PM.0005

Adoption of controlled-release fertilizers to transition to low-carbon agriculture

GHG Methodology

Version 1.0

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Methodology:

Adoption of controlled-release fertilizers to transition to low-carbon agriculture

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List of definitions

Additionality	Refers to the concept that any GHG project should result in greenhouse gas emissions mitigation (GHG reductions or removals) that would not have occurred without the project. In other words, the project's positive impact on reducing or removing emissions should be "additional" to what would have happened under the baseline scenario.
Ammonia volatilization	The process by which ammonia (NH_3) gas is released into the atmosphere from ammonium-containing fertilizers (e.g., urea). This can lead to indirect GHG emissions when ammonia is subsequently converted to nitrous oxide (N_2O) in the environment.
Baseline scenario	The baseline scenario represents the emissions that would occur based on the business as usual agricultural management practices. In other words, this includes fertilizer management and other relevant activities, without the use of Controlled-release fertilizer (CRF)
Carbon credit (emission reduction certificate)	A carbon credit represents at least 1 tonne of CO2 (tCO_2), or 1 tonne of CO2e (tCO2e) reduced or removed for a certain period of time. One tonne (metric ton) (t) equals 1000 kg. For carbon equivalency, Proba uses the AR-5 assessment from UNFCCC[1].
Carbon dioxide equivalent - CO_2e	A metric used to compare the emissions of various greenhouse gases based on their Global Warming Potential (see GWP definition). It expresses the impact of different gases in terms of the equivalent amount of CO2, facilitating a standardized approach to assessing overall greenhouse gas emissions.
Conservativeness	When there is uncertainty or a choice between two or more assumptions, values, methodologies, or procedures, the option that is more likely to result in lower estimates of GHG emission reductions or removals must be selected. This approach ensures that claimed climate benefits are not overestimated.
Controlled-release fertilizer (CRF) and Slow-release fertilizers (SRF)	Slow- or controlled-release fertilizer is defined as a fertilizer containing a plant nutrient in a form which delays its availability for plant uptake and use after application, or which extends its availability to the plant significantly longer than a reference 'rapidly available nutrient fertilizer' such as ammonium nitrate or urea, ammonium phosphate or potassium chloride. Such delay of initial availability or extended time of continued availability may occur by a variety of mechanisms. These include

[1] https://ghgprotocol.org/sites/default/files/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_0.pdf

	controlled water solubility of the material by semi-permeable coatings, occlusion, protein materials, or other chemical forms, by slow hydrolysis of water-soluble low molecular weight compounds, or by other unknown means. Definition based on Trenkel (2010).
Cradle-to-gate	A life cycle assessment boundary that includes all greenhouse gas emissions associated with a product's life cycle stages up to the point it reaches the project's location. This includes emissions from raw material extraction, production, and transportation to the project's location. It excludes emissions from field application or any subsequent stages beyond the project's location.
Crediting period	The "crediting period" refers to the specific duration of time during which a GHG project is eligible to generate and issue emission reduction certificates for the GHG emissions it reduces or removes. This period is predefined and ensures that the project's emissions impact is monitored, verified, and credited only within that set timeframe. A crediting period can be renewed once or multiple times.
Cumulative N_2O emissions	Total N_2O emissions calculated over a specific period, leveraging direct or indirect methods. This means these can be calculated with either direct flux measurements using specialized equipment (e.g., gas chambers, spectrometers) or estimated using emission factors or models. Both direct N_2O emissions and indirect N_2O emissions (from nitrate leaching and ammonia volatilization) are included.
Denitrification	A microbial process in which nitrate (NO_3^-) is reduced stepwise to nitrogen gas (N_2), typically under anaerobic conditions in soil. During this process, nitrous oxide (N_2O) can be produced as an intermediate product and may accumulate instead of fully being reduced to N_2.
Emission factors	Emission factors are coefficients that quantify the amount of greenhouse gases released into the atmosphere per unit of activity, substance, or process. They are essential tools in calculating emissions and facilitating the estimation of a project's total greenhouse gas emissions. The Intergovernmental Panel on Climate Change (IPCC) has established a three-tier system for the development and application of emission factors (Tier 1, Tier 2, and Tier 3). These tiers are presented in Appendix A.1 Tier definitions.
Enhanced Efficiency Fertilizers (EEF)	Fertilizers developed to regulate the release of N from fertilizers, allowing for improved N uptake and utilization by plants, thereby lowering losses and increasing crop productivity per unit of fertilizer.
GHG project	Activity or activities that alter the conditions of a GHG Baseline and

	which cause GHG emissions reductions or GHG removals. The intent of a GHG project is to convert the GHG impact into emission reduction certificates.
Global Warming Potential (GWP)	The time-integrated radiative forcing resulting from a pulse emission of a specific greenhouse gas, relative to the radiative forcing from a pulse emission of an equivalent mass of carbon dioxide (CO_2) (Woolf et al., 2021). It provides a common scale to compare the climate impact of different gases over a specific time horizon, typically 100 years.
Inorganic fertilizers	Fertilizers manufactured through chemical processes or mined from natural deposits and then processed to be concentrated and standardized. These include: nitrogen fertilizers (e.g., urea, ammonium nitrate), phosphorus fertilizers (e.g., superphosphate), potassium fertilizers (e.g., potassium chloride). They are typically water-soluble and immediately available to plants, which makes them highly efficient but also potentially leachable.
Insetting	Insetting refers to the practice of implementing sustainability interventions within a company's own value chain to reduce greenhouse gas (GHG) emissions or enhance carbon sequestration. Unlike offsetting, which typically involves purchasing carbon credits for activities outside the value chain, insetting focuses on reducing emissions directly linked to the company's operations, suppliers, or production processes.
IPCC	The Intergovernmental Panel on Climate Change is a United Nations body, assessing science related to climate change to provide policymakers with regular scientific updates.
Land Management Unit (LMU) / Field level	A Land Management Unit (LMU) is a clearly defined area of land under consistent management, where fertilizer application and CRF product use can be directly monitored and attributed. The LMU level allows GHG emissions and reductions to be accurately measured and linked to specific land parcels, each with defined boundaries and documented management practices. It is aligned with the GHG Protocol's *Land Sector and Removals Guidance* definition [2].
Leakage	In the context of a GHG project, leakage refers to the unintended increase in greenhouse gas emissions outside the project boundaries as a direct result of the project's activities.
Nitrate leaching	The vertical movement of nitrate through soil profile into deep layers along with irrigation water or rainfall. This process can lead to

[2] https://ghgprotocol.org/land-sector-and-removals-guidance

	groundwater contamination (e.g., because nutrients and cations can be leached). and the indirect emission of nitrous oxide (N_2O) when nitrates are converted by microbial activity in anaerobic conditions.
Nitrate runoff	The horizontal movement of water across the soil surface, carrying with it dissolved and particulate nutrients from fertilizers as well as (fine) soil particles to nearby water bodies. Runoff can result in surface water pollution and contribute to eutrophication. Additionally, when nitrogen compounds in runoff reach water bodies, they can undergo microbial activities which result in indirect emissions of nitrous oxide (N_2O).
Nitrification	A microbial process in which ammonia (NH_3) in fertilizers is oxidized to nitrite (NO_2^-) and then to nitrate (NO_3^-). This process can produce nitric oxide (NO) and nitrous oxide (N_2O) as by-products.
Nitrogen stabilizer	They are compounds incorporated into fertilizer products that are used in agriculture to prolong the availability of nitrogen in soil, thereby improving its efficiency. These stabilizers typically work by inhibiting the conversion of ammonium to nitrate, reducing nitrogen loss through leaching and denitrification. (e.g., Nitrification inhibitors, urease inhibitors, or a combination of both)
Nitrogen Use Efficiency (NUE)	Nitrogen Use Efficiency (NUE) refers to the effectiveness with which crops utilize applied nitrogen for growth and yield. It can be defined as biomass production (or crop yield) per unit of N applied to the crop.
N-rate	The amount of nitrogen applied to a field, typically expressed in kilograms of nitrogen per hectare (kg N/ha), used to meet crop nutrient requirements.
Offsetting	Offsetting refers to the practice of compensating for greenhouse gas (GHG) emissions by supporting projects outside a company's value chain that reduce or remove emissions. This is typically achieved by purchasing carbon credits from verified initiatives.
Organic fertilizer	Fertilizer product containing organic carbon and nutrients of solely biological origin and excluding materials which are fossilized or embedded in geological formations. Note: Organic fertilizers are different from fertilizers authorized in organic farming, which may include some mineral fertilizers such as phosphate rock (IFA's Fertilizer Terminology, 2020)
Proba Standard	The Proba Standard aims at controlling and reducing the risks related to GHG projects, their climate impact (emission reduction) and the corresponding issuance of emission reduction certificates and

	subsequent claims. It does so by relying on and aligning with internationally recognized standards frameworks and initiatives such as the Core Carbon Principles by the ICVCM and the ICROA Code of Best Practice. The Proba Standard sets out detailed procedures for identification and validation of GHG projects, and verification of emission reductions and removals, based on ISO 14064-2 . More information about the Proba Standard can be found at https://proba.earth/document-library.
Product Carbon Footprint (PCF)	Sum of GHG emissions and GHG removals in a product system , expressed as CO2 equivalents and based on a life cycle assessment using the single impact category of climate change (ISO 14067:2018)
Project boundaries	The project boundaries of a GHG project delineate the spatial, temporal, and operational limits within which the GHG emissions, reductions, and removals are quantified and monitored, encompassing specific activities, sources, sinks, and reservoirs related to the project.
Project Overview Document (POD)	A document that offers a detailed summary of a GHG project's key elements, including governance, emission calculations, risk management, methodologies, and monitoring processes (see Proba Standard).
Sourcing Region	A geographically distinct area characterized by common environmental, climatic, and land use conditions. It may encompass an entire country, a jurisdiction, or a specific part of it, and is typically defined by administrative boundaries, agroecological zones, or sourcing areas. It is aligned with the GHG Protocol's *Land Sector and Removals Guidance* definition [3].
Tier 1, 2 and 3	In the context of greenhouse gas (GHG) emissions reporting and inventory management, data and methodologies are categorized into three tiers (Tier 1, Tier 2, and Tier 3), as defined by the Intergovernmental Panel on Climate Change (IPCC). These tiers represent varying levels of accuracy, data specificity, and complexity. For more information see Appendix A.1 Tier definitions.
Verification and Validation Bodies (VVBs)	Third-party assurance entities, preferably ISO-accredited, are responsible for verifying that a project's activities and claims of emissions reductions and/or removals are conducted in accordance with established standards and methodologies, ensuring their accuracy and credibility.

[3] https://ghgprotocol.org/land-sector-and-removals-guidance

List of abbreviations

AR6	IPCC Sixth Assessment Report
CRF	Controlled-release fertilizer
EEF	Enhanced Efficiency Fertilizers
EF	Emission Factor
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
LMU	Land Management Unit level
MRV	Monitoring, Reporting, and Verification
N_2O	Nitrous Oxide
NH_3	Ammonia
NO	Nitric oxide
NO_2^-	Nitrite
NO_3^-	Nitrate
NUE	Nitrogen Use Efficiency
PCF	Product Carbon Footprint
POD	Project Overview Document
SDG	Sustainable Development Goal
SRF	Slow Release Fertilizer
SOC	Soil Organic Carbon
VVB	Verification and Validation Body

1 Introduction

1.1 Background

Fertilizers are important in agriculture, supplying critical nutrients like nitrogen, phosphorus and potassium to crops. They enhance soil fertility and are key to feeding the global population by boosting crop yields.

The production and application of nitrogen fertilizers contribute to greenhouse gas (GHG) emissions, especially nitrous oxide (N_2O), a greenhouse gas (GHG) with a Global Warming Potential 273 times more potent than CO_2 (IPCC, 2021). This impact is a major concern for climate change due to the global warming potential of these emissions. It is essential to reduce N_2O emissions associated with the application of inorganic nitrogen-containing fertilizers. The use of controlled-release fertilizers (CRF) and slow release fertilizers (SRF) have been identified as an effective strategy to reduce nitrogen losses and related emissions in agricultural systems (Akiyama et. al., 2010, Grados et al., 2022). Note: Throughout this methodology, the term "Controlled-Release Fertilizers (CRF)" is used as a practical convention and also encompasses Slow-Release Fertilizers (SRF), unless explicitly stated otherwise.

CRF products can provide an effective solution to reducing nitrous oxide emissions associated with nitrogen fertilizer use. By gradually releasing nitrogen over an extended period, CRFs align nitrogen availability with plant uptake, significantly improving fertilizer use efficiency. Unlike conventional fertilizers, which often release nitrogen quickly and in amounts that exceed plant needs, CRFs minimize nitrogen loss to the environment, including leaching and volatilization processes that contribute to nitrous oxide emissions. Through advanced mechanisms such as coatings, encapsulation, or matrix systems, CRFs offer a more predictable nitrogen release, reducing the risk of excessive nitrogen release and ensuring that plants receive the right amount of nitrogen at the right time. The use of CRF results in multiple emission reductions and efficiency improvements, including:

- <u>Reduction in direct N_2O emissions</u>: CRF products release nitrogen gradually, aligning with plant uptake and reducing the availability of excess nitrogen in the soil. This controlled release minimizes conditions that favor nitrous oxide (N_2O) emissions production (Grados et al., 2022, Fan et al., 2022)

- **Reduction in indirect N_2O emissions**: By decreasing nitrogen losses through leaching and volatilization, CRFs reduce the amount of reactive nitrogen that can contribute to indirect N_2O emissions in downstream ecosystems (Grados et al., 2022).
- **Improvement of Nitrogen Use Efficiency (NUE)**: CRF products can enhance NUE due to reduction of N losses which improves the availability of nitrogen to plants. The frequency and rate of nitrogen application can be reduced considerably for various crops (Yang et al., 2016) This may lead to higher crop yield[4] for the same nitrogen input or maintaining the same crop yield with less nitrogen inputs.
- **Reduction in nitrogen application rates and associated emissions**: CRF products enable lower total nitrogen application rates at the field level due to their improved nitrogen use efficiency. This leads to lowering the overall Product Carbon Footprint of nitrogen inputs and reduced field operations and fuel-related emissions.

