GHG Methodology

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

PM.0002

Version 0.95

Proba World BV
Laan van Kronenburg 14
1183 AS Amstelveen
The Netherlands

Methodology:

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

13 May, 2025

Methodology ID	PM.0002
Version	0.95
Status	Draft methodology
Type	New methodology
Developer	Proba World BV
Contact Information	methodologies@proba.earth

Table of Contents

List of definitions

Additionality	Refers to the concept that any GHG project should result in greenhouse gas emissions mitigation (GHG reductions or removals) that would not have occurred without the project. In other words, the project's positive impact on reducing or removing emissions should be "additional" to what would have happened under the baseline scenario.
Ammonia volatilization	The process by which ammonia (NH_3) gas is released into the atmosphere from ammonium-containing fertilizers (e.g., urea). This can lead to indirect GHG emissions when ammonia is subsequently converted to nitrous oxide (N_2O) in the environment.
Baseline scenario	The baseline scenario represents the emissions that would occur based on the business as usual agricultural management practices. In other words, this includes fertilizer management and other relevant activities, without the use of low-carbon fertilizers.
Buffer pool	A Buffer Pool is a shared reserve of Carbon Credits established to cover potential losses in GHG Projects, ensuring the integrity of emission reductions or removals over time. Each GHG Project contributes to Proba's Buffer Pool when Carbon Credits are being issued. These Carbon Credits can only be used by Proba to compensate for reversals.
Carbon credit (emission reduction certificate)	A carbon credit represents at least 1 tonne of CO2 (tCO_2), or 1 tonne of CO2e (tCO2e) reduced or removed for a certain period of time. One tonne (metric ton) (t) equals 1000 kg. For carbon equivalency, Proba uses the AR-5 assessment from UNFCCC[1].
Carbon dioxide equivalent - CO_2e	A metric used to compare the emissions of various greenhouse gases based on their Global Warming Potential (see GWP definition). It expresses the impact of different gases in terms of the equivalent amount of CO2, facilitating a standardized approach to assessing overall greenhouse gas emissions.
Conservativeness	When there is uncertainty or a choice between two or more assumptions, values, methodologies, or procedures, the option that is more likely to result in lower estimates of GHG emission reductions or removals must be selected. This approach ensures that claimed climate benefits are not overestimated.
Cradle-to-gate	A life cycle assessment boundary that includes all greenhouse gas emissions associated with a product's life cycle stages up to the point it reaches the project's location. This includes emissions from raw material extraction, production, and transportation to the project's

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

	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.
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.
Fugitive emissions	Unintended releases of gases or vapors from pressurized equipment due to leaks, equipment malfunctions, or other unforeseen incidents. In fertilizer production, common sources include, but are not limited to, valves, joints, seals, and storage tanks.
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.
Greenfield facility	A project where a new facility is built from the ground up on undeveloped land, where no previous building or infrastructure existed that served the same purpose.
Inorganic fertilizers	Fertilizers manufactured through chemical processes or mined from natural deposits and then processed to be concentrated and standardized. These include: nitrogen fertilizers (e.g., urea, ammonium nitrate), phosphorus fertilizers (e.g., superphosphate), potassium fertilizers (e.g., potassium chloride). They are typically water-soluble and immediately available to plants, which makes them highly efficient but also potentially leachable.

Insetting	Insetting refers to the practice of implementing sustainability interventions within a company's own value chain to reduce greenhouse gas (GHG) emissions or enhance carbon sequestration. Unlike offsetting, which typically involves purchasing carbon credits for activities outside the value chain, insetting focuses on reducing emissions directly linked to the company's operations, suppliers, or production processes.
IPCC	The Intergovernmental Panel on Climate Change is a United Nations body, assessing science related to climate change to provide policymakers with regular scientific updates.
Land Management Unit (LMU) / Field level	A Land Management Unit (LMU) is a clearly defined area of land under consistent management, where fertilizer application can be directly monitored and attributed. The LMU level allows GHG emissions and reductions to be accurately measured and linked to specific land parcels, each with defined boundaries and documented management practices. It is aligned with the GHG Protocol's *Land Sector and Removals Guidance* definition [2].
Leakage	In the context of a GHG project, leakage refers to the unintended increase in greenhouse gas emissions outside the project boundaries as a direct result of the project's activities.
Nut-rate	In this methodology, the application rate is defined in terms of nutrient applied (not just nitrogen), to account for cases where the low-carbon fertilizer reduces emissions associated with any of the primary nutrients: nitrogen (N), phosphorus (P), or potassium (K).
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_2O) when nitrates are converted by microbial activity in anaerobic conditions.
Nitrogen stabilizers mixtures	Fertilizers mixed with nitrogen stabilizers before application, either at the field level or through distribution channels.
Nitrogen Use Efficiency (NUE)	Nitrogen use efficiency 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 nitrogen applied to the crop.
Nutrient Use Efficiency (NutUE)	Nutrient use efficiency refers to the effectiveness with which crops utilize applied nutrients (NPK) for growth and yield. It can be defined as biomass production (or crop yield) per unit of nutrient applied to the crop.

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

Offsetting	Offsetting refers to the practice of compensating for greenhouse gas (GHG) emissions by supporting projects outside a company's value chain that reduce or remove emissions. This is typically achieved by purchasing carbon credits from verified initiatives.
Organic fertilizer	Fertilizer products containing organic carbon and nutrients of solely biological origin and excluding materials which are fossilized or embedded in geological formations. Note: Organic fertilizers are different from fertilizers authorized in organic farming, which may include some mineral fertilizers such as phosphate rock.
Proba Standard	The Proba Standard aims at controlling and reducing the risks related to GHG projects, their climate impact (emission reduction) and the corresponding issuance of emission reduction certificates and subsequent claims. It does so by relying on and aligning with internationally recognized standards frameworks and initiatives such as the Core Carbon Principles by the ICVCM and the ICROA Code of Best Practice. The Proba Standard sets out detailed procedures for identification and validation of GHG projects, and verification of emission reductions and removals, based on ISO 14064-2 . More information about the Proba Standard can be found at https://proba.earth/document-library.
Product Carbon Footprint (PCF)	The total amount of greenhouse gases (GHGs) emitted directly or indirectly by a product throughout its life cycle. It is typically measured in units of carbon dioxide equivalents (CO_2e) to account for the varying global warming potentials (GWP) of different GHGs.
Project boundaries	The project boundaries of a GHG project delineate the spatial, temporal, and operational limits within which the GHG emissions, reductions, and removals are quantified and monitored, encompassing specific activities, sources, sinks, and reservoirs related to the project.
Project Overview Document (POD)	A document that offers a detailed summary of a GHG project's key elements, including governance, emission calculations, risk management, methodologies, and monitoring processes (see Proba Standard).
Runoff	The horizontal movement of water across the soil surface, carrying with it dissolved and particulate nutrients from fertilizers as well as (fine) soil particles to nearby water bodies. Runoff can result in surface water pollution and contribute to eutrophication. Additionally, when nitrogen compounds in runoff reach water bodies, they can undergo microbial activities which result in indirect emissions of nitrous oxide (N_2O).
Sourcing Region	A geographically distinct area characterized by common environmental, climatic, and land use conditions. It may encompass

	an entire country, a jurisdiction, or a specific part of it, and is typically defined by administrative boundaries, agroecological zones, or sourcing areas. It is aligned with the GHG Protocol's *Land Sector and Removals Guidance* definition [3].
Tier 1, 2 and 3	In the context of greenhouse gas (GHG) emissions reporting and inventory management, data and methodologies are categorized into three tiers (Tier 1, Tier 2, and Tier 3), as defined by the Intergovernmental Panel on Climate Change (IPCC). These tiers represent varying levels of accuracy, data specificity, and complexity. For more information see Appendix A.1 Tier definitions.
Verification and Validation Bodies (VVBs)	Third-party assurance entities, preferably ISO-accredited, are responsible for verifying that a project's activities and claims of emissions reductions and/or removals are conducted in accordance with established standards and methodologies, ensuring their accuracy and credibility.

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

List of abbreviations

AR6	IPCC Sixth Assessment Report
EF	Emission Factor
GHG	Greenhouse Gas
IFA	International Fertilizer Association
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
LMU	Land Management Unit level
MRV	Monitoring, Reporting, and Verification
N_2O	Nitrous Oxide
NH_3	Ammonia
NO	Nitric oxide
NO_2^-	Nitrite
NO_3^-	Nitrate
NUE	Nitrogen Use Efficiency
NutUE	Nutrient Use Efficiency
PCF	Product Carbon Footprint
POD	Project Overview Document
SDG	Sustainable Development Goal
T&D	Transmission and distribution
VVB	Verification and Validation Body

1. Introduction

1.1 Background

Fertilizer production has traditionally been energy-intensive, relying heavily on fossil fuels which contribute significantly to global greenhouse gas (GHG) emissions. This conventional production method not only requires high energy inputs but also releases substantial amounts of CO_2 and other GHGs during its production processes. For instance, the production and usage of nitrogen fertilizers account for approximately 5% of global greenhouse gas (GHG) emissions.[4] As such, the development of more sustainable practices and technologies in the field of fertilizer production is a critical area of focus for reducing the agricultural sector's environmental impact. At the same time, the true impact of low-carbon fertilizers is only realized when these products are adopted on a large scale by farmers.

1.2 Applicability of methodology

- This methodology applies globally to interventions that introduce low-carbon inorganic fertilizers as a replacement for high-emission conventional fertilizers in managed soils.
- Project developers must ensure that the applicability, eligibility and additionality criteria presented in this methodology are fulfilled.
- This methodology is applicable to both offsetting and insetting projects. In alignment with emerging SBTi guidance, insetting projects should prioritize direct mitigation, where the intervention can be physically linked to specific emissions sources within the company's value chain through a robust chain of custody model. Where such traceability is not yet possible, indirect mitigation may be used as an interim measure, provided it supports the transformation of the relevant value chain over time. Section 1.4 Additionality, explains the requirements for these different types of projects.
- Project developers must demonstrate that nutrient inputs are applied at appropriate rates based on regional agronomic guidelines or best practices, supporting optimal nutrient use efficiency (NutUE). This ensures 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 fertilizer substitution. Where regional baseline fertilization is excessive, project developers must clearly disclose this and structure their projects to support improved, agronomically appropriate nutrient application rates.

[4] https://www.nature.com/articles/s43016-023-00698-w#

For this purpose, project developers must do a *NutUE Performance Test*, as defined in section 3 Baseline Scenario.

- This methodology allows for partial substitution of conventional fertilizers, where only specific nutrient components (e.g., nitrogen in an NPK fertilizer) are replaced with a low-carbon alternative while others remain unchanged. Emission reductions are calculated only for the substituted component, ensuring accurate impact attribution.
  - Project developers must provide evidence of nutrient composition, demonstrate agronomic equivalence based on Nutrient Use Efficiency (NutUE), and ensure transparent calculation of emissions reductions specific to the replaced fraction. This approach enables crediting for verified reductions while allowing for a gradual transition to low-carbon fertilizers.
- Project developers must be able to prove that the intervention leads to an actual replacement of high-emission conventional fertilizers on the spatial level of their project (see 2.3 Spatial boundaries).
  - For LMU type of projects: If the baseline is defined using historical data (e.g., farmer logs) at the LMU level, the corresponding regional baseline must also be provided to support the assessment of additionality. If regional data is used instead, then the regional baseline becomes the default baseline for the LMU.
  - For sourcing region type of projects: The regional baseline de facto defines the project's baseline.
- For both the baseline and project intervention, project developers must provide evidence of the product carbon footprint (PCF) related to the fertilizers in scope. More information on the evidence that must be sourced can be found on section 4.5 Evidence for EF.
- Project developers must provide verifiable evidence that the introduced low-carbon fertilizer serves as a viable substitute for the conventional high-emission fertilizer in terms of agronomic effectiveness. The substitution rate must be justified based on the expected NutUE. For instance, if the low-carbon fertilizer has a higher or lower nitrogen use efficiency (NUE) compared to the conventional fertilizer, project developers must justify the adjusted application rate (and thus substitution rate) based on peer-reviewed literature, field trial data, or agronomic models. Specifically:
  - If the low-carbon fertilizer is expected to have **lower** nutrient use efficiency (for either N, P or K), then this *must* always be accounted for in the calculation of the GHG impact.
  - If the low-carbon fertilizer is expected to have **higher** nutrient use efficiency (for either N, P or K), then this *can* be accounted for in the calculation of the GHG impact, but the reduction must be proven based on regional data (see 3. Baseline Scenario, 1.b. Projects with Nut-rate reduction). This is only applicable for Land

Management Unit spatial level type of projects, where both the regional and project nutrient application rates can be tracked.

