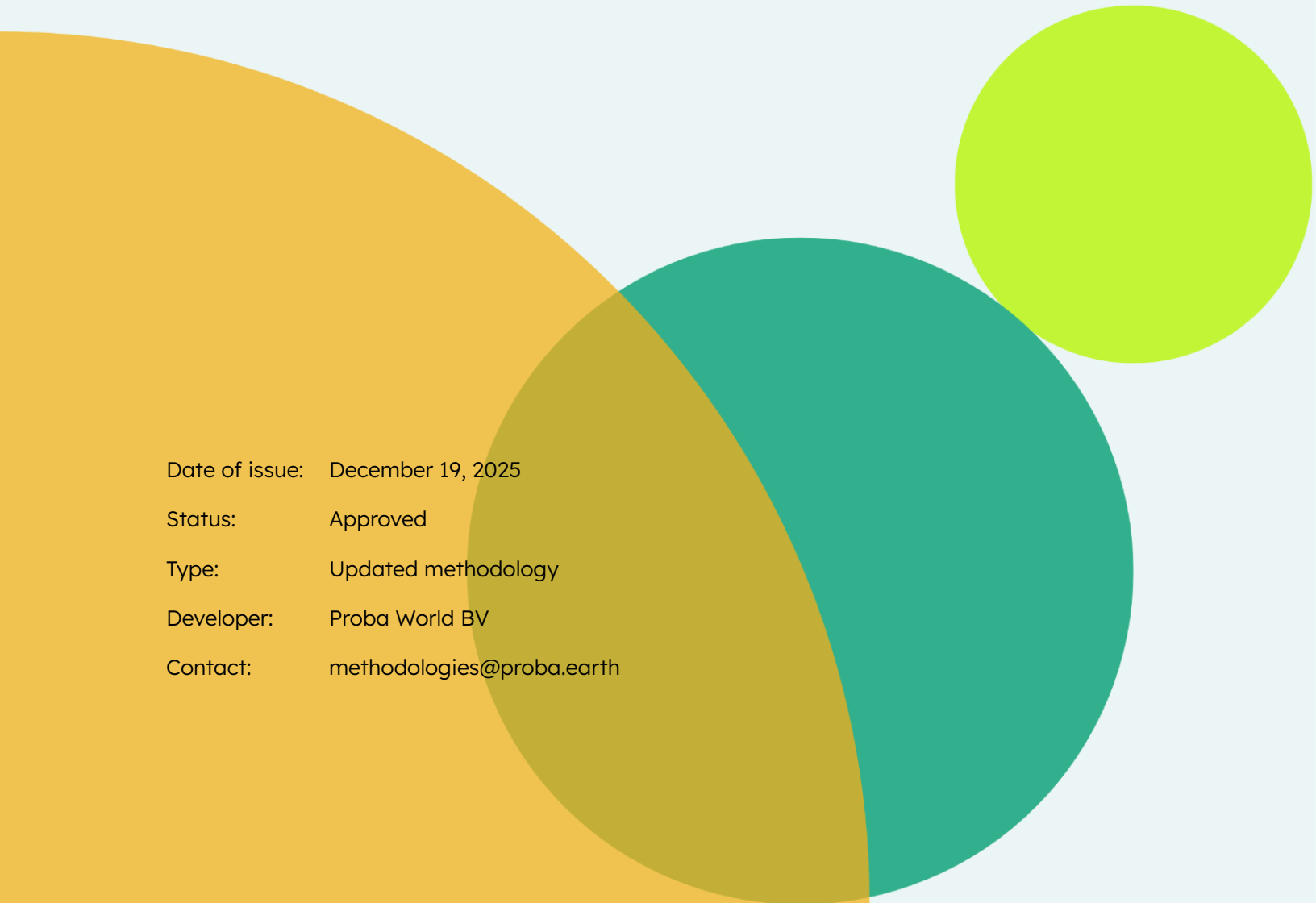


PM.0004

Adoption of nitrogen stabilizers to transition to low-carbon agriculture

GHG Methodology
Version 1.1



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Update log

| Date | Version | Description | Section |
|-----------|---------|---|--------------------------------------|
| 5/12/2025 | 1.1 | Included dedicated guidance for grasslands, covering both grazed pastures and cut-and-carry systems. | 1.2 Applicability of the methodology |
| 5/12/2025 | 1.1 | Clarified requirements for the concentration (dose rate) of nitrogen stabilizer active ingredients, including regulatory compliance considerations. | 1.3 Eligible products |
| 5/12/2025 | 1.1 | Specified rules for the renewal of the crediting period and clarified the conditions for retroactive crediting. | 1.5 Crediting period |
| 5/12/2025 | 1.1 | Categorized risks according to their type for clearer delineation and assessment. | 1.7 Risks |
| 5/12/2025 | 1.1 | Streamlined the rules for leakage assessment and updated the approach for applying leakage deductions. | 1.8 Leakage & permanence |
| 5/12/2025 | 1.1 | Added tables illustrating the differences among the various spatial boundaries. | 2.3 Spatial boundaries |
| 5/12/2025 | 1.1 | Added streamlined guidance for baseline determination. | 3 Baseline scenario |
| 5/12/2025 | 1.1 | Added simplified guidance for selecting in-field emission factors, using a hierarchical decision tree. | 4.1 EF-data reference approaches |
| 5/12/2025 | 1.1 | Restructured the appendices to minimize overlap and improve navigation. | Appendix |
| 5/12/2025 | 1.1 | Added references to the supporting templates directly within the text (VVB guidelines, POD template, and additionality template). | General |

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List of definitions

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| 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. This can lead to indirect GHG emissions when ammonia is subsequently converted to nitrous oxide (N ₂ O) in the environment. |
| Annual crops | These plant species complete their entire life cycle from seed to growth to flowering to seed production and death within a single growing season or a single year |
| 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 nitrogen stabilizers. |
| Carbon dioxide equivalent - CO ₂ e | 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 CO ₂ , facilitating a standardized approach to assessing overall greenhouse gas emissions. |
| Carbon credit/Emission reduction certificate | A carbon credit represents at least 1 tonne of CO ₂ (tCO ₂), or 1 tonne of CO ₂ e (tCO ₂ e) reduced or removed for a certain period of time. One tonne (metric ton) (t) equals 1000 kg. For carbon equivalency, Proba uses the AR-6 assessment from UNFCCC ¹ . |
| Compound fertilizers | Fertilizer products composed of both stabilized and non-stabilized nitrogen components, such as bulk-blended formulations. |
| 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. |
| 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 |

¹ <https://ghgprotocol.org/sites/default/files/2024-08/Global-Warming-Potential-Values%20%28August%202024%29.pdf>

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| | 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 ₂ O emissions | Total N ₂ O 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. |
| 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 ₂ O) 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. |
| Farming system | For the purpose of this methodology, the term farming system is defined to include both cropland with annual or perennial crops, and grassland managed as cut-and-carry grassland or grazed pasture. |
| Feed Conversion Ratio | Feed Conversion Ratio is the amount of feed dry matter consumed per unit of animal product produced. It expresses the efficiency with which animals convert feed into output and is calculated as kilograms of feed dry matter divided by kilograms of animal product. |
| Grassland | Grasslands are a land-use category that includes pasturelands, rangelands, and other areas dominated by grasses and herbaceous vegetation. These lands may be managed for grazing, harvested for hay |

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| | <p>or silage, or left unmanaged. Within managed grasslands, two distinct system types are relevant:</p> <ul style="list-style-type: none"> • Grazed pasture refers to managed grassland where livestock directly consume the standing vegetation. • Cut-and-carry grassland refers to managed grassland where vegetation is harvested and transported to livestock as hay, silage, or fresh forage. |
| Grazing | The act of livestock feeding directly on standing vegetation such as grasses or other herbaceous plants in rangelands, grasslands, or pastures |
| 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 nitrogen stabilizer 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 <i>Land Sector and Removals Guidance</i> definition ² . |
| 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. |
| IFA Enhanced Efficiency Fertilizer Emission Factor Database | A comprehensive database of agricultural N ₂ O emission factors for scientists, researchers, and environmental professionals. https://fertilizerdatabase.com |
| Insetting | Insetting refers to the practice of implementing sustainable 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. |

² <https://ghgprotocol.org/land-sector-and-removals-guidance>

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| 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 groundwater contamination (e.g., because nutrients and cations can be leached), and the indirect emission of nitrous oxide (N ₂ O) when nitrates are converted by microbial activity in anaerobic conditions. |
| 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 ₂ O) as by-products. |
| Nitrogen stabilizer | Nitrogen stabilizers 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 stabilizers mixtures | Fertilizers mixed with nitrogen stabilizers before application, either at the field level or through distribution channels. This includes compound fertilizers in which only a portion of the nitrogen is stabilized (e.g., bulk-blended products combining stabilized and non-stabilized nitrogen forms). |
| 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 among other metrics |
| 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 ₂ O). |
| 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. |
| Pasture | Land used for grazing by livestock, where the vegetation is managed to maintain or improve its productivity |

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| Perennial crops | These plant species live for more than two years and continue growing and producing biomass or harvestable yield over multiple growing seasons without needing to be replanted each year. |
| 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 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). A methodology specific POD template can be shared upon request. |
| Stabilized Nitrogen (N) Fertilizer | Fertilizers incorporated with a nitrogen stabilizer (nitrification inhibitor (NI), urease inhibitor (UI), or both). The treatment with nitrogen stabilizers can occur either during or after the fertilizer production process. |
| 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 . |
| 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. |
| Quality criteria | A set of scientifically grounded requirements that determine whether a study provides reliable, well-documented, and context-appropriate evidence for deriving emission factors. These are specific to this methodology and are defined in the appendix A.2 Quality criteria of experimental design of studies . |
| 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 <i>Land Sector and Removals Guidance</i> |

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| | 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 . |
| Yield | The quantity of biological output produced per unit of land area within a defined monitoring period. Yield may refer to: <ul style="list-style-type: none"> • Crop yield: harvested grain, tubers, or other crop products (e.g., tonnes of maize grain per hectare). • Forage yield: harvested grass or fodder biomass from cut-and-carry grasslands, typically expressed in fresh weight or dry matter (DM) per hectare. |
| 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

| | |
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| AR6 | IPCC Sixth Assessment Report |
| AFOLU | Agriculture, Forestry, and Other Land Use |
| AI | Active Ingredient |
| EEF | Enhanced Efficiency Fertilizers |
| EF | Emission Factor |
| GHG | Greenhouse Gas |
| IFA | International Fertilizer Association |
| IPCC | Intergovernmental Panel on Climate Change |
| KPI | Key Performance Indicators |
| LCA | Life Cycle Assessment |
| LMU | Land Management Unit level |
| MRV | Monitoring, Reporting, and Verification |
| NI | Nitrification Inhibitor |
| NH ₃ | Ammonia |
| N ₂ O | Nitrous Oxide |
| NO ₃ ⁻ | Nitrate |
| NO | Nitric oxide |
| NO ₂ ⁻ | Nitrite |
| NUE | Nitrogen Use Efficiency |
| PCF | Product Carbon Footprint |
| POD | Project Overview Document |
| SDG | Sustainable Development Goal |
| SOC | Soil Organic Carbon |
| UI | Urease Inhibitor |
| UINI | Combination of Urease and Nitrification Inhibitors |
| 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 (N₂O), a greenhouse gas (GHG) with a Global Warming Potential 273 times more potent than CO₂ (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 N₂O emissions associated with the application of inorganic and organic nitrogen-containing fertilizers. The use of nitrogen stabilizers is identified as an effective strategy to reduce nitrogen losses and related emissions in agricultural systems (Gao & Cabrera Serrenho, 2023).

Nitrogen stabilizers are compounds added to nitrogen containing inorganic or organic fertilizers, to reduce nitrogen loss and GHG emissions by slowing down specific biological processes. These stabilizers act as chemical agents that delay the microbial or enzymatic processes responsible for nitrogen losses, such as ammonia volatilization and nitrate leaching. The key products involved are urease inhibitors (UI) for urea containing fertilizers, nitrification inhibitors (NI) for urea and/or ammonium containing fertilizers, and their combinations (UINI) for urea containing fertilizers.

- Urease inhibitors work by blocking the active site of the urease enzyme, which slows down the conversion of urea into ammonia (NH₃). This process reduces the amount of nitrogen lost to the atmosphere as NH₃, helping to slow down ammonia volatilization (Cantarella et al., 2018).
- Nitrification inhibitors slow down the conversion of ammonium to nitrite and subsequently to nitrate, which can reduce nitrate leaching and the production of nitrous oxide (N₂O), especially during the early and peak uptake stages of the crop⁴.

As such, applying nitrogen stabilizers on the fields, along with the commonly-used N additions, can lead to a reduction of GHG emissions. Key impacts of nitrogen stabilizers include:

- **Reduction in direct N₂O emissions:** Nitrogen stabilizers reduce direct N₂O emissions by slowing processes like nitrification, minimizing N₂O formation in the soil.

⁴ Nitrate leaching can still occur under certain conditions, such as after harvest if residual nitrate remains in the soil and is mobilized by precipitation

- **Reduction in indirect N₂O emissions:** Nitrogen stabilizers reduce indirect N₂O emissions by slowing down ammonia (NH₃) volatilization from urea through urease inhibitors (UI) and by inhibiting the nitrification of ammonium through nitrification inhibitors (NI). These mechanisms reduce nitrogen losses as ammonia (via UI) and nitrate (via NI), thereby limiting the processes that contribute to indirect N₂O emissions.
- **Increase of crop yields through improved Nitrogen Use Efficiency (NUE):** Nitrogen stabilizers can enhance NUE due to reduction of N losses which improves the availability of nitrogen to plants. This may lead to higher crop yield⁵ for the same nitrogen input. As a result, the same amount of fertilizer can produce more output, reducing emissions per unit of agricultural product.
- **Cradle-to-gate emissions of nitrogen stabilizer:** On the other hand, the production and transportation of nitrogen stabilizers results in (cradle-to-gate) GHG emissions, which must also be accounted for.