1.2 Applicability of the methodology

- This methodology is globally applicable to projects that introduce controlled-release fertilizers as a replacement for conventional fertilizers in managed soils.
- Project developers must ensure that the applicability, eligibility and additionality criteria presented in this methodology are fulfilled.
- This methodology is applicable to both offsetting and insetting projects. In alignment with emerging SBTi guidance, insetting projects should prioritize direct mitigation, where the intervention can be physically linked to specific emissions sources within the company's value chain through a robust chain of custody model. Where such traceability is not yet possible, indirect mitigation may be used as an interim measure, provided it supports the transformation of the relevant value chain over time. Section 1.4 Additionality, explains the requirements for these different types of projects.
- Project developers must be able to demonstrate that without the intervention (e.g., baseline scenario), there would be human-induced net N additions to soils (e.g., inorganic and/or organic fertilizers), which would lead to direct and indirect emissions.
    - The baseline fertilizer (i.e. the product that would be used in the absence of the CRF may contain multiple nutrients (e.g., nitrogen, phosphorus, and potassium) and come in various formulations (e.g., DAP, MAP, NPK blends, ammonium sulfate nitrate, etc.). All these fertilizer types are within the scope of this methodology.

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[4] For the purposes of this methodology crop yield is the same as crop productivity or biomass production

However, the impact of the CRF is attributed only to the nitrogen (N) component of the product and emission reductions are calculated proportionally based on the nitrogen fraction replaced by CRF, regardless of the baseline product's composition. and emission reductions are calculated proportionally based on the nitrogen fraction replaced by CRF, regardless of the baseline product's composition.

- Project developers must demonstrate that nitrogen inputs are applied at appropriate rates based on regional agronomic guidelines or best practices (e.g., nutrient recommendations from agricultural retailers, industry-supported agronomy platforms, etc.), supporting optimal nitrogen use efficiency (NUE). See Appendix D for different metrics for NUE. Where regional data is unavailable or unreliable, project developers may propose farm-level NUE benchmarks, provided they are supported by transparent historical records and justified environmental comparability. This ensures that baseline fertilization is not excessive and avoids rewarding projects that apply nitrogen beyond typical regional norms, which could otherwise inflate emission reductions due to the CRF's effect on the excess nitrogen. Where regional baseline fertilization is excessive, project developers must clearly disclose this and structure their projects to support improved, agronomically appropriate nitrogen application rates. For this purpose, project developers must do a *NUE Performance Test,* as defined in section 3 Baseline Scenario.
- Project developers must be able to prove that because of the intervention (e.g., project), the introduction of the CRF leads to the reduction of the net GHG emissions, which are in scope of this methodology (see section 2.1 Scope of activities).
- When CRF products are applied, project developers may reduce the nitrogen (N) application rate compared to conventional fertilizers, provided there is a demonstrable improvement in nitrogen use efficiency (NUE). This reduction must be supported by robust agronomic evidence showing that the CRF product maintains or enhances crop productivity while using less nitrogen. Any potential crop yield reduction must be assessed, and it **may** be addressed as a source of leakage. Project developers must follow the procedure outlined in the section 1.8 Leakage & Permanence, which includes specific guidelines
- For both the **baseline** and **project intervention**, project developers must provide scientific proof of the emission factors (EFs) related to the specific characteristics and activities of the project.
    - This scientific proof must be sourced from one of the following: 1) a relevant meta-analysis, or 2) original scientific literature.

    - The EFs used must be retrieved from studies that meet specific quality criteria, and project developers must demonstrate that the characteristics and activities of both the baseline and project intervention are consistent with the key environmental factors and management practices described in the supporting scientific evidence. The quality criteria and variables are detailed in the appendix A.2 Emission Factor Selection Criteria based on Scientific Studies. Where this alignment is demonstrated, even a single study may be leveraged to generate the EF applied at the project or baseline level.
    - For sourcing region type of projects, a representative average emission factor (Tier 2 - type [5]), derived from aggregated region-specific EFs, may be used, provided that it is based on sufficient data.
    - In cases where there is no supporting scientific evidence of the impact of the CRFs on the GHG emissions related to specific crops, cropping systems, and agroecologies, an aggregated EF reduction impact can be used (from a meta-analysis). The procedure of selecting an appropriate value is described in section 4.3. Uncertainty and must be properly justified and documented.
  - Project developers must be able to prove that the intervention leads to an actual replacement of conventional fertilizers on the spatial level of their project (see 2.3 Spatial boundaries).
    - For LMU type of projects: If the baseline is defined using historical data (e.g., farmer logs) at the LMU level, the corresponding regional baseline must also be provided to support the assessment of additionality. If regional data is used instead, then the regional baseline becomes the default baseline for the LMU.
    - For sourcing region type of projects: The regional baseline de facto defines the project's baseline.
- This methodology is applicable to projects that introduce changes to management practices on top of the usage of CRFs (e.g., adopting improved tillage methods, introducing cover crops, or similar)[6] **if one of the following conditions are met**:
  1. The project intervention is supported by scientific evidence and the relevant EF derived from these scientific studies are used, **OR**

[5] Explanation of the Tier approach can be seen in the appendix A.1 Tier definitions
[6] This methodology aims to support multiple interventions on the fields (which might be the case for many projects), however it is crucial that these interventions do not negatively affect the impact of the CRFs (or on the other hand the CRFs do not interfere with other interventions already in place). For this reason the conditions were added.

2. There is sufficient scientific proof that these practices (that come on top of the introduction of CRFs) do not negatively affect the CRF-induced reduction of emissions (bare minimum).

- This methodology can work **synergistically** with other GHG methodologies or programs that target emissions reductions or removals in areas outside the scope of this methodology. For instance, a program could combine the application of CRFs with a soil management practice designed to sequester CO_2, thereby achieving complementary climate benefits while ensuring that the integrity of the emission reductions from activities under this methodology is maintained. In case this methodology is used in conjunction with other methodologies or programs then the project developer must:
    - explicitly mention that in the POD and
    - demonstrate that benefits are not quantified more than once (to mitigate the risk of double counting the impact of CRFs across two projects) and
    - provide a separate monitoring framework to ensure that combined interventions do not undermine CRF's effectiveness in long-term consistency
- The project developer must be transparent and report on additional activities that happen along with or because of the introduction of CRFs, which can lead to material changes of emissions on the field. Some (non-exhaustive) examples of such activities:
    - Switching from low-emission fuel to high-emission fuel for field operations
    - Increasing or reducing the number of tractor passes or field operations (e.g., less application of CRF products)
    - Switching to a fertilizer product with higher or lower embedded emissions per kg of nitrogen applied
    - Installing the infrastructure to accommodate irrigation events
    - Conducting irrigation events (e.g., fertigation with CRF) that consume energy or water
- This methodology has been developed in accordance with the Proba Standard, ensuring that all guidelines, principles, and requirements outlined in the standard are fully adhered to. Users of this methodology are expected to follow the Proba Standard to ensure consistency, credibility, and compliance with the broader framework established by Proba.

1.3 Eligible products

- In this methodology, the eligible products are controlled-release fertilizers (CRF) and slow-release fertilizers (SRF)
- Other enhanced efficiency fertilizer products, such as biostimulants, and bio-inhibitors (BIs), are currently excluded from this methodology when used as standalone products. That is because:
    - There is currently no consistent, peer-reviewed evidence base or emission factors that support their inclusion across diverse conditions.
    - Once robust methods and supporting data are available, these products may be incorporated through future methodology updates.
- However, blends that include a CRF product combined with a stabilizer are eligible.
- Coatings of all biodegradability levels are eligible under this methodology. However preference must be given to CRFs with a coating that is (1) biodegradable > (2) non-biodegradable but bio-based > (3) non-biodegradable.
    - The Project Overview Document (POD) must transparently disclose the coating type and classify it according to the above hierarchy.
    - For CRFs classified as biodegradable, Project developers must define biodegradability levels and accepted tests, referencing EU Regulation (EU 2024/2770)[7].
    - For non-biodegradable CRFs, the maximum duration of the crediting period is subject to specific conditions described in Section 1.5 Crediting period. This clause is included to ensure that, while all CRF coatings are eligible, carbon finance is used to address the potential long-term environmental risks associated with non-biodegradable coatings and support a transition to biodegradable alternatives.
    - This means that non-biodegradable (e.g. polymer-coated) fertilizers are only temporarily allowed under this methodology.

1.3.1 Methods of application

- Application methods such as fertigation (e.g., applying CRF through drip irrigation systems), precision agriculture techniques (e.g., variable rate application or site-specific deployment), and field application techniques (e.g., row application or broadcasting) are all considered eligible. In all cases, project developers must provide supporting documentation

[7] EU Regulation 2024/2770 requires ≥ 90% degradation/mineralisation in soil within 48 months after the product's functional period (mandatory from 17 October 2028). Accepted test methods include ISO 17556:2019, ASTM D5988-18, or equivalent. See https://eur-lex.europa.eu/eli/reg_del/2024/2770/oj/eng

that describes the chosen delivery method and its compatibility with the cropping system to ensure optimal nitrogen use efficiency and reduction of nitrogen losses.

- The following methods of integrating CRF into fertilization practices are eligible:
  - Application of CRF as a sole product.
  - Application of CRF in blends with other fertilizers, provided that:
    - The CRF component in the blend is clearly defined and quantified. Documentation that is verifying the CRF percentage in the final fertilizer mix should be provided.
    - Only the portion of the nitrogen applied through CRF is considered eligible for emission reduction claims. Reductions must be calculated proportionally, based on the verified CRF content of the total nitrogen applied.
  - In cases where the CRF is blended with both conventional fertilizer and a nitrogen stabilizer, emission reductions can be claimed proportionally for each component (e.g., CRF, stabilizer) based on their documented contribution. Alternatively, if a published or peer-reviewed study is available for the specific blend, the emission factor from that study may be taken into consideration to quantify the total reduction.

1.3.2 Regulatory compliance

For CRF products to be eligible they must be registered in the country or region where they are being applied. In addition, compliance to regional guidelines is essential to ensure that the application rate is in line with local regulations.

1.4 Additionality

Additionality refers to the concept that a GHG reduction project should result in emissions reductions beyond what would have occurred under a "business-as-usual" scenario or existing regulations, ensuring the reductions are truly "additional" and not simply complying with mandatory requirements.

Project developers are encouraged to use the *Proba Additionality Assessment Template* [8] to assess and demonstrate additionality, as defined in section 3.6 of the *Proba Standard*.

Alternatively, established tools and approaches can support project developers in assessing additionality, particularly for financial and common practice assessments. These include the

[8] https://proba.earth/hubfs/Project_Design/Proba_Additionality_Assessment_Template.pdf

UNFCCC's CDM Tool for the Demonstration and Assessment of Additionality (Version 07.0) [9] and the CDM Tool for Common Practice (Version 03.1) [10]. These tools offer structured guidance for conducting barrier analyses, determining financial attractiveness, and assessing market penetration levels of a given practice. While originally developed for offsetting contexts, they can be adapted for insetting projects when transparently applied and justified in the POD.

Depending on whether the project developer aims to use the generated claims (emission reduction certificates) in either offsetting or insetting scenarios, different requirements apply.

For the offsetting scenario the project developer must prove the following three aspects of additionality:

- Regulatory additionality: The project developer must prove that the introduction of the use of CRF was not caused by local, regional or national regulations. To achieve that, the project developer must prove that there is a) no regulation enforcing the use of CRFs and b) there is a lack of financial incentive of regulatory directives to realize the proposed intervention. If subsidies are available, the project developer must show that available funding does not cover the financial gap to realize the intervention.
    - If a regulation is implemented and actively enforced during the crediting period that mandates the use of CRF products, the crediting period for the project will end at that point, as the project would no longer meet the criteria for additionality.
- Prevalence: The project developer must prove that the introduction of the use of CRF products is not a common practice in each region included within the project area. Common practice is defined as per the guidelines of the Standard that the project developer follows. Moreover, the intervention must lead to an increase in the uptake of the CRF product, in the spatial boundaries of the project.
- Financial additionality: The project developer must prove that the financial incentive from carbon finance will lead to the increased adoption of the CRF products by the farmers. Transparency on financial assistance, such as subsidies, is also required. This financial analysis may be treated as confidential by the VVB and Proba and is not required to be published in the public registry.

For the insetting scenario, the project developer must demonstrate regulatory additionality by confirming that the use of CRF products is not mandated by the regulation. In addition, the Project Overview Description (POD) must be transparent and document information on:

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[9] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-01-v7.0.0.pdf
[10] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-24-v1.pdf

- Prevalence additionality: An explanation must be provided that the use of CRF products is not a common practice within the company's sourcing region, crop system, or market segment relevant to the intervention.
- Financial additionality: An explanation must be provided carbon finance is positively affecting the adoption of CRF products within the company's sourcing region, crop system, or market segment. Transparency on financial assistance, such as subsidies, is also required.

Note: Additionality must be reassessed when renewing the crediting period to confirm that the project remains eligible under the Proba Standard. Project developers are responsible for monitoring regulatory changes, financial conditions, and market adoption that may affect the project's additionality. The use of a dynamic baseline is required to reflect these developments and ensure the continued credibility of the emission reductions being claimed, as seen in section 3. Baseline scenario.

1.5 Crediting period

The crediting period is the timeframe during which a validated project can generate emission reduction certificates. After the end of the crediting period, the project needs to be re-validated, to ensure that additionality is still present, the baseline scenario is reassessed, and the project complies with the latest version of this methodology. If these requirements of the methodology are not fulfilled at the time of project re-validation then the crediting period can not be renewed.

For GHG projects utilizing CRF products, the crediting period can be set up to a **maximum of 7-years**. This duration strikes a balance between providing enough time for projects to demonstrate their environmental impact and maintaining flexibility for project adjustments and improvements (e.g., new technologies or regulations).

Note: The crediting does not "force" farmers in the project to use CRF products, but allows them to generate emission reduction certificates if they do. For example, if a farmer applies CRF products in only 4 out of 7 years, they would receive emission reduction certificates only for these four years.

Retroactive crediting

This methodology allows for retroactive crediting, in the case the application of CRF products was introduced within a maximum of **two years** prior to the submission of the validation of the POD.

In such cases, the crediting period will begin at the moment the intervention was first implemented, provided that the project developer can fulfill the requirements set by this methodology (e.g., proof of additionality, baseline, scientific evidence, documentation etc.) and in addition demonstrate that the intervention was implemented with the intention of utilizing carbon finance.