- This methodology is applicable to projects that introduce changes to management practices on top of the usage of low-carbon fertilizers (e.g., adopting improved tillage methods, introducing cover crops, or similar), if another relevant GHG methodology is used, which ensures that the additional emission reductions are quantified, verified and accounted for accurately and transparently. This is only applicable for Land Management Unit spatial level type of projects, where these types of interventions can be tracked and verified.
- 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 introduction of low-carbon fertilizers with the application of nitrogen stabilizers, thereby achieving complementary climate benefits while ensuring that the integrity of the emission reductions from activities under this methodology is maintained. In case this methodology is used in conjunction with other methodologies or programs then the project developer must:
    - explicitly mention that in the POD and
    - demonstrate that benefits are not quantified more than once (to mitigate the risk of double counting the impact of nitrogen stabilizers across two projects)
    - provide a separate monitoring framework to ensure that combined interventions do not undermine each other's effectiveness in long-term consistency
- The project developer must be transparent and report on additional activities that happen along with or because of the introduction of low-carbon fertilizers, 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
    - Introducing N stabilizers
    - Adding irrigation events that consume energy or water
- This methodology has been developed in accordance with the Proba Standard, ensuring that all guidelines, principles, and requirements outlined in the standard are fully adhered to. Users of this methodology are expected to follow the Proba Standard to ensure consistency, credibility, and compliance with the broader framework established by Proba.

1.3 Eligible products

1.3.1 Types of fertilizers

- In this methodology, the eligible products are inorganic fertilizers.
- Organic fertilizers are currently excluded from this methodology.
- Both solid and liquid fertilizers are eligible.
- Fertilizers that partially substitute components of conventional fertilizers (e.g., the nitrogen part of an NPK fertilizer) with low-carbon alternatives.

1.3.2 Regulatory compliance

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

1.4 Additionality

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

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

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

- <u>Regulatory additionality</u>: The project developer must prove that the introduction of the low-carbon fertilizers 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 low-carbon fertilizers 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.
    - Many countries, states, regions, or economic zones have set GHG emission targets for sectors like green hydrogen or fertilizer production, supported by directives and subsidies, or incorporated the sector into a compliance system (e.g. green hydrogen production being eligible to receive tradable EUAs in the EU, Carbon Border Adjustment Mechanism, etc.), making some project 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 low-carbon fertilizer 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 low-carbon fertilizers 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. For reference, CDM defines common practice as greater than 20% adoption [5].
- Financial additionality: The project developer must prove that the financial incentive from carbon finance will lead to the increased adoption of the low-carbon fertilizers by the farmers.
    - For that purpose, a financial analysis can be provided, that calculates costs and benefits, and compares financial aspects between a GHG Project, the chosen baseline, and possible alternative scenarios. Project developers can use the tool developed by the Carbon Development Mechanism (CDM) titled "*Combined tool to identify the baseline scenario and demonstrate additionality*"[6] for this purpose. This financial analysis may be treated as confidential by the VVB and Proba and is not required to be published in the public registry.

For the insetting scenario, the project developer must demonstrate regulatory additionality by confirming that the use of low-carbon fertilizers 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 low-carbon fertilizers is not a common practice within the company's sourcing region, crop system, or market segment relevant to the intervention.
- Financial additionality: An explanation must be provided that carbon finance is positively affecting the adoption of low-carbon fertilizers 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

[5] Twenty percent is the precedent for a common practice threshold established in Section 18 of the CDM Methodological tool: Common practice. (https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-24-v1.pdf)
[6] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-02-v7.0.pdf

monitoring regulatory changes, financial conditions, and market adoption that may affect the project's additionality. The use of a dynamic baseline is required to reflect these developments and ensure the continued credibility of the emission reductions being claimed, as seen in section 3. Baseline scenario.

1.5 Crediting Period

The crediting period is the timeframe during which a validated project can generate emission reduction certificates. After the end of the crediting period, the project needs to be re-validated, to ensure that additionality is still present, the baseline scenario is reassessed, and the project complies with the latest version of this methodology.

For GHG projects adopting low-carbon fertilizers, the crediting period can be set up to a **maximum of 7 years**, depending on the trend in regulatory and industry landscapes toward more sustainable production practices. 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 period does not "*force*" farmers in the project to use low-carbon fertilizers during the entire period, but allows them to generate emission reduction certificates if they do. For example, if a farmer uses low-carbon fertilizers in only 4 out of 10 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 low-carbon 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, provided that the project developer can fulfill the requirements set by this methodology (e.g., proof of additionality, baseline, scientific evidence, documentation etc.) and in addition demonstrate that the intervention was implemented with the intention of utilizing carbon finance.

1.6 Co-benefits & no harm principle

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

Proba encourages such projects to contribute to at least one or more UN Sustainable Development Goals[7], and expects that project developers, engineers or managers will consider these when preparing and designing a project.

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

For instance, the SDG Impact Assessment Tool offers a structured approach to help assess and align projects with the SDGs[8]. *Figure 1* illustrates the SDGs related to sustainable fertilizer production, as presented in a report from the International Fertilizer Association (IFA)[9].

Figure 1: Sustainable Development Goals that are in line with sustainable fertilizer production

Project Developers must adhere to the "*Environmental and Social Do not Harm Principle*" by conducting thorough assessments to identify and evaluate potential environmental and social impacts of their GHG projects.

They must implement appropriate mitigation measures to address any identified negative impacts, ensuring that the project does not adversely affect local ecosystems or communities, particularly vulnerable populations.

Continuous monitoring and adaptive management strategies must be employed to ensure ongoing compliance with this principle throughout the project lifecycle. This process must be clearly defined and explained in the POD.

1.7 Risks

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

[7] https://sdgs.un.org/goals
[8] sdgimpactassessmenttool.org
[9] https://www.fertilizer.org/wp-content/uploads/2023/01/2020_IFA_The_SDGs_and_Sustainable_Fertilizer_Production.pdf

- Events which may occur during the crop season, and may lead a) to decreased crop yields or b) additional applications of fertilizers must be thoroughly explained and documented as part of the verification cycle. Such events can negatively impact the emission reductions of the project. Examples of such events include, but are not limited to, diseases, pests, extreme weather events (e.g. heavy thunder storms and hailstorms).
- The crop producer might not actually apply the reported amount of product, either as an unintentional action or miscalculation or a deliberate error or falsification.
- The crop yield might be incorrectly measured or reported.
- If the emission factors were selected directly from scientific literature, which was funded by the fertilizer industry, there might be a risk of conflict of interest. In case of potential conflict of interest, cross-check with broader relevant (scientific or validated) literature is required.
- Farmers, perceiving low-carbon fertilizers as more sustainable and thus as lower-impact products, may apply them at higher rates than agronomically recommended. Over-application could diminish the expected emission reductions by increasing total nitrogen inputs and the resulting emissions. To mitigate this risk, project developers must monitor actual nutrient application rates and crop yields to ensure that NutUE is maintained or improved relative to the baseline. Clear guidance on proper fertilizer use should be provided to farmers to prevent unintended increases in emissions.

1.8. Leakage & permanence

1.8.1. Leakage

Leakage in the context of a GHG project is the net increase in GHG emissions that occur outside the project boundary, directly resulting from the project's activities (IPCC, 2006).

For interventions in scope of this methodology, there are two main leakage risks:

1. The replaced fertilizers can be displaced to other areas that would not have used them, thus leading to an increase of emissions in that area. For example, farmers outside the project area may adopt these conventional products at lower cost, as a result of market changes driven by the introduction of low-carbon fertilizers, which could negate the emission reductions achieved by the project. 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. These can include:
    - Obtain written confirmation from the fertilizer supplier that the low-carbon fertilizer used in the project is newly produced or procured, and is not simply replacing supply, which is intended for other markets.

- Track national or regional fertilizer trade data (e.g. imports, exports, or sales volumes) to check whether the use of conventional fertilizers increases in nearby markets as a result of the project.
- If the project reduces demand for conventional fertilizers and there is no evidence of increased supply or use elsewhere, the project developer may justify that leakage is low.

To conservatively account for the risk of market leakage from the displacement of conventional fertilizers, project developers must assess the likelihood of leakage in the Project Overview Document (POD). Based on this assessment, the following tiered default deductions shall be applied to the project's calculated emission reductions at the time of the emission reduction certificate issuance:

Leakage Risk Level	*Example Conditions*	*Deduction*
Low	Low likelihood of redirection of conventional fertilizers to other regions or markets. Small/medium-scale projects which are not expected to disrupt regional/national level supply chains. Expected for most LMU type of projects.	0%
Medium (default)	Uncertain destination of displaced conventional fertilizers, limited visibility in regional markets.	5%
High	High likelihood of redirection of conventional fertilizers to other regions or markets. Expected for large-scale regional level projects.	10%

This deduction is reversible. After a period of **4 years**, the project developer may submit evidence demonstrating that the project did not result in increased use or redistribution of conventional fertilizers elsewhere. If such evidence is accepted by the verification 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.

(recommended updated table, to replace above)

Project scale	Scenario	Traceability of the displacement	Deduction
<1.000 ha	A	Leakage risk is considered negligible.	0%
1,000 – 10,000 ha	B	Full traceability of conventional fertilizer use and supplier confirmation that displaced volumes were reduced or absorbed locally	0%
	C	Partial traceability, no supplier confirmation, but no known redirection to other regions	5%
	D	No traceability and no supplier confirmation	7%
>10.000 ha	E	Supplier or regional authority confirms displaced conventional fertilizer was not redirected to other regions	0%
	F	No traceability and no supplier or market confirmation on fate of displaced fertilizer	10%
	G	Evidence of redirection (e.g. supplier contracts, trade/export data showing diversion to other regions or countries)	20%

2. There is a decrease in crop yield within the project area, leading to increased production elsewhere to meet demand. If the yield decreases, it is assumed that production will need to shift to other areas, potentially resulting in more emissions due to the additional fertilizer application or land use in those areas. The switch to low-carbon fertilizers is expected (at least) to maintain the same crop yields. Crop producers are unlikely to implement and maintain a project practice that results in yield declines, since their livelihoods depend on crop harvests as a source of income. Nevertheless, to ensure leakage is not occurring, the following nutrient use efficiency (NutUE) check must be done to prevent leakage.
   At the end of the crediting period, the project developer must:
   - Demonstrate that the NutUE has not declined by more than 10% in the project scenario by:
     - comparing average with-project NutUE (excluding years with extreme weather events) during the project period to average baseline NutUE during the historical period (farmer log based approach), **OR**
     - comparing the ratio of average baseline NutUE to average regional crop yield during the historical period with the ratio of average with-project

NutUE to average regional NutUE during the project period (market based approach) [10].

- 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 NutUE increases, so that there is no leakage. It is expected that this adjustment will probably happen *during* the crediting period, if the crop producer identifies a crop yield decline, thus fixing the crop yield issue, and preventing the leakage to happen in the first place.

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.