1.2 Applicability of the methodology

- This methodology is globally applicable to projects that introduce nitrogen stabilizer containing products (see section [1.3 Eligible products](#)) to managed soils.
- This methodology is applicable to farming systems such as arable land used for crop cultivation (annual and perennial crops) and managed grassland used for grazing or harvested feed production (forage).
- Partial substitution of conventional nitrogen fertilizer with nitrogen stabilizer-containing products is applicable, provided that the stabilizer component is clearly defined, the substitution is documented, and the corresponding emissions reductions are calculated only for the portion of nitrogen treated with the stabilizer.
- 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 N stabilizer) 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. However, the impact of the N stabilizer is attributed only to the nitrogen (N) component of the product.

⁵ For the purposes of this methodology crop yield is the same as crop productivity or biomass production

- 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 linked to fertilizer substitution. 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 nitrogen stabilizer leads to the reduction of the net GHG emissions, which are in scope of this methodology (see section [2.1 Scope of activities](#)).
- 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. Guidance for the selection of the EF is presented in section [4.1 EF-data reference approaches](#).
- This methodology is applicable to projects that introduce changes to management practices on top of the usage of nitrogen stabilizers (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 this scientific studies are used, OR
 2. There is sufficient scientific proof that these practices (that come on top of the introduction of nitrogen stabilizers) do not negatively affect the stabilizer-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 nitrogen stabilizers with a soil management practice designed to sequester CO₂, thereby achieving complementary climate benefits while ensuring that the integrity of the emission reductions from activities under this

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 N stabilizers (or on the other hand the N stabilizers do not interfere with other interventions already in place). For this reason the conditions were added.

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 nitrogen stabilizers across two projects)
- provide a separate monitoring framework to ensure that combined interventions do not undermine stabilizer 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 N stabilizers, 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 (or vice versa)
 - Increasing the number of tractor passes or field operations (e.g., separate pass for applying the stabilizer)
 - Switching to a fertilizer product with higher embedded emissions per kg of nitrogen applied
 - Adding irrigation events (e.g., fertigation with stabilizers) that consume energy or water
- Project developers must ensure that the applicability, eligibility and additionality criteria presented in this methodology are fulfilled.
- This methodology can be used for 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 supply chain through a robust chain of custody model. Specifically, this is guided by SBTi's Corporate Net-Zero Standard Version 2.0 Consultation Draft⁷ which prioritizes direct mitigation when possible. When traceability to either specific emissions sources or the activity pool currently cannot be established, or if insurmountable barriers persist in addressing a source of emissions, this methodology also acknowledges the role of indirect mitigation as an intermediate measure. The traceability of the insetting activities can be ensured with activities such as chain-of-custody documentation, blockchain-based tracking systems, farm-level purchase and application records, or third-party verified sourcing certificates. Section [1.4 Additionality](#), explains the requirements for these different types of projects.

⁷ <https://files.sciencebasedtargets.org/production/files/Net-Zero-Standard-v2-Consultation-Draft.pdf>

- 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

1.3.1 Types of eligible nitrogen stabilizers

- In this methodology, the eligible products are nitrogen stabilizers, specifically urease inhibitors (UI), nitrification inhibitors (NI), and combinations of both (UINI). By default only active ingredients for which there is sufficient scientific evidence (see section [4.1 EF-data reference approaches](#)) are eligible under this methodology.
- Other enhanced efficiency fertilizer products, such as control or slow-release fertilizers, biostimulants and bio-inhibitors (BI) are currently excluded from this methodology.
- **Solid vs liquid forms:** Both solid and liquid formulations of nitrogen stabilizers are eligible. The selection should be based on the active ingredient, its proven effectiveness in either form and its compatibility with the carrier fertilizer type to ensure proper integration, and efficiency in reducing nitrogen losses.
- **Application method of stabilizer:** The following methods of integrating nitrogen stabilizers into fertilization practices are eligible:
 - Pre-mixed N stabilized fertilizers: Fertilizers pre-treated with nitrogen stabilizers during manufacturing.
 - Post-mixed N stabilized fertilizers: Fertilizers mixed with nitrogen stabilizers before application, either at the field level or at distribution channels.
 - Compound fertilizers: composed of both stabilized and non-stabilized nitrogen components, such as bulk-blended formulations. Eligibility in such cases applies to the stabilized portion of the product, provided that appropriate documentation is included in the POD, and emission reductions are proportionally assigned.
 - Direct soil application: Nitrogen stabilizers applied separately before or after fertilization to control nitrogen transformations in the soil.

1.3.2 Regulatory compliance and active ingredient concentration

Regulatory compliance:

For nitrogen stabilizer products to be eligible they must meet the regulatory requirements for use in the country or region of application. In addition, compliance to regional guidelines is essential to ensure that the application rate is in line with local regulations.

In regions like the U.S. and Europe, there are regulatory bodies that provide guidelines and information regarding which products are approved for use in agriculture. For example, in the U.S., UI are regulated under the Association of American Plant Food Control Officials (AAPFCO)⁸, while NI falls under the jurisdiction of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)⁹. Both regulatory bodies provide oversight and guidance on the use of various fertilizer products, including products such as nitrogen stabilizers.

In the EU, Regulation (EU) 2022/1519¹⁰, which amends Regulation (EU) 2019/1009, establishes the requirements for compounds to be classified under Product Function Categories (PFCs) and comply with EU fertilizer regulations. Specifically PFC5¹¹ describes the approved nitrogen stabilizer products, such as NI and UI, that can be used in fertilizers. The regulation outlines the composition requirements for stabilized N fertilizers, including:

- For NI: The inhibitor content is based on the total nitrogen present in the form of ammonium nitrogen and urea nitrogen and the fertilizer-product must contain minimum 50% of total N in the form ammonium and urea.
- For UI: The inhibitor content is based on the urea nitrogen content and the fertilizer-product must contain minimum 50% of total N in the form of urea.

⁸ <http://www.aapfco.org/>

⁹ [Federal Insecticide, Fungicide, and Rodenticide Act \(FIFRA\) and Federal Facilities | US EPA](#)

¹⁰ [02019R1009-20241120 - EN - EUR-Lex](#)

¹¹ Product Function Category 5: includes products such as nitrification and urease inhibitors, and outlines composition and performance requirements to ensure both environmental safety and agronomic efficacy

N stabilizer active ingredient concentration / dose rate:

The Active Ingredient (AI) concentration¹² of the N stabilized fertilizer affects the effectiveness of the inhibition and therefore their effectiveness in reducing GHG emissions and maintaining or improving NUE.

For N stabilized fertilizers that are pre-mixed, this concentration is typically part of the registration under regional and/or national fertilizer regulations. The concentration must fall within the range recommended by the producer of the stabilizer, as well as the range mandated by the regulation. The key requirement is to ensure that the product remains sufficiently effective at the time of field application. This means that for pre-mixed N stabilized fertilizers, the concentration must be at a level that preserves its functional efficacy throughout all stages of storage, handling, and distribution. Producers of nitrogen stabilizers establish recommended dose rates through extensive experiments across diverse environmental conditions.

It is acknowledged that in some regions where the regulatory framework is less stringent, N stabilized products might be sold and used with insufficient AI concentration to reduce GHG emissions. Project developers must ensure that the selected N stabilizers are designed according to the best industry standards. If the efficacy of the products is expected to be lower due to less effective inhibitors or insufficient dose rates or losses of AI during storage, the project developer must report this and adjust the emission factor reduction proportionately.

Project developers must report on the concentration of the active ingredients of the products that they used, along with the recommended dose rates from the N stabilizer producer (for the post-mix products).

Attention must also be given to ensuring that the selected rate allows for the intended environmental benefits of the stabilized fertilizer to be achieved, without causing any adverse impacts (see [Section 1.7 Risks](#)). In such cases, the Validation and Verification Body (VVB) must carefully verify that the application rate was selected appropriately and in accordance with these criteria.

Effectiveness of products:

The effectiveness of nitrogen stabilizers can vary depending on environmental conditions such as temperature, soil texture, pH, and moisture. For instance, higher temperatures may accelerate the degradation of certain active ingredients of nitrification inhibitors (NI), reducing their inhibitory effectiveness in the soil.

¹² These rates can be expressed as a percentage of active ingredient (AI) linked to the corresponding nitrogen form (e.g., % on NH₄-N for nitrification inhibitors, % on urea-N for urease inhibitors).

Project developers must ensure that the selected N stabilizer is suitable for the specific agroecological context and management practices of the project.

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*¹³ 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 UNFCCC's CDM Tool for the Demonstration and Assessment of Additionality (Version 07.0)¹⁴ and
 - the CDM Tool for Common Practice (Version 03.1)¹⁵.

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 inseting 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 inseting 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 nitrogen stabilizers 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 nitrogen stabilizers 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.

¹³ https://proba.earth/hubfs/Project_Design/Proba_Additionality_Assessment_Template.pdf

¹⁴ <https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-01-v7.0.0.pdf>

¹⁵ <https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-24-v1.pdf>

- Countries, states, regions, or economic zones have set GHG emission targets, supported by directives and subsidies, or incorporated the sector into a compliance system, making some projects de facto not additional.
- If a project falls under planned regulations, additionality can still be achieved if the project can prove its intervention goes beyond the set goals or realizes its impact ahead of the planned regulation timeline. In this case, the project may only be additional for a limited time until the regulation comes into effect and becomes business-as-usual.
- If a regulation is implemented and actively enforced during the crediting period that mandates the use of nitrogen stabilizer 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 nitrogen stabilizers 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 fertilizer 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 N stabilized fertilizers 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 inseting scenario, the project developer must demonstrate regulatory additionality by confirming that the use of nitrogen stabilizers is not mandated by the regulation. In addition, the Project Overview Description (POD) must be transparent and document information on:

- Prevalence additionality: An explanation must be provided that the use of nitrogen stabilizers is not a common practice within the company's sourcing region, farming system, or market segment relevant to the intervention.
- Financial additionality: An explanation must be provided that carbon finance is positively affecting the adoption of nitrogen stabilizers within the company's sourcing region, crop system, or market segment.

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.

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. Renewals of the crediting period are permitted and may be carried out multiple times, provided that each renewal follows a full re-validation process and continues to meet the applicability criteria, methodological requirements and alignment with Proba standard and the latest version of the GHG methodology.

For GHG projects utilizing nitrogen stabilizers, 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 nitrogen stabilizers, but allows them to generate emission reduction certificates if they do. For example, if a farmer applies nitrogen stabilizers in only 4 out of 7 years, they would receive emission reduction certificates only for those years.

Retroactive crediting

This methodology allows for retroactive crediting, in the case the adoption of N stabilized fertilizers was realized 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, as evidenced by verifiable documentation such as purchase receipts, supplier delivery notes, application records, or other dated records that clearly establish the start date. The project developer must also fulfill the requirements set by this methodology (e.g., proof of additionality, baseline, scientific evidence, documentation) and demonstrate that the intervention was implemented with the intention of utilizing carbon finance. To avoid double counting, emission reductions that have already been claimed, credited, or reported under another carbon standard are not eligible for crediting 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 nitrogen-based fertilizers, enriched with nitrogen stabilizers.

Project developers are recommended to report on co-benefits for credibility purposes.

Proba encourages GHG projects to contribute to at least one or more UN Sustainable Development Goals, and expects that project developers 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 POD, along with how the impact is achieved, measured (e.g., through KPIs¹⁶). In this case, relevant KPIs must be selected by the project developer and monitored throughout the years.

For instance, the SDG Impact Assessment Tool offers a structured approach to help assess and align projects with the SDGs¹⁷.

Some examples that could be relevant with this type of project include:

- **Zero hunger (SDG 2)**: Numerous studies indicate that the use of urease and nitrification inhibitors enhances crop yields while simultaneously reducing N₂O emissions (Wang et al., 2021, Meng et al., 2020, Ding et al., 2018). 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 nitrogen stabilizer improves water quality, protecting freshwater ecosystems and ensuring cleaner water supplies (Qiao et al., 2015).
- **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. For example, Akiyama et al. (2010) stated that NIs significantly reduce nitrogen losses through nitrate leaching and emissions, which can help maintain soil fertility and reduce environmental degradation.

¹⁶ KPIs (Key performance indicators) measure a company's success vs. a set of targets, objectives, or industry peers

¹⁷ <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.

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. The risk analysis and mitigation strategy must be re-evaluated at the third year of the crediting period, as part of the verification.

Some of the risks that should be addressed are the following:

- General:
 - 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. In case of potential conflict of interest, cross-check with broader relevant (scientific or validated) literature is required.
 - The farmer might not actually apply the reported amount of product, either as an unintentional action or miscalculation or a deliberate error or falsification.
 - Events which may occur during the crop season, and may lead a) to decreased crop yields or b) additional applications of fertilizers and nitrogen stabilizers 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 events¹⁸ (e.g., heavy thunderstorms and hailstorms).
 - Nitrogen stabilizer overdose could induce eco-toxicological side effects for plant growth and incur greater economic costs (Macadam et al., 2003; Yang et al., 2016). This is especially a risk for cases where the nitrogen stabilizer is not incorporated into the fertilizer. To prevent this, evidence of proper application rate of N stabilizer or, if that is not possible, monitoring of N dynamics is recommended.
 - While stabilizer products are subject to regulatory approval and maximum residue levels in many jurisdictions, misapplication or excessive dosage could pose risks. To mitigate this, adherence to registered application rates, as outlined in section [1.3.2](#)

¹⁸ 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).