Conditions for non-biodegradable CRFs

The methodology acknowledges that non-biodegradable CRFs contribute to the accumulation of microplastics in soils and the wider environment. At the same time, fully biodegradable CRF coatings are not yet widely available at scale, limiting immediate substitution. The production of biodegradable coatings requires significant investments from fertilizer producers. This methodology therefore imposes a transition pathway, enabling project developers to adopt CRFs today while requiring them to make a gradual shift towards biodegradable alternatives and help making them commercially viable. To operationalize this transition, the following crediting period rules are imposed for non-biodegradable CRFs:

- First crediting period: maximum of 3 years. This period must be used to build a business case and improve commercial viability of biodegradable CRFs.
- Second crediting period: maximum of 5 years, conditional upon submitting a committed transition plan to produce or distribute biodegradable CRFs within the project region. This plan must be submitted together with an updated POD as described in the section 6.2 Reporting.
- After two crediting periods, only biodegradable CRFs are eligible, with a crediting period of up to 7 years.
- Projects requesting renewal of the crediting period must undergo re-validation against the latest version of this methodology, allowing for updates in line with global developments on CRF biodegradability. Proba will closely monitor developments in technology, legislation, and scientific research which, if relevant, may lead to revisions of the conditions for non-biodegradable CRFs. Such revisions - typically resulting in more stringent transition requirements - will also apply to existing projects seeking renewal.

In addition, the Project Overview Document (POD) must be transparent on the use of non-biodegradable products and the requirements for coating types, as outlined in Section 1.3 Eligible products, must be followed. Under all circumstances, non-biodegradable fertilizers are only temporarily allowed under this methodology.

1.6 Co-benefits & no harm principle

This methodology does not prescribe any calculation methods for quantifying additional benefits resulting from the application of CRF products. Project developers are recommended to report on co-benefits for credibility purposes.

Proba encourages such projects to contribute to at least one or more UN Sustainable Development Goals[11], and expects that project developers, engineers or managers will consider these when preparing and designing a project.

If the project developer aims to claim one or more co-benefits, these must be clearly defined in the Project Overview Document (POD), along with how the impact is achieved, measured (e.g., through KPIs). In this case, relevant KPIs must be selected by the project developer and monitored throughout the years. Examples of relevant co-benefit indicators (KPIs) include:

- Percentage reduction in nitrate concentration in surface or groundwater (mg/L)
- Soil organic carbon (SOC) improvement (t/ha/year)
- Water use efficiency (kg yield/m^3 water)

For instance, the SDG Impact Assessment Tool offers a structured approach to help assess and align projects with the SDGs[12]. Some examples that could be relevant with this type of project include:

- **Zero hunger (SDG 2)**: The use of CRF products enhances crop yields while simultaneously reducing N_2O emissions (Govil et al., 2024). In doing so, these projects contribute to improving food production while promoting sustainable agricultural practices, aligning with SDG 2, which aims to ensure food security and sustainable food production for a growing global population.
- **Clean water and sanitation (SDG 6)**: By reducing nitrogen leaching into groundwater and surface water, the application of CRF products improves water quality, protecting freshwater ecosystems and ensuring cleaner water supplies (IPCC, 2022).
- **Climate action (SDG 13):** By reducing nitrous oxide emissions, these projects reduce GHG emissions and directly contribute to climate change mitigation, aligning with global goals and efforts to combat climate change.
- **Life on land (SDG 15):** Reduced nitrogen runoff can lead to healthier soils and ecosystems. This also contributes to SDG 15 by supporting sustainable use of terrestrial ecosystems and avoiding land degradation and biodiversity loss.

[11] https://sdgs.un.org/goals
[12] http://sdgimpactassessmenttool.org

Project developers must adhere to the Environmental and Social do no harm principle by conducting thorough assessments to identify and evaluate potential environmental and social impacts of their GHG projects. They must also implement appropriate mitigation measures to address any identified potential risks and negative impacts, ensuring that the project does not adversely affect local ecosystems or communities, particularly vulnerable populations.

As such, in the POD, at least the following must be established:

- monitoring frequency
- risk indicators (e.g., groundwater quality, community grievances)
- corrective pathways if harm is detected.

Proba's *Environmental and Social do no harm principle Template* [13] can be used for this purpose.

1.7 Risks

The project developer must provide a risk analysis outlining all the possible risks associated with the GHG project. Moreover, the project developer must devise and present a mitigation strategy for those risks. Some of the risks that should be addressed are the following:

- Events which may occur during the crop season, and may lead a) to decreased crop yields or b) additional applications of fertilizers and CRF products must be thoroughly explained and documented as part of the verification cycle. Such events can negatively impact the emission reductions of the project. Examples of such events include, but are not limited to, diseases, pests, extreme weather events[14] (e.g., heavy thunderstorms and hailstorms).
- The farmer might not actually apply the reported amount of product, either as an unintentional action or miscalculation or a deliberate error or falsification.
- Improper use of CRF products, such as incorrect application rates or timing, may reduce effectiveness and environmental benefits. For LMU type of projects, the fertilization schedule must be submitted during verification.
- In certain cases, CRFs (not SRFs) use polymer coatings that may degrade into microplastic residues. While these coatings are designed to be stable during nutrient release, their long-term breakdown in soil ecosystems raises concerns.

[13] Available upon request
[14] The IPCC defines extreme weather events as occurrences outside the historical range of variability, such as droughts, heatwaves, floods, and storms, which can disrupt agricultural activities and nutrient cycling processes (IPCC, 2021).

    - Project developers must assess and document the type of coating[15], following the hierarchy and the guidelines described in section 1.3 Eligible products
    - Project developers must comply with the crediting period restrictions specified in section 1.5 Crediting period
    - Project developers must present their transition plan on moving to higher hierarchy level options during the project period (e.g. having non-biodegradable CRFs as an intermediate solution) and must be included in the POD, as described in section 6.2 Reporting .
- The crop yield might be incorrectly measured or reported.
- If the emission factors were selected directly from scientific literature, which was funded by the fertilizer industry, there might be a risk of conflict of interest.

1.8 Leakage & permanence

1.8.1. Leakage

Leakage in the context of a GHG project is the net increase in GHG emissions that occurs outside the project boundary, directly resulting from the project's activities (IPCC, 2006). While projects are credited only for reductions within the project area, potential leakage must be assessed to ensure environmental integrity.

For interventions in scope of this methodology there may be two main risks of leakage:

1. Leakage must be accounted for when the fertilizer volumes no longer used in the project area are demonstrably sold and used by non-project actors. Given the global nature of fertilizer markets, it is not feasible to monitor all potential displacement of conventional fertilizers at a global scale. However, project developers must take reasonable steps to assess and mitigate leakage risks within the project region. The project developer must provide reasonable evidence of how these volumes were managed. Evidence can include:
    - written confirmation from fertilizer supplier or distributor that production or delivery volumes were reduced;
    - project-level fertilizer application data showing reduction in conventional fertilizer use without corresponding increase elsewhere;

[15] In recognition of emerging regulatory schemes regarding polymer-coated fertilizers and microplastic pollution, project developers are encouraged to prioritize CRF products with biodegradable coatings. From 2028 onward, the EU will require only biodegradable polymers for polymer-coated fertilizers under its revised Fertilizing Products Regulation (EU 2019/1009). Future versions of this methodology will align accordingly.

- national or regional sales/trade data showing stable or decreasing conventional fertilizer volumes;
- market analysis or reports indicating no increase in non-project sales.

Where this cannot be confirmed, conservative deductions apply to account for potential leakage risk. These deductions can be adjusted retrospectively if new evidence is submitted. Specifically, after a period of 4 years, the project developer may submit evidence demonstrating that the project did not result in leakage elsewhere. If such evidence is accepted by the verification and validation body, the reserved emission reductions may be credited retroactively or released from a buffer pool. If sufficient evidence is not provided at that time, the deduction remains permanent. *Table 1* presents a standardized stratification of the deductions depending on the scale of the project.

Table 1: Market leakage deduction for different scenarios

Project scale[16]	Scenario	Traceability of the displacement	Deduction
<1.000 ha	A	Leakage risk is considered negligible.	0%
1.000 - 10.000 ha	B	Project shows displaced fertilizer was not used outside the project (e.g. supplier confirmation, farm data, or market data)	1%
	C	Fate of displaced fertilizer unknown or unconfirmed (no evidence)	5%
>10.000 ha	D	Project shows displaced fertilizer was not used outside the project (e.g. supplier confirmation, farm data, or market data).	2%
	E	Displaced fertilizer may have been used outside the project (uncertain or evidence of redirection). No evidence, or indications of redistribution in trade/sales data.	10%

[16] The project scale classification is based on commonly observed thresholds in land-based GHG methodologies, where projects below 1,000 ha are typically considered small-scale with negligible market influence, while projects above 10,000 ha are likely to affect regional fertilizer supply chains. These thresholds reflect practical differences in traceability, monitoring capacity, and risk of market leakage, and are consistent with scale categories used in AFOLU methodologies under carbon standards.

2. The use of CRF products is expected (at least) to maintain the same crop yields. However, a decrease in crop yield within the project area might lead to increased production elsewhere to meet demand. If the yield decreases, it is assumed that production will need to shift to other areas, potentially resulting in more N_2O emissions due to the additional fertilizer application or land use in those areas. Crop producers are unlikely to implement and maintain a project practice that results in yield declines, since their livelihoods depend on crop harvests as a source of income.

   Nevertheless, to ensure leakage is not occurring, the following nitrogen use efficiency (NUE) check[17] must be done to prevent leakage:

   At the end of the crediting period, the project developer must:

   - Demonstrate that the crop yield and NUE has not declined by more than 10% in the project scenario by:
     - comparing the average within-project crop yield and NUE (excluding years with extreme weather events) to the average **historical** baseline crop yield and NUE (farmer log based approach) [18], **OR**
     - comparing the average within-project crop yield and NUE to the average **regional** baseline crop yield and NUE during the project period (market based approach) [19].
- When none of the above options can be proven, then:
  - that specific intervention becomes ineligible for future crediting, **and**
  - the project developer must adjust the project intervention to make sure that the NUE increases, so that there is no leakage. It is expected that this adjustment will probably happen *during* the crediting period, if the crop producer identifies a crop yield decline, thus fixing the crop yield issue, and preventing the leakage to happen in the first place.

1.8.2 Permanence

The intervention focuses on the *reduction* of direct and indirect N_2O emissions. Once the CRF products have delayed nitrogen loss and crops have utilized the nitrogen more efficiently, the

[17] The NUE can be measured/assessed using different metrics as described in the Appendix D (non-exhaustive list). The project developer is required to perform the NUE check with at least the PFP metric. Depending on their cropping system it is recommended to use further metrics, as presented in the Appendix, that make sense for their specific case.
[18] To reduce the impact of inter-annual variability, project developers may apply a weighted multi-year average NUE, excluding years with documented extreme weather. Additionally, yield-normalized NUE metrics (e.g., NUE per tonne of crop biomass) may be used where appropriate, provided they are transparently justified in the POD.
[19] To demonstrate that crop yields have not declined by more than 10%, project developers can employ remote sensing (e.g., NDVI-based crop productivity assessments) or similar methods, beside self-reported farmer logs to generate realistic insights.

potential for nitrogen to escape as direct and indirect N_2O is reduced permanently for that growing cycle. Since these reductions are tied to specific agricultural cycles, rather than carbon sequestration, the risk of reversals is not applicable.

2 Project boundary

2.1 Scope of activities

The activities that are in scope of this methodology, which can lead to the reduction of net GHG emissions, are the following:

- Project developers replacing conventional fertilizers on the Land Management Unit (LMU)[20] level with CRFs, without altering nitrogen application rates.
- Project developers replacing conventional fertilizers with CRFs on the LMU level and reducing their total nitrogen application rates. The reduced in-field emissions from soils (e.g., direct and indirect N_2O emissions), resulting from both the improved nitrogen use efficiency of CRFs and the reduction in nitrogen application rates (with a focus on the Product Carbon Footprint), can be accounted for as part of the intervention.
    - (Optional) Reduced number of fertilizer applications: Reducing the N-rate can result in reduced number of fertilizer applications. This can directly decrease emissions from farm machinery by limiting the number of passes through the field. CRF products due to their prolonged nitrogen delivery profiles, often allow for fewer application events compared to conventional fertilizers, thereby cutting fuel use and associated CO_2 emissions. These avoided machinery emissions can be accounted for in the GHG reduction quantification
- Project developers distribute CRFs within a defined region (e.g. sourcing region type of project). In this type of intervention, reduction of the application of the nitrogen rate is de facto not applicable, since there is no way to track this reduction on the field level.

Optional: This methodology allows for the inclusion of other management practices in addition to the use of CRF products, provided there is scientific evidence demonstrating that these practices do not lead to an increase in GHG emissions. As mentioned in section 1.2 Applicability, this methodology can work **synergistically** with other GHG methodologies or programs that target emissions reductions or removals in areas outside the scope of this methodology. For instance, it can be combined with approaches involving the introduction of low-carbon fertilizers, stabilized fertilizers with nitrification/urease inhibitors.