1.8.2 Permanence

The intervention focuses on reducing emissions through the adoption of fertilizers with a lower product carbon footprint (PCF) compared to conventionally produced fertilizers. These emission reductions occur on a per-growing-cycle basis and are considered permanent once achieved within that cycle.

Since these reductions are tied to specific agricultural cycles, rather than carbon sequestration, the risk of reversals is not applicable.

[10] 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.

2. Project boundary

2.1 Scope of activities

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

- Project developers replacing conventional fertilizers[11] on the Land Management Unit (LMU)[12] level with low-carbon alternatives, without altering nutrient application rates.
- Project developers replacing conventional fertilizers on the Land Management Unit (LMU) level with alternatives that reduce in-field emissions.
- Project developers replacing conventional fertilizers with low-carbon alternatives on the LMU level and reducing their total nutrient application rates, and thus potentially reducing their in-field emissions.
- Project developers distribute low-carbon fertilizers within a defined region (e.g. sourcing region-type of project). The intervention targets emissions reductions from upstream fertilizer production, without requiring (or allowing the quantification of) changes in nitrogen application rates at the farm level [13].

Optional: This methodology allows for the inclusion of other management practices in addition to the adoption of low-carbon 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. For instance, it can be combined with approaches involving the introduction of controlled-release fertilizers (CRFs), stabilized fertilizers with nitrification / urease inhibitors.

[11] The terms “*conventional*” and “*low-carbon*” refer to the production emissions of the fertilizers (PCF)
[12] *Land Management Unit* and *Sourcing Region* are spatial levels, which are explained in section 2.3 Spatial boundary
[13] In this type of intervention, reduction of the application of the nutrient rate is de facto not applicable, since there is no way to track this reduction on the field level.

2.2 GHG sources

In this methodology, the impact of the low-carbon fertilizers starting from their production up until their application on the field is in scope. Specifically the activities (as seen in *Figure 2*) that result in GHG emissions and are in scope include:

1. Fertilizer production emissions (cradle-to-gate emissions of fertilizers).
2. Transportation of the fertilizers from the production location to the project location. Certain PCFs include these emissions already. If this is the case, then these must be updated to reflect the actual transportation emissions of the baseline and project and avoid potential double counting.
3. Field spreading of the fertilizers using machinery [14]. This is not expected to be impacted in most cases where the low-carbon fertilizer is physically similar to the baseline fertilizer. However, if the product has a significantly different weight or volume than the baseline fertilizer, which might lead to more or less tractor passes or consumption of fuel, then this needs to be accounted for. 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: Emissions from the application of fertilizers, specifically nitrous oxide (N_2O) emissions, are included only for LMU type of projects and only for nitrogen-containing fertilizers[15]. These emissions can be significant and must be accounted for when the intervention affects the type or amount of nitrogen applied. Both direct and indirect N_2O emissions must be estimated using either a relevant peer-reviewed study (e.g., product-specific trials, scientific studies or meta-analyses) or IPCC[16] guidelines. Projects that do not involve nitrogen fertilizers or are implemented at the sourcing region level can not account for application-phase emissions. 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.

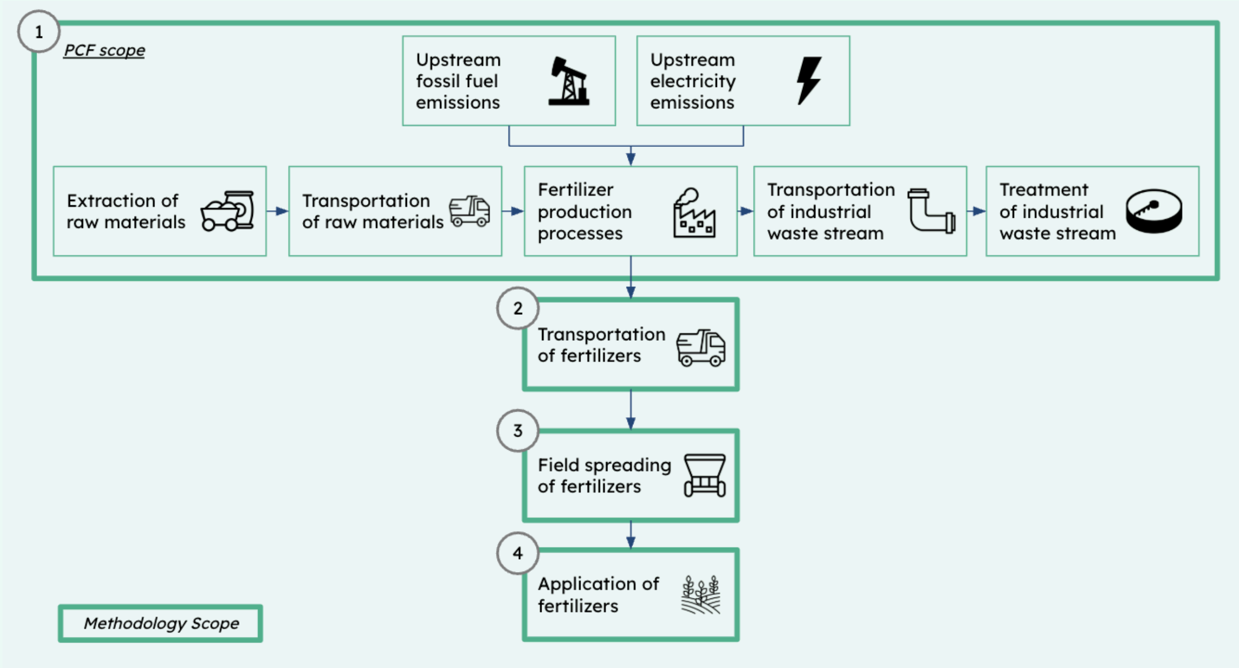
The activities in scope are presented in *Figure 2* below:

[14] 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, "*The project developer must be transparent and report on additional activities that happen along with or because of the introduction of low-carbon fertilizers, which can lead to material changes of emissions on the field*"

[15] Sourcing region types of projects are excluded from claiming a GHG benefit from reduced application emissions, as there is no way to trace the actual application rate on the fields.

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

Figure 2: Activities in scope for the GHG sources calculations



Greenhouse gases emitted for each activity that is covered under this methodology are presented in *Table 1* below. It should be noted that all the emissions should be expressed as carbon dioxide equivalents (CO_2e), as described in the [Appendix A](#).

Table 1: Emission sources covered under this methodology

	Activity/Source	***GHG***	***Included***	***Justification***
Baseline	(1) Fertilizer production emissions	CO_2e	Yes	Significant source that must be accounted for
	(2) Transportation of inorganic fertilizers	CO_2	Yes	Main emission from combustion of fuel
		CH_4	No	Typically not material
		N_2O	No	Typically not material
	(3) Field spreading of inorganic fertilizers	CO_2	Yes	Main emission from combustion of fuel
		CH_4	No	Typically not material
		N_2O	No	Typically not material
	(4) Application of inorganic fertilizers	CO_2	No	Out of scope
		CH_4	No	Out of scope
		N_2O	Yes	N_2O is the major emitted GHG from the use of nitrogen

	Activity/Source	GHG	Included	Justification
				fertilizers
Project	(1) Fertilizer production emissions	CO_2e	Yes	Significant source that must be accounted for
	(2) Transportation of low-carbon inorganic fertilizers	CO_2	Yes	Main emission from combustion of fuel
		CH_4	No	Typically not material
		N_2O	No	Typically not material
	(3) Field spreading of low-carbon inorganic fertilizers	CO_2	Yes	Main emission from combustion of fuel
		CH_4	No	Typically not material
		N_2O	No	Typically not material
	(4) Application of low-carbon inorganic fertilizers	CO_2	No	Out of scope
		CH_4	No	Out of scope
		N_2O	Yes	N_2O is the major emitted GHG from the use of nitrogen fertilizers

2.3 Spatial boundaries

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

- **Land Management Unit (LMU) level**: The primary boundary are the fields where fertilizers are applied and a specific crop type is cultivated (similar to *LMU* and including *Harvested area* as per the GHG Protocol [17]). The location from which the fertilizer is sourced from, must also be accounted for to calculate the transport emissions of the fertilizer.
- **Sourcing Region level:** Instead of accounting for the emissions at the individual LMU level, these spatial boundaries rely on average regional data to estimate the impact on the emissions. In essence, the sourcing region level tracks the replacement of conventional fertilizer(s) that would be used in the region, by the low-carbon fertilizer product. The regional boundary accounts for the collective impact of low-carbon fertilizer use in a broader landscape. This approach aggregates data from multiple fields, farmers, or cooperatives

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

within a defined region (similar to *sourcing region* as per the GHG Protocol). The quantification can be based on aggregated EF data (for the cradle-to-gate emissions of fertilizers).

- The project developer must collect average regional data such as:
    - baseline fertilizers used (which will be replaced by the low-carbon fertilizers)
    - crop types
    - low-carbon fertilizer distribution volume
    - nutrient application rates & crop yields

Some distinctions between the two levels:

- Sourcing region type of projects can be used when LMU field level type of data can not be accessed.
- Since LMUs allow monitoring on the field level, it is also possible to claim the potential reduction of nutrient application rate, if applicable (see section 1.2 Applicability of the methodology). This is not possible for the sourcing region type of projects
- 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.

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

Boundaries must be set in a way that captures all relevant emissions sources and potential leakages. Local and regional regulations, as well as environmental sensitivity[18], must also be considered when defining these boundaries.

If a project includes multiple scenarios, such as different crops 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, crops, and management practices are included in the project scope.

During verification, where the actual implementation of the project is assessed, the reported scenarios must be grouped based on similar management practices. The emission impact must then be calculated separately for each group to maintain methodological consistency and accuracy in reporting.

2.4 Temporal boundary

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

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 target crop and can vary based on the timing of fertilizer application.
- The start of the temporal boundaries is defined as the date of the first application of the fertilizer.
- The end of the temporal boundaries is defined as the final harvest date of the target crop within the participating field.
- 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 Service[19], which provides crop calendar charts for various regions and major crops. However, it is critical to supplement these sources with local, region-specific data when determining the exact temporal boundaries and ensuring that EFs appropriately account for nitrogen dynamics across the entire crop cycle.

For sourcing region level projects:

- The recommended period for the temporal boundaries is **1 year**.

[19] 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 introduction of low-carbon fertilizers**.

The project developer can establish the baseline based on the following approaches, depending on the spatial level selected and whether a nutrient application rate (Nut-rate) reduction is implemented (if applicable):

1. Baseline Nutrient-rate

- 1.a Land Management Unit approach: Projects without Nut-rate reduction:
  - The baseline Nut-rate is defined in a counterfactual approach, meaning that it is based on what would have happened if the project had not been implemented. Specifically, the volume of the fertilizer that is replaced, is based on the volume of the fertilizer in the project intervention, adjusted based on the nutrient content of the baseline and project fertilizers. At the same time, to avoid the rewarding of cropping systems that are overapplying nutrients, the project Nut-rate must not be much higher than the average regional Nut-rate, unless there is a strong agronomic justification for it.
- 1.b. Land Management Unit approach: Projects with Nut-rate reduction:
  - The baseline Nut-rate is defined based on a historical/regional approach. Specifically, the project developer must perform an analysis of an average N rate used for similar agricultural practices. This can be done either by historic farmer log data or from regional data sources. To add to that, there must be concrete scientific proof that the application of the specific type of low-carbon fertilizer has an increased NutUE, compared to the baseline fertilizer mix. Throughout the crediting period, the baseline Nut-rate must be updated regularly (see dynamic baseline), meaning that the Nut-rate reduction potential might be affected.
- 1.c Sourcing Region level approach: Projects without Nut-rate reduction:
  - The baseline Nut-rate is defined in a counterfactual approach, meaning that it is based on what would have happened if the project had not been implemented. Specifically, the volume of the fertilizer that is replaced, is based on the volume of the fertilizer in the project intervention, adjusted based on the N-content of the baseline and project fertilizers types.