[Regulatory compliance and application rate](#), is required and must be documented in the POD.

- Over time, it is possible that microbial adaptation may reduce the effectiveness of nitrogen stabilizers. However, a study by Duff et al. (2022) showed that non-target bacterial and fungal communities were not significantly affected by long-term inhibitor treatments, supporting the notion that these nitrogen management strategies can mitigate emissions without disrupting overall microbial diversity and composition.
- Only for LMUs:
 - In case the nitrogen stabilizer is not incorporated into the fertilizer during manufacturing (stabilized N fertilizer), but rather sold separately from the fertilizer, then there is a risk that the nitrogen stabilizer is not actually used (e.g., resold).
 - The crop yield might be incorrectly measured or reported.

1.8 Leakage & permanence

1.8.1. Leakage

Leakage refers to a net increase in GHG emissions outside the project boundary that is directly caused by project 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 fertilizer volumes no longer used in the project area are demonstrably sold and used by non-project actors¹⁹. 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;
 - national or regional sales/trade data showing stable or decreasing conventional fertilizer volumes;

¹⁹ This risk of leakage is not applied to nitrogen stabilizers/fertilizers mixtures and post-application treatments.

- 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 ²⁰.

Table 1: Market leakage deduction for different scenarios

| Project scale ²¹ | 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% |

2. The use of nitrogen stabilizers alongside the same quantity of fertilizer is expected (at least) to maintain the same yields per hectare. However, a decrease in yield within the project area might lead to increased production elsewhere to meet demand. If the yield decreases, it is

²⁰ Note on Applicability for Fertilizer Distribution Projects (sourcing region type of project): For projects where the intervention is defined by the distribution or sale of a fixed quantity of N stabilized fertilizer rather than activities on a defined project area, the hectare-based stratification in Table 1 must be converted to an equivalent scale in tonnes of fertilizer relevant to the sourcing or sales region. This requires identifying the main crop types in the sourcing region, determining the average nutrient application rates per crop type, and estimating the share of each crop in the region. Using this information, the total volume of fertilizer sold or displaced can be expressed as the equivalent hectares affected, which then determines the applicable leakage deduction tier from Table 1. This ensures the leakage risk classification is consistent across both area-based and volume-based project types.

²¹ 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.

assumed that production will need to shift to other areas, potentially resulting in more N₂O emissions due to the additional fertilizer application or land use in those areas. Such leakage may also arise when lower pasture yields increase the need of imported feed, or when reduced animal productivity per hectare results in additional animals or land area being required in other locations. Farmers are unlikely to implement and maintain a project practice that results in yield declines, since their livelihoods depend on crop harvests and/or animal output as a source of income.

Nevertheless, to ensure leakage is not occurring, the following nitrogen use efficiency (NUE) check²² must be done to prevent leakage:

The project developer must, both at a 3 year checkpoint following the project start and at the end of the crediting period:

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

- Demonstrate that the yield²³ and NUE has not declined by more than 10% in the project scenario by:
 - comparing the average within-project yield and NUE (excluding years with extreme weather events or animal disease outbreaks) to the average **historical** baseline crop yield and NUE (farmer log based approach)²⁴, **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)²⁵.
- 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 producer identifies a yield decline, thus fixing the yield issue, and preventing the leakage to happen in the first place.

²² 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.

²³ Crop yield (for cropping system), forage yield (for grassland) or animal productivity (for grazed pasture)

²⁴ 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.

²⁵ 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.

1.8.2 Permanence

The intervention focuses on the *reduction* of direct and indirect N₂O emissions. Once the nitrogen stabilizers have delayed nitrogen loss and crops have utilized the nitrogen more efficiently, the potential for nitrogen to escape as direct and indirect N₂O 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:

- a. Introduction of the use of nitrogen stabilized fertilizers on cropping systems (without making any claims on nitrogen application rate reduction)
- b. Introduction of the use of nitrogen stabilizer on managed grasslands, which can be either grazed pasture or cut-and-carry grasslands used for harvested feed production or both (see [List of definitions](#))
 - o b.i. grazed pasture: is only eligible for LMU type of projects
 - o b.ii. cut-and-carry: is treated similar to cropping systems

Optional for LMU type of projects: This methodology allows for the inclusion of other management practices in addition to the adoption of N stabilized fertilizers, 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.

2.2 GHG sources

In this methodology, the impact of the stabilized fertilizer 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/N stabilizer production emissions (cradle-to-gate emissions of fertilizers). These must be accounted for both the baseline fertilizer and the project fertilizer. The project fertilizer may refer to either a stabilized N fertilizer or a combination of a conventional fertilizer and a separately applied stabilizer.
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 ²⁶. The use of stabilized fertilizer 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. CO₂ emissions from this activity should 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 receipts, 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 (arable and grassland): The impact of both direct and indirect N₂O emissions resulting from the application of stabilized fertilizer 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 N₂O emissions must be estimated. If changes in organic fertilization (for example increased application of manure) happen as part of the intervention, which can affect the in-field emissions, then this needs to be accounted for as well. The indirect emissions must be accounted for in both the baseline and the project. That is because in certain cases the introduction of the use of nitrogen stabilizers (specifically NI) might, on the one hand decrease the direct N₂O emissions but on the other hand increase the (NH₃ volatilization) indirect emissions (Wu et al., 2021).
5. Urine deposition in grazed pasture systems (only applicable to LMU): If the intervention of the project includes grazed pastures, then the N₂O emissions arising from livestock urine deposited on the field are in scope. According to the IPCC 2019 Refinement to the 2006 Guidelines for National Greenhouse Gas Inventories, urine deposited by grazing animals represent a major source of direct and indirect soil N₂O emissions in managed fields. Nitrogen stabilizers have shown the potential to reduce N₂O emissions (direct and indirect) arising from livestock urine deposition in grazing systems (Adhikari et al., 2021; Matse et al., 2025). Both direct and indirect N₂O emissions must be estimated using either a relevant peer-reviewed study (e.g., product-specific trials, scientific studies or meta-analyses) or

²⁶ 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. As mentioned in section [1.2 Applicability of the methodology](#), “The project developer must be transparent and report on additional activities that happen along with or because of the introduction of N stabilized fertilizers, which can lead to material changes of emissions on the field”

IPCC²⁷ guidelines. N₂O emissions from livestock dung deposition are excluded from the assessment, as they are small in magnitude and are considered the same in both the baseline and intervention scenarios. While nitrification inhibitors may provide a small reduction in N₂O from dung, this effectiveness is negligible and considered out of scope.

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

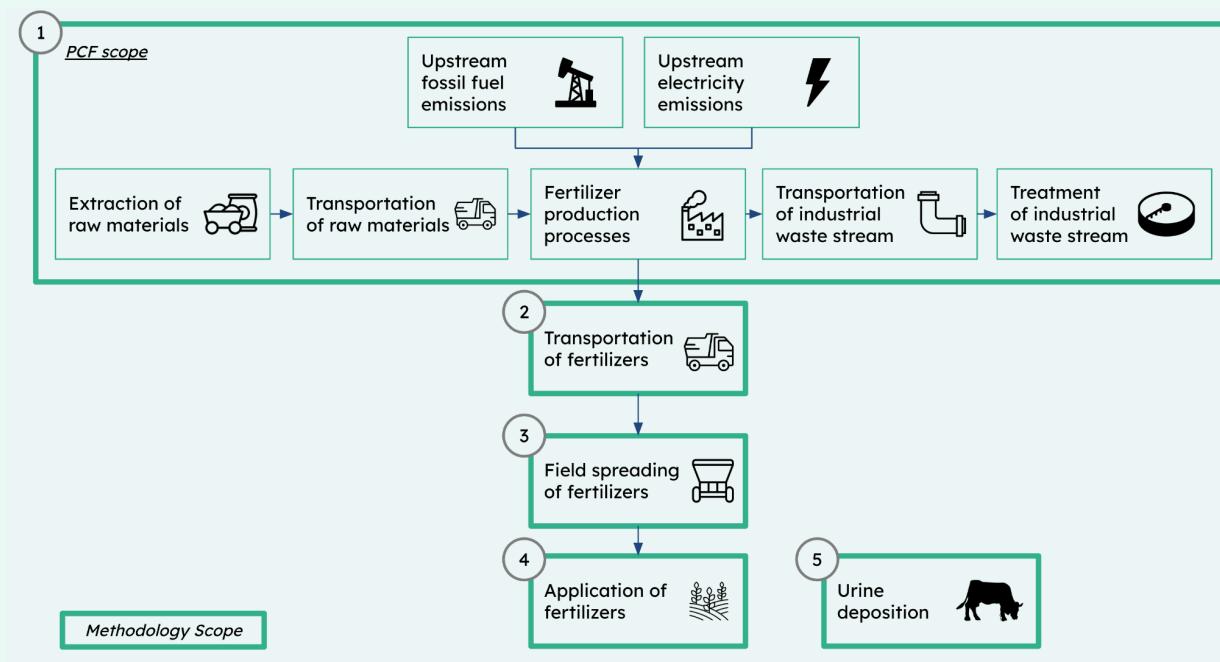


Figure 1: Activities in scope for the GHG sources calculations

While it is acknowledged that there are other GHG sources on agricultural fields, such as CO₂ emissions from soil respiration or methane (CH₄) emissions from organic matter decomposition or livestock enteric fermentation, these sources are not expected to be affected by the nitrogen stabilizers (Chen et al., 2023). 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 nitrogen stabilizers. However, methane (CH₄) emissions are only in scope for crop systems involving anaerobic conditions, such as flooded rice paddies. Project developers must assess and report CH₄ emissions in rice projects using relevant emission factors or direct measurements according to the IPCC 2019 Refinement to the 2006 Guidelines for National Greenhouse Gas Inventories protocol²⁸. For all other crop systems, CH₄ is excluded due to negligible impact.

²⁷ https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch11_Soils_N2O_CO2.pdf

²⁸ https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch05_Cropland.pdf

It is also acknowledged that the introduction of nitrogen stabilizers can influence bioecological cycles and affect microbial community dynamics, potentially leading to impacts beyond direct and indirect N₂O emissions, such as changes in soil nutrient availability and other indirect emissions. However, these negative effects are assumed to be minimal compared to the reduction in N₂O emissions. It is the responsibility of the project developer to confirm that this holds true for their specific project and to transparently report any such effects if relevant under their environmental conditions and management practices. The GHG sources that are in scope are presented in Table 2.

Table 2: GHG sources in scope

| Type | Activity/Source | GHG | Included | Justification |
|----------|---|-------------------|-------------|--|
| Baseline | (1) PCF (cradle-to-gate emissions) of the fertilizer used | CO ₂ e | Yes | Relevant to compare with the production emissions of the stabilized N fertilizer |
| | (2) Transportation of fertilizers | CO ₂ | Yes | Main emission from combustion of fuel |
| | | CH ₄ | No | Typically not material |
| | | N ₂ O | No | Typically not material |
| | (3) Field spreading of fertilizers | CO ₂ | Yes | Main emission from combustion of fuel |
| | | CH ₄ | No | Typically not material |
| | | N ₂ O | No | Typically not material |
| | (4a) Direct emissions resulting from the application of 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 ₂ O | Yes | N ₂ O is the major emitted GHG from the use of N fertilizer. |
| | (4b) Indirect emissions resulting from the application fertilizers (volatilisation, leaching) | CO ₂ | No | Out of scope |
| | | CH ₄ | No | Out of scope |
| | | N ₂ O | Yes | Volatilisation of ammonia (NH ₃) and leaching/runoff of N, mainly as NO ₃ ⁻ , which can be transformed to N ₂ O in the future |
| | (5a) Direct emissions resulting from urine deposition on grazed pastures | CO ₂ | No | Included, if the crop system involves anaerobic conditions (e.g., flooded rice). |

| Type | Activity/Source | GHG | Included | Justification |
|---------|--|-------------------|-------------|--|
| | systems | CH ₄ | No | Included, if the crop system involves anaerobic conditions (e.g., flooded rice). |
| | | N ₂ O | Yes | N ₂ O is the major emitted GHG from the use of N fertilizer. |
| | (5b) Indirect emissions resulting from urine deposition on grazed pastures systems | CO ₂ | No | Out of scope |
| | | CH ₄ | No | Out of scope |
| | | N ₂ O | Yes | Volatilisation of ammonia (NH ₃) and leaching/runoff of N, mainly as NO ₃ ⁻ , which can be transformed to N ₂ O in the future |
| Project | (1a) PCF (cradle-to-gate emissions) of the fertilizer used | CO ₂ e | Yes | Relevant to compare with the production emissions of the stabilized N fertilizer |
| | (1b) PCF (cradle-to-gate emissions) of the nitrogen stabilizer | CO ₂ e | Yes | The emissions related to the production of the stabilizer product must be accounted for |
| | (2) Transportation of stabilized fertilizers | CO ₂ | Yes | Main emission from combustion of fuel |
| | | CH ₄ | No | Typically not material |
| | | N ₂ O | No | Typically not material |
| | (3) Field spreading of stabilized fertilizers | CO ₂ | Yes | Main emission from combustion of fuel |
| | | CH ₄ | No | Typically not material |
| | | N ₂ O | No | Typically not material |
| | (4a) Direct emissions resulting from the application of fertilizers in combination with nitrogen stabilizers | 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) |

| Type | Activity/Source | GHG | Included | Justification |
|------|---|------------------|----------|--|
| | | N ₂ O | Yes | N ₂ O is the major emitted GHG from the use of N fertilizer |
| | (4b) Indirect emissions resulting from the application of fertilizers in combination with nitrogen stabilizers (volatilisation, leaching) | CO ₂ | No | Out of scope |
| | | CH ₄ | No | Out of scope |
| | | N ₂ O | Yes | Volatilisation of ammonia (NH ₃) and leaching/runoff of N, mainly as NO ₃ ⁻ , which can be transformed to N ₂ O in the future |
| | (5a) Direct emissions resulting from the application of nitrogen stabilizers on grazed pastures systems | CO ₂ | No | Included, if the crop system involves anaerobic conditions (e.g., flooded rice). |
| | | CH ₄ | No | Included, if the crop system involves anaerobic conditions (e.g., flooded rice). |
| | | N ₂ O | Yes | N ₂ O is the major emitted GHG from the use of N fertilizer. |
| | (5b) Indirect emissions resulting from the application of nitrogen stabilizers on grazed pastures systems | CO ₂ | No | Out of scope |
| | | CH ₄ | No | Out of scope |
| | | N ₂ O | Yes | Volatilisation of ammonia (NH ₃) and leaching/runoff of N, mainly as NO ₃ ⁻ , which can be transformed to N ₂ O in the future |

Effect of crop yield increase on GHG emissions:

It is possible that the yield increases, as a result of the introduction of the use of nitrogen stabilizers. 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](#))²⁹.
- 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. Local and regional regulations, as well as environmental sensitivity³⁰, must also be considered when defining these boundaries.
- 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.
- If a project includes multiple scenarios, such as different farming systems or fertilizer types, 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, farming systems, 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 must then be calculated separately for each group to maintain methodological consistency and accuracy in reporting.
- This methodology allows two possible levels of spatial boundaries as presented in Table 3.