[20] Land Management Unit and Sourcing Region are spatial levels, which are explained in section 2.3 Spatial boundary

2.2 GHG sources

In this methodology, the impact of the CRF products starting from their production up until their application on the field is in scope. Specifically the activities (as seen in *Figure 1*) that result in GHG emissions and are in scope include:

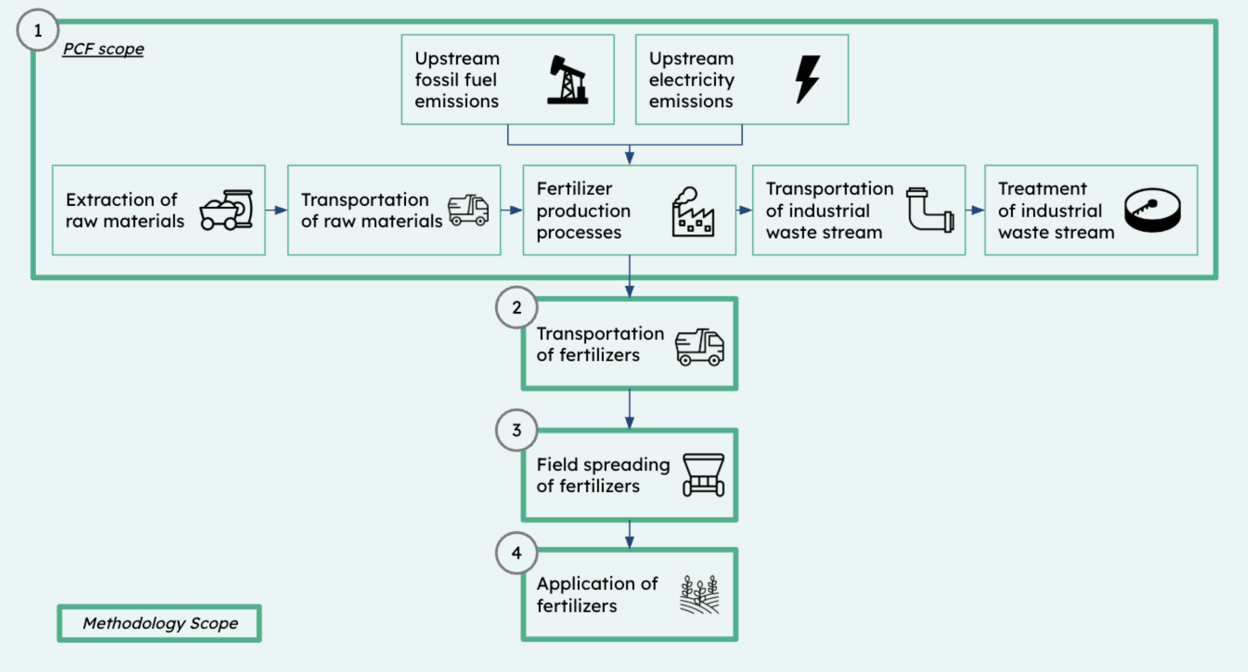
1. Fertilizer production emissions (cradle-to-gate emissions of fertilizers).
2. Transportation of the fertilizers from the production location to the project location. Certain PCFs include these emissions already. If this is the case, then these must be updated to reflect the actual transportation emissions of the baseline and project and avoid potential double counting.
3. Field spreading of the fertilizers using machinery [21]. The use of CRF products may result in a different number of fertilizer applications compared to conventional practices, potentially leading to more or fewer tractor passes and associated fuel use. Any resulting change in fuel consumption must be accounted for if it is material. Material is defined as more than 5% change from the total project GHG emissions in scope. CO_2 emissions from this activity must be calculated using standardized emission factors (e.g., per liter of diesel or per hour of equipment operation), and must be supported by verifiable records such as machinery logs, fuel invoices, etc (see section 6.1 Monitoring). The project developer must be transparent in his choice to include or not the emissions from this activity. In addition, an intervention might include the switch to low-carbon fuel for the fertilizer spreading. This can be included in this activity. This activity can only be accounted for as a GHG benefit for LMU type of projects.
4. Application of fertilizers: The impact of both direct and indirect N_2O emissions resulting from the application of fertilizers and CRF products is in scope. These emissions are the primary GHG emissions source considered in the project, as they directly result from the transformation of nitrogen in the soil after the fertilizer application. Both direct and indirect N_2O emissions must be estimated using either a relevant peer-reviewed study (e.g., product-specific trials, scientific studies or meta-analyses) or IPCC[22] guidelines. If changes in organic fertilization (for example increased application of manure) happen as part of the

[21] It is acknowledged that there are various other activities related to farming that might lead to GHG emissions. However, for the purposes of this methodology we consider that field spreading of fertilizers is the one with the highest material impact.
[22] https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch11_Soils_N2O_CO2.pdf

intervention, which can affect the in-field emissions, then this needs to be accounted for as well.

The activities in scope are presented in *Figure 1* below:

Figure 1: Activities in scope for the GHG sources calculations



While it is acknowledged that there are other GHG sources on agricultural fields, such as CO_2 emissions from soil respiration or methane (CH_4) emissions from organic matter decomposition, these sources are not expected to be affected by the CRF products. Therefore, these emissions are typically considered out of scope for the purposes of this methodology, as they do not directly contribute to the emission reductions associated with the use of CRF products. Project developers must justify the exclusion of these GHG emission sources due to their cropping system specifics.

However, CH_4 and CO_2 emissions are in scope for crop systems involving anaerobic conditions, such as flooded rice paddies. Project developers must assess and report CH_4 and CO_2 emissions in this type of projects using relevant emission factors or direct measurements as described in section [4 Calculation of GHG emissions]() and [Appendix A.2](). For all other crop systems, CH_4 and CO_2 are excluded due to negligible impact.

The GHG sources that are in scope are presented in Table 1.

Table 2: GHG sources in scope

	Activity/Source	*GHG*	*Included*	*Justification*
Baseline	(1) PCF (cradle-to-gate emissions) of the fertilizer (conventional)	CO_2e	Yes	Relevant to compare with the production emissions of the CRF product
	(2) Transportation of fertilizers	CO_2	Yes	Main emission from combustion of fuel
		CH_4	No	Typically not material
		N_2O	No	Typically not material
	(3) Field spreading of inorganic fertilizers	CO_2	Yes	Main emission from combustion of fuel
		CH_4	No	Typically not material
		N_2O	No	Typically not material
	(4a) Direct emissions resulting from the application of inorganic and/or organic[23] fertilizers	CO_2	Conditional	Included if the crop system involves anaerobic conditions (e.g., flooded rice)
		CH_4	Conditional	Included if the crop system involves anaerobic conditions (e.g., flooded rice)
		N_2O	Yes	N_2O is the major emitted GHG from the use of N fertilizer.
	(4b) & (4c) Indirect emissions resulting from the application of inorganic and/or organic fertilizers (volatilisation, leaching)	CO_2	No	Out of scope
		CH_4	No	Out of scope
		N_2O	Yes	Volatilisation of ammonia (NH_3) and leaching/runoff of N, mainly as NO_3^-, which can be transformed to N_2O in the future
Project	(1) PCF (cradle-to-gate emissions) of the CRF product	CO_2e	Yes	The emissions related to the production of the CRF product must be accounted for

[23] GHG emissions from organic fertilizers are considered the same in both the baseline and project scenarios. This is because the intervention only replaces the inorganic fertilizer with a CRF product The N inputs from organic fertilizers stay unchanged.

	(2) Transportation of CRF fertilizer products	CO_2	Yes	Main emission from combustion of fuel
		CH_4	No	Typically not material
		N_2O	No	Typically not material
	(3) Field spreading of CRF product	CO_2	Yes	Main emission from combustion of fuel
		CH_4	No	Typically not material
		N_2O	No	Typically not material
	(4a) Direct emissions resulting from the application of CRF products	CO_2	Conditional	Included if the crop system involves anaerobic conditions (e.g., flooded rice)
		CH_4	Conditional	Included if the crop system involves anaerobic conditions (e.g., flooded rice)
		N_2O	Yes	N_2O is the major emitted GHG from the use of N fertilizer
	(4b) & (4c) Indirect emissions resulting from the application of CRF products (volatilisation, leaching)	CO_2	No	Out of scope
		CH_4	No	Out of scope
		N_2O	Yes	Volatilisation of ammonia (NH_3) and leaching/ runoff of N, mainly as NO_3^-, which can be transformed to N_2O in the future

Effect of crop yield increase on GHG emissions:

It is possible that the crop yield increases, as a result of the introduction of the use of CRF products. This is an *additional benefit* which:

- Does not impact the reduction of the GHG emissions per hectare (see section 5. Net reduction of GHG emissions[24]).

[24] In principle, an increase in nitrogen uptake due to higher yields could reduce emissions, since more nitrogen is taken up by the plant and less is lost to the environment. However, in this methodology, emission reductions are quantified based on emission factors (EFs), not nitrogen mass balance equations (in other words the calculation is done ex-ante). The delta in emissions, and therefore the creditable reduction, is entirely derived from the difference in EFs between the baseline and the project intervention (use of CRF), per unit of nitrogen applied. This means that there is no recalculation of emissions based

- Does impact the reduction of GHG emissions per tonne of crop, which is relevant for the Product Carbon Footprint of the crop.

2.3 Spatial boundaries

The spatial boundaries of a project are defined by the geographic area where the activities impacting GHG emissions take place. These boundaries must include the entire area influenced by the application of CRF products. The two possible levels of spatial boundaries are:

- **Land Management Unit (LMU) level**: The primary boundary are the fields where CRF products are applied and a specific crop type is cultivated (similar to *LMU* and including *Harvested area* as defined by the GHG Protocol [25]). The location from which the fertilizer is sourced from, must also be accounted for to calculate the transport emissions of the fertilizer.
- **Sourcing Region level:** Instead of monitoring emissions at the individual LMU level, these spatial boundaries rely on average regional data to estimate the impact on the emissions. In essence, the sourcing region level tracks the replacement of conventional fertilizer(s) that would be used in the region, by the CRF products. The regional boundary accounts for the collective impact of CRF product use in a broader landscape. This approach aggregates data from multiple fields, farmers, or cooperatives within a defined region (similar to the sourcing *region* as defined by the GHG Protocol). The quantification must be based on aggregated EF data from scientific studies (see 4 Calculation of GHG emissions approaches 1) or 2). To achieve that, project developers must stratify the region based on the most relevant environmental factors and management practices (see A.2.1 Alignment with the key environmental factors and management practices).
    - The project developer must collect average regional data such as:
        - baseline fertilizers used (which will be replaced by the CRF product)
        - crop types
        - CRF product distribution volume
        - nitrogen application rates
        - crop yields
        - Optional: average environmental factors or management practices in the region, which can help select a more specific EF and/or emission reduction percentage

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on crop yield alone. While yield may improve NUE and potentially lower emissions, proper equipment (e.g. gas chambers) cannot be installed in every field to measure the actual fluxes, neither an extended samples lab analysis
[25] https://ghgprotocol.org/land-sector-and-removals-guidance

Some distinctions between the two levels:

- Sourcing region type of projects can be used when LMU field level type of data can not be accessed. In this case, aggregated emission factors must be used (as explained in section 4 Calculation of GHG emissions), which is expected to come with a higher (compounded) uncertainty when aggregating for regional EFs, thus being on the conservative side. As such, project developers are expected to be incentivized in opting for LMU type of projects due to the higher emission reduction potential, caused by the lower uncertainty. This is aligned with SBTi's and GHGP's directions of moving towards field level projects which can offer more transparency and traceability.
- Since LMUs allow monitoring on the field level, it is also possible to claim the potential reduction of nitrogen application rate, if applicable (see section 1.2 Applicability of the methodology). This is not possible for the sourcing region type of projects.

Project developers must justify their selection of spatial boundaries based on factors such as the access to farmer level data, homogeneity and level of insights.

Boundaries must be set in a way that capture all relevant emissions sources and potential leakages. Local and regional regulations, as well as environmental sensitivity[26], must also be considered when defining these boundaries.

If a project includes multiple scenarios (intervention groups), such as different crops, fertilizer types, or CRF blends, the project developer must explicitly define the scope of these scenarios within the Project Overview Document (POD). This ensures clarity on what combinations of fertilizers, crops, and management practices are included in the project scope. During verification, where the actual implementation of the project is assessed, the reported scenarios must be grouped based on similar management practices. The emission impact should then be calculated separately for each group to maintain methodological consistency and accuracy in reporting.

[26] Environmental sensitivity refers to the vulnerability of ecosystems or regions to environmental impacts, such as water or air pollution, soil degradation, or biodiversity loss.

Practical guidance for project developers on selecting between spatial level approaches:

- **Use LMU Level if:**
  - You have access to field-level data, including crop type, fertilizer use, and yields for each participating farm or field.
  - You aim for higher accuracy and lower uncertainty in emission estimates, potentially enabling greater GHG reduction claims.
  - You want to monitor site-specific changes, such as reductions in nitrogen application rate or improved efficiency at the farm level.

- **Use Sourcing Region Level if**:
  - Field-level data is not available, and you need to rely on aggregated regional information (e.g., from cooperatives, national/regional data, or supplier records).
  - Your project operates at a large scale involving many farmers with similar practices, but without granular farm-level visibility.
  - You are willing to accept higher uncertainty and more conservative emission reductions in exchange for streamlined data collection.

2.4 Temporal boundaries

The temporal boundaries define the start and the end of the monitoring and reporting process.

For Land Management Unit level projects:

- The boundaries follow the entire cultivation cycle of the target crop and can vary based on the timing of fertilizer application.
- The start of the temporal boundaries is defined as the date of the first application of the fertilizer.
- The end of the Temporal Boundaries is defined as the final harvest date of the target crop within the participating field [27]
- The project developer must select and justify the temporal boundaries based on the crop's fertilizer application schedule, which can vary by region. A crop calendar must be consulted

[27] It is acknowledged that the nitrogen can remain in significant portions in the soil till after the harvesting period, thus being at risk for later conversion and N losses as N_2O emissions. However, this methodology relies on scientifically validated EFs for both the baseline and project intervention, which cover the same measurement timeframe. In case direct on-field measurements are done to measure the emissions, then it is crucial that the timeframe of the measurement is similar for both the baseline and the project intervention.

to determine the specific timeline for each region. An example resource for this is the USDA Foreign Agricultural Service[28], which provides crop calendar charts for various regions and major crops. However, it is critical to supplement these sources with local, region-specific data when determining the exact temporal boundaries and ensuring that EFs appropriately account for nitrogen dynamics across the entire crop cycle.

For sourcing region type of projects:

- The recommended period for the temporal boundaries is **1 year**.
- This temporal boundary is used because, at the sourcing region scale, CRF products sales may span multiple cropping systems and planting seasons. Within one calendar year, it is possible to capture several crop cycles for short-duration or row crops (e.g., maize, wheat, etc.), reflecting an accurate representation of nitrogen use and related emissions across a variety of cropping systems and management practices.

[28] https://ipad.fas.usda.gov/ogamaps/cropcalendar.aspx

3 Baseline scenario

The baseline scenario represents the emissions that would occur based on the business as usual agricultural management practices. In other words, this includes fertilizer management and other relevant activities, **without the use of CRF products**. The project developer can establish the baseline based on the following approaches, depending on the spatial level selected and whether a nitrogen application rate reduction takes place (if applicable):

1. Baseline N-rate

- 1.a Land Management Unit approach: Projects without N-rate reduction:
    - For projects where the total nitrogen application rate remains unchanged, the baseline N-rate is determined using a counterfactual approach, which means it is based on what would have occurred if the project had not been implemented. The baseline N-rate corresponds to the nitrogen content in the conventional fertilizer that is replaced, adjusted for the nitrogen content in the CRF used in the project. To ensure environmental integrity, projects must demonstrate that the nitrogen application in the project is not significantly higher than average regional nitrogen application rates, unless strong agronomic justification is provided.
- 1.b. Land Management Unit approach: Projects with N-rate reduction:
    - For projects that reduce nitrogen application rates, the baseline N-rate is established using a regional approach. Project developers must conduct a market or regional analysis to identify the average nitrogen application rate used in comparable cropping systems under similar agronomic conditions. In addition, there must be scientific evidence demonstrating that the use of CRF products improves nitrogen use efficiency (NUE) compared to conventional fertilizers. Since baseline conditions may change over time, the baseline N-rate must be regularly updated over the crediting period in accordance with a dynamic baseline approach. This ensures the N-rate reduction and associated emission reductions remain accurate.
    - In case historical farm-level data (farmer logs) are available such as fertilizer type, crop yield reports, and field management logs, these may be used to establish the baseline nitrogen application rate and corresponding fertilizer type. In such cases, the baseline is based on the historical practices of each field, and

a schedule of baseline activities must be developed, outlining fertilizer type, nitrogen application rate, and crop yield.

