification is required.	All projects undergo independent 3rd party validation and verification.	Flexible validation process using technical experts; verification process is more akin to the ISO standard.	Employs a 'technical expert' assessment that does not follow ISO standard for verification..
Permanence	Only CCS projects foresee specific rules to manage permanence. Other project types are considered to generate permanent emission reductions. In the case of CCS in geological formations, the CDM uses a combination of buffer pool, liability provisions, and actions to manage the risk of reversals in the design and operation of projects. No CCS CDM project has been registered yet.	Prescribes the allocation of a risk-adjusted percentage of forest GHG reductions to go into a buffer account, which is currently oversubscribed with credits.	Based on experience for stand-alone VCS projects, the allocation of GHG units to the buffer is expected to be successfully managed.	Too early to tell… no track record. Since only a moderate number of programs can be expected in the buffer, more stringency than for projects is needed.	Too early to tell… no track record. Since only a moderate number of programs can be expected in the buffer, more stringency than for projects is needed.	Includes no assessment of permanence risk, nor set aside of GHG units to manage risks.
Leakage	The leakage risk differs considerably between project types. While activity shifting leakage appears to be consistently addressed, lifecycle leakage is included in some methodologies only. Also, market leakage is not universally addressed, which can result in overestimating emission reductions (in particular, in the energy sector).	Leakage risks can be high for certain forest project types (such as avoided deforestation); projects must monitor, quantify and deduct for leakage.	Provides added confidence in leakage management since performance at the higher scale is measured and reported.	Requires the assessment of leakage risk, plus quantification and deductions for leakage.	Requires the assessment of leakage risk, and addressing risk in program design, but no quantification or deductions for leakage.	Includes no assessment of leakage risk, and no quantification or deductions for leakage.