²⁹ 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 (no stabilizer) and the project intervention (with stabilizer), per unit of nitrogen applied. This means that there is no recalculation of emissions based on 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 is feasible to measure the N uptake of the crop. In theory, the EFs already integrate the average response under specific conditions (including, in some cases, crop performance), and applying an additional yield-based adjustment would introduce double-counting or untraceable assumptions.

³⁰ Environmental sensitivity refers to the vulnerability of ecosystems or regions to environmental impacts, such as water or air pollution, soil degradation, or biodiversity loss.

Table 3: Differences between the two levels of spatial boundaries allowed under this methodology

| | <i>Land Management Unit (LMU) level</i> | <i>Sourcing Region level</i> | |
|--|---|---|--|
| <i>Definition</i> | A clearly defined area of land under consistent management, where N stabilized fertilizer application to a specific crop or grassland system type ³¹ can be directly monitored and attributed. This is similar to <i>LMU</i> as per the GHG Protocol ³² . | A geographically distinct area characterized by common environmental, climatic, and land use conditions. This is similar to the <i>Sourcing region</i> as per the GHG Protocol. | |
| <i>Data availability</i> | <ul style="list-style-type: none"> • Individual LMU level data • Average regional data from multiple fields, farmers, or cooperatives within a defined region | <ul style="list-style-type: none"> • Average regional data from multiple fields, farmers, or cooperatives within a defined region | |
| <i>EF selection options</i> | <ul style="list-style-type: none"> • For both options, the quantification of the emission reductions must be based on the guidelines presented in section 4.1 EF-data reference approaches. | | |
| <i>Baseline is defined based on</i> ³³ : | <ul style="list-style-type: none"> • Historical LMU data • Regional data • Counterfactually | <ul style="list-style-type: none"> • Regional data • Counterfactually | |
| <i>NUE check</i> ³⁴ | <ul style="list-style-type: none"> • Comparison of LMU historic NUE with regional NUE | <ul style="list-style-type: none"> • Transparency on regional NUE | |
| <i>Types of interventions allowed</i> | <i>a. Cropping system</i> | Allowed | Allowed |
| | <i>b.i. Grazed pasture</i> | Allowed | Not allowed (since field level monitoring is not possible) |
| | <i>b.ii. Cut-and-carry</i> | Allowed | Allowed |
| <i>Emission reduction quantification of additional practices on top of the usage of N stabilized fertilizers</i> | Allowed | Not allowed | |
| <i>Default deduction to the total net GHG emission reductions</i> ³⁵ | 0% | 5% | |

³¹ Grassland LMUs must be explicitly defined as either (a) grazed grassland or (b) cut-and-carry grassland

³² <https://ghgprotocol.org/land-sector-and-removals-guidance>

³³ Explanation on section [3 Baseline scenario](#)

³⁴ This is to ensure that the baseline fertilization is not excessive and avoids rewarding projects that apply nutrients beyond typical regional norms, which could otherwise inflate emission reductions linked to the improved NutUE

³⁵ In alignment with the SBTi and GHG Protocol's guidance encouraging greater transparency and traceability through field-level interventions, this methodology applies a 5% deduction to the net GHG emission reductions when the sourcing region spatial boundary is used. This deduction is intended to further incentivize the adoption of LMU type of projects.

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, livestock type (if applicable), 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.

- **Use Sourcing Region Level if:**
 - LMU 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 end of the monitoring and reporting process.

For Land Management Unit level projects:

- The boundaries follow the entire cultivation cycle of the farming system and can vary based on the timing of fertilizer application.
- The starting of the temporal boundaries is defined as the date of the first application of the fertilizer³⁶.
- The ending of the temporal boundaries is defined as the final harvest date of the target crop within the participating field³⁷.
- Grassland systems (both grazed pastures and cut-and-carry), are typically perennial and undergo multiple grazing or harvesting events per year. Therefore, the temporal boundary for grassland LMUs is defined as a fixed annual reporting period (1 year), covering all fertilizer applications, grazing events, and forage harvests occurring within that year.

³⁶ For grazed pasture systems, the starting point is defined as the date when livestock begin grazing on the pasture, since nitrogen inputs from urine deposition commence at that time and contribute to soil emission dynamics.

³⁷ Note: 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 N₂O emissions. At the same time, the stabilized N fertilizer can remain in the soil after the harvest, thus potentially reducing the emissions that would have otherwise occurred. However, this methodology relies on scientifically validated EFs for both the baseline and project intervention, which cover the same measurement timeframe. In case direct in-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.

- 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 to determine the specific timeline for each region. An example resource for this is the USDA Foreign Agricultural Service³⁸, which provides crop calendar charts for various regions, various farming systems, 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 level projects:

- The recommended period for the temporal boundaries is **one year**.
 - This temporal boundary is used because, at the sourcing region scale, fertilizer sales and corresponding N stabilizer use may span multiple farming 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, vegetables), forage harvests, and grazing activity, reflecting an accurate representation of nitrogen use and related emissions across a variety of cropping systems and management practices.
 - The recommended period is one year, but can be longer depending on the specificities of the project as explained above.

³⁸ <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 nitrogen stabilizers**.

Depending on the spatial level selected, the project developer must establish a) the baseline nitrogen application rate (N-rate) and b) the baseline fertilizer type. Guidance on how to select the corresponding approach is presented in Table 4. There are three approaches for defining the baseline: a) historical, b) counterfactual or c) regional. These different approaches are presented in Table 5. Finally, if the project is done on a LMU level, then a NUE Performance Test as presented later in this section must be conducted.

Table 4: Baseline parameter determination and nitrogen use efficiency testing by spatial level and farming system³⁹

| Spatial level | Farming system of the N stabilized fertilizer introduction intervention | Baseline N-rate | Baseline Fertilizer Type | NUE Performance test |
|-----------------|---|---------------------------|--|---|
| LMU | a. Cropping system | 1. Counterfactual | 1. Historical ⁴⁰ 2. Counterfactual ⁴¹ | ● Mandatory |
| | b.i. Grazed pasture | | | ● Not applicable |
| | b.ii. Cut-and-carry | | | ● Mandatory |
| Sourcing region | a. Cropping system | 1. Regional ⁴² | 1. Regional ⁴³ 2. Counterfactual ⁴⁴ | ● Not applicable |
| | b.ii. Cut-and-carry | | | ● Must be transparent on region's average NUE |

Description of NutUE Performance test

1. This includes comparing the LMU's historic NUE with regional benchmark NUE values⁴⁵
2. The purpose is to verify that the project's baseline practices are following the region's guidelines and are not overapplying nutrients, which might in thus inflate the potential in-field emission reductions.

³⁹ The options for defining baseline parameters are presented with a fallback hierarchy, where option 1 is the priority approach and option 2 is the secondary option if priority data are not available.

⁴⁰ **Example:** In the past the LMU used CAN 50% of the time and Urea the other 50%. The baseline would be the mix.

⁴¹ **Example:** Project fertilizer = stabilized urea, Baseline: Urea

⁴² This is relevant for projects aiming to generate emission reduction units for their own fertilizer supply shed. In this case, they need to define the crop mix and corresponding proportions as well as the average regional N-rates. These can then be claimed by companies for which their crop demand shed matches the fertilizer supply shed, and thus can make inventory-based claims. In contrast, project-based emission reduction claims do not require this crop level analysis.

⁴³ Required for inventory-based emission reduction claims (see previous footnote).

⁴⁴ If the aim is to generate project-based claims, then a counterfactual baseline can be used.

⁴⁵ If regional benchmark NUE values are not available, agronomic recommendations from a recognized scientific institution or body should be used as a reference.

- If the historical NUE was too low, and N was overapplied, then project intervention must include the reduction of N rate to be aligned with proper agricultural practices. In these cases, the baseline N rate is still defined as the project N rate. This ensures that the emission reduction is not overestimated, and that cropping systems that were overapplying are not rewarded more than they should.
3. The following data and equation must be provided and used for the calculation:
- Total fertilizer applied per hectare (kg N/ha)
 - Total yield per hectare (t/ha)
 - Equation:

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

4. 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: Different metrics of GHG emissions](#)) of the last 4 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.
5. 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
6. The NUE test must be conducted during the first validation of the project and then at least every 3 years during the project verification.

Table 5: Explanation of the different baselining approaches and their accepted data

| Approach | Baseline N-rate | Baseline Fertilizer type | Accepted data sources ⁴⁶ |
|-----------------|---|--|--|
| Historical | <ul style="list-style-type: none"> Not applicable | <ul style="list-style-type: none"> Defined based on the historical range of fertilizer products and their corresponding proportions used at the LMU level for similar agricultural practices. | <ol style="list-style-type: none"> Official farm records or verified input purchase records for the relevant LMU, covering multiple past seasons of similar agricultural practices. Insights from agronomic experts can also be taken into account to make sure the baseline is defined accurately for the specific farming system. Documented agronomic data or extension service records specific to the LMU or its immediate surroundings for similar farming system management conditions. Farmer surveys or structured interviews, supported by corroborating evidence such as receipts, cooperative sales data, or supplier records. <p>Note: Data from the last 3 growing seasons must be used.</p> |
| Regional | <ul style="list-style-type: none"> Not applicable | <ul style="list-style-type: none"> Defined based on the range of fertilizer products and their corresponding proportions that could realistically be used in the project's farming system within the sourcing region. | <ol style="list-style-type: none"> Official national statistics: Government-published agricultural, trade, and production datasets (e.g., USDA, Eurostat, national statistical offices). International organization databases: FAOSTAT, World Bank, OECD, UN Comtrade. Recognized industry association reports: International Fertilizer Association (IFA), The Fertilizer Institute, Fertilizers Europe, and other (regional) bodies. Peer-reviewed literature: Studies providing robust, transparent, and recent regional market data. Certified third-party market research: Subscription-based or commercial datasets from reputable providers (e.g., CRU, Argus, ICIS). If historic farmer log data are available, then these can be used to support the market analysis. Other credible public sources: NGO reports, open-access market surveys, or expert-verified datasets, with clear documentation of methodology and limitations. <p>Note: The most recent regional data must be prioritized.</p> |
| Counter-factual | <ul style="list-style-type: none"> Defined based on the project's fertilizer N-rate. | <ul style="list-style-type: none"> Defined based on the project's fertilizer type. | <ol style="list-style-type: none"> Project-level data proving the fertilizer type or N-rate (see section 6. Monitoring, Reporting and Verification) |

⁴⁶ The accepted sources options are presented with a fallback hierarchy (descending priority).

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 CO₂e for each verification period.

The total (baseline or project) emissions can be calculated as the sum of the subsequent activities. If only one intervention takes place in the project, then:

$$E = \sum_{a=i}^v E_a \quad (2a)$$

If multiple interventions take place in the project, then:

$$E = \sum_x \sum_{a=i}^v E_{a,x} \quad (2b)$$

Where:

E = Total (baseline or project) GHG emissions (tCO₂e)

$E_{a,x}$ = Emissions of activity a for the intervention x (tCO₂e).

The approaches for quantifying baseline and project emission are listed in Table 6. 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 follow the guidelines presented in section [4.1 EF-data reference approaches](#).