  - In case the project intervention includes the reduction of N-rate, because the historical NUE was too low, and N was overapplied, then the baseline N-rate must be set as the project N-rate (with the higher NUE), so that the emission reduction is not overestimated

- 1.c Sourcing Region level approach: Projects without N-rate reduction:
  - The baseline N-rate is defined in a counterfactual approach, meaning that it is based on what would have happened if the project had not been implemented. Specifically, the volume of fertilizer that is replaced is based on the volume of CRF products used in the project intervention. This volume is then adjusted to account for differences in nitrogen content between the baseline and project fertilizer types.
- 1.d Sourcing Region level approach: Projects with N-rate reduction:
  - Not applicable under this methodology

2. NUE Performance test

- 2.a Land Management Unit level approach:
  - This includes calculating the historic baseline (farmer logs) NUE based on the total N fertilizer input and crop yield data. This NUE must be compared to regional benchmark NUE values[29] to verify that the project's baseline practices are following the region's guidelines. The following data and equation must be provided and used for the calculation:
    - Total fertilizer applied per hectare (kg N/ha)
    - Total crop yield per hectare (t/ha)
    - Equation:

$$NUE = \frac{Crop\ Yield\ (t/ha)}{Total\ Fertilizer\ N\ applied\ (kg\ N/ha)} \tag{1}$$

  - NUE can vary from year to year due to weather patterns, pest diseases, or changes in soil conditions. Project developers are required to use multi-year historical data, such as a moving average (see Appendix C) of the last 3–5

[29] If regional benchmark NUE values are not available, agronomic recommendations from a recognized scientific institution or body should be used as a reference

growing seasons, to better represent typical practices. Single-year data may only be used in exceptional cases (e.g., newly established farms) and must be clearly justified.
    - If a field or region follows a crop rotation system (e.g., legumes in one year, cereals in the next), the baseline NUE must be specific to the focus crop in the rotation.
- 2.b Sourcing Region level approach
    - In case a sourcing region spatial boundary approach is taken, where CRFs are sold across a region (see 2.3 Spatial Boundaries), the project developer must provide the regional NUE based on a relevant source such as peer-reviewed scientific studies, government agricultural extension reports, industry best practices, or other recognized sources.

3. Baseline Fertilizer Type

- 3.a Land Management Unit level approach
    - This baseline reflects current agricultural management decisions. Each season, conventional fertilizer serves as the baseline, as it remains a viable and accessible alternative. This approach captures the additional emissions that would occur if a CRF product was not used, allowing for the calculation of measurable and additional GHG emission reductions with each application. Since this is a counterfactual baseline approach, the baseline is defined every crop cycle. If available, historical farm-level data (such as fertilizer type, crop yield reports, and field management logs) can be used to help establish the baseline fertilizer type.
- 3.b Sourcing Region level approach
    - The baseline fertilizer type is determined using a regional-counterfactual approach. Specifically, the project developer must conduct a regional market analysis to identify the range of fertilizer products that could realistically be used in the context of the project's farming systems. This analysis should consider factors such as crop type, management practices, and input availability. The result is a baseline fertilizer mix, consisting of representative fertilizers and their respective proportions.

- This baseline fertilizer mix reflects current agricultural management decisions as it serves as a viable and credible alternative to the CRF products used in the project intervention, rather than relying on historical application records.

4. Dynamic baseline

- Given that in many regions and markets regulatory changes and the industry standards are evolving rapidly and this can have a severe impact on baseline calculations, a dynamic baseline is required. Project developers must assess the regional baseline at least **every 3 years** during the crediting period. If the regional baseline has changed, then the project's baseline must be re-established based on the regional baseline. Specifically, in such cases, project developers must reapply the baseline determination approach used at validation, updating inputs with the most recent regional or project-specific data to recalculate the baseline. Moreover, updates which affect additionality (regulatory changes, subsidies, tax incentives, etc.) must be transparently presented in the verification report.

Where multiple options or data sources are available, conservative estimates must be used, to avoid overestimating the impact of the project interventions [30].

4 Calculation of GHG emissions

The project developer must calculate the **total GHG emissions** for both the baseline and project scenario. To achieve that, they need to use the equations presented in this section. Baseline and project emissions for each activity step must be transformed into tonnes of CO_2e for each verification period.

The total (baseline or project) emissions can be calculated as the sum of the subsequent activities (a), as seen in Table 3.

If only *one intervention* [31] takes place in the project, then:

[30] Specifically, the project developer must select the emission factors, fertilizer application rates and any other relevant data so that the total baseline emissions are not overestimated and the total project emissions are not underestimated.
[31] "One intervention" refers to a group of project activities that share similar characteristics, such as the same type of controlled-release fertilizer (CRF), crop, and management conditions, applied across a set of farms. It is the responsibility of the project developer to define and group interventions in a logical and consistent way to ensure that subsets of the project are comparable, thereby simplifying MRV and emissions quantification.

$$E = \sum_{a=i}^{n} E_a \tag{2a}$$

If multiple interventions (x) take place in the project, then:

$$E = \sum_{x} \sum_{a=i}^{v} E_{a,x} \tag{2b}$$

Where:

E	=	Total (baseline or project) GHG emissions (tCO_2e)
$E_{a,x}$	=	Emissions of activity a for the intervention x (tCO_2e).
x	=	Total amount of interventions

The three approaches for quantifying baseline and project emission are listed in Table 3. In cases where more than one EF-data reference approach is allowed for a given activity, then the same approach must be used to calculate both the project and baseline scenarios. Regarding the prioritization of the EF sources, the project developers must prioritize granular data compared to aggregated data whenever possible (Tier 3 > Tier 2 > Tier 1). Specifically for the EF selection, Approach 2 (see Table 2) is the preferred approach, followed by 1, depending on the availability of data and the practicality in the implementation (also see A.1.1. Prioritization of EF sources and Tiers).

Table 3: Summary of equations used to calculate the total emissions and approaches to retrieve the EF

Activity & equation	Approach 1: Emission factors from scientific literature	Approach 2: Direct measurement	Approach 3: LCA /PCF data
(1a) Fertilizer cradle-to-gate emissions $E_{1a} = EF_{IN} \cdot FIN \cdot A$	X		X
(1b) CRF product cradle-to-gate emissions $E_{1b} = EF_{CRF} \cdot FCRF \cdot A$	X		X
(2) Transportation of fertilizers $E_2 = \sum_{c} \sum_{x} (EF_m \cdot Q_{x,c,m} \cdot D_{x,c,m})$	X		
(3) Field spreading of fertilizer products $E_3 = \sum_{cf} \sum_{mf} (EF_{mf} \cdot D_{cf,mf} \cdot N_f)$	X		
(4a) Direct N_2O emissions $E_{4a} = [(FIN \cdot EF_{in,direct\_N2O}) + (FON \cdot EF_{org,direct\_N2O})] \cdot 44/28 \cdot A \cdot GWP_{N_2O}$	X	X	
(4b) Indirect ammonia volatilization $E_{4b} = [(FIN \cdot NH_3\, volatilized_{in}) + (FON \cdot NH_3\, volatilized_{org})] \cdot EF_{.indirect\_v} \cdot 44/28 \cdot A \cdot GWP_{N_2O}$	X	X	
(4c) Indirect leaching and runoff of N $E_{4c} = [(F_{in} \cdot EF_{in,\,indirect\_l} \cdot N\, leaching_{in}) + (F_{org} \cdot EF_{org,\,indirect\_l} \cdot N\, leaching_{org})] \cdot 44/28 \cdot A \cdot GWP_{N_2O}$	X	X	

4.1 EF-data reference approaches

Approach 1: Emission factors retrieved from scientific studies

For the quantification of GHG emissions (direct and indirect N_2O emissions), EFs originating from available scientific literature can be used. Documented emissions of N_2O should be supported by emission factors that are among others characterized by lower uncertainties than Tier 1 EF. Definitions of Tier 1, 2, and 3 EF are described in detail in the Appendix A.

Tier 2 emission factors must meet specific criteria to be considered valid and applicable for use by project developers in this GHG methodology. These criteria ensure that the EFs or emission reduction percentages reflect characteristics of the project and are derived from scientific studies of high experimental quality standards.

Project developers can extract EF from scientific studies that are relevant to their environmental factors and management practices and aggregate them to create relevant Tier 2 - type of EF. Higher-tier emission factors (Tier 3 > Tier 2 > Tier 1) must be prioritized. If lower-tier EF are used, the project developer must justify why higher-tier options were not feasible (see Appendix A.1.1 Prioritization of EF sources and Tiers)

The guidelines for selecting suitable EFs are organized into three main sections, which the project developer must follow:

1. **Alignment with the influential environmental factors and management practices (with high relative importance) of the study:** Emission factors must be selected based on their relevance to both the project's key environmental factors and management practices from the referenced studies to ensure consistency and applicability. Where exact alignment between the study conditions and the project characteristics is not available, project developers may use emission factors derived from studies that partially align with key parameters (e.g., soil type, climate type, fertilizer, etc.). In such cases, developers must select a conservative EF value from the available data (use of standard deviation ranges). The procedure of selecting an appropriate value is described in section 4.3. Uncertainty and must be properly justified and documented.
2. **Utilization of meta-analyses papers:** Meta-analyses can be valuable when emission factors from individual studies are limited or when a broader evidence base is needed to support a representative value. Meta-analyses must report or assess heterogeneity (I^2) among studies. If I^2 is not provided, developers must provide evidence of variability (e.g., range, SD, forest

plot) and justify reliability. If high heterogeneity is evident (e.g., $I^2 > 75\%$ or clear visual spread), an uncertainty buffer of 10% must be applied unless justified via subgroup analysis. Project developers may use data from meta-analyses as sources of emission factors or emission reduction percentages, provided that a clear and well-documented selection process is followed. In meta analyses, emission reduction results are typically presented across several subgroup factors (such as soil type, crop type, etc.), each with its own range of values. When multiple relevant subgroups apply, project developers can identify where these ranges overlap and select a conservative value from within that intersection (see 4.3 Uncertainty). If multiple eligible and relevant meta-analyses exist and the project developer wants to use them, then an average EF (reduction) must be calculated across all qualified sources. If applicable, the average must be accompanied by a weighted uncertainty estimate to ensure transparency and reflect variability across sources.

3. **Experimental design (of studies/trials):** The experimental trails/scientific studies and meta analyses used to extract EFs or emission reduction percentages must follow high experimental design quality criteria/standards.

Note: Details and specific instructions for each of these sections are explained in the Appendix A.2.

When a range of possible emission factors is provided (f.i. based on a meta-analysis), the methodology requires that the selected EF must have a confidence level of at least 95%. This means that the EF value chosen should fall within the range where there is greater than 95% certainty that it accurately represents the true emission factor under the specified conditions.

This procedure should be thoroughly presented/documented in order for third-party “Verification and validation bodies (VVBs)” to investigate and assess the suitability of the selected EFs during the implementation and reporting stages of the project.

Approach 2: Direct measurements

This approach is focusing on the utilization of project-specific emissions/emission factors that are derived from direct measurement on the field (e.g., using chambers), which provide actual data that reflect field conditions. The measurement methods should be conducted by qualified scientific teams and the process must follow the guidelines presented in the Appendix A.2.3 Quality criteria of experimental design (of studies/trials).

A detailed explanation of the methods used to calculate and account for uncertainties must be included (uncertainty analysis).

Approach 3: LCA or PCF data

This approach utilizes PCF (or LCA[32]) data to evaluate the GHG emissions associated with the baseline fertilizer and CRF products. It captures emissions generated across all stages, from raw material extraction and chemical synthesis to manufacturing, production, and transportation, up to the point where the products reach the farm entrance gate (cradle-to-gate).

The project developer is responsible for providing a PCF report related to the fertilizers (baseline or project). If such a PCF is unavailable, the developer may use an available PCF that best represents the project's characteristics and conditions.

The evidence for the PCF reports of the fertilizers (baseline or project) must be sourced from one of the following sources in descending priority, depending on availability of data:

- 1) fertilizer producers through verified Environmental Product Declarations (EPDs), PCFs or sustainability reports,
- 2) widely accepted industry tools and platforms, such as CoolFarmTool, ecoinvent, Agri-footprint database,
- 3) Tier 1-2 industry reports such as the one published by the International Fertilizer Society titled "The carbon footprint of fertilizer production: regional reference values" or,
- 4) Relevant scientific literature

The reports must comply with internationally recognized frameworks, such as ISO 14040/14044 (for LCA), ISO 14067 (for PCF) or similar, ensuring that results are credible and comparable with each other.

They must be independently verified by a qualified third party to ensure transparency, reliability, and adherence to industry best practices. Special care must be given, to ensure that the PCF method between the baseline and the project products is at least consistent to make sure that we are comparing similar metrics.

4.2 Equation of each activity step

The following equations shall be applied to quantify GHG emissions for both the baseline and project intervention. The differentiation between baseline and project conditions is reflected in the selection of the appropriate emission factors (EFs) used in the calculation.