- 1.d Sourcing Region level approach: Projects with Nut-rate reduction:
    - Not applicable under this methodology.

2. NutUE Performance test

- 2.a Land Management Unit level approach:
    - This includes calculating the project's historic (based on farmer log) baseline NutUE based on the total Nut fertilizer input and crop yield data. This NutUE must be compared to regional benchmark NutUE values[20] to verify that the project's baseline practices are following the region's guidelines and are not overapplying nutrients. The following data and equation must be provided and used for the calculation:
        - Total fertilizer applied per hectare (kg Nut/ha)
        - Total crop yield per hectare (t/ha)
        - Equation:

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

    - NutUE 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 E) of the last 3–5 growing seasons, to better represent typical practices. Single-year data may only be used in exceptional cases (e.g., newly established farms) and must be clearly justified.
    - If a field or region follows a crop rotation system (e.g., legumes in one year, cereals in the next), the baseline NUE must be specific to the focus crop in the rotation.
- 2.b Sourcing Region level approach
    - In case a sourcing region spatial boundary approach is taken, where low-carbon fertilizers are sold across a region (see 2.3 Spatial Boundaries), the project developer must provide the regional NutUE based on a relevant source such as peer-reviewed scientific studies, government agricultural extension reports, industry best practices, or other recognized sources.

3. Baseline Fertilizer Type (All Applicable Scenarios)

- The baseline fertilizer type is determined using a regional-counterfactual approach, regardless of whether an N-rate reduction is applied (if applicable).

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

- Specifically, the project developer must conduct a regional market analysis to identify the range of fertilizer products that could realistically be used in the context of the project's farming systems. This analysis should consider factors such as crop type, management practices, and input availability. The result is a baseline fertilizer mix, consisting of representative fertilizers and their respective proportions. If historic farmer log data are available, then these can be used to support defining the baseline fertilizer type.
- This baseline fertilizer mix reflects current agricultural management decisions as it serves as a viable and credible alternative to the low-carbon fertilizer used in the project intervention

4. Dynamic baseline

- Given that in many regions and markets regulatory changes and the industry standards are evolving rapidly and this can have a severe impact on baseline calculations, a dynamic baseline is required. Project developers must assess the regional baseline **at least every 3 years** during the crediting period. If the regional baseline has changed, then the project's baseline must be re-established based on the regional baseline. Moreover, updates which affect additionality (regulatory changes, subsidies, tax incentives, etc.) must be transparently presented in the verification report.

4. GHG Emission calculations

The project developer must calculate the **total GHG emissions** for both the baseline and project scenario. These emissions must be transformed into tonnes of CO_2e for each verification period.

4.1.a Baseline PCF emissions

As mentioned in section 3. Baseline scenario, the baseline emissions represent the greenhouse gas (GHG) emissions that would have occurred in the absence of the project intervention. They are calculated based on a regional-counterfactual approach, reflecting current agricultural management practices and viable fertilizer alternatives available in the region.

The project developer must conduct a regional market analysis to determine a realistic mix of conventional fertilizer types that could be used in the project's context. The output of the analysis must be a **weighted mix** of fertilizer types, each associated with a proportion representing its share in the counterfactual scenario.

Baseline emissions are calculated by summing the emissions from each fertilizer type in the baseline mix, weighted by their proportion and using appropriate emission factors (EFs):

$$E_{PCF,\,baseline} = \sum_{i=1}^{n} (A_i \times N\%_i \times EF_i) \quad (2)$$

Where:

i	=	index of each fertilizer type in the baseline mix
A_i	=	application rate of fertilizer i, derived from the total Nut-rate and share of fertilizer i, in kg product/ha
$N\%_i$	=	nutrient content of fertilizer i, in % by weight
EF_i	=	emission factor associated with fertilizer type i , in kg CO_2e per kg N applied

The total baseline Nut-rate (kg N/ha) is apportioned across the baseline fertilizer mix in proportion to each product's share. This ensures that the sum of N from all fertilizers equals the total baseline Nut-rate, even if N% varies across fertilizers. As such,

$$A_i = \left(\frac{Nrate \times S_i}{N\%_i}\right) \quad (3)$$

Where:

$Nrate$	=	total baseline Nut-rate, in kg N/ha

S_i	=	share of fertilizer i in the baseline mix (e.g., 0.5 for 50%)

4.1.b Project PCF emissions

Project emissions represent the GHG emissions resulting from the actual implementation of the intervention using a low-carbon product. The project fertilizer is the actual product applied under the intervention scenario. Its total N content and product composition must be clearly documented and verifiable.

If only one low-carbon fertilizer product is used, the project emissions are calculated as:

$$E_{PCF,\,project} = A \times N\% \times EF \qquad (4)$$

Where:

A	=	application rate of low-carbon fertilizer, in kg product/ha
$N\%$	=	nutrient content of low-carbon fertilizer, in % by weight
EF	=	emission factor associated with the low-carbon fertilizer, in kg CO_2e per kg N applied

If more than one low-carbon fertilizer product is used, project emissions must be calculated using a weighted Sum (Σ) approach, based on each product's share in the overall N applied:

$$E_{PCF,\,project} = \sum_{j=1}^{n} (A_j \times N\%_j \times EF_j) \qquad (5)$$

Where:

j	=	index of each low-carbon fertilizer type in the project
A_j	=	application rate of low-carbon fertilizer j, in kg product/ha
$N\%_j$	=	nutrient content of fertilizer j, in % by weight
EF_j	=	emission factor associated with low-carbon fertilizer type j, in kg CO_2e per kg N applied

4.2. Transportation of fertilizers (baseline or project)

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

$$E_2 = \sum_{c} \sum_{x} (EF_m \cdot Q_{x,c,m} \cdot D_{x,c,m}) \quad (6)$$

Where:

E_2	=	Emissions of the transportation of fertilizers (tCO_2e/year)
EF_m	=	Emission factor of the mode of transportation m (tCO_2e/tonne-km)
$Q_{x,c,m}$	=	Quantity of fertilizer product x sent to fertilizer usage location c via the mode of transportation m (t/year)
$D_{x,c,m}$	=	Distance traveled of fertilizer product x to the fertilizer usage location c via the mode of transportation m (km). If the specific fertilizer 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.

4.3 Field spreading of fertilizers (baseline or project)

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 year (N_f).

$$E_3 = \sum_{cf} \sum_{mf} (EF_{mf} \cdot D_{cf,mf} \cdot N_f) \quad (7)$$

Where:

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

4.4 Application of fertilizers

Fertilizers emit greenhouse gases (GHGs) when applied to fields, with nitrogen-based fertilizers having significant GHG emissions, primarily as nitrous oxide (N_2O). For example:

- During the usage of nitrogen fertilizers, both direct and indirect GHG emissions are generated (Menegat et al., 2022). Direct N_2O emissions are those emitted directly from the fields where fertilizers are applied. Indirect N_2O emissions occur when nitrogen lost to the atmosphere as NH_3 (from ammonia volatilization) or leached as nitrate into water systems is later converted to N_2O outside the original application site (Lam et al., 2018).
- In contrast, phosphorus-based (P) and potassium-based (K) fertilizers typically do not emit substantial quantities of GHGs emissions. However, if the project produces a P or K-based fertilizer that emits significant GHGs compared to the baseline, those emissions must be accounted for, and the method for calculating and verifying these emissions must be provided.

As mentioned in section 3. Baseline scenario, if the GHG project aims to produce a new type of fertilizer, which will replace a commonly used fertilizer, the project developer must provide proof of the effect of this new fertilizer when compared to the baseline fertilizer, on GHG emissions and crop yield. The quantification of this effect can be achieved through the use of an appropriate methodology or framework.

The project developer must select such a methodology or framework that fits with the particular project (fertilizer type, soil type, soil characteristics, crop growth conditions, crop type, etc.). An example of such a methodology is presented in the Appendix C, which is based on the IPCC guidelines.

As such, two scenarios are identified, based on the effect of the fertilizer on the GHG emissions:

Positive GHG impact

If emissions from the project's fertilizer application are estimated to be **lower** than those associated with the baseline’s fertilizer product, the GHG reduction can only be claimed after these estimations have been calculated using a relevant methodology and validated through cross-verification with field data (e.g. farmer log). If the impact is estimated to be minimal, it must be approached conservatively, and such reductions must not be claimed without substantial empirical evidence, in order to avoid the risk of claiming unrealized GHG impact.

Negative GHG impact

If emissions from the project’s fertilizer product application are estimated to be **higher** than those associated with the fertilizer product that was used in the baseline scenario, the GHG reduction must always be quantified. If the emissions are substantial enough to offset the positive impacts of all other phases, the project must be thoroughly reviewed. In such a case, it may be necessary for the project developer to redesign the fertilizer product and re-evaluate its chemical properties to mitigate these excess GHG emissions.

4.5 Evidence for PCF EF

- 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[21]:
    - 1) fertilizer producers through verified Environmental Product Declarations (EPDs), PCFs or sustainability reports[22],
    - 2) widely accepted industry tools and platforms, such as CoolFarmTool, ecoinvent, Agri-footprint database,
    - 3) Tier 1-2 industry reports such as the one published by the International Fertilizer Society titled "*The carbon footprint of fertilizer production: regional reference values*"[23] or,
    - 4) Relevant scientific literature
- Project developers must prioritize Tier 3 emission factors: product- and supplier-specific PCFs based on primary data (e.g. EPDs, LCAs, or manufacturer-declared footprints aligned with ISO 14067 or GHG Protocol). If Tier 3 data is not available, the use of Tier 2 or Tier 1 values must be justified (also see Appendix A: Data selection).
- All emission factors must be:
    - Validated (e.g. third-party verified or traceable to the producer),
    - Recent (preferably <10 years),
    - Technologically and regionally appropriate, and
    - Consistent with the project boundaries.

4.6 Notes on calculations

1. **Partial nutrient substitution within multi-nutrient fertilizers (e.g., NPK) is allowed**. For example, if only one nutrient component of an NPK fertilizer is replaced with a low-carbon alternative (e.g., replacing conventional urea in an NPK 15-15-15 with low-carbon urea):
    - The project emissions calculation must isolate the N component of the product.
    - The carbon footprint of the other components remains unchanged and is treated as neutral or excluded.
    - Emission reductions are only claimed for the difference in EF for the low-carbon nutrient fraction.

[21] The selection must be justified in the POD by the project developer
[22] An example of which activities should be included in such a PCF is presented in the Appendix D: Product Carbon Footprint (PCF)
[23] https://www.fertilizerseurope.com/wp-content/uploads/2020/01/The-carbon-footprint-of-fertilizer-production_Regional-reference-values.pdf

    - The project developer must clearly document the composition of the NPK fertilizer, the substitution pathway, and any assumptions made about the emissions associated with the P and K components.
2. **Interventions targeting upstream inputs (e.g., low-carbon ammonia) are allowed**. If the intervention involves switching to low-carbon ammonia as a precursor input, and not directly the final fertilizer type:
    - The project EF must reflect the reduction in cradle-to-gate emissions due to the use of low-carbon ammonia in the production process.
    - In this case, the EF of the final fertilizer product (e.g., urea, AN, UAN) is adjusted downward based on LCA or process data comparing conventional and low-carbon ammonia inputs. Projects must demonstrate traceability and control over the supply chain to credibly attribute emissions reductions to upstream interventions like low-carbon ammonia.
    - For upstream interventions (e.g., ammonia), double-counting must be avoided, as the same reduction cannot be claimed both by the fertilizer producer and the end-user unless clearly delineated by market rules or accounting frameworks.
3. Project developers must prioritize the use of the most specific and accurate emission factor (EF) data available, following the hierarchy: Tier 3 > Tier 2 > Tier 1. Tier 3 EFs, derived from site- or product-specific measurements or life cycle assessments are preferred, as they offer the highest contextual accuracy. If unavailable, developers must use Tier 2 EFs based on national or regional data, and only rely on Tier 1 IPCC defaults as a last resort. All EF sources must be transparently documented, including their tier level, origin, and justification for use.