Table 6: Summary of equations used to calculate the total emissions and approaches to retrieve the EF

| Activity & equation | Approach 1: Product Carbon Footprint | Approach 2: In-field EF Decision Tree | Approach 3: Other EFs from literature |
|--|---|--|--|
| <u>(1a) Fertilizer cradle-to-gate emissions</u> $E_{1a} = EF_{in} \cdot F_{in} \cdot A$ | X | | |
| <u>(1b) Stabilizer cradle-to-gate emissions</u> $E_{1b} = EF_{st} \cdot F_{st} \cdot A$ | X | | |
| <u>(2) Transportation of fertilizers</u> $E_2 = \sum_c \sum_x (EF_m \cdot Q_{x,c,m} \cdot D_{x,c,m})$ | | | X |
| <u>(3) Field spreading of fertilizer products</u> $E_3 = \sum_{cf} \sum_{mf} (EF_{mf} \cdot D_{cf,mf} \cdot N_f)$ | | | X |
| <u>(4a) Direct N₂O emissions from fertilizer application</u> $E_{4a} = [(F_{in} \cdot EF_{in,direct,N2O}) + (F_{org} \cdot EF_{org,direct,N2O})] \cdot 44/28 \cdot A \cdot GWP_{N2O}$ | | X | |
| <u>(4b) Indirect ammonia volatilization from fertilizer application</u> $E_{4b} = [(F_{in} \cdot NH_3 \text{ volatilized}_{in} \cdot EF_{in,indirect,NH3}) + (F_{org} \cdot NH_3 \text{ volatilized}_{org} \cdot EF_{org,indirect,NH3})] \cdot 44/28 \cdot A \cdot GWP_{N2O}$ | | X | |
| <u>(4c) Indirect leaching and runoff of N from fertilizer application</u> $E_{4c} = [(F_{in} \cdot EF_{in,indirect,l} \cdot N \text{ leaching}_{in}) + (F_{org} \cdot EF_{org,indirect,l} \cdot N \text{ leaching}_{org})] \cdot 44/28 \cdot A \cdot GWP_{N2O}$ | | X | |
| <u>(5a) Direct N₂O emissions from urine deposition</u> $E_{5a} = (Ur \cdot EF_{ur,direct,N2O}) \cdot 44/28 \cdot A \cdot GWP_{N2O}$ | | X | |
| <u>(5b) Indirect ammonia volatilization from urine deposition</u> $E_{5b} = (Ur \cdot NH_3 \text{ volatilized}_{ur}) \cdot EF_{ur,indirect,NH3} \cdot 44/28 \cdot A \cdot GWP_{N2O}$ | | X | |
| <u>(5c) Indirect leaching and runoff of N from urine deposition</u> $E_{5c} = (Ur \cdot EF_{ur,indirect,l} \cdot N \text{ leaching}_{in}) \cdot 44/28 \cdot A \cdot GWP_{N2O}$ | | X | |

4.1 EF-data reference approaches

This section explains how a project developer can select emission factors for each activity in scope.

Approach 1: Product Carbon Footprint

For each fertilizer and N stabilizer used in the project, the project developer must select the corresponding Product Carbon Footprint (PCF). This sub-section sets out the evidence requirements for determining the PCF of fertilizers used in both the baseline and project scenarios. It defines acceptable evidence sources, methodological requirements, and reporting obligations to ensure that PCF values are reliable, comparable, and transparently documented. The requirements are presented in table 7 below.

Table 7: Evidence requirements for fertilizer PCFs

| Evidence type | Requirements |
|---------------|--|
| Source | <ul style="list-style-type: none"> ● The evidence for the PCF of the fertilizers (baseline or project) must be sourced from one of the following sources in descending priority, depending on availability of data ⁴⁷: <ul style="list-style-type: none"> ○ fertilizer/N stabilizer producers through verified Environmental Product Declarations (EPDs), PCFs, LCAs or sustainability reports, ○ widely accepted industry tools and platforms, such as CoolFarmTool, ecoinvent, Agri-footprint database, IFASTAT, Carbon Footprint Calculator for Fertilizer Products⁴⁸ ○ Tier 1-2 industry reports, such as the one published by the International Fertilizer Society titled “<i>The carbon footprint of fertilizer production: regional reference values</i>” ⁴⁹ or, ○ Relevant scientific literature ○ Non-validated individual PCF data directly provided by fertilizer/N stabilizer suppliers. If only non-validated individual PCF values are available, their use is allowable under the following conditions: <ul style="list-style-type: none"> ■ a) The PCF must be cross-verified against at least one value from higher-tier sources (preferably for a comparable fertilizer type and manufacturing context). Significant deviations must be explained and justified. |

⁴⁷ The selection must be justified in the POD by the project developer

⁴⁸ https://app.calcfert.com/login/?redirect_to=https%3A%2F%2Fapp.calcfert.com%2F

⁴⁹

https://www.fertilizerseurope.com/wp-content/uploads/2020/01/The-carbon-footprint-of-fertilizer-production_Regional-reference-values.pdf

| Evidence type | Requirements |
|---------------------------------------|--|
| | <ul style="list-style-type: none"> ■ b) The underlying methodology must be aligned with ISO 14067, ISO 14040/44 or the GHG Protocol Product Standard ■ c) The lack of third-party verification must be clearly disclosed |
| <i>Method</i> | <ul style="list-style-type: none"> ● The project developer must clearly present the calculation method used for determining the product carbon footprint (PCF) of fertilizers. Accepted methods include: <ul style="list-style-type: none"> ○ a) ISO 14067 (Carbon footprint of products), ○ b) ISO 14040/14044 (Life cycle assessment principles and requirements), ○ c) the GHG Protocol Product Standard. |
| <i>Accreditation body</i> | <ul style="list-style-type: none"> ● The body that conducted the calculation of the PCF must be disclosed. |
| <i>Year of accreditation</i> | <ul style="list-style-type: none"> ● The year that the accreditation of the PCF was done must be disclosed. ● This should be preferably less than 10 years old. ● Project developers must report any changes in fertilizer formulations or suppliers that affect emission factors through the monitoring framework (section 6 Monitoring, Reporting and Verification) and must be transparently reported and justified in the verification report. |
| <i>Baseline and project alignment</i> | <ul style="list-style-type: none"> ● The same data source and methodological standard must be prioritized for both baseline and project PCFs to ensure comparability. ● If different sources or methods are used, these must be explicitly disclosed, with a clear explanation of methodological differences and their potential impact on the results. Specifically in this case, project developers must: <ul style="list-style-type: none"> ○ Explain methodological differences: Describe any differences in system boundaries, functional units, and allocation rules between the standards. ○ Identify EF differences: Specify where and how the emission factor values differ as a result of these methodological variations. ○ Apply a conservative approach: Where uncertainties or discrepancies exist between standards, use a conservative estimation method to ensure the integrity of the results. |
| <i>Uncertainty reporting</i> | <ul style="list-style-type: none"> ● The reported measure of uncertainty must be disclosed (e.g. standard deviation, confidence interval, or similar) |
| <i>Relevance to the project</i> | <ul style="list-style-type: none"> ● The relevance of the selected PCF must be justified. ● This must be cross checked with the actual fertilizer product used in the project (based on the documentation supplied in the MRV). |

Approach 2: In-field EF Decision Tree

For the selection of the baseline and project in-field emission factors (direct and indirect) the hierarchy tree presented in *Figure 2* must be used.

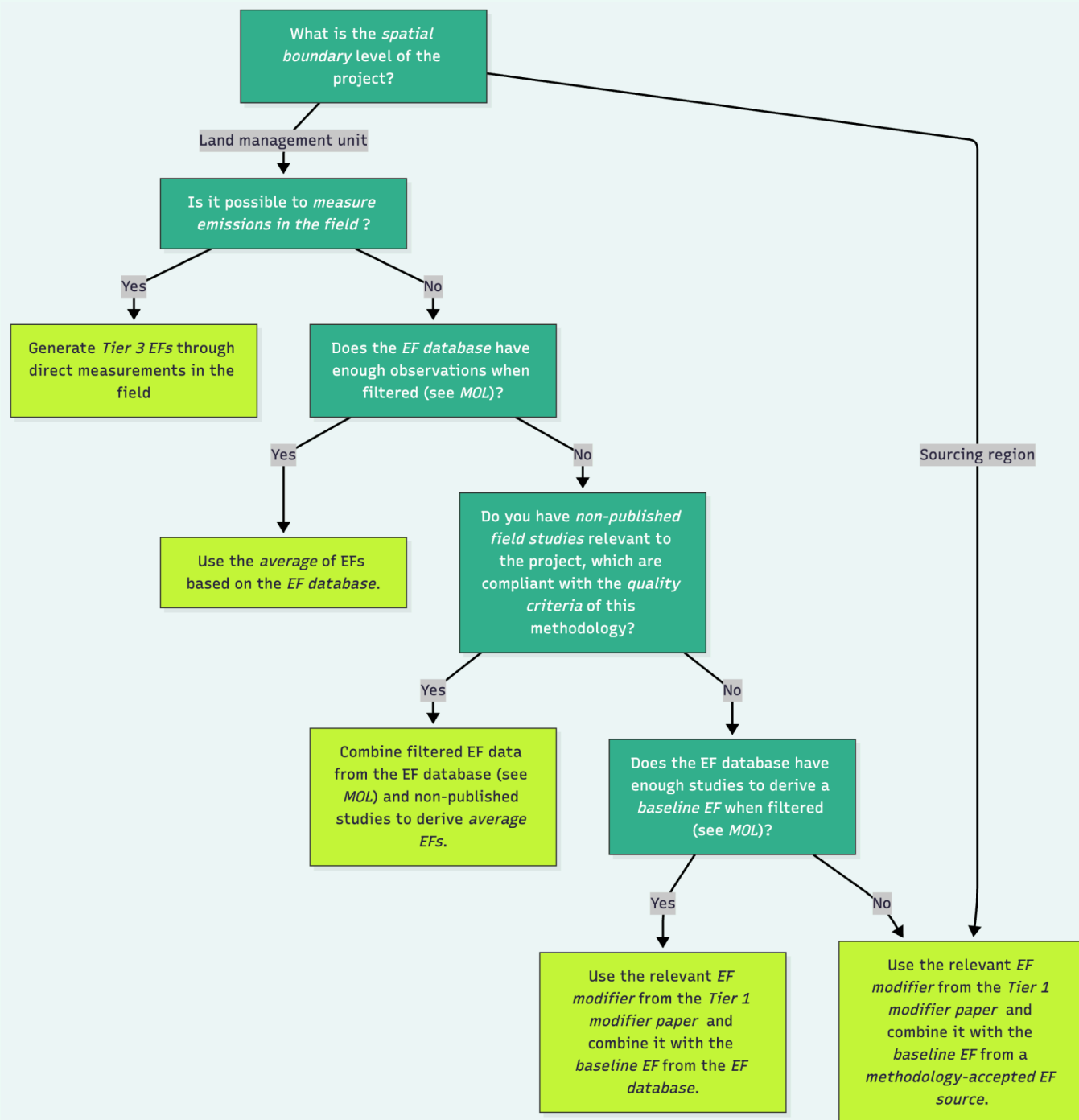


Figure 2 : Decision tree for the selection of in-field emission factors. Note that explanation regarding the various terms is presented in Table 8.

Table 8: Explanation of the various terms presented in the hierarchy tree (see Figure 2) for the selection of in-field EFs

| Term presented in Figure 2 | Explanation and comments |
|---------------------------------------|---|
| <i>Average EF</i> | <ul style="list-style-type: none"> When aggregating the results from multiple observations of studies an average emission factor must be derived, along with the corresponding uncertainty. An example of how the uncertainty can be propagated is presented in Appendix B: Uncertainty factor calculation. Both the baseline and project EF must be calculated from the EF database for LMU-type projects, when there are enough datapoints (see MOL). |
| <i>Baseline EF</i> | <ul style="list-style-type: none"> The EF database is the primary source for deriving the baseline EF under this methodology. When filtering results in the EF database for baseline data, the N stabilizer type should de facto not be selected and any results relevant to N stabilizers should be excluded. When there are not enough datapoints in the EF database, then other methodology-accepted sources can be used to derive the baseline EF. |
| <i>EF database</i> | <ul style="list-style-type: none"> For the quantification of in-field emissions (direct and indirect N₂O emissions), EFs originating from the <i>IFA Enhanced Efficiency Fertilizer Emission Factor Database</i> can be used⁵⁰. The database consolidates global data related to fertilizer emissions and the effectiveness of nitrogen stabilizers. This database provides EFs derived from studies that align with current agricultural practices and environmental conditions. It offers validated EFs for a variety of scenarios, ensuring consistency and accuracy in GHG quantification while minimizing uncertainties. The database is developed through a structured, transparent procedure, which can be found in the webpage. The procedure includes the selection of relevant scientific studies based on predefined quality criteria (see Appendix A.2 Quality criteria of experimental design of studies), ensuring that only high-quality, peer-reviewed studies are considered. Project developers can suggest studies, which fit the quality criteria, to be included in the database. |
| <i>EF modifier</i> | <ul style="list-style-type: none"> An EF modifier allows the quantification of percentile change of a baseline EF. In other words, these modifiers can be applied to average EFs from multiple studies or existing baseline Tier 1 EFs, which are the default factors used in GHG inventories and project-level accounting. |
| <i>Measure emissions in the field</i> | <ul style="list-style-type: none"> 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 gas chambers), which provide actual data that reflect field conditions. The measurement methods must be conducted by qualified personnel and the process must comply with the quality criteria presented in the Appendix A.2 Quality criteria of experimental design of studies. |