[32] The Life Cycle Assessment (LCA) should focus on the "climate change" impact category, which quantifies greenhouse gas (GHG) emissions typically expressed in CO_2-equivalents (CO_2e)

(1a) Fertilizer cradle-to-gate emissions

$$E_{1a} = EF_{SN} \cdot FSN \cdot A \qquad (3)$$

Where:

E_{1a}	=	Fertilizer cradle-to-gate emissions (kg CO_2eq)
FIN	=	Quantity of fertilizer applied (kg fertilizer / ha)
EF_{IN}	=	Emission factor for the cradle-to-gate of the fertilizer (kg CO_2eq / kg fertilizer)
A	=	Area of the intervention (ha)

(1b) CRF product cradle-to-gate emissions

$$E_{1b} = FCRF \cdot EF_{CRF} \cdot A \qquad (4)$$

Where:

E_{1b}	=	CRF product cradle-to-gate emissions (kg CO_2eq)
$FCRF$	=	Quantity of CRF product applied (kg CRF product / ha)
EF_{CRF}	=	Emission factor for the cradle-to-gate of the CRF product (kg CO_2eq / kg CRF)
A	=	Area of the intervention (ha)

(2) Transportation of fertilizers

The emissions are calculated for each product to be applied (x), based on the distance between the factory and the usage location (c), and the mode of transportation used (m).

$$E_2 = \sum_{c} \sum_{x} (EF_m \cdot Q_{x,c,m} \cdot D_{x,c,m}) \quad (5)$$

Where:

E_2	=	Emissions of the transportation of the products (tCO_2eq)
EF_m	=	Emission factor of the mode of transportation m (tCO_2eq/tonne-km)
$Q_{x,c,m}$	=	Quantity of product x sent to fertilizer usage location c via the mode of transportation m (tonne)
$D_{x,c,m}$	=	Distance traveled of product x to the usage location c via the mode of transportation m (km). If the specific usage location is not known (for example for sourcing region type of projects), a conservative average distance can be assumed, provided that it is thoroughly justified in the POD.

(3) Field spreading of fertilizer products

These emissions include activities from the machinery used during the application process. The emissions are calculated based on the vehicle type or the field spreading machinery (mf) which apply the fertilizer on the field (cf), the distance traveled within the field ($D_{cf,mf}$), the fuel type and the number of times the fertilizer is spread per year (N_f).

$$E_3 = \sum_{cf} \sum_{mf} (EF_{mf} \cdot D_{cf,mf} \cdot N_f) \quad (6)$$

Where:

E_3	=	Emissions of the application of fertilizers (tCO_2e/year)
EF_{mf}	=	Emission factor of the vehicle type or application machinery mf using a specific fuel type (tCO_2e/tonne-km)
$D_{cf,mf}$	=	Distance traveled within the field cf via the vehicle type or application machinery mf for one spread (km)
N_f	=	Number of times the fertilizer is spread per year

(4a) Direct N_2O emissions

This approach is based on equations provided by the IPCC[33].

$$E_{4a} = [(FIN \cdot EF_{in,direct\_N2O}) + (FON \cdot EF_{org,direct\_N2O})] \cdot 44/28 \cdot A \cdot GWP_{N_2O} \tag{7a}$$

Where:

E_{4a}	=	Direct N_2O emissions from managed soils due to fertilizer application (kg CO_2eq)
F_{in}	=	Quantity of inorganic N fertilizer applied (kg N / ha)
F_{org}	=	Quantity of organic N fertilizer applied (kg N / ha) [It should be included only when there is sufficient scientific evidence of its nitrogen content and the related emissions]
$EF_{in,direct\_N2O}$	=	Emission factor for N_2O emissions from N inputs from inorganic fertilizer (kg N_2O-N / kg N input)
$EF_{org,direct\_N2O}$	=	Emission factor for N_2O emissions from N inputs from organic fertilizer (kg N_2O-N / kg N input)
$44/28$	=	Molar mass ratio of N_2O to N applied to convert N_2O-N emissions to N_2O emissions. [It should be applied only when the unit of the reported EF is in kg N_2O-N, rather than kg N_2O]
A	=	Area of the intervention (ha) [34]
GWP_{N_2O}	=	Global warming potential of nitrous oxide (kg CO_2e / kg N_2O) [Based on IPCC AR6, the 100-year GWP for N_2O is 273]

If direct N_2O measurements are in scope as part of the project, that follow Approach 2: Direct Measurements and the guidelines outlined in Appendix A.2.3 Quality Criteria of Experimental Design (of studies/trials), then those measured cumulative emissions can be used to replace emission factor-based calculations and the equation can then be adjusted accordingly (see equation 7b).

The same logic can be applied to the equations of the other activities.

[33] https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch11_Soils_N2O_CO2.pdf

[34] In case a sourcing region level approach is used, the emissions are calculated based on the total amount of CRF product distributed. As such the area of the intervention is not relevant.

$$E_{4a} = EF_{direct\_N2O\_c} \cdot A \cdot GWP_{N_2O} \quad (7b)$$

Where:

$EF_{direct\_N2O\_c}$	=	Cumulative emissions, derived from the periodic flux measurements which are taken over the growing season, and the values are integrated over time. This integration provides the total N_2O emissions for the monitoring period (kg N_2O/ha)
A	=	Area of the intervention (ha)
GWP_{N_2O}	=	Global warming potential of nitrous oxide (kg CO_2e / kg N_2O) [Based on IPCC AR6, the 100-year GWP for N_2O is 273]

(4b) Indirect emissions originated from ammonia volatilization

$$E_{4b} = [(F_{in} \cdot EF_{in,\,indirect\_NH3} \cdot NH_3\,vol_{in}) + (F_{org} \cdot EF_{org,\,indirect\_NH3} \cdot NH_3\,vol_{org})] \cdot 44/28 \cdot A \cdot GWP_{N_2O} \quad (8)$$

Where:

E_{4b}	=	Indirect N_2O emissions from ammonia volatilization due to fertilizer application (kg CO_2eq)
F_{in}	=	Quantity of inorganic N fertilizer applied (kg N / ha)
F_{org}	=	Quantity of organic N fertilizer applied (kg N / ha) [It should be included only when there is sufficient scientific evidence of its nitrogen content and the related emissions]
$EF_{in,\,indirect\_NH3}$	=	Emission factor for N_2O emissions from volatilized NH_3 originating form inorganic fertilizer (kg N_2O-N / kg NH_3-N volatilized)
$EF_{org,\,indirect\_NH3}$	=	Emission factor for N_2O emissions from volatilized NH_3 originating form iorganic fertilizer (kg N_2O-N / kg NH_3-N volatilized)
$NH_3\,vol_{in}$	=	Fraction of inorganic N fertilizer that volatilises as NH_3 (kg NH_3-N volatilized)
$NH_3\,vol_{org}$	=	Fraction of organic N fertilizer N that volatilises as NH_3 (kg NH_3-N volatilized)

$44/28$	=	Molar mass ratio of N_2O to N applied to convert N_2O-N emissions to N_2O emissions [It should be applied only when the unit of the reported EF is in kg N_2O-N, rather than kg N_2O]
A	=	Area of the intervention (ha)
GWP_{N_2O}	=	Global warming potential of nitrous oxide (kg CO_2e / kg N_2O) [Based on IPCC AR6, the 100-year GWP for N_2O is 273]

(4c) Indirect emissions originated from leaching and runoff of N

It should be determined whether leaching emissions are relevant based on soil type, climate, and management practices in the project area.

$$E_{4c} = [(F_{in} \cdot EF_{in,\, indirect\_l} \cdot N\ leaching_{in}) + (F_{org} \cdot EF_{org,\, indirect\_l} \cdot N\ leaching_{org})] \cdot 44/28 \cdot A \cdot GWP_{N_2O} \quad (9)$$

Where:

E_{4c}	=	Indirect GHG emissions from N leaching/runoff due to fertilizer application (kg CO_2eq)
F_{in}	=	Quantity of inorganic N fertilizer applied (kg N / ha)
F_{org}	=	Quantity of organic N fertilizer applied (kg N / ha) [It should be included only when there is sufficient scientific evidence of its nitrogen content and the related emissions]
$EF_{in,\, indirect\_l}$	=	Emission factor for N_2O emissions from N leaching/runoff originating from inorganic fertilizer (kg N_2O-N/kg N leaching/runoff)
$EF_{org,\, indirect\_l}$	=	Emission factor for N_2O emissions from N leaching/runoff originating from organic fertilizer (kg N_2O-N/kg N leaching/runoff)
$N\ leaching_{in}$	=	Fraction of inorganic N fertilizer that is lost through nitrate leaching and runoff (kg N leached/runoff)
$N\ leaching_{org}$	=	Fraction of organic N fertilizer that is lost through nitrate leaching and runoff (kg N leached/runoff)
$44/28$	=	Molar mass ratio of N_2O to N applied to convert N_2O-N emissions to N_2O emissions

		[It should be applied only when the unit of the reported EF is in kg N_2O-N, rather than kg N_2O]
A	=	Area of the intervention (ha)
GWP_{N_2O}	=	Global warming potential of nitrous oxide (kg CO_2e / kg N_2O) [Based on IPCC AR6, the 100-year GWP for N_2O is 273]

4.3 Uncertainty

To ensure the credibility and conservativeness of emission reduction estimates, this methodology provides two approaches for addressing uncertainty, depending on the type of project and the tier of data used.

Option 1 – LMU type of projects with Tier 3 Data

For field-level (LMU) projects using Tier 3 data, the project developer must conduct a quantitative uncertainty assessment. To do that the tool developed by the GHG Protocol Initiative [35] can be used. This Excel-based tool automates the aggregation steps for developing a basic uncertainty assessment for GHG inventory data, following the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National GHG Inventories. The tool is supplemented by a guidance document [36], which describes the functionality of the tool and gives a better understanding of how to prepare, interpret, and utilize uncertainty assessments. In the Appendix B, the equations to calculate the propagation of uncertainty for single and multi source data are presented.

This approach allows for more precise project-specific estimates and may support higher claims when uncertainty is well-characterized and transparently reported.

Option 2 – LMU and sourcing region type of projects with Tier 1 or Tier 2 Data

For both LMU and sourcing region types of projects using Tier 1 or Tier 2 data, a simplified, conservative approach must be followed to ensure robustness of estimates:

- **Meta-Analysis Based Factors**: When using meta-analyses to derive emission factors or emission reduction percentages, project developers should combine multiple context-specific variables, such as soil type, crop type, application rate, and product

[35] https://ghgprotocol.org/calculation-tools-and-guidance
[36] https://ghgprotocol.org/sites/default/files/2023-03/ghg-uncertainty.pdf

characteristics, to ensure the selected EF (from the EF ranges) is both conservative and grounded in the most relevant evidence. For that purpose 95% confidence interval (CI) must be used.

- **Conservative Parameter Selection**: Project developers must select values from the conservative end of available ranges. Specifically, rather than selecting the absolute minimum of the 95% confidence interval (CI), the chosen value should correspond to a point located 25% of the distance from the mean toward the lower (more conservative) bound of the interval.
- **Regional Deduction**: For sourcing region types of projects, a fixed 5% deduction (as explained in section 2.3 Spatial boundaries) must be applied to the estimated reductions to account for the higher uncertainty associated with aggregated data and absence of field-level monitoring.

This approach provides a practical and reliable framework for uncertainty management in cases where project-specific measurements are not feasible.

5 Net reduction of GHG emissions

The project developer can *estimate* the GHG emission reductions of the project during the crediting period based on the best available data at the time of the validation of the POD.
The issuance of the emission reduction certificates is done on a yearly basis, after updating the project design parameters (see section 6.1 Monitoring), and verifying the GHG emission reduction by a VVB. The *project emissions* and therefore the *net reduction of GHG emissions* are *dynamic* as they can change from year to year, depending on the management practices on the field (e.g., crop cultivated, selected inorganic fertilizer, selected CRF product, nitrogen application rate, etc.).

The GHG emission reduction is defined as the difference between the baseline emissions and the project emissions. To conservatively account for potential leakage, a (potentially reversible) leakage deduction factor is applied to the total net emission reductions. This factor reflects the assessed risk that the project activity may indirectly cause an increase in GHG emissions outside the project boundary, either through market displacement of conventional fertilizers or unintended yield impacts. The applicable leakage deduction is determined based on the classification described in section 1.8 Leakage & permanence.

To calculate the net GHG emissions reduction, the following equation can be used:

$$ER = (BE - PE) \cdot (1 - LP) \cdot (1 - UP) \tag{10}$$

Where:

ER	=	Net GHG emissions reduction (tCO_2e)
BE	=	Baseline emissions (tCO_2e)
PE	=	Project emissions (tCO_2e)
LP	=	Leakage penalty (%). If leakage is reversible, the credited emissions can be adjusted retroactively or the corresponding amount can be released from the buffer pool.
UP	=	Uncertainty penalty for sourcing region type of projects (%)

The *net GHG emissions reduction* for the entire project is a key metric, representing the total annual reduction in emissions, expressed in tonnes of CO_2e. However, it is equally important to present the impact of the intervention using different metrics that can be used by various stakeholders. Examples of these metrics are presented in Appendix C.

6 Monitoring, reporting, and verification (MRV)

The MRV process is a structured approach to quantifying, tracking, reporting, and verifying greenhouse gas (GHG) emissions and reductions achieved through the application of CRF products. The goal of the MRV approach is to ensure accurate, consistent, and credible measurement and reporting of emissions over time, enabling the issuance of high-quality emission reduction certificates.

The monitoring plan includes:

- The type of information that needs to be collected
- The evidence for each datapoint
- The frequency of reporting

6.1 Monitoring

For this methodology, the monitoring focuses on collecting three key types of data:

A. **Project scoping:** Key project details defined before the project start, submitted once during the POD validation phase (see *Table 3).*
B. **Project design parameters:** Variables monitored and reported during each verification cycle to ensure compliance and accuracy (see *Table 4*). Those must be completed for each specific intervention that is outlined in the project scoping. As seen in *Table 4*, the evidence required for these design parameters primarily rely on traditional methods such as farmer logs and market-based assessments. Where feasible, it is recommended to integrate for advanced approaches such as satellite monitoring, IoT sensors, and blockchain-based recordkeeping in regional approaches, to enhance efficiency, accuracy, and transparency.
C. **Project impact:** Outcomes calculated during each verification cycle, based on the monitored project design parameters. Again, the impact must be calculated and presented separately for each intervention in scope.