4.7 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 [24] 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

[24] https://ghgprotocol.org/calculation-tools-and-guidance

(IPCC) Guidelines for National GHG Inventories. The tool is supplemented by a guidance document [25], which describes the functionality of the tool and gives a better understanding of how to prepare, interpret, and utilize uncertainty assessments. 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 type of projects using Tier 1 or Tier 2 data, a simplified, conservative approach must be followed to ensure robustness of estimates:

- **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 reductions.
- **Meta-Analysis Based Factors**: When using meta-analyses to derive emission factors or emission reduction percentages, developers should combine multiple context-specific variables, such as soil type, crop type, application rate, and product characteristics, to ensure the selected EF (from the EF ranges) is both conservative and grounded in the most relevant evidence.
- **Regional Deduction**: For sourcing region types of projects, a fixed 5% deduction (as explained in section 2.3 Spatial boundaries) must be applied to the estimated reductions to account for the higher uncertainty associated with aggregated data and absence of field-level monitoring.

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

[25] https://ghgprotocol.org/sites/default/files/2023-03/ghg-uncertainty.pdf

5. Net GHG emissions reductions

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 actual project details.

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:

$$ER = BE - PE - LE \tag{8}$$

Where:

ER	=	Net GHG emissions reduction (tCO_2e)
BE	=	Baseline emissions (tCO_2e)
PE	=	Project emissions (tCO_2e)
LE	=	Leakage emissions (tCO_2e)

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

6. Monitoring, Reporting and Verification

The MRV process is a structured approach to quantifying, tracking, reporting, and verifying greenhouse gas (GHG) emissions and reductions achieved through the distribution or use of low-carbon 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 [26].

The monitoring plan includes:

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

6.1 Monitoring

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

A. **Project scoping:** Key project details defined before the project start, submitted once during the POD validation phase (see *Table 2).*
B. **Project design parameters:** Variables monitored and reported during each verification cycle to ensure compliance and accuracy (see *Table 3*). Those must be completed for each specific intervention that is outlined in the project scoping. As seen in *Table 3*, the evidence required for these design parameters primarily rely on traditional methods such as farmer logs and market-based assessments. Where feasible, it is recommended to integrate for advanced approaches such as satellite monitoring, IoT sensors, and blockchain-based recordkeeping in regional approaches, to enhance efficiency, accuracy, and transparency.
C. **Project impact:** Outcomes calculated during each verification cycle (see *Table 4*), based on the monitored project design parameters. Again, the impact must be calculated and presented separately for each intervention in scope.

[26] https://proba.earth/hubfs/Product/The_Proba_standard.pdf?hsLang=en

Table 2: Project scoping

Index	***Name***	***Description***	***Background from this methodology***	***Evidence required***	***Frequency of reporting***
A1	Scope of activities	Present list of interventions that are in scope of the project, on the LMU or on the Sourcing Region level	Section 2.1 Scope of activities	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 GHG emissions	N/A	
A3	Spatial boundary and size (hectares or similar)	Present coordinates delineating the: • locations of the field (for Land Management Unit level boundary) • boundaries of the region (for Sourcing Region level boundary)	Section 2.3 Spatial boundaries	Satellite imagery, coordinates	
A4	Temporal boundary (for monitoring)	Define the temporary boundary for the project	Section 2.4 Temporal boundaries	N/A	

Table 3: Project design parameters for Land Management Unit level intervention

Index	Category name	Subcategory name	Description	Evidence required for baseline[27]	Evidence required for project	Frequency of reporting
B1.1	Crop type	-	Type of crop being cultivated	Farmer log or market based information	Farmer log	Reconfirmed or updated for every verification
B1.2	Fertilizer	PCF	Cradle to gate emissions	• Third party verified manufacturer's PCF report • Relevant literature values • National/regional PCF datasets	• Third party verified manufacturer's PCF report • Relevant literature values • National/regional PCF datasets	
		Type	Type of fertilizer (mix) being applied	Market based information or farmer log (historical-regional approach, see 3. Baseline scenario)	Proof of purchase and product label	
		Nut-rate	Nutrient application rate (NPK) in each fertilizer	Market based information or farmer log (historical-regional approach, see 3. Baseline scenario)	Fertilizer product description (f.i. label or safety data sheet)	
		Application rate & method	Application rate of the fertilizer(s) & method, timing, splitting	Farmer log or market based information	Farmer logs detailing actual application dates, rates, and area covered for each fertilizer applied. If Nut-rate reduction is part of the intervention, also supply scientific evidence.	
B1.3	Crop yield	-	Amount of crops harvested	Farmer log or market based information	Proof of crop yield productivity (e.g., crop insurance reporting records)	

[27] As described in section 3. Baseline scenario, the baseline is dynamic and must be updated at least every two years.

Index	Category name	Subcategory name	Description	Evidence required for baseline[27]	Evidence required for project	Frequency of reporting
B1.4	NutUE	-	Nutrient use efficiency, which must be compared to historical or regional benchmark NutUE values to verify that the baseline practices are following the region's guidelines	Market based information or farmer log (historical-regional approach, see 3. Baseline scenario)	Calculated based on crop yield and Nut-rate	
B1.5	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	
B1.6	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	
B1.7	(Optional) Additional management practices	-	Optional only if additional management practices are implemented, along with the low-carbon fertilizer, which lead to an extra reduction of GHG emissions	-	• Scientific evidence of the emission factor, that is related to this intervention • Proof that the additional practice actually took place (remote sensing, video imagery, farmer log, or similar)	
B1.8	Emission	-	List of EFs selected for each	See Appendix A: Data selection		

Index	Category name	Subcategory name	Description	Evidence required for baseline[27]	Evidence required for project	Frequency of reporting
	factors		activity in scope. Source, justification, and tier (1–3) of all EFs used in calculations			

Table 5: Project design parameters for Sourcing Region level intervention

Index	Category name	Subcategory name	Description	Evidence required for baseline	Evidence required for project	Frequency of reporting
B2.1	Crop types	-	The types of crops grown in the region, allowing emissions to be weighted based on the proportion of total cultivated hectares for each specific crop	Regional databases / sources	Regional databases / sources	Reconfirmed or updated for every verification
B2.2	Fertilizer	Types	Types of fertilizer mix being applied on the region	Market based information (historical-regional approach, see 3. Baseline scenario)	Proof of sale (or purchase) of fertilizer	
		Nut-rate	Nutrient application rate in each fertilizer	Market based information (historical-regional approach, see 3. Baseline scenario)	Proof of sale (or purchase) of fertilizer	
		Application rate	Average application rates of the fertilizers	Regional databases / sources	Regional databases / sources	
B2.3	Crop yield	-	Average crop yields (for NutUE check)	Regional databases / sources	Farmer log or sale proof from a representative sample of farmers	

Index	Category name	Subcategory name	Description	Evidence required for baseline	Evidence required for project	Frequency of reporting
B2.4	NutUE	-	For transparency purposes it is recommended to present the relevant (to the project interventions) NutUE of the region	Regional databases / sources	Calculated based on crop yield and average application rates	
B2.5	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	
B2.6	Emission factors	-	List of EFs selected for each activity in scope. Source, justification, and tier (1-3) of all EFs used in calculations	See Appendix A: Data selection		

Table 4: Project impact (for LMU or Sourcing Region type of projects intervention)

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

6.2 Reporting

To ensure transparency and accountability, monitoring reports must contain:

- A general description of the project:
  - For LMU type of projects: the location and outline of individual fields where fertilizer products would be applied and baseline emissions would occur.
  - For Sourcing Region projects: the defined regional boundary and the aggregate intervention area across the sourcing region.
- A description of the data collection process, frequency of monitoring, and procedures for archiving data, as presented in section 6.1 Monitoring. Note that in this methodology the baseline is dynamic and must be updated according to section 3. Baseline scenario.
- A recordkeeping plan to maintain accurate documentation that shows when and where fertilizer application has occurred:
  - For LMU type of projects: This includes field records, field investigations, farm implementation measures, machinery receipts, delivery notes and/or invoices
  - For Sourcing Region type of projects: This includes fertilizer product distribution data, regional sales volumes, or aggregation of application reports from participating cooperatives or farming associations
- The roles of individuals involved in monitoring and data collection (e.g., responsibilities).
- 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

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

References

Chai, R., Ye, X., Ma, C., Wang, Q., Tu, R., Zhang, L., & Gao, H. (2019). Greenhouse gas emissions from synthetic nitrogen manufacture and fertilization for main upland crops in China. Carbon Balance and Management, 14(1). https://doi.org/10.1186/s13021-019-0133-9

Clean Development Mechanism (CDM). (n.d.). Assessment tool for the methodological approach to leakage in agriculture, forestry, and other land use projects. https://cdm.unfccc.int/EB/050/eb50_repan13.pdf

Clean Development Mechanism (CDM). (n.d.). Tool for the demonstration and assessment of additionality. https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-02-v7.0.pdf

Fertilizers Europe. (2020). The carbon footprint of fertilizer production: Regional reference values. https://www.fertilizerseurope.com/wp-content/uploads/2020/01/The-carbon-footprint-of-fertilizer-production_Regional-reference-values.pdf

GHG Protocol. (n.d.). Calculation tools and guidance. https://ghgprotocol.org/calculation-tools-and-guidance

GHG Protocol. (2022). Quantifying greenhouse gas emissions. https://ghgprotocol.org/sites/default/files/2022-12/Chapter3.pdf

GHG Protocol. (2023). Uncertainty in greenhouse gas inventories. https://ghgprotocol.org/sites/default/files/2023-03/ghg-uncertainty.pdf

Hoxha, A., Christensen, B., & International Fertiliser Society. (2018). The carbon footprint of fertiliser production : regional reference values. Colchester: International Fertiliser Society. https://www.fertilizerseurope.com/wp-content/uploads/2020/01/The-carbon-footprint-of-fertilizer-production_Regional-reference-values.pdf

International Fertilizer Association (IFA). (2020). The SDGs and sustainable fertilizer production. https://www.fertilizer.org/wp-content/uploads/2023/01/2020_IFA_The_SDGs_and_Sustainable_Fertilizer_Production.pdf

Kim, G. W., Alam, M. A., Lee, J. J., Kim, G. Y., Kim, P. J., & Khan, M. I. (2017). Assessment of direct carbon dioxide emission factor from urea fertilizer in temperate upland soil during warm and cold cropping season. European Journal of Soil Biology, 83, 76–83. https://doi.org/10.1016/j.ejsobi.2017.10.005

Lam, S. K., Suter, H., Davies, R., Bai, M., Mosier, A. R., Sun, J., & Chen, D. (2018). Direct and indirect greenhouse gas emissions from two intensive vegetable farms applied with a nitrification inhibitor. Soil Biology & Biochemistry, 116, 48–51. https://doi.org/10.1016/j.soilbio.2017.10.008

Menegat, S., Ledo, A., & Tirado, R. (2022). Greenhouse gas emissions from global production and use of nitrogen synthetic fertilizers in agriculture. Scientific Reports, 12(1). https://doi.org/10.1038/s41598-022-18773-w

South Coast Air Quality Management District (SCAQMD). (n.d.). Guidelines for fugitive emissions calculations. https://www.aqmd.gov/docs/default-source/planning/annual-emission-reporting/guidelines-for-fugitive-emissions-calculations.pdf

United Nations. (n.d.). Sustainable Development Goals. https://sdgs.un.org/goals

Yara International. (2022). Fertilizer industry handbook. https://www.yara.com/siteassets/investors/057-reports-and-presentations/other/2022/fertilizer-industry-handbook-2022-with-notes.pdf

Zoeteman, B. C. J., van de Meent, D., & Vermaat, J. E. (2021). Sustainable development goal impact assessment tool. https://sdgimpactassessmenttool.org/en-gb

Appendix A: Data selection

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. Here's a detailed look at each:

Table 5: Tier 1, 2 and 3 explanation

Tier 1	Tier 2	Tier 3
This is the most basic level of calculation which uses default emission factors provided by the IPCC or other authoritative sources. These factors are generally based on a **broad average of data** and are meant for use when more specific data are not available. It is ideal for initial assessments, small-scale projects, or regions where data collection capabilities are limited. It requires the least amount of data and provides estimates that are less precise.	These methodologies are more accurate than Tier 1 and involve **country-specific or region-specific** emission factors. These factors take into account the specific characteristics of fuels or technology used in a particular geographic area. They are used when more detailed, reliable data are available and a greater degree of accuracy is required.	This is the most sophisticated level that uses highly **detailed data and advanced statistical or modeling techniques**. This tier often involves continuous emission measurements and may incorporate real-time data collection. It is appropriate for detailed monitoring and reporting, often used in large industries or for regulatory compliance where precise data tracking is necessary.