⁵⁰ The *IFA Emission Factor Database for Nitrogen Stabilizers* is currently available at <https://fertilizerdatabase.com/>

| Term presented in Figure 2 | Explanation and comments |
|--|---|
| | <ul style="list-style-type: none"> ● In addition, to ensure that field measurements are conducted rigorously and provide data that meet high quality standards, alignment with the guidelines from the following studies is recommended: <ul style="list-style-type: none"> ● Hutchings et al. (2024) Preconditions for Including the Effects of Urease and Nitrification Inhibitors in Emission Inventories, ● Lyons et al., (2024b) Field Trial Guidelines for Evaluating Enhanced Efficiency Fertilizers. |
| <i>Methodology - accepted EF sources</i> | <ul style="list-style-type: none"> ● For the quantification of GHG emissions (direct and indirect N₂O emissions), EFs originating from available scientific literature (individual studies, meta analyses), GHG or national EF inventories can be used. Many countries maintain national GHG emission factor inventories to support environmental reporting and policy. For example, the Netherlands provides detailed, annually updated emission data and country-specific emission factors through its Emission Registration system, available at: www.emissieregistratie.nl ● Utilization of meta-analyses papers, GHG or national EF inventories: These sources 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 (I²) among studies. If I² 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., I² > 75% or clear visual spread), an uncertainty buffer of 10% must be applied unless justified via subgroup analysis. Project developers may use data from these sources and use emission factors or emission reduction percentages, provided that a clear and well-documented selection process is followed. For example, 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 section 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 (see appendix A.3 Utilization of meta-analyses papers). |
| <i>MOL</i> | <ul style="list-style-type: none"> ● MOL is defined as the minimum observation limit when filtering the EF database ● 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. To achieve that the following rule must be followed when filtering in the EF database: <ul style="list-style-type: none"> ○ When filtering for “fertilizer” AND “N stabilizer” AND “Crop” AND “Köppen classification” AND “Soil texture” the observations from just one study can be used (if more are available, then these can be used by averaging their results). Note that by fertilizer and N stabilizer we refer to the molecules (e.g. urea, CAN, DCD, DMPP). ○ If there are no studies when filtering the above, then either or both of the following groupings can be made: a) fertilizer groups, or b) N stabilizer groups. In this case: <ul style="list-style-type: none"> ■ The minimum allowed observations are five |

| Term presented in Figure 2 | Explanation and comments | | | | | | | | | | | | | | | | | | | | | | | |
|--|--|------------|-------------|----------------------------------|--|-----|-----|--|---------------|------------|------------|---------------|------------|------------|---------------|------------|-------------|--|--------------------|------------|------------|--------------------|------------|-------------|
| | <ul style="list-style-type: none"> ■ The N stabilizer groups include: NI, UI and NIUI ■ The fertilizer groups include: <table border="1" data-bbox="680 326 1598 591" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th rowspan="2"></th> <th rowspan="2">Group name</th> <th colspan="2">Content of respective N form (%)</th> </tr> <tr> <th>Min</th> <th>Max</th> </tr> </thead> <tbody> <tr> <td rowspan="3">Groups for NI (Urea + Ammonium content)</td> <td>A (NI)</td> <td>50%</td> <td>70%</td> </tr> <tr> <td>B (NI)</td> <td>70%</td> <td>90%</td> </tr> <tr> <td>C (NI)</td> <td>90%</td> <td>100%</td> </tr> <tr> <td rowspan="2">Groups for UI / UINI (Urea content)</td> <td>A (UI/UINI)</td> <td>50%</td> <td>75%</td> </tr> <tr> <td>B (UI/UINI)</td> <td>75%</td> <td>100%</td> </tr> </tbody> </table> <ul style="list-style-type: none"> ● When filtering for baseline EF, the same apply with the exclusion of the “N stabilizer” filtering requirement | | Group name | Content of respective N form (%) | | Min | Max | Groups for NI (Urea + Ammonium content) | A (NI) | 50% | 70% | B (NI) | 70% | 90% | C (NI) | 90% | 100% | Groups for UI / UINI (Urea content) | A (UI/UINI) | 50% | 75% | B (UI/UINI) | 75% | 100% |
| | Group name | | | Content of respective N form (%) | | | | | | | | | | | | | | | | | | | | |
| | | Min | Max | | | | | | | | | | | | | | | | | | | | | |
| Groups for NI (Urea + Ammonium content) | A (NI) | 50% | 70% | | | | | | | | | | | | | | | | | | | | | |
| | B (NI) | 70% | 90% | | | | | | | | | | | | | | | | | | | | | |
| | C (NI) | 90% | 100% | | | | | | | | | | | | | | | | | | | | | |
| Groups for UI / UINI (Urea content) | A (UI/UINI) | 50% | 75% | | | | | | | | | | | | | | | | | | | | | |
| | B (UI/UINI) | 75% | 100% | | | | | | | | | | | | | | | | | | | | | |
| <i>Non-published field studies</i> | <ul style="list-style-type: none"> ● For EF sourced from non-published studies, their use is allowable under the following conditions: <ul style="list-style-type: none"> ○ a) The study must be third party verified, and the verification body must be disclosed. ○ b) The EF (reduction) must be cross-checked against published sources, for a comparable N stabilizer. Significant deviations must be explained and justified. ○ b) The underlying methodology of the study must be aligned with the quality criteria presented in this methodology. | | | | | | | | | | | | | | | | | | | | | | | |
| <i>Quality criteria</i> | <ul style="list-style-type: none"> ● Tier 2 emission factors must meet specific quality criteria to be considered valid and applicable for use by project developers in this GHG methodology. ● The quality criteria are presented in the appendix A.2 Quality criteria of experimental design of studies. ● These criteria ensure that the EFs or emission reduction percentages reflect the characteristics of the project and are derived from scientific studies of high experimental quality standards. | | | | | | | | | | | | | | | | | | | | | | | |
| <i>Spatial boundary</i> | <ul style="list-style-type: none"> ● See section 2.3 Spatial boundaries. | | | | | | | | | | | | | | | | | | | | | | | |
| <i>Tier 1 EF modifier paper</i> | <ul style="list-style-type: none"> ● An synthesis article for developing Tier 1 emission factor modifiers for nitrogen stabilized fertilizers using global meta-analysis data has been written. ● The method and results of the analysis can be shared upon request. | | | | | | | | | | | | | | | | | | | | | | | |
| <i>Tier 3 EFs</i> | <ul style="list-style-type: none"> ● See appendix A.1 Tier definitions | | | | | | | | | | | | | | | | | | | | | | | |

Approach 3: Other emission factors from literature

When transportation or field spreading of fertilizers is included in the intervention, an appropriate emission factor must be applied. The same requirements outlined under *Approach 1: Product Carbon Footprint* also apply here.

4.2 Equations of each activity

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.

(1a) Fertilizer cradle-to-gate emissions

$$E_{1a} = EF_{SN} \cdot F_{in} \cdot A \quad (3)$$

Where:

| | | |
|-----------|---|--|
| E_{1a} | = | Fertilizer cradle-to-gate emissions (kg CO ₂ eq) |
| F_{in} | = | Quantity of fertilizer applied (kg fertilizer / ha) |
| EF_{IN} | = | Emission factor for the cradle-to-gate of the fertilizer (kg CO ₂ eq / kg fertilizer) |
| A | = | Area of the intervention (ha) |

(1b) Nitrogen stabilizer cradle-to-gate emissions

$$E_{1b} = F_{ST} \cdot EF_{ST} \cdot A \quad (4)$$

Where:

| | | |
|----------|---|--|
| E_{1b} | = | Nitrogen stabilizer cradle-to-gate emissions (kg CO ₂ eq) |
| F_{ST} | = | Quantity of nitrogen stabilizer applied |

- For stabilized N fertilizers = (kg stabilizer / kg fertilizer) × (total fertilizer applied per ha)
- For nitrogen stabilizer mixtures (which are applied separately) = (kg stabilizer / ha)

EF_{ST} = Emission factor for the cradle-to-gate of the nitrogen stabilizer (kg CO₂eq / kg stabilizer)

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 (tCO₂eq)

EF_m = Emission factor of the mode of transportation m (tCO₂eq/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 ($D_{cf,mf}$), and the number of times the fertilizer is spread per the defined temporal boundaries (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 (tCO₂eq)
- EF_{mf} = Emission factor of the vehicle type or application machinery m (tCO₂eq/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 defined temporal boundaries

(4a) Direct N₂O emissions (from fertilizer application)

This approach is based on equations provided by the IPCC⁵¹.

$$E_{4a} = [(F_{in} \cdot EF_{in,direct_N2O}) + (F_{org} \cdot EF_{org,direct_N2O})] \cdot 44/28 \cdot A \cdot GWP_{N_2O} \quad (7a)$$

Where:

- E_{4a} = Direct GHG emissions from managed soils due to fertilizer application (kg CO₂eq)
- 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 N₂O emissions from N inputs from inorganic fertilizer (kg N₂O-N / kg N input)
- $EF_{org,direct_N2O}$ = Emission factor for N₂O emissions from N inputs from organic fertilizer (kg N₂O-N / kg N input)
- 44/28 = Molar mass ratio of N₂O to N applied to convert N₂O-N emissions to N₂O emissions.
[It should be applied only when the unit of the reported EF is in kg N₂O-N, rather than kg N₂O]

⁵¹ https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch11_Soils_N2O_CO2.pdf

- A = Area of the intervention (ha)⁵²
- GWP_{N_2O} = Global warming potential of nitrous oxide (kg CO₂e / kg N₂O)
[Based on IPCC AR6, the 100-year GWP for N₂O is 273]

If cumulative emissions are available, then the equation can be adjusted. The same logic can be applied to the equations of the other activities.

$$E_{4a} = EF_{direct_N2O_c} \cdot A \cdot GWP_{N_2O} \quad (7b)$$

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 N₂O emissions for the monitoring period (kg N₂O/ha)

(4b) Indirect emissions originated from ammonia volatilization (from fertilizer application)

$$E_{4b} = [(F_{in} \cdot EF_{in,indirect_NH3} \cdot NH_3 \text{ volatilized}_{in}) + (F_{org} \cdot EF_{org,indirect_NH3} \cdot NH_3 \text{ volatilized}_{org})] \cdot 44/28 \cdot A \cdot GWP_{N_2O} \quad (8)$$

Where:

- E_{4b} = Indirect volatilized NH₃ GHG emissions from managed soils due to fertilizer application (kg CO₂eq)
- 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 N₂O emissions from volatilized NH₃ originating from inorganic fertilizer (kg N₂O-N / kg NH₃-N volatilized)
- $EF_{org,indirect_NH3}$ = Emission factor for N₂O emissions from volatilized NH₃ originating from organic fertilizer (kg N₂O-N / kg NH₃-N volatilized)

⁵² In case a Sourcing Region level approach is used, the emissions are calculated based on the total amount of stabilized N fertilizer distributed. As such the area of the intervention is not relevant.

| | |
|----------------------------------|---|
| $NH_3 \text{ volatilized}_{in}$ | = Fraction of inorganic N fertilizer that volatilises as NH_3 (kg NH_3 -N volatilized) |
| $NH_3 \text{ volatilized}_{org}$ | = 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 (from fertilizer application)

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

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

Where:

| | |
|-------------------------|---|
| E_{4c} | = Indirect N leaching/runoff GHG 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] |
| $EF_{in, indirect_l}$ | = 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 ₂ O to N applied to convert N ₂ O-N emissions to N ₂ O emissions [It should be applied only when the unit of the reported EF is in kg N ₂ O-N, rather than kg N ₂ O] |
| A | = Area of the intervention (ha) |
| GWP_{N_2O} | = Global warming potential of nitrous oxide (kg CO ₂ e / kg N ₂ O) [Based on IPCC AR6, the 100-year GWP for N ₂ O is 273] |

(5a) Direct N₂O emissions from urine deposition on grazed pastures

This approach is based on equations provided by the IPCC⁵⁵. First, equation 10 must be used to calculate the amount of nitrogen included in the deposited urine on grazed pastures based on the grazing animal's total population.

$$Ur = \sum_T [(N_T \cdot EX_T) \cdot L_T] \quad (10)$$

Where:

| | |
|--------|--|
| Ur | = Total amount of nitrogen that is deposited via urine on grazed pasture by grazing livestock (kg N/ha) |
| T | = Livestock species/category that are grazing on the grazed pasture |
| N_T | = Number of population of livestock species/category T on the grazed pasture (number of head/ha) |
| EX_T | = Average amount of urine per head of species/category T that is deposited on the grazed pasture (kg urine/per head) |
| L_T | = Fraction of total nitrogen in urine for each livestock species/category T that is deposited on the grazed pasture (kg N/liters of urine) |

⁵⁵ https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch11_Soils_N2O_CO2.pdf

The following equations (11, 12, 13) must be used to calculate direct and indirect N₂O emissions that originate from urine deposition on grazed pastures

$$E_{5a} = (Ur \cdot EF_{ur,direct_N2O}) \cdot 44/28 \cdot A \cdot GWP_{N2O} \quad (11)$$

Where:

| | | |
|-----------------------|---|---|
| E_{5a} | = | Direct GHG emissions from grazed pastures due to urine deposition (kg CO ₂ eq) |
| Ur | = | Total amount of nitrogen that is deposited via urine on grazed pasture by grazing livestock (kg N/ha) |
| $EF_{ur,direct_N2O}$ | = | Emission factor for direct N ₂ O emissions from N inputs from urine deposition (kg N ₂ O-N / kg N input) |
| 44/28 | = | Molar mass ratio of N ₂ O to N applied to convert N ₂ O-N emissions to N ₂ O emissions. [It should be applied only when the unit of the reported EF is in kg N ₂ O-N, rather than kg N ₂ O] |
| A | = | Area of the intervention (ha) ⁵⁴ |
| GWP_{N2O} | = | Global warming potential of nitrous oxide (kg CO ₂ e / kg N ₂ O) [Based on IPCC AR6, the 100-year GWP for N ₂ O is 273] |

(5b) Indirect emissions originated from ammonia volatilization (from urine deposition)

$$E_{5b} = (Ur \cdot NH_3 \text{ volatilized}_{ur}) \cdot EF_{ur,indirect_NH3} \cdot 44/28 \cdot A \cdot GWP_{N2O} \quad (12)$$