Table 3: Project scoping

Index	Name	Description	Background from this methodology	Evidence required	Frequency of reporting
A1	Scope of activities	Present list of interventions that are in scope of the project, ot the LMU or on the Sourcing Region level	Section 2.1	N/A	Once during POD validation or update during verification if they change during the crediting period
A2	GHG sources	Explain which GHG sources are in scope of the intervention	Section 2.2	N/A	
A3	Spatial boundary and size (hectares or similar)	Present coordinates delineating the: • locations of the field (for Land Management Unit level boundary) • boundaries of the region (for Sourcing Region level boundary)	Section 2.3	• Satellite imagery or GIS-based shapefiles or geospatial coordinates • coordinates via national land ownership databases or other proof of ownership	
A4	Temporal boundary (for monitoring)	Define the temporary boundary for the project	Section 2.4	N/A	

Table 4: Project design parameters for Land Management Unit level intervention

Index	Category name	Subcategory name	Description	Evidence required for baseline[37]	Evidence required for project	Frequency of reporting
B1.1	Crop type	-	Type of crop being cultivated	Farmer log or market based information	Farmer log	Reconfirmed or updated for every verification
B1.2	Fertilizer (conventional)	Type	Type of fertilizer being applied	Farmer log or market based information	-	
		Fertilizer PCF	Cradle-to-gate emissions of conventional fertilizer	PCF report from manufacturer or credible database		
		N rate	Nitrogen rate in each fertilizer, % total N, %urea-N, % ammonium-N	Farmer log or market based information	-	
		Application rate & method	Application rate of the fertilizer, method, timing and splitting	Farmer log or market based information	-	
B1.3	Controlled-release fertilizer	Type	Type of CRF product being applied	-	Proof of purchase (or sale from the distributor), product label & regulatory eligibility	
		CRF PCF	Cradle-to-gate emissions of CRF product		PCF report from manufacturer or credible database	
		Blend composition	In case the fertilizer is a blend (e.g., partially CRF and partially conventional)	-	Product label Details on the composition	

[37] As described in section 3. Baseline scenario, the baseline is dynamic

Index	Category name	Subcategory name	Description	Evidence required for baseline[37]	Evidence required for project	Frequency of reporting
					and proportion (%) of each N component	
		N rate	Nitrogen rate in each fertilizer, % total N, %urea-N, % ammonium-N	-	CRF product description (f.i. label or safety data sheet)	
		Application rate	Application rate of the CRF product	-	Farmer logs related to days of application	
B1.4	Crop yield	-	Amount of crops harvested	Farmer log or market based information	Proof of crop yield productivity (e.g., Crop insurance reporting records)	Reconfirmed or updated for every verification
B1.5	NUE	Project NUE	Nitrogen use efficiency	Farmer log The baseline NUE should be compared to historical or regional benchmark NUE values to verify that the baseline practices are following the region's guidelines.	Calculated based on crop yield and N-rate Project's NUE should demonstrate that reduced nitrogen rates maintain NUE within the same range as the baseline	
		Regional or historical NUE	Regional or historical NUE	Regional database (or similar) or farmer logs (for the historical NUE).	-	
B1.6	(Optional) Field operations	Fuel consumption for spreading	GHG emissions resulting from tractor/machinery fuel use during fertilizer application events	Farm machinery logs, fuel receipts *In scope if there is a reduction in the number	Farm machinery logs, fuel receipts *In scope if there is a reduction in the number of	

Index	Category name	Subcategory name	Description	Evidence required for baseline[37]	Evidence required for project	Frequency of reporting
				of fertilizer applications due to the intervention	fertilizer applications due to the intervention	
	Field spreading emissions	Machinery type	Type of vehicle(s) used to spread the fertilizer	Farmer log	Farmer logs related to days of application	
		Distance traveled per field spread	Distance that the machinery (e.g. tractor) travels to spread the fertilizer	Farmer log	Farmer logs related to days of application	
		Number of field spreading events per cropping cycle	Based on the type of fertilizer, spreading method, etc. different number of field spreading events might happen.	Farmer log	Farmer logs related to days of application	
		Fuel type	Fuel type that was used (e.g. biofuel)	Fuel purchase invoice	Fuel purchase invoice	
B1.7	(Optional) Additional management practices	-	Optional only if additional management practices are implemented, along with the CRF product introduction, which lead to an extra reduction of GHG emissions.	-	• Scientific evidence of the emission factor, that is related to this intervention • Proof that the additional practice actually took place (remote sensing, video imagery, farmer log, or similar)	
B1.8	(Optional) Additional data for more detailed EF	Influential environmental and/or management practices	Optional. In case more detailed EF are selected, then additional information are required	Farmer log or market based information	For each additional data point, sufficient evidence is required	

Index	Category name	Subcategory name	Description	Evidence required for baseline[37]	Evidence required for project	Frequency of reporting
B1.9	Emission factors	-	List of EFs selected for each activity in scope	Relevant evidence depending on the approach selected (see section 4.1 EF-data reference approaches)		

Table 5: Project design parameters for Sourcing Region level intervention

Index	Category name	Subcategory name	Description	Evidence required for baseline	Evidence required for project	Frequency of reporting
B2.1	Crop types	-	The types of crops grown in the region, allowing emissions to be weighted based on the proportion of total cultivated hectares for each specific crop	Regional databases / sources	Regional databases / sources	Reconfirmed or updated for every verification
B2.2	Fertilizer	Types	Type of fertilizer being applied on the region	Regional databases / sources	-	
		N rate	Nitrogen rate in each fertilizer, % total N, %urea-N, % ammonium-N	Regional databases / sources	-	
		Application rate	Average application rates of the fertilizer	Regional databases / sources	-	
B2.3	Controlled-release fertilizer	Type	Type of CRF product being applied	-	Proof of sale (or purchase) of the CRF product	

		N rate	Nitrogen rate in each fertilizer, % total N, %urea-N, % ammonium-N	-	CRF product description (f.i. label or safety data sheet)	
		Application rate	Application rate of the CRF product	-	Farmer logs related to days of application	
B2.4	Crop yield	-	Average crop yields, to showcase the impact of the intervention per tonne of crop produced	Regional databases / sources	Farmer log or sale proof from a representative sample of farmers	
B2.5	NUE	Nitrogen use efficiency or the region	For transparency purposes it is recommended to present the relevant (to the project interventions) NUE of the region	Regional databases / sources	Calculated based on crop yield and average application rates	
B2.6	(Optional) Additional data for more detailed EF	Influential environmental and/or management practices	In case more detailed EFs are selected, then additional information are required	Regional databases / sources	Regional databases / sources	
B2.7	Emission factors	-	List of EFs selected for each activity in scope	Relevant proof depending on the approach selected (see section 4.1 EF-data reference approaches)		

Table 6: Project impact (for LMU or Sourcing Region type of intervention)

Index	Category name	Subcategory name	Calculation method	Frequency of reporting
C1.	Net reduction of GHG emissions	-	Section 5	Updated every verification
C2.	Different metrics of GHG emissions	Per unit of land area	Appendix C	
		Per unit of crop produced		
		Per unit of nitrogen containing fertilizer applied		
C3.	Transition plan for non-biodegradable coating (if applicable)	-	See section 1.5 Crediting period	

6.2 Reporting

Monitoring reports must include:

- A general description of the project, including:
  - For LMU type of projects: the location and outline of individual fields where CRF products would be applied and baseline emissions would have occurred.
  - For sourcing region type of projects: the defined regional boundary and the aggregate intervention area across the sourcing region.
- A description of the data collection process, frequency of monitoring, and procedures for archiving data, as presented in section 6.1 Monitoring. Note that in this methodology the baseline is dynamic and must be updated according to section 3. Baseline scenario.
- A recordkeeping plan to maintain accurate documentation that shows when and where CRF product application has occurred
  - For LMU type of projects: This includes field records, field investigations, farm implementation measures, machinery receipts, delivery notes and/or invoices
  - For sourcing region type of projects: This includes CRF product distribution data, regional sales volumes, or aggregation of application reports from participating cooperatives or farming associations.
- The roles of individuals involved in monitoring and data collection (e.g., responsibilities).
- Disclosure of coating types and transition plan:
  - The POD must specify the type of CRF coating used (biodegradable, non-biodegradable but bio-based, or non-biodegradable) [38], in line with section 1.3 Eligible products.
  - Where non-biodegradable CRFs are applied, the POD must also include the transition plan required under section 1.5 Crediting period, outlining the timeline and commitments for moving toward biodegradable CRFs.
  - Monitoring reports must include yearly updates on the implementation status of the transition plan, until biodegradable CRFs are fully adopted.
- The monitoring time period must be documented in every report.
- Monitoring reports must be submitted once per temporal boundary (see 2.4 Temporal Boundaries).
- All monitoring reports must be accessible at the demand of the *Validation, Verification Bodies* (VVB) for validation and verification procedures.

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[38] Biodegradability is defined as per EU 2024/2770 (see https://eur-lex.europa.eu/eli/reg_del/2024/2770/oj/eng)

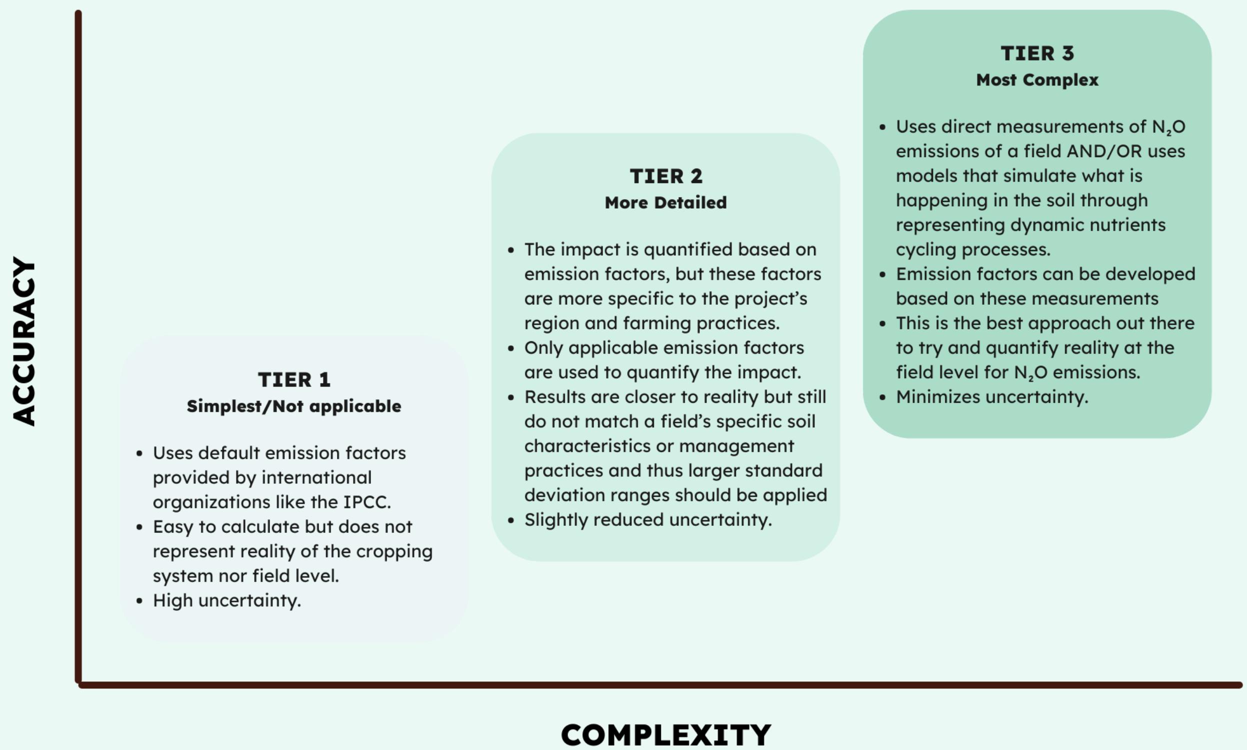
6.3 Verification

An approved Validation and Verification Body (VVB) must be selected to execute the verification process based on the monitoring plan and reports to confirm that the project's requirements are met, ensuring the accuracy of the calculated GHG reductions resulting from the use of CRF products. Information regarding the frequency of the verification process can be found in the Proba Standard. No additional requirements for site inspections are prescribed for this methodology. The project developer must define a proper site inspection plan in the POD.

It is acknowledged that most of the critical variables, like crop type, fertiliser rate and yield, rely heavily on farmers logs and market-based information. Project developers must transparently define a verification plan in collaboration with the VVB to ensure that key variables, particularly fertilizer rate and crop yield, are accurately represented. This plan must outline how critical claims will be substantiated using independent or verifiable data sources where applicable. The verification approach must be documented in the POD and implemented during the verification period.

Appendix A: Emission factor description and usability

A.1 Tier definitions



Tiers 1, 2, and 3 represent progressively detailed approaches for quantifying emissions related to fertilizer use (baseline) and during the application of CRF products (project), suitable for different levels of data availability and analysis precision:

- **Tier 1** is the most generic approach, utilizing global default EF for generalized estimates. It relies on broad quantification with minimal data requirements (e.g., IPCC 2019 tables). Tier 1 is only applicable in this methodology for estimating direct and indirect N_2O emissions in cases where no project-specific or region-specific (Tier 2) data are available.
- **Tier 2** EF can be derived from existing meta-analyses, systematic reviews, EF databases or scientific literature. This approach allows for more accurate quantification of emissions associated with both the baseline fertilizer application and the intervention using CRF

products. Empirical equations are used, with contextualized EF reflecting to the highest potential possible the agricultural practices, soil types, and environmental/climatic conditions of a particular area. Detailed procedures and guidelines of how to select appropriate EF is discussed below.

- **Tier 3** represents the most detailed and accurate approach, relying on either advanced biogeochemical process-based modeling[39] or site-specific data collection through field measurements during the project implementation. This tier quantifies emissions related to baseline fertilizer use and CRF products application by incorporating site-specific data, such as soil properties, actual site precipitation and temperature data, timing of specific practices (e.g., planting, fertilization, irrigation, harvesting), and crop yield.

  Field-based data collection, including direct N_2O measurements (e.g., via static chambers), fertilizer/CRF inputs, crop yield outputs, and associated environmental variables such as soil moisture, temperature, and pH, can provide high accuracy and credibility to the reduction claims.

A.1.1. Prioritization of EF sources and Tiers

- Priority should be given to Tier 3 (site-specific data or field measurements) whenever such data is available. If a project developer does not use this tier, they must explain why a more granular approach was not feasible. As such, EF Approach 1 should be followed (see section 4.1 EF-data reference approaches).
- Tier 2 should be used when Tier 3 data is unavailable, and the available literature or scientific data provides sufficient relevance to estimate emissions accurately (see section A.2.1 Alignment with the key environmental factors and management practices). As such, EF Approaches 1 and 3 are the next best options.
- Tier 1 can be used when neither Tier 2 nor Tier 3 data is available. In such cases, Tier 1 emission factors must be chosen based on the disaggregation options that are provided by IPCC and may be used to estimate the baseline emissions. For estimating the project's impact an emission reduction percentage which is derived from scientific literature or meta-analyses, must be applied.
- If there is a lack of scientific literature or data related to the intervention or region, the project cannot make a claim about emission reductions, as this methodology is based on a science-driven approach.