When evaluating data sources, the project developer must prioritize them in the following order: Tier 3, Tier 2, and Tier 1. This hierarchy ensures that the most robust and reliable data is used first, minimizing potential uncertainty. More information on the impact of data quality on the Uncertainty Factor can be found in section 7. Net GHG emissions reductions.

Tier 3 sources, as defined by the IPCC, offer the highest level of accuracy and detail, making them the most reliable for greenhouse gas (GHG) emissions reporting and inventory management. Tier 2 sources provide moderate accuracy and detail, serving as a secondary option when Tier 3 data is not available. Tier 1 sources are the least detailed and accurate, used only when higher-tier data cannot be accessed. This prioritization ensures the most precise and credible data for effective GHG emissions management.

Overall, baseline emissions must not be overestimated and project emissions underestimated, to guarantee true impact. When in doubt and if no Tier 3 values are available, lower values should be used for baseline emissions (best in class), and higher values should be used for project emissions.

If available, the Project Developer should use a 3-year average of the available data. When a range of relevant data is available (quantities or emission factors) the most **conservative** should be selected, so that the GHG yield is not overestimated.

Appendix B: CO_2e and Global Warming Potential

CO_2e is a metric used to compare the emissions of various greenhouse gases based on their Global Warming Potential (see GWP definition). It expresses the impact of different gases in terms of the equivalent amount of CO2, facilitating a standardized approach to assessing overall greenhouse gas emissions.

The table below lists the GWP of three key greenhouse gases relative to CO_2:

Table 6: Carbon dioxide equivalents per GHG [28]

Greenhouse Gas	Chemical Formula	Global Warming Potential (GWP)
Carbon Dioxide	CO_2	1
Methane (n-f)	CH_4	29.8
Nitrous Oxide	N_2O	273

As such, the equation for calculating the emissions of a GHG expressed in CO_2e is the following:

$$E_{CO_2e} = E_{GHG} \cdot GWP \tag{9}$$

Where:

E_{CO_2e}	=	Emissions of GHG expressed in CO_2e (t CO_2e/year)
E_{GHG}	=	Emissions of GHG (t GHG/year)
GWP	=	Global warming potential of GHG (t CO_2e/t of GHG)

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

Appendix C: Application emissions calculation example

Illustrative example of minimal impact

Let's assume the case of low-carbon ammonia, which is produced by using renewable energy sources, and differs from the conventional ammonia (which is produced by traditional fossil-fuel-based methods) **only in its production phase**.

While it offers significant environmental benefits during production by reducing GHG emissions, once synthesized, low-carbon ammonia has **chemical properties identical to those of conventional ammonia-based products**.

Therefore, when applied in agricultural fields, the emissions associated with green ammonia are **similar** to those from conventional ammonia-based products. This means that there is no delta in the GHG emissions of the fertilizer application activity, and as such no credits should be issued based on the field application.

Usage of IPCC GHG calculation procedures

In estimating direct and indirect emissions of N_2O, the methodology utilizes terminology and emission factors presented in the most recent refinement of 2019 to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories[29]. The 2019 updates introduce a categorization of emission factors regarding different conditions such as wet and dry climates, and different fertilizer types including urea, ammonium-based, nitrate-based, and ammonium-nitrate-based. The correct emission factor should be chosen according to the specific characteristics of the project. The Project Developer must review the IPCC document and select the appropriate option to conduct the calculations. In the following table, the emission factors that are presented in the IPCC report are described.

Table 7: Emission factors for fertilizer application based on the IPCC report

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

Emission factor	Description	Value	Units	When to use
EF_1	Direct N_2O emissions from nitrogen inputs to managed soils	0.01	kg N_2O-N per kg N input	When applying inorganic or organic nitrogen fertilizers, incorporating crop residues, or when nitrogen is mineralized from soil organic matter due to land-use change.
EF_{1FR}	Direct N_2O emissions from flooded rice fields	0.004	kg N_2O-N per kg N input	When nitrogen fertilizers are applied to flooded rice paddies.
EF_2	N_2O emissions from drained/managed organic soils	Varies (see IPCC 2013, Table 2.5 [30])	kg N_2O-N per ha	When organic soils (like histosols) are drained or managed for agriculture.
EF_{3PRP}	Direct N_2O emissions from urine and dung deposits	0.004	kg N_2O-N per kg N deposited	When grazing animals deposit urine and dung directly on pastures, ranges, or paddocks.
EF_4	Indirect N_2O from atmospheric deposition of NH_3 and NO_x	0.01	kg N_2O-N per kg NH_3-N and NO_x-N	When nitrogen volatilized as ammonia (NH_3) or nitrogen oxides (NO_x) from applied fertilizers or manure and is then redeposited on land or water.
EF_5	Indirect N_2O from leaching and runoff	0.0075	kg N_2O-N per kg N leached/runoff	When nitrogen from fertilizers or organic amendments is lost through leaching or runoff, especially in areas with high rainfall or irrigation.

Note: If there is adequate scientific evidence that provides region-specific emission factors, considering the local climatic conditions, soil types, and crop characteristics, etc, these emission factors should be used for the calculations instead of the default IPCC values.

Direct emissions

$$E_{N2O\_Direct} = (FSN + FON) \cdot EF_1 \cdot MWN_2O \cdot GWPN_2O \tag{10}$$

$$FSN = MSN \cdot NCSN \tag{11}$$

[30] https://www.ipcc.ch/site/assets/uploads/2018/03/Wetlands_Supplement_Entire_Report.pdf

$$FON = MON \cdot NCON \tag{12}$$

Where:

E_{N2O_Direct}	=	Annual direct N_2O-N emissions from managed soils (kg N_2O-N $yr^{-1}ha^{-1}$)
FSN	=	Inorganic N fertilizer applied to soils (kg N $yr^{-1}ha^{-1}$)
FON	=	Organic N additions applied to soils (kg N $yr^{-1}ha^{-1}$)
MSN	=	Mass of N containing inorganic fertilizer applied, kg $yr^{-1}ha^{-1}$
MON	=	Mass of N containing organic fertilizer applied, kg $yr^{-1}ha^{-1}$
$NCSN$	=	N content of inorganic fertilizer applied g N (100g fertilizer)$^{-1}$
$NCON$	=	N content of organic fertilizer applied g N (100g fertilizer)$^{-1}$
MWN_2O	=	Ratio of molecular weights of N_2O to N (44/28), kg N_2O(kg N)$^{-1}$
$GWPN_2O$	=	Global Warming Potential for N_2O, CO_2e kg e (kg N_2O)$^{-1}$
EF_1	=	Emission factor for N_2O emissions from N inputs to managed soils (kg N_2O-N per kg N input)

Indirect emissions (Ammonia volatilization):

$$E_{N2O\_ATD} = (FSN \cdot FracGASF + FON \cdot FracGASM) \cdot EF_4 \cdot MWN_2O \cdot GWPN_2O \tag{13}$$

Where:

E_{N2O_ATD}	=	Annual indirect N_2O-N emissions from atmospheric deposition (kg N_2O-N $yr^{-1}ha^{-1}$)

$FracGASF$	=	Fraction of inorganic N fertilizer that volatilizes as NH_3 and NOx
$FracGASM$	=	Fraction of organic N additions and urine/dung that volatilize as NH_3 and NOx
EF_4	=	Emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces

Indirect emissions (Leaching and Runoff):

$$E_{N2O\_L} = (FSN + FON) \cdot FracLEACH(H) \cdot EF_5 \cdot MWN_2O \cdot GWPN_2O \tag{14}$$

Where:

E_{N2O_L}	=	Annual indirect N_2O-N emissions from leaching and runoff (kg N_2O-N $yr^{-1}ha^{-1}$)
$FracLEACH(H)$	=	Fraction of all N added/mineralized in managed soils that is lost through leaching and runoff
EF_5	=	Emission factor for N_2O emissions from N leaching and runoff (kg N_2O-N per kg N leached and runoff)

Total emissions (Direct + Indirect)

$$E_x = E_{N2O\_Total} = (E_{N2O\_Direct} + E_{N2O\_ATD} + E_{N2O\_L}) \cdot Nha \tag{15}$$

Where:

E_{N2O_Total}	=	Total emissions resulted from direct and indirect N_2O emissions
Nha	=	Total amount of hectares

Appendix D: Example of Product Carbon Footprint (PCF) activities

D.1. Scope of PCF

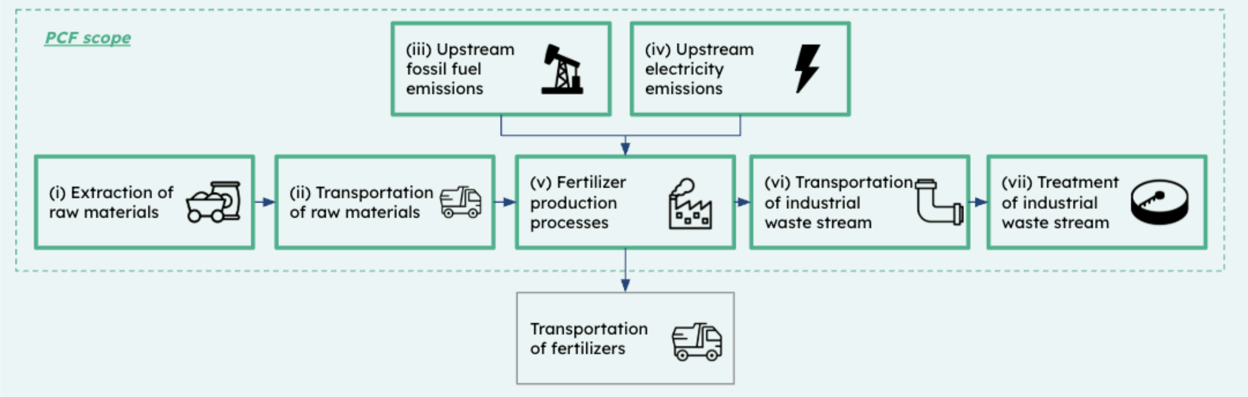


Figure 3: Activities in scope for the PCF calculation

This activities that should be taken into account in the PCF **include:**

- **Fertilizer production processes (v)**: The key production processes within a fertilizer factory, such as the ammonia and nitric acid production, are sources of GHG emissions.
- **Energy supply from fossil fuel (iii) and electricity (iv):** Many fertilizer factories rely on fossil fuels to power production processes and provide heat and electricity, directly contributing to GHG emissions. During the extraction, transportation and use of natural gas used in fertilizer production, methane can leak from pipelines and other infrastructure.
- **Other emissions:** Additional emissions related to fertilizer production can also be accounted for. While these sources typically have a lower impact compared to the emissions presented above, they are still significant. These sources include: extraction of raw materials (i), transportation of raw materials (ii), transportation of industrial waste stream (vi), treatment of industrial waste stream (vii).