Where:

| | | |
|-------------------------|---|---|
| E_{5b} | = | Indirect volatilized NH ₃ GHG emissions from grazed pastures due to urine deposition (kg CO ₂ eq) |
| Ur | = | Total amount of nitrogen that is deposited via urine on grazed pasture by grazing livestock (kg N/ha) |
| $EF_{ur,indirect_NH3}$ | = | Emission factor for N ₂ O emissions from volatilized NH ₃ originating from urine deposition (kg N ₂ O-N / kg NH ₃ -N volatilized) |

⁵⁴ In case a Sourcing Region level approach is used, the emissions are calculated based on the total amount of stabilized N fertilizer distributed. As such the area of the intervention is not relevant.

| | |
|---------------------------------|---|
| $NH_3 \text{ volatilized}_{ur}$ | = Fraction of the N from the deposited urine 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] |

(5c) Indirect emissions originated from leaching and runoff of N (from urine deposition)

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

$$E_{5c} = (Ur \cdot NH_3 \text{ volatilized}_{ur}) \cdot EF_{ur,indirect_v} \cdot 44/28 \cdot A \cdot GWP_{N_2O} \quad (13)$$

Where:

| | |
|---------------------------|---|
| E_{5c} | = Indirect volatilized NH_3 GHG emissions from grazed pastures due to urine deposition (kg CO_2eq) |
| Ur | = Total amount of urine N deposited on grazed pasture by grazing livestock (kg N/ha) |
| $EF_{ur,indirect_l}$ | = Emission factor for N_2O emissions from N leaching/runoff originating from urine deposition (kg N_2O -N / kg NH_3 -N volatilized) |
| $N \text{ leaching}_{ur}$ | = Fraction of the N from the deposited urine 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 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, 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, in cases where project-specific measurements are not feasible:

- Conservative parameter selection: Project developers must select values from the conservative end of available ranges. While not necessarily the lowest value, selections should lean towards the lower half of the range to avoid overestimating emission reductions.
- Meta-analysis and GHG inventories based factors: When using these sources 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 characteristics (if available), to ensure the selected EF (from the EF ranges) is both conservative and grounded in the most relevant evidence. Details are presented in the appendix [A.3 Utilization of meta-analyses paper](#).
- 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.

5 Net reduction of GHG emissions

The project developer can *estimate* the GHG emissions reduction 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. In other words, 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 fertilizer, selected stabilizer, 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:

$$ER = (BE - PE) \cdot (1 - LP) \cdot (1 - UP) \quad (14)$$

Where:

| | | |
|-----------|---|---|
| <i>ER</i> | = | Net GHG emissions reduction (tCO ₂ e) |
| <i>BE</i> | = | Baseline emissions (tCO ₂ e) |
| <i>PE</i> | = | Project emissions (tCO ₂ e) |
| <i>LP</i> | = | Leakage penalty (%). If leakage is reversible, the credited emissions can be adjusted retroactively or the corresponding amount can be released from the buffer pool. |
| <i>UP</i> | = | 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 CO₂e. 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 nitrogen stabilizers (alongside organic or inorganic fertilizers) or stabilized N fertilizers. 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 Project Developers must follow the monitoring, reporting and verification (MRV) procedures of the latest version of the Proba Standard.

The MRV 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 9*).
- B. **Project design parameters:** Variables monitored and reported during each verification cycle to ensure compliance and accuracy (see *Table 10*). Those must be completed for each specific intervention that is outlined in the project scoping. As seen in *Table 10*, 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. All monitored parameters for each monitoring period must be listed in the following standardized format: a) Data / parameter: , b) Data unit: , c) Description: , d) Source of data: , e) Measurement procedures (if any): , f) Monitoring frequency: , g) QA/QC procedures: , h) Any comment:
- 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 9: Project scoping

| <i>Index</i> | <i>Name</i> | <i>Description</i> | <i>Background from this methodology</i> | <i>Evidence required</i> | <i>Frequency of reporting</i> |
|--------------|---|--|---|--------------------------------|---|
| A1 | Scope of activities | Present list of interventions that are in scope of the project, on 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: <ul style="list-style-type: none"> • locations of the field (for Land Management Unit level boundary) • boundaries of the region (for Sourcing Region level boundary) | Section 2.3 | Satellite imagery, coordinates | |
| A4 | Temporal boundary (for monitoring) | Define the temporary boundary for the project | Section 2.4 | N/A | |

Table 10: Project design parameters for Land Management Unit level intervention

| Index | Category name | Subcategory name | Description | Evidence required for baseline | Evidence required for project | Frequency of reporting |
|-------|---------------------|---------------------------|--|---|---|---|
| B1.1 | Farming system type | - | Type of farming system: <ul style="list-style-type: none"> • arable crop • grazed pasture • cut-and-carry grassland | Farmer log or market based information | Farmer log | Reconfirmed or updated for every verification |
| B1.2 | Fertilizer | Fertilizer PCF | Cradle-to-gate emissions | <ul style="list-style-type: none"> • Third party verified manufacturer's PCF report • Credible database e.g. National/regional PCF datasets | <ul style="list-style-type: none"> • Third party verified manufacturer's PCF report • Credible database e.g. National/regional PCF datasets | |
| | | Type | Type of fertilizer being applied | Farmer log or market based information | Proof of purchase and product label | |
| | | N rate | Nitrogen rate in each fertilizer, % total N, %urea-N, % ammonium-N | Farmer log or market based information | Fertilizer product description (f.i. label or safety data sheet) | |
| | | Application rate & method | Application rate of the fertilizer & method, timing, splitting | Farmer log or market based information | Farmer logs related to days of application | |
| B1.3 | Nitrogen stabilizer | Nitrogen stabilizer PCF | Cradle-to-gate emissions | - | <ul style="list-style-type: none"> • Third party verified manufacturer's PCF report • Credible database e.g. National/regional PCF datasets | |
| | | Type | Type of nitrogen stabilizer being applied | - | Proof of purchase (or sale from the distributor), product label & regulatory eligibility | |

| Index | Category name | Subcategory name | Description | Evidence required for baseline | Evidence required for project | Frequency of reporting |
|-------|---------------|---------------------------|---|--|---|---|
| | | Application rate & method | Application rate of the nitrogen stabilizer & method, timing, splitting | - | <ul style="list-style-type: none"> For <u>stabilized N fertilizer</u>: fertilizer application rate based on, product label and farmer logs For <u>stabilizer/fertilizer mixtures</u>: the product label, instructions/ recommendation from the manufacturer and farmer log For <u>compound fertilizers</u> containing both stabilized and non-stabilized N components (e.g., bulk blends), project developers must report the application rate specific to the stabilized fraction, using manufacturer documentation, product composition data, and field-level application records. | |
| B1.4 | Yield | - | <p>For croplands:</p> <ul style="list-style-type: none"> amount of crops harvested <p>For grasslands:</p> <ul style="list-style-type: none"> cut-and-carry: harvested forage yield (kg DM/ha) grazed pasture: forage yield estimates and number of livestock units (N_r) | Farmer log or market based information | Proof of yield (e.g., Crop insurance reporting records) | Reconfirmed or updated for every verification |

| Index | Category name | Subcategory name | Description | Evidence required for baseline | Evidence required for project | Frequency of reporting |
|-------|---------------------------|---|---|---|---|------------------------|
| B1.5 | NUE | Project NUE | Nitrogen use efficiency, which must be compared to historical or regional benchmark NUE values to verify that the baseline practices are following the region's guidelines. | Farmer log | Calculated based on the metrics presented in Appendix D | |
| | | Regional or historical NUE | Regional or historical NUE | Regional database (or similar) or farmer logs (for the historical NUE). | - | |
| B1.6 | Transportation emissions | Distance | Average distance between the production location and the use location of the fertilizer | Data from distributor | Data from distributor | |
| | | Vehicle type | Type of vehicle(s) used to transport the fertilizer | Data from distributor, industry reports | Data from distributor, industry reports | |
| B1.7 | 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 | |

| Index | Category name | Subcategory name | Description | Evidence required for baseline | Evidence required for project | Frequency of reporting |
|-------|---|---|---|--|--|------------------------|
| B1.8 | (Optional) Additional management practices | - | Optional only if additional management practices are implemented, along with the nitrogen stabilizer introduction, which lead to an extra reduction of GHG emissions. | - | <ul style="list-style-type: none"> 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) | |
| B1.9 | (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 | |
| B1.10 | 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) | | |
| B1.11 | Grazing livestock & productivity (grazed pastures only) | - | Number of livestock units (NT) | Counterfactual approach | Grazing management plans, livestock logs, herd records | |

Table 11: 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 | Farming system | - | The types of farming systems in the region, allowing emissions to be weighted based on the | Regional databases / sources | Regional databases / sources | Reconfirmed or updated for every verification |

| Index | Category name | Subcategory name | Description | Evidence required for baseline | Evidence required for project | Frequency of reporting |
|-------|----------------------|-------------------------|--|---|---|------------------------|
| | | | proportion of total cultivated hectares for each specific farming system | | | |
| B2.2 | Fertilizer | Fertilizer PCF | Cradle-to-gate emissions | <ul style="list-style-type: none"> • Third party verified manufacturer's PCF report • Credible database e.g. National/regional PCF datasets | <ul style="list-style-type: none"> • Third party verified manufacturer's PCF report • Credible database e.g. National/regional PCF datasets | |
| | | Types | Type of fertilizer being applied on the region | Regional databases / sources | Proof of sale (or purchase) of fertilizer | |
| | | N rate | Nitrogen rate in each fertilizer, % total N, %urea-N, % ammonium-N | Regional databases / sources | Proof of sale (or purchase) of fertilizer | |
| | | Application rate | Average application rates of the fertilizer | Regional databases / sources | Regional databases / sources | |
| B2.3 | Nitrogen stabilizers | Nitrogen stabilizer PCF | Cradle-to-gate emissions | - | <ul style="list-style-type: none"> • Third party verified manufacturer's PCF report • Credible database e.g. National/regional PCF datasets | |
| | | Type | Type of nitrogen stabilizer being applied | - | Proof of sale (or purchase) of stabilized N fertilizer / fertilizer-stabilizer mixture | |
| | | Application rate | Application rate of the nitrogen stabilizer | - | <ul style="list-style-type: none"> • For <u>stabilized N fertilizer</u>: fertilizer application rate | |

| Index | Category name | Subcategory name | Description | Evidence required for baseline | Evidence required for project | Frequency of reporting |
|-------|-------------------------------------|---------------------------------------|--|--|--|------------------------|
| | | | | | based on, product label and regional fertilizer application rate <ul style="list-style-type: none"> For <u>stabilizer- fertilizer mixtures</u>: the product label, instructions/ recommendation from the manufacturer | |
| B2.4 | Yield | - | Average yields for NUE check (if applicable) | Regional databases / sources | Farmer log or sale proof from a representative sample of farmers | |
| B2.5 | NUE | Nitrogen use efficiency of 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 the metrics presented in Appendix D | |
| B2.6 | Transportation emissions | Distance | Average distance between the production location and the use location of the fertilizer | Market analysis or relevant industry reports on distance between production and use location of the products. | <ul style="list-style-type: none"> A conservative average distance can be assumed, provided that it is thoroughly justified Receipts of transport services if available | |
| | | Vehicle type | Type of vehicle(s) used to transport the fertilizer | Market analysis or relevant industry reports presenting the typical vehicles used to transport these products. | <ul style="list-style-type: none"> Similar data as baseline Receipts of transport services, if available | |
| B2.7 | (Optional) Additional data for more | Influential environmental and/or | In case more detailed EFs are selected, then additional information are required | Regional databases / sources | Regional databases / sources | |

| Index | Category name | Subcategory name | Description | Evidence required for baseline | Evidence required for project | Frequency of reporting |
|-------|------------------|----------------------|---|---|-------------------------------|------------------------|
| | detailed EF | management practices | | | | |
| B2.8 | 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 12: Project impact (for LMU or Sourcing Region level intervention)

| Index | Category name | Subcategory name | Calculation method | Frequency of reporting |
|-------|------------------------------------|--|--|----------------------------|
| C1. | Net reduction of GHG emissions | - | Section 5 Net reduction of GHG emissions | Updated every verification |
| C2. | Different metrics of GHG emissions | Per unit of land area | Appendix C | |
| | | Per unit of crop/forage produced | | |
| | | Per unit of nitrogen containing fertilizer applied | | |
| | | Per unit of animal product produced | | |

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 nitrogen stabilizers 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](#).
- A recordkeeping plan to maintain accurate documentation that shows when and where nitrogen stabilizers application has occurred
 - For LMU type of projects: This includes field records, field investigations, farm implement measures, machinery receipts, delivery notes and/or invoices.
 - For sourcing region type of projects: This includes N stabilized fertilizer or nitrogen stabilizer distribution data, regional sales volume, or aggregation reports from participating cooperatives or farming associations
- The roles of individuals involved in monitoring and data collection (e.g., responsibilities).
- 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.