[39] The use of process-based models for deriving the Emission Factors is not eligible in this version of the methodology.

A.2 Emission factor selection criteria based on scientific studies

A.2.1 Alignment with the key environmental factors and management practices

- Scientific studies used for deriving EFs must align as closely as possible with the project's geographical and agricultural context. This ensures that the baseline and project emissions reflect realistic, applicable, and relevant conditions. However, it is recognized that full alignment may not always be possible. In such cases, project developers must apply conservative assumptions and clearly document their justification as described in section 4.3 Uncertainty. Key criteria must include:
    - **Environmental factors:** The study must be conducted in a location with environmental conditions similar to the project area. The most influential environmental variables should be prioritized, based on relevance (for instance as identified in the study of Hui-dan Lü, Wang, Pan, & Zhao (2023) "*Assessment of the crucial factors influencing the responses of ammonia and nitrous oxide emissions to controlled release nitrogen fertilizer: A meta-analysis*"). For example, since CRF nutrient release can vary with temperature, project developers must select emission factors that reflect the temperature regime of the project region to ensure credible estimates.
    - **Management practices:** The study must involve management practices that match the baseline and project interventions, such as:
        - Fertilizer type
        - N application rate
        - Use of the same category of CRF product
        - Crop type
    - If there is only partial alignment, project developers must adopt a conservative EF and document the rationale for its selection.
    - The CRF products used in the study must follow the criteria mentioned in section 1.3 Eligible products and be commercially available.
    - **Temporal relevance:** The studies that EF are retrieved from should be recent enough to reflect current climatic conditions, agricultural technologies and practices. A common practice is to utilize studies published within the last 30 years,

provided there have been no significant changes in agricultural practices, technologies or climatic conditions (due to climate change) in the region. If such changes have occurred, more recent studies (e.g., within the past 10 years) should be considered, in order to accurately reflect the current conditions.

A.2.2 Utilization of meta-analyses papers

Meta-analyses papers can serve as valuable sources for EF extraction as it is described in section 4.1 EF-data reference approaches, provided they meet specific quality criteria:

- **Heterogeneity:** Meta-analyses must report or assess heterogeneity (I^2) among studies. If I^2 is not provided, developers must provide evidence of variability (e.g., range, SD, forest plot) and justify reliability. If high heterogeneity is evident (e.g., $I^2 > 75\%$ or clear visual spread), an uncertainty buffer of 10% must be applied unless justified via subgroup analysis.
- **Representation of diversity**: The meta-analysis must include studies with diverse environmental and management conditions. It should provide distinctions based on factors such as regions, soil types, or other relevant characteristics that can be correlated to the project's specific conditions.
- **Study alignment**: Each individual study within the meta-analysis must adhere to the project's regional, temporal, and management relevance criteria. The meta-analysis should offer a clear breakdown of data categorized by region, soil type, or other variables to enable alignment with the project's characteristics.
- **Data extraction**: When a meta-analysis provides average EFs, in order to use them project developers must ensure that these averages align with their project's specific characteristics, including environmental factors and management practices as mentioned in section A.2.1. If the provided averages do not sufficiently match the project's conditions, wherever feasible, project developers should extract raw data from the meta-analysis and create new averages that better reflect the project's specific context. In such cases, detailed documentation of the procedure must be provided to ensure transparency and traceability.
- **Uncertainty consideration**: Each average EF must be accompanied by its reported average standard deviation. Meta-analyses must report standard deviations (SDs) or confidence intervals for derived average EFs. An additional uncertainty penalty must be applied if raw data is unavailable or if inclusion criteria for individual studies are unclear.

A.2.3 Quality criteria of experimental design (of studies/trials)

The robustness of the experimental design is critical to ensure that the EF values derived are reliable and reproducible. To achieve this, the following criteria must be met:

- **Temporal coverage and measurement period:** Scientific studies often recommend a two-year temporal coverage to account for year-to-year variability in environmental conditions. However, due to practical limitations, a one-year experiment is also acceptable, provided that more plot-level replications (e.g., multiple experimental units under different conditions) are included to strengthen reliability and improve data robustness. The duration measurement period should align with the crop cycle and seasonal variations to ensure comprehensive data. Emissions should be measured over a period that captures all significant nitrogen loss events, including heavy rainfall, drought, or temperature fluctuations, if they occurred. For fertilizers with extended nutrient release characteristics, it is recommended to extend the measurement period post-harvest to capture potential lagged N_2O emissions.
- **Replication**: A minimum of three replicates per treatment is required (Abalos et al., 2014; Fan et al., 2022) to account for variability in environmental and management conditions. A lack of replication may undermine the reliability of the results.
- **Controls**: The experiment must include treatment without CRF products (baseline) and a control without nitrogen fertilizer application.
- **Standardized measurements**: Emissions must be quantified using scientifically recognized methods. For instance, chamber-based measurements for direct N_2O emissions or isotopic techniques for tracking nitrogen transformations.
- **Consistency across treatments**: Environmental and management conditions (e.g., fertilizer application rates, irrigation) must be consistent across treatments (control and intervention) to ensure comparability. Differences in these conditions can skew results and reduce the validity of derived EFs.
- **Data reporting**: Studies must clearly present key information, including:
    - Mean cumulative N_2O emissions (direct and/or indirect) for control and treatment groups
    - EF for each treatment
    - CRF product type, application rate
    - Associated uncertainty ranges (e.g., standard error)
    - Environmental conditions (e.g., soil texture, rainfall, air or soil temperature)

    - Number of replicates
- **Field-based measurements**: Measurements must be conducted under field conditions. Measurements reported from laboratory experiments are not considered applicable for this methodology.

For on-field measurements, project developers must adhere to the relevant guidelines to ensure that field measurements are conducted rigorously and provide data that meet the quality standards required to provide emissions from the field and eventually Tier 3 EF to be developed. An example is the Lyons et al., (2024b) study "*Field Trial Guidelines for Evaluating Enhanced Efficiency Fertilizers*".

Appendix B: Uncertainty Factor calculation

The uncertainty factor of the data depends on the source and quality of the data, which leads to different calculation methods for data collected from different sources.

B.1 Uncertainty propagation for single-source data

The overall uncertainty in the net GHG emission reduction can be derived by combining the uncertainties from both the baseline and project emissions. This can be done using the following propagation of uncertainty formula:I

$$UF = \sqrt{(\sigma_{BE})^2 + (\sigma_{PE})^2 - 2 \cdot \sigma_{BE\,PE}} \quad (11)$$

Where:

UF_i	=	Uncertainty of source i (source i can refer to literature i /field plot i, etc.)
σ_{BE}	=	uncertainty in the baseline emissions (%)
σ_{PE}	=	uncertainty in the project emissions (%)
$\sigma_{BE\,PE}$	=	covariance between the uncertainties of the two values (if they are correlated). Since the baseline and project emissions are independent (no correlation between them), the covariance is typically considered zero.

B.2 Uncertainty propagation of multi-source data

When combining EF from multiple sources into one, the following equation can be used:

$$UF = UF_{avg} = \frac{\sqrt{\sum_{i=1}^{n} UF_i^2}}{n} \tag{12}$$

Where:

$UF = UF_{avg}$	=	will be the Uncertainty Factor (%) used in calculating the actual GHG emissions reduction, which is the average of the uncertainties in the relevant data from all the from 1 to n sources
UF_i	=	Single-Source Uncertainty Factor of source i
n	=	number of independent Single-Sources that have similar conditions to the actual project being implemented

Appendix C: Different metrics of GHG emissions

A commodity-based approach for quantifying the impact is particularly relevant for downstream stakeholders. For example, a food company may want to use this data for their Product Carbon Footprint (PCF) reports or Life Cycle Assessments (LCAs), where the GHG emissions per tonne of crop is crucial. For a fertilizer producer, the focus may be on the GHG emissions per tonne of CRF product applied (again for the cradle-to-grave PCF/LCA), while for a farmer, the GHG emissions per hectare might be more relevant. In Table 7 the key metrics that can be applied are presented.

Table 7: Metrics that can be used for the project GHG emissions

Metric	Description	Example	Unit
Per unit of crop produced **[PCF of crop]**	This metric correlates emissions reductions to crop yield, making it valuable for assessing GHG emissions throughout the food supply chain. By expressing emissions reductions relative to the amount of crop produced, it helps food companies track improvements in sustainability while lowering their carbon footprint. This approach directly links emission reductions with crop yield.	Companies within the food industry (such as food producers) can use this metric to demonstrate that the production of their crops are associated with lower emissions	tCO_2e / ton of crop
Per unit of nitrogen containing fertilizer applied **[PCF of fertilizer]**	This metric demonstrates the emissions reductions achieved per ton of nitrogen fertilizer applied, providing insight into the efficiency of nitrogen use. It directly quantifies the impact of improved fertilizer management strategies, such as the use of CRF products, and demonstrates how much N_2O emissions are saved for every kilogram of fertilizer used.	Fertilizer companies looking to show progress in nitrogen use efficiency and claim reduction in their Scope 3 emissions.	tCO_2e / ton of fertilizer
Per unit of land area	This metric provides clear insights into GHG emissions reductions on a field level. By quantifying emissions reductions per hectare, this metric	Companies within the food industry (such as food producers) can use this metric to demonstrate that the production	tCO_2e / ha

	allows for direct comparison between different fields or farms, making it critical for broader environmental claims.	of their crops are associated with lower emissions	

To showcase the impact of the project intervention, these metrics can be compared against the metrics for each of two baseline approaches (see section 3 Baseline scenario).

The quantification of the field emissions (direct and indirect N_2O) derived from this methodology, can be directly used by supply chain participants as an input for the Product Carbon Footprints (PCFs) of the crops.

When calculating the **impact per tonne of crop produced** (for the PCF of the crop), it is essential to account for variations in annual crop yield, which can be heavily influenced by external factors such as weather patterns, pests, or regional events. These fluctuations may not accurately reflect the impact of the intervention itself but instead represent broader external trends. To address this, a normalization process is recommended, such as using a moving average for the crop yield.

A **moving average** is a statistical method used to smooth out short-term fluctuations and highlight longer-term trends by creating a series of averages from subsets of data points. Mathematically, it is a type of convolution, where the crop yield data is combined with a filter function, in this case, a simple averaging filter (sometimes referred to as a "boxcar filter"). For a moving average, this filter computes the mean of crop yields within a fixed window size (e.g., 3–5 years). For crop rotation scenarios, only the years with the same type of crop are relevant for each moving average. The window shifts forward through the data series, excluding the oldest value and including the next, producing a smoothed trend line.

This approach effectively reduces the noise caused by year-to-year variability, allowing for a clearer understanding of the intervention’s impact. By comparing the normalized yields with the farmer log and regional baseline scenario, stakeholders, such as (downstream) reporting companies, can better distinguish the intervention's true contribution to emission reductions from region-wide external factors. Additionally, reporting **both** the raw and smoothed yield data provides transparency and ensures that all stakeholders involved understand the normalization process.

Appendix D: Different NUE metrics

Nitrogen Use Efficiency (NUE) is a crucial metric to evaluate how effectively nitrogen (N) inputs are converted into agricultural outputs. It plays a key role in both productivity and environmental sustainability, and forms a critical part of assessing the baseline conditions, potential leakage, and intervention effects in projects that utilize CRF products. While numerous definitions of NUE exist, this methodology adopts a practical approach by recognizing a core set of indicators, which can be used individually or in combination, depending on data availability and project context. These metrics have been adapted from the definitions and framework proposed by the Sustainable Plant Nutrition Responsible Practices Network (SPRPN) in their 2024 issue brief “Defining Nutrient Use Efficiency in Responsible Plant Nutrition [40].

NUE indicator	*Description*	*Calculation*	*Unit*	*Practicality*
Partial Factor Productivity (PFP)	Yield of crop harvested per unit of fertilizer nitrogen applied.	$PFP = Y/N$ Where: $Y = reported\ crop\ yield$ $N = N\ application\ rate$	kg crop/kg N	[Must be measured and must be reported in every project] Highly practical, easy to calculate from standard or reported crop yield and N rate application data.
NUE based on Outputs/Inputs (NUEpb)	Ratio of total N output (harvested) to total N input. Indicates system-level nitrogen use	$NUEpb = R/(N + M + B + D)$ Where: $R = Total\ nitrogen\ removed\ in\ harvested\ crop\ biomass$ $N = N\ application\ rate$ $M = N\ from\ manure\ or\ organic\ amendments$	Fraction or %	Comprehensive but data-intensive. It is related to a more detailed analysis at research or institutional level.

[40] https://sprpn.org/wp-content/uploads/2023/08/Issue-Brief-04_English.pdf

	efficiency.	$B = N\ from\ biological\ fixation$ $D = Atmospheric\ deposition\ of\ reactive\ nitrogen$		
N Balance (NUEfg)	Difference between N inputs and N outputs. Indicates potential for environmental losses.	$NUEfg = U/(N + M + B + D)$ Where: $U = N\ uptake\ in\ crops$ $N = N\ application\ rate$ $M = N\ from\ manure\ or\ organic\ amendments$ $B = N\ from\ biological\ fixation$ $D = Atmospheric\ deposition\ of\ reactive\ nitrogen$	kg N/ha	Requires full N input/output accounting. It is challenging for most farmers but useful for environmental assessments.
Agronomic Efficiency (AE)	Increase in crop yield per unit of N applied compared to untreated control. Reflects crop gain efficiency from fertilizer.	$AE = (Y - Yo)/N$ Where: $Y = reported\ crop\ yield$ $Yo = crop\ yield\ from\ unfertilized\ plot$ $N = N\ application\ rate$	kg crop/kg N	Less practical, it requires untreated control plots, which may be hard to implement widely.
Recovery Efficiency (RE)	Proportion of applied N that is taken up by the crop. Indicates the effectiveness of N uptake.	$RE = (U - Uo)/N$ Where: $Uo = N\ uptake\ in\ crop\ from\ unfertilized\ plot$ $U = N\ uptake\ in\ crop\ from\ fertilized\ plot$ $N = N\ application\ rate$	Fraction or %	Less practical, it requires plant N uptake data or lab analysis and control plots, which may be hard to implement widely.

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