Activities that do not need to be **included** in the PCF are:

- **Construction emissions**: The construction of the fertilizer factory generates GHG emissions primarily from the use of construction machinery, the manufacturing processes of building materials and transportation of these materials to the site. These activities predominantly release CO_2, contributing to the factory's initial carbon footprint. The GHG emissions related to the construction of the fertilizer factory are not included in this methodology, as it is assumed that the existing fertilizer factories had similar construction emissions. If these emissions are projected to be significantly higher or lower than those from existing fertilizer production facilities, a separate methodology should be employed to account for these differences. Similarly, for retrofit projects, a specific methodology should also be used to accurately account for these emissions. Land use changes resulting from the construction of raw material extraction and waste treatment facilities are not included in the scope of this methodology, unless the newly built operation/facility is located on the following types of land:

  - In the EU: land that has been deforested later than December 31st, 2020[31]
  - Wetland/peatland
  - Land that is within or partly within a protected area or natural reserve, such as: national parks, nature reserves, land marked as an indigenous reserve where land rights require consultation with the indigenous authority or land where local communities have traditional ownership or stewardship to use the land

- **Steam, heat and cooling upstream and transmission and distribution (T&D) emissions:** Steam, heat, and cooling are assumed to be part of the production processes and not supplied from a third party. As such, this methodology does not account for the related upstream and T&D emissions of steam, heat, and cooling. In case the new fertilizer facility is part of an industrial park and receives these utilities from another production facility, then these emissions should also be included in the calculations. If the steam, heat or cooling provided to the fertilizer facility is a by-product of another process and would otherwise go unused, assigning them zero emissions can be justified. This is because these emissions would have occurred regardless of the fertilizer production, and utilizing this by-product improves overall efficiency by avoiding additional emissions. However, setting these emissions to zero should be decided on a case-by-case basis and properly justified.
- **Transportation of employees to the factory:** The transportation of employees to and from the factory contributes to GHG emissions, primarily through the use of fossil fuel-powered vehicles. These emissions are deemed out of scope for the boundaries of this calculation. Employee transportation does not reflect the core operational changes and is deemed negligible relative to the production level changes.
- **Temporary capture of carbon in fertilizers:** Commonly used fertilizers, such as urea ($CO(NH_2)_2$), might contain carbon. However, the carbon in such fertilizers is not sequestered; it is part of the molecular structure that decomposes in the soil, eventually converting back to CO_2 through microbial activity and chemical processes.[32] As such this temporary capture of carbon is not included in the methodology's calculations, as it is

[31] Aligned with the cut-off date from the European Regulation on Deforestation-free products (EUDR)
[32] https://www.fertilizerseurope.com/wp-content/uploads/2020/01/The-carbon-footprint-of-fertilizer-production_Regional-reference-values.pdf

expected that the produced fertilizer will be applied on the field and the carbon will be converted back to CO_2.

- **Packaging emissions**: Packaging emissions stem from the production, transportation and disposal of fertilizer bags, primarily releasing CO_2 during manufacturing and additional methane (CH_4) and CO_2 if decomposed in landfills. This methodology excludes these emissions, assuming there will not be a material change in packaging compared to the baseline. If a GHG Project introduces packaging methods significantly altering emissions, a separate methodology is required to account for these changes.

- **Storage Emissions**: Such emissions originate from the energy used for heating, cooling and ventilation in fertilizer storage facilities, primarily generating CO_2. These emissions are excluded from the methodology because it assumes the commonly used fertilizers are stored under similar conditions, resulting in equivalent emissions.

D.2. Example of calculating the PCF

Below, a summary of the equations per activity along with the emission factors and activity data is presented.

Table 8: Summary of equations used to calculate the total emissions

Activity	Emission factors needed	Activity data needed
(i) Extraction of raw materials $E_i = \sum_l \sum_r (EF_{r,l} \cdot Q_{r,l})$	- Emission factors of the extraction of raw materials per extraction location	- Quantities of extracted raw materials
(ii) Transportation of raw materials $E_{ii} = \sum_l \sum_r (EF_m \cdot Q_{r,l,m} \cdot D_{r,l,m})$	- Emission factors for each mode of transportation used by suppliers, per region (as EF can vary from region to region)	- Quantities of transported raw materials by sourcing location/supplier - Distance traveled by each mode of transport for each raw material stream
(iii) Upstream fossil fuel emissions $E_{iii} = \sum_f (EF_{u,f} \cdot Q_f)$	Supplier-specific method - Fuel-provider-specific emission factors on extraction, production and transportation of fuels per unit of fuel consumed Average-data method - Average emission factors for upstream emissions per unit of consumption	- Quantities and types of fossil fuel consumed
(iv) Upstream electricity emissions	Supplier-specific method - Emission factor of the upstream emissions of (purchased) electricity	- Electricity consumption

Activity	Emission factors needed	Activity data needed
$E_{iv} = \frac{EC}{(1-TDL)} \cdot EF_{u,z}$	- Transmission & distribution loss rate (%), specific to grid where energy is generated and consumed <u>Average-data method</u> - Grid-region, country, or regional emission factors of the upstream emissions of (purchased) electricity - Country/regional average transmission & distribution loss rate (%)	
<u>(v) Fertilizer production processes</u> $E_{v,a} = \sum_{x} \sum_{p} (EF_{p,x} \cdot Q_{x}) + FE$ *or* $E_{v,b} = \sum_{x} EF_{x} \cdot Q_{x} + FE$	<u>Process-specific method</u> - Emission factors of the production processes of the fertilizers (relevant for existing facility process change) <u>Average-data method</u> - Country/regional emission factor of the total production of the fertilizer (relevant for calculating the baseline in the case of greenfield facilities). Once the factory is operational the actual (Tier 3) data should be used.	- Quantities of produced fertilizers (or inputs consumed, depending on emission factor data), for each industrial process
<u>(vi) Transportation of industrial waste stream</u> $E_{vi} = \sum_{tf} \sum_{w} (EF_{m} \cdot Q_{w,tf,m} \cdot D_{w,tf,m})$	- Emission factors for each mode of transportation	- Quantities of different waste streams generated - Distance traveled by each mode of transport for each waste stream
<u>(vii) Treatment of industrial waste stream</u> $E_{vii} = \sum_{tf} \sum_{w} (EF_{w,tf} \cdot Q_{w,tf})$	- Emission factors of the waste treatment method per waste stream	- Quantities of waste streams going to the different waste treatment facilities

<u>(i) Extraction of raw materials</u>

The emissions are calculated for each raw material (r), based on the extraction location (l) from which it is sourced.

$$E_{i} = \sum_{l} \sum_{r} (EF_{r,l} \cdot Q_{r,l}) \tag{2}$$

Where:

E_i	=	Emissions of extraction of raw materials (tCO_2e/year)
$EF_{r,l}$	=	Emission factor of the extraction raw material r in location l (tCO_2e/t of raw material r)
$Q_{r,l}$	=	Quantity of raw material r extracted from location l for the fertilizer production per year (t of raw material r/year)

(ii) Transportation of raw materials

The emissions are calculated for each raw material (r), based on the distance between the extraction location (l) and the fertilizer factory, and the mode of transportation used (m).

$$E_{ii} = \sum_{l} \sum_{r} (EF_m \cdot Q_{r,l,m} \cdot D_{r,l,m}) \quad (3)$$

Where:

E_{ii}	=	Emissions of the transportation of raw materials (tCO_2e/year)
EF_m	=	Emission factor of the mode of transportation m (tCO_2e/tonne-km)
$Q_{r,l,m}$	=	Quantity of raw material m transported from location l via the mode of transportation m (t/year)
$D_{r,l,m}$	=	Traveled distance of raw material m from location l via the mode of transportation m (km)

(iii) Upstream fossil fuel emissions

These upstream emissions relate to the production, transportation and distribution of the fossil fuels, from the extraction site until the delivery to the fertilizer factory. They are calculated as the sum of the emissions of all the fossil fuels used for the production:

$$E_{iii} = \sum_{f} (EF_{u,f} \cdot Q_f) \quad (4)$$

Where:

E_{iii}	=	Emissions of the upstream of fossil fuels (tCO_2e/year)
$EF_{u,f}$	=	Emission factor of the upstream of fossil fuel f (tCO_2e/unit of fuel). Upstream fuel emission factor = life cycle emission factor – combustion emission factor
Q_f	=	Quantity of fossil fuel f produced and transported to the fertilizer factory (unit of fuel. For example, t/year, m^3/year, MJ/year, etc.)

(iv) Upstream electricity emissions

These emissions relate to the upstream emissions of (purchased) electricity, including the transmission and distribution losses. The emissions are calculated based on the total electricity consumed [33, 34].

$$E_{iv} = \frac{EC}{1-TDL} \cdot EF_{u,z} \tag{5}$$

Where:

E_{iv}	=	Emissions of the upstream of electricity (tCO_2e/year)
TDL	=	Transmission & distribution loss rate of the grid (%)
EC	=	Electricity consumption related to the fertilizer production (MWh/year)
$EF_{u,z}$	=	Emission factor of the upstream of electricity (tCO2e/MWh). Companies should check the emission factor source to establish whether or not T&D losses have been taken into account or not.

For industrial facilities that purchase 100% green electricity, since it is transported through the normal grid, any losses (typically 5-10%) will be replenished by the average electricity in the grid. In this case, the emission factor for the grid's upstream electricity should be applied, but only for the electricity lost during transmission.

Zero emissions from T&D losses can only be assumed in the following scenarios (accompanied by robust documentation and certification):

- There is a direct line from a renewable source (e.g. in the case of on-site PV installation or similar)

[33] https://ghgprotocol.org/sites/default/files/2022-12/Chapter3.pdf
[34] https://ghgprotocol.org/sites/default/files/2022-12/AppendixD.pdf

- There is a setup where all lost energy during T&D is contractually covered by additional renewable energy generation (sometimes managed through renewable energy certificates that include T&D)

(v) Fertilizer production processes

This stage includes the GHG emissions of all the industrial processes (p) within the fertilizer factory, including the consumption of fossil fuels as a feedstock or energy source.

Estimating emissions associated with each industrial process should be based on activity level data (Tier 3). The data for the calculations should be given based on the amount of material *produced* (e.g fertilizer) rather than *consumed* (e.g. natural gas). If the available data are consumption-based, proper conversion and a scientific explanation should be provided. The emissions of all the GHG should be accounted for and expressed as carbon dioxide equivalents (see Appendix A: Additional Information).

The first step is to conduct a thorough assessment of all potential sources of process and fugitive emissions in the factory.

Example process sources include:

- Steam Methane Reforming (SMR)
- Urea Production
- Nitric Acid Production
- Lime Calcination
- Fossil Fuel Combustion for Process Heat

Common fugitive sources include:

- Valves, flanges and joints in piping systems
- Seals and gaskets in equipment
- Storage tanks and containers
- Compressors, pumps and pressure relief devices
- Any connections or fittings that may leak
- Startup of backup furnaces

The total emissions from a factory are therefore calculated for each fertilizer product (x) and process (p):

$$E_{v,a} = \sum_{x} \sum_{p} (EF_{p,x} \cdot Q_x) + FE \tag{6}$$

Where:

$E_{v,a}$	=	Emissions of fertilizer production processes (tCO_2e/year)
$EF_{p,x}$	=	Emission factor of industrial process p, expressed for the amount of fertilizer x produced (tCO_2e/t of x)
Q_x	=	Quantity of fertilizer x produced (t of x/year)
FE	=	Fugitive emissions (tCO_2e/year) [35]

For the estimation of the baseline for greenfield facilities

If industry data are not available for each process but are available for the entire production, then the following formula can be used:

$$E_{v,b} = \sum_{x} EF_x \cdot Q_x + FE \tag{7}$$

Where:

$E_{v,b}$	=	Emissions of fertilizer production processes (tCO_2e/year)
EF_x	=	Emission factor of production for fertilizer x (tCO_2e/t fertilizer x)
Q_x	=	Quantity of fertilizer x produced (t of x/year)
FE	=	Fugitive emissions (tCO_2e/year)

For more information, see also the [2006 IPCC Guidelines for National Greenhouse Gas Inventories] (CHEMICAL INDUSTRY EMISSIONS).