6.3 Verification

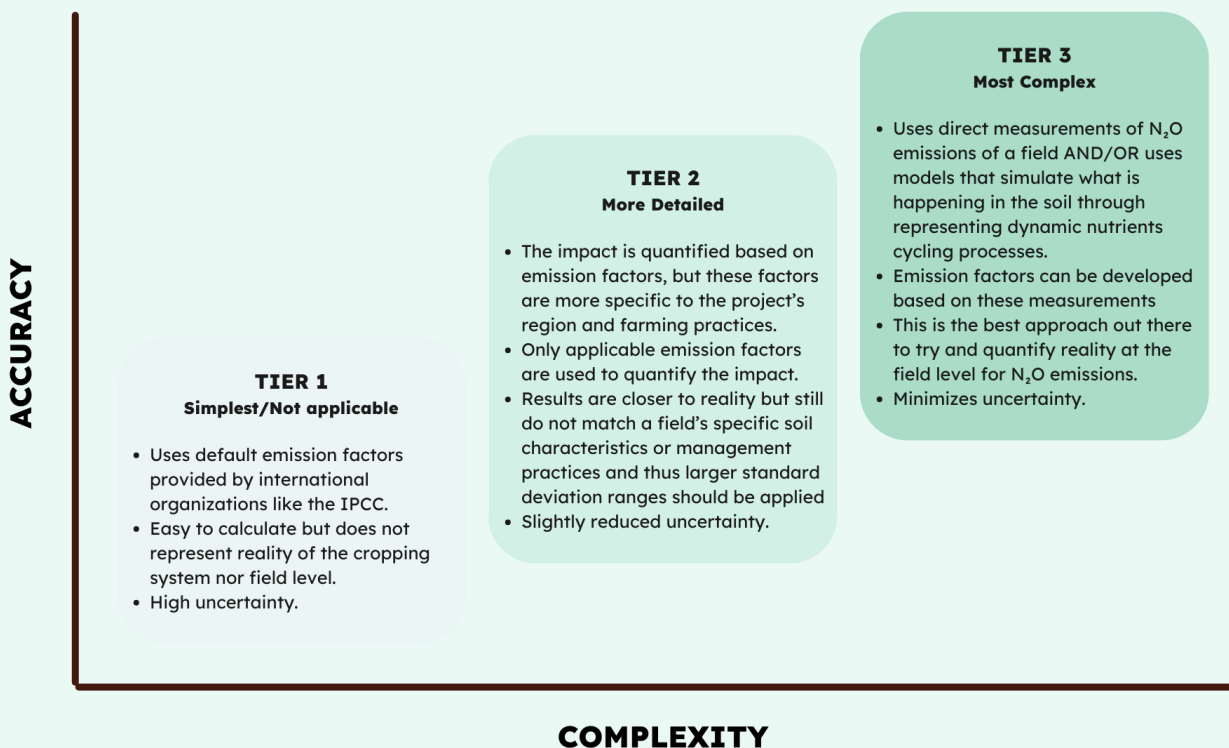
A Proba approved Validation and Verification Body (VVB) must be selected to execute the verification process based on the monitoring plan and reports to confirm that the project's requirements are met, ensuring the accuracy of the calculated GHG reductions resulting from the use of nitrogen stabilizers. 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. Specific VVB guidelines have been developed for projects introducing nitrogen stabilizers, and VVBs must apply these guidelines when conducting the verification⁵⁵.

⁵⁵The VVB guidelines document can be shared with VVBs upon request

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 to ensure that key variables are accurately represented. The VVB must assess the robustness of these data sources and validate their consistency with the monitoring plan as described in the VVB guidelines document.

Appendix A: Emission factors

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 nitrogen stabilizers, 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 refinement tables). Tier 1 is only applicable in this methodology for estimating direct and indirect N₂O emissions in cases where no project-specific or region-specific (Tier 2) data are available, as described in section [4.1 EF-data reference approaches](#).
- **Tier 2** EF can be derived from existing meta-analyses, systematic reviews, regional databases, scientific literature or the IFA EF database. This approach allows for more accurate quantification of emissions associated with both the baseline fertilizer application and the intervention using nitrogen stabilizers. 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.

- **Tier 3** represents the most detailed and accurate approach, relying on either advanced biogeochemical process-based modeling⁵⁶ or site-specific data collection through field measurements during the project implementation. This tier quantifies emissions related to baseline fertilizer use and nitrogen stabilizer 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 N₂O measurements (e.g., via static chambers), fertilizer/nitrogen stabilizer inputs, crop yield outputs, and associated environmental variables such as soil type, soil moisture levels, temperature, and pH, can provide high accuracy and credibility to the reduction claims.

A.2 Quality criteria of experimental design of studies

Project developers must follow the key quality criteria presented in Table 13 and, where relevant, the optional criteria in Table 14 when selecting scientific studies to derive emission factors (EFs) for use in this methodology. These criteria serve as mandatory guidelines to ensure that only scientifically robust, well-designed, and context-appropriate studies are used to inform baseline and project EF selection.

The quality criteria were developed based on a review of established academic approaches, particularly key meta-analyses that have shaped understanding of nitrogen stabilizer performance. They are further supported by the empirical recommendations of Hutchings et al. (2024), which outline the evidentiary and field-validation requirements necessary for including urease and nitrification inhibitor effects in national emission inventories. The academic sources that informed the development of these criteria are listed in the “References” section (Akiyama et al., 2010; Abalos et al., 2014; Gilsanz et al., 2015; Fan et al., 2022; Charteris et al., 2020; de Klein et al. 2020).

These same quality criteria were also applied in the construction of the IFA Enhanced Efficiency Fertilizer Emission Factor Database (<https://fertilizerdatabase.com>), ensuring methodological alignment between the evidence base used to populate the database and the evidence required for project-level EF selection

⁵⁶ Note: The use of process-based models for deriving the EF is not eligible in this version of the methodology.

Table 13: Explanation of the quality criteria

| No | Category | Description of quality criteria |
|----|--|--|
| 1 | Publication date | Only studies published after 1995 must be considered for extraction of EFs. |
| 2 | Peer-reviewed | The studies must be peer-reviewed. In certain cases, non-peer-reviewed studies or experiments may also be included if they demonstrate strong experimental design and provide complete, high-quality data suitable for EF extraction. |
| 3 | Field data priority, laboratory data | The studies must be based on field experiments to ensure the real-world applicability of the results. Small-scale experiments, such as laboratory incubations or soil column studies, are excluded, as they may not accurately reflect field conditions. |
| 4 | Replicated results | Only studies with at least three replicates per treatment must be used. Studies that lack replication or do not report the number of replicates are not accepted. |
| 5 | Categorization of nitrogen stabilizers | Studies must at least provide data categorized by nitrogen stabilizer type, such as urease inhibitors (UI), nitrification inhibitors (NI), or a combination of both (UI+NI), and active ingredients such as DCD, DMPP, etc. Specific product names are also valuable information. |
| 6 | Measurement period and temporal coverage | Studies must report emissions over cumulative measurement periods (preferably at least two growing seasons), considering significant nitrogen loss events (if they occurred) and the residual fertilizer nitrogen in the soil, which can undergo nitrification after harvest. Additionally, the effects of stabilizers may persist beyond a single growing season. The measurement period must cover the full “envelope” of an N ₂ O emission peak (pre- and post-event) in order to avoid cumulative emission overestimation (Charteris et al., 2020; de Klein et al. 2020). This requires that measurements continue until nitrous oxide emissions in the treatment plots are no longer significantly different from those in the control plots. |
| 7 | Standardized emission measurements methods | Accepted measurements methods include chamber-based measurements (automatic or manual) for N ₂ O emissions, isotopic techniques for tracking nitrogen transformations, and advanced approaches such as flux gradient and eddy covariance methods. |
| 8 | Environmental and management factors | Studies must provide detailed documentation of the key factors influencing fertilizer-related emissions and the effectiveness of nitrogen stabilizers. These include environmental factors such as location, soil type, texture, moisture, pH, temperature, and rainfall, as well as management practices like fertilizer type, application rate, inhibitor type, application method (e.g., incorporated, broadcasted, or injected), and timing of the application. |
| 9 | GHG Emissions reported | Studies must report emissions from the “Conventional Fertilizer (Reference)” plot, the “Fertilizer with nitrogen stabilizers (Enhanced)” plot and “Unfertilized control (Background)” plot under identical environmental and management conditions. Emissions from the unfertilized plot should be subtracted from both the “reference” and “enhanced” treatment plots to ensure accurate comparisons. This adjustment ensures that the reported emissions are solely attributable to the fertilizer application or the intervention of the nitrogen stabilizer. |

| No | Category | Description of quality criteria |
|----|----------------------------------|---|
| 10 | Reported emissions and equations | Studies must report direct N ₂ O emissions and if available indirect N ₂ O emissions (based on the nitrate leaching and ammonia volatilization fraction). If only a fraction is reported then the calculation of indirect N ₂ O emissions is based on the EFs that are provided by IPCC. The studies must include a clear description of the equation used to calculate the emissions factor (EF), particularly if emissions are reported in the form of an EF. When studies do not report the EF directly, then the seasonal N ₂ O emissions must be estimated by integrating the average daily fluxes over the measurement period. |
| 11 | Standard deviation | Studies must report standard deviation or standard error for the measured emissions data. |

Table 14: Desirable but non-essential criteria

| No | Category | Description of optional quality criteria |
|----|---|---|
| 1 | Crop productivity metrics (e.g., grain yield, biomass production) | Reporting of crop productivity metrics, such as grain yield or biomass production, is valuable. However, studies can still be used if this information is not provided. |
| 2 | Transparency in materials and methods | The materials and methods must be clearly described in sufficient detail to allow for replication or validation of the findings. |

A.3 Utilization of meta-analyses papers

Meta-analyses papers can serve as valuable sources for EF, provided they meet the following 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:** The meta-analysis should offer a clear breakdown of data categorized by region, soil type, or other variables to enable partial alignment with the project's characteristics.

- **Data extraction:** When a meta-analysis provides average EFs and/or EF reduction %, in order to use them project developers must ensure that these averages align partially with their project's specific characteristics. 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. The use of the uncertainty ranges is described in Section [4.3. Uncertainty](#), where the methodology outlines how standard deviations or confidence intervals should be incorporated to ensure that emission reduction estimates remain credible and conservatively quantified, particularly when Tier 1 or Tier 2 data are used.

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:

$$UF = \sqrt{(\sigma_{BE})^2 + (\sigma_{PE})^2 - 2 \cdot \sigma_{BEPE}} \quad (15)$$

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 (%)

σ_{BEPE} = 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:

$$UF = UF_{avg} = \frac{\sqrt{\sum_{i=1}^n UF_i^2}}{n} \quad (16)$$

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 fertilizer or nitrogen stabilizer applied (again for the cradle-to-grave PCF/LCA), while for a farmer, the GHG emissions per hectare might be more relevant. In Table 15 the key metrics that can be applied are presented.

Table 15: Metrics that can be used for the project GHG emissions

| <i>Metric</i> | <i>Description</i> | <i>Example</i> | <i>Unit</i> |
|--|--|--|--|
| 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 ₂ e / ton of crop |
| Per unit of animal product produced [PCF of animal product] | This metric expresses GHG emission reductions relative to the amount of animal product generated (such as milk, meat, or liveweight gain). It is particularly relevant when nitrogen stabilizers are applied to grasslands used for livestock production, where improved forage productivity, nitrogen efficiency, and reduced emissions from urine depositions can contribute to more sustainable animal output. By linking emission reductions directly to animal products (via food conversion ratios), this metric helps livestock producers, dairies, and downstream food companies quantify emission reduction in relation to animal production systems. | Dairy processors or livestock supply chains demonstrating that each kilogram of milk is associated with lower fertilizer-derived N ₂ O emissions due to improved fertilizer management on grasslands. | tCO ₂ e / kg of animal product (milk, meat, or liveweight gain) |
| 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 nitrogen stabilizers, and demonstrates how much N ₂ O 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 ₂ e / 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 allows for direct comparison between different fields or farms, making it critical for broader environmental claims. | 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 ₂ e / ha |
|-----------------------|---|---|-------------------------|

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 N₂O) 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 nitrogen stabilizer projects. 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”⁵⁷

Table 16: Metrics that can be used for the NUE

| NUE indicator | Description | Calculation | Unit | Practicality |
|-------------------------------------|---|---|---------------|---|
| Partial Factor Productivity (PFP) | Yield of crop harvested per unit of fertilizer nitrogen applied. | $PFP = Y/N$ Where: $Y = \text{reported crop yield}$ $N = \text{N application rate}$ | 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 efficiency. | $NUE_{pb} = R/(N + M + B + D)$ Where: $R = \text{Total nitrogen removed in harvested crop biomass}$ $N = \text{N application rate}$ $M = \text{N from manure or organic amendments}$ $B = \text{N from biological fixation}$ $D = \text{Atmospheric deposition of reactive nitrogen}$ | Fraction or % | Comprehensive but data-intensive. It is related to a more detailed analysis at research or institutional level. |

⁵⁷ https://sprpn.org/wp-content/uploads/2023/08/Issue-Brief-04_English.pdf

| | | | | |
|---------------------------|--|---|---------------|---|
| | | | | |
| N Balance (NUEfg) | Difference between N inputs and N outputs. Indicates potential for environmental losses. | $NUEfg = U/(N + M + B + D)$ <p>Where:</p> <p>$U = N$ uptake in crops</p> <p>$N = N$ application rate</p> <p>$M = N$ from manure or organic amendments</p> <p>$B = N$ from biological fixation</p> <p>$D = Atmospheric$ deposition of reactive nitrogen</p> | 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. | $AE = (Y - Y_0)/N$ <p>Where:</p> <p>$Y = reported$ crop yield</p> <p>$Y_0 = crop$ yield from unfertilized plot</p> <p>$N = N$ application rate</p> | 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. | $RE = (U - U_0)/N$ <p>Where:</p> <p>$U_0 = N$ uptake in crop from unfertilized plot</p> <p>$U = N$ uptake in crop from fertilized plot</p> <p>$N = N$ application rate</p> | 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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