[35] For a detailed method to calculate the fugitive emissions, see EPA's "*Greenhouse Gas Inventory Guidance: Direct Fugitive Emissions from Refrigeration, Air Conditioning, Fire Suppression, and Industrial Gases*" https://www.aqmd.gov/docs/default-source/planning/annual-emission-reporting/guidelines-for-fugitive-emissions-calculations.pdf

(vi) Transportation of industrial waste stream

The emissions are calculated for each waste stream (w), based on the distance between the fertilizer factory and the waste treatment/disposal facility (tf), and the mode of transportation used (m).

$$E_{vi} = \sum_{tf} \sum_{w} (EF_{m} \cdot Q_{w,tf,m} \cdot D_{w,tf,m}) \quad (8)$$

Where:

E_{vi}	=	Emissions of the transportation of the industrial stream (tCO_2e/year)
EF_{m}	=	Emission factor of the mode of transportation m (tCO_2e/tonne-km)
$D_{w,tf,m}$	=	Distance traveled of the waste stream w to treatment facility tf via the mode of transportation m (km)
$Q_{w,tf,m}$	=	Quantity of the waste stream w transported to treatment facility tf via the mode of transportation m (t/year)

(vii) Treatment of industrial waste stream

The emissions are calculated for each waste stream (w), based on the treatment process in each waste treatment/disposal facility (tf). The emissions of all the GHG should be accounted for and expressed as carbon dioxide equivalents (CO_2e) (see Appendix A: Additional Information).

$$E_{vii} = \sum_{tf} \sum_{w} (EF_{w,tf} \cdot Q_{w,tf}) \quad (9)$$

Where:

E_{vii}	=	Emissions of the waste treatment method (tCO_2e/year)
$EF_{w,tf}$	=	Emission factor of treating the waste stream w via the treatment process in the waste treatment facility tf (tCO_2e/t of waste w)
$Q_{w,tf}$	=	Quantity of waste stream w treated via the treatment process in the waste treatment facility tf (t of waste/year)

D.3. Example of PCF Documentation

The following design parameters and data should be accounted for to calculate the PCF:

Table 9: Design parameters

Design Parameter	Description	Activity	Data correlation	Proof for verification
$2r$	List of raw materials	(i), (ii)	-	Documentation from raw material suppliers
l	List of extraction locations of raw materials	(i), (ii)	Specify which raw materials (r) are extracted at each location (l)	Documentation from raw material suppliers
m	List of modes of transportation of raw materials, waste and fertilizer products	(ii), (vi), (viii)	Specify which raw materials (r), waste streams (w) and fertilizer products (x) are transported via each mode of transport (m)	Documentation from transportation service for the raw materials, waste streams and fertilizer products
f	List of fossil fuel used in fertilizer production	(iii)	-	Documentation from the fuel suppliers
p	List of industrial processes of the fertilizer production	(v)	-	Project proponent records
x	List of fertilizers produced	(v), (viii)	-	Project proponent records
w	List of waste streams	(vi), (vii)	-	Project proponent records and documentation from waste stream treatment facilities

tf	List of waste treatment facilities	(vi), (vii)	Specify which waste streams (w) are treated at each treatment facility (tf)	Documentation from waste stream treatment facilities

Table 10: Data (A)

Data	Description	Unit	Activity	Example Sources	Proof for verification
$EF_{r,l}$	Emission factor of the extraction raw material r in location l	tCO_2e/ t of raw material r	(i)	• https://ndep.nv.gov/uploads/air-permitting-docs/ndep-mining-emissions-guidance.pdf	Documentation from raw material suppliers.
EF_{m}	Emission factor of the mode of transportation m	tCO_2e/tonne-km	(i), (vi), (viii)	• https://www.cbo.gov/system/files/2022-12/58566-co2-emissions-transportation.pdf	Documentation types of vehicles used and their emission factors
$EF_{u,f}$	Emission factor of the upstream of fossil fuel f	tCO_2e/unit of fuel	(iii)	• https://unhsimap.org/cmap/resources/fera-naturalgas • https://pubs.acs.org/doi/10.1021/acs.est.2c01205 • https://www.epa.gov/climateleadership/ghg-emission-factors-hub • https://www.co2emissiefactoren.nl	-
$EF_{u,z}$	Emission factor of the upstream of electricity	tCO_2e/MWh	(iv)	• https://www.epa.gov/system/files/documents/2024-02/ghg-emission-factors-hub-2024.pdf • https://ember-climate.org/data-catalogue/yearly-electricity-data/ • https://ourworldindata.org/grapher/carbon-intensity-electricity • https://data.jrc.ec.europa.eu/dataset/919df040-0252-4e4e-ad82-c054896e1641 • https://iea.blob.core.windows.net/assets/69b838f4-12ad-4f51-9155-9da6435b5d53/IEA_UpstreamLifeCycleEmissionFactors_Documentation.pdf	Documentation from the energy provider. To prevent double-counting and double-claiming of greenhouse gas reductions, the project must provide verifiable evidence of using renewable electricity. Acceptable evidence includes Guarantees of Origin (GoOs), Renewable Energy Certificates (RECs), or a Power Purchase Agreement (PPA). A PPA is recommended as it provides the most robust assurance of direct linkage to a specific renewable energy source.
TDL	Transmission & distribution loss rate of the grid	Percentage	(iv)	• https://www.eia.gov/tools/faqs/faq.php?id=105&t=3 • https://data.worldbank.org/indicator/EG.ELC.LOSS.ZS • https://www.sciencedirect.com/science/article/pii/S2352484724001355#fig0045	Documentation from the energy provider
$EF_{p,x}$	Emission factor of industrial process p,	tCO_2e/t of product (or input) x	(v)	• Estimated (based on industry averages or existing processes) and then measured for the GHG Project	Documentation verifying the processes included and their emission factors

Data	Description	Unit	Activity	Example Sources	Proof for verification
	expressed for the amount of produced fertilizer x			calculations. • 2006 IPCC Guidelines for National Greenhouse Gas Inventories • Electrolysers (Direct carbon footprint of hydrogen generation via PEM and alkaline electrolysers) https://www.sciencedirect.com/science/article/abs/pii/S0360319923018189 Fugitive emissions: • https://www.epa.gov/sites/default/files/2015-07/documents/fugitiveemissions.pdf • https://www.aqmd.gov/docs/default-source/planning/annual-emission-reporting/guidelines-for-fugitive-emissions-calculations.pdf • https://online.ucpress.edu/elementa/article/doi/10.1525/elementa.358/112487/Estimation-of-methane-emissions-from-the-U-S	
EF_x	Tier 1 or 2 emission factor of production for fertilizer x	tCO_2e/t of fertilizer x	(v)	• https://www.fertilizerseurope.com/wp-content/uploads/2020/01/The-carbon-footprint-of-fertilizer-production_Regional-reference-values.pdf • https://fertiliser-society.org/store/energy-consumption-and-greenhouse-gas-emissions-in-fertiliser-production/ • https://www.sciencedirect.com/science/article/abs/pii/S0301479720311361?via%3Dihub • https://www.researchgate.net/publication/312569476_GHG_EMISSIONS_AND_ENERGY_EFFICIENCY_IN_EUROPEAN_NITROGEN_FERTILISER_PRODUCTION_AND_USE • https://cbmjournal.biomedcentral.com/articles/10.1186/s13021-019-0133-9	-
$EF_{w,tf}$	Emission factor of treating the waste stream w via the treatment	tCO_2e/t of waste w	(vii)	• https://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch6ref2.pdf	Documentation from the waste treatment facilities

Data	Description	Unit	Activity	Example Sources	Proof for verification
	process in the waste treatment facility tf				

Table 11: Data (B). These data are estimated for the POD and measured for the verification, monitoring and reporting

Data	Description	Unit	Activity	Measurement method
$Q_{r,l}$	Quantity of raw material r extracted from location l for the fertilizer production per year	t of raw material r/year	(i)	Documentation from the raw material supplier
$Q_{r,l,m}$	Quantity of raw material m transported from location l via the mode of transportation m	t/year	(ii)	Documentation from the transportation service
$D_{r,l,m}$	Distance traveled of raw material m from location l via the mode of transportation m	km	(ii)	Documentation from the transportation service
Q_f	Quantity of fossil fuel f produced and transported to the fertilizer factory	unit of fuel (t/year, m^3/year, MJ/year, etc.)	(iii)	Documentation from the fuel supplier
EC	Electricity consumption related to the fertilizer production	MWh/year	(iv)	Generally accepted measurement methods using calibrated tools (Digital Kilowatt-Hour Meters, smart meters, etc.)
Q_x	Quantity of fertilizer produced x	t of x/year	(v)	Generally accepted measurement methods using calibrated tools (belt/hopper scales, mass/volume flow meters, etc.)
FE	Fugitive emissions	tCO_2e/y	(v)	Generally accepted measurement methods using calibrated tools (Flame Ionization Detectors (FIDs), optical gas imaging, fixed and portable gas analyzers, etc.)
$Q_{w,tf,m}$	Quantity of waste stream w transported to treatment facility tf via the mode of transportation m	t/year	(vi)	Documentation from the transportation service
$Q_{w,tf}$	Quantity of waste stream w treated via the treatment	t of waste/year	(vii)	Documentation from the waste treatment facilities

Data	Description	Unit	Activity	Measurement method
	process in the waste treatment facility tf			

Appendix E: Different metrics of GHG emissions

A commodity-based approach for quantifying the impact is particularly relevant for downstream stakeholders. For example, a food company may want to use this data for their Product Carbon Footprint (PCF) reports or Life Cycle Assessments (LCAs), where the GHG emissions per tonne of crop is crucial. For a fertilizer producer, the focus may be on the GHG emissions per tonne of CRF product applied (again for the cradle-to-grave PCF/LCA), while for a farmer, the GHG emissions per hectare might be more relevant. In Table 12 the key metrics that can be applied are presented.

Table 12: Metrics that can be used for the project GHG emissions

Metric	***Description***	***Example***	***Unit***
Per unit of crop produced **[PCF of crop]**	This metric correlates emissions reductions to crop yield, making it valuable for assessing GHG emissions throughout the food supply chain. By expressing emissions reductions relative to the amount of crop produced, it helps food companies track improvements in sustainability while lowering their carbon footprint. This approach directly links emission reductions with crop yield.	Companies within the food industry (such as food producers) can use this metric to demonstrate that the production of their crops are associated with lower emissions	tCO_2e / ton of crop
Per unit of nitrogen containing fertilizer applied **[PCF of fertilizer]**	This metric demonstrates the emissions reductions achieved per ton of nitrogen fertilizer applied, providing insight into the efficiency of nitrogen use. It directly quantifies the impact of improved fertilizer management strategies, and demonstrates how much emissions are saved for every kilogram of fertilizer used.	Fertilizer companies looking to show progress in nitrogen use efficiency and claim reduction in their Scope 3 emissions.	tCO_2e / ton of fertilizer
Per unit of land area	This metric provides clear insights into GHG emissions reductions on a field level. By quantifying emissions reductions per hectare, this metric 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_2e / 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 emissions 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.