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

Methodology: Low-carbon fertilizer production

Production of inorganic fertilizers using more sustainable processes

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Contact Information	methodologies@proba.earth
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Table of Contents

Summary

This methodology document serves as a guide for evaluating the impact of adopting more sustainable practices in fertilizer production on reducing greenhouse gas (GHG) emissions compared to a baseline scenario. It is designed specifically for GHG Projects that focus on constructing new fertilizer production facilities (greenfield) or upgrading existing production facilities to produce low-carbon inorganic fertilizers, based on nitrogen, phosphorus, or potassium (NPK).

A monitoring procedure is included to ensure accurate, consistent, and credible measurement and reporting of the GHG emissions reductions. This procedure helps Project Developers to systematically evaluate and compare GHG emissions across different fertilizer production activities.

This methodology has been written in line with the "*Proba Standard*"[1] . It will be periodically reviewed and updated where needed to stay in line with the latest scientific consensus and regulatory context requirements, as described in the "Methodology Approval and Development Process" [2] document.

To effectively use this methodology document, Project Developers should follow the outlined procedures step-by-step, ensuring all data for GHGs emission calculation are accurately collected and reported. Additionally, they should follow any relevant updated versions or sections of the methodology and comply with the requirements to maintain the integrity and credibility of the Carbon Credits.

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

List of tables

List of figures

List of equations

List of definitions

Additionality	Refers to the concept that any GHG Project should result in greenhouse gas emissions improvements 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 business-as-usual 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	Hypothetical reference case that best represents the conditions most likely to occur in the absence of a proposed GHG Project.
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 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.
Carbon Credit	A Carbon Credit represents at least 1 tonne of CO2 (tCO2), 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[3]
Carbon footprint	The total amount of greenhouse gases (GHGs) emitted directly or indirectly by an individual, organization, event, or 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.
Conservativeness	Use of conservative assumptions, values, Methodologies, and procedures to ensure that GHG emission reduction or removal enhancements are not over-estimated.
Crediting Period	The "Crediting Period" refers to the specific duration of time during which a GHG Project is eligible to generate and issue Carbon Credits 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.

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

Denitrification	A microbial process in which nitrate (NO_3^-) is reduced to gaseous forms of nitrogen, including nitrous oxide (N_2O) and nitrogen (N_2), typically occurring under anaerobic conditions in soil.
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 based on fuel consumption, industrial processes, or agricultural practices, facilitating the estimation of a project's total greenhouse gas emissions.
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 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 removal enhancements. The intent of a GHG Project is to convert the GHG impact into Carbon Credits.
Global Warming Potential (GWP)	A metric that measures the heat absorbed by any greenhouse gas in the atmosphere, as a multiple of the heat that would be absorbed by the same mass of carbon dioxide (CO2). GWP is calculated over a specific time period, typically 100 years, providing a common scale for comparing the climate impact of different gases.
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.
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.
Leakage	In the context of a GHG Project, leakage refers to the unintended increase in greenhouse gas emissions outside the Projects Boundaries as a direct result of the Project's activities.
Leaching	The vertical movement of dissolved nutrients, such as nitrates, through the soil profile into groundwater. This process can lead to groundwater contamination and the indirect emission of nitrous oxide (N_2O), a potent greenhouse gas, when nitrates are converted by microbial activity in anaerobic conditions.
Nitrification	A microbial process in which ammonia (NH_3) in fertilizers is oxidized to nitrite (NO_2^-) and then to nitrate (NO_3^-). This process can produce nitric oxide (NO) and nitrous oxide (N_2O) as by-products.
Project Overview Document (POD)	A document that offers a detailed summary of a project's key elements, including governance, baseline 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 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 processes that produce nitrous oxide (N_2O).

Proba Standard	The Proba Standard aims at controlling and reducing the risks related to the GHG Projects, their climate impact (the Carbon Yield) and the corresponding issuance of Credits and subsequent claims. It does so by relying on and aligning with internationally recognized standards frameworks and initiatives such as the Core Carbon Principles by the ICVCM and the ICROA Code of Best Practice. The Proba Standard sets out detailed procedures for identification and validation of GHG Projects, and verification of emission reductions and removals, based on ISO 14064-2 . More information about the Proba Standard can be found at https://proba.earth/document-library.
Project Boundaries	The Project Boundaries of a GHG Project delineate the spatial, temporal, and operational limits within which the GHG emissions, reductions, and removals are quantified and monitored, encompassing specific activities, sources, sinks, and reservoirs related to the Project.
Tier 1, 2 and 3 data	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.

List of abbreviations

CDM	Carbon development mechanism
CO_2e	Carbon dioxide equivalents
GHG	Greenhouse gases
IFA	International Fertilizer Association
IPCC	Intergovernmental Panel on Climate Change
MRV	Monitoring, Reporting, and Verification
POD	Project overview document
T&D	Transmission and distribution
VVB	Validation and Verification Body

1. Introduction

1.1. Fertilizer production

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.

1.2. Applicability of methodology

This methodology is designed for GHG Projects focused on the production of low-carbon inorganic fertilizers, such as those based on nitrogen, phosphorus, or potassium.

It is applicable to projects upgrading existing facilities (retrofit) or constructing new fertilizer facilities (greenfield).

Applicability of this methodology, in terms of geographical boundaries, is not limited to a specific country or region.

This methodology is applicable for GHG Projects that have an impact on the fertilizer production related activities, as presented on *Figure 1*.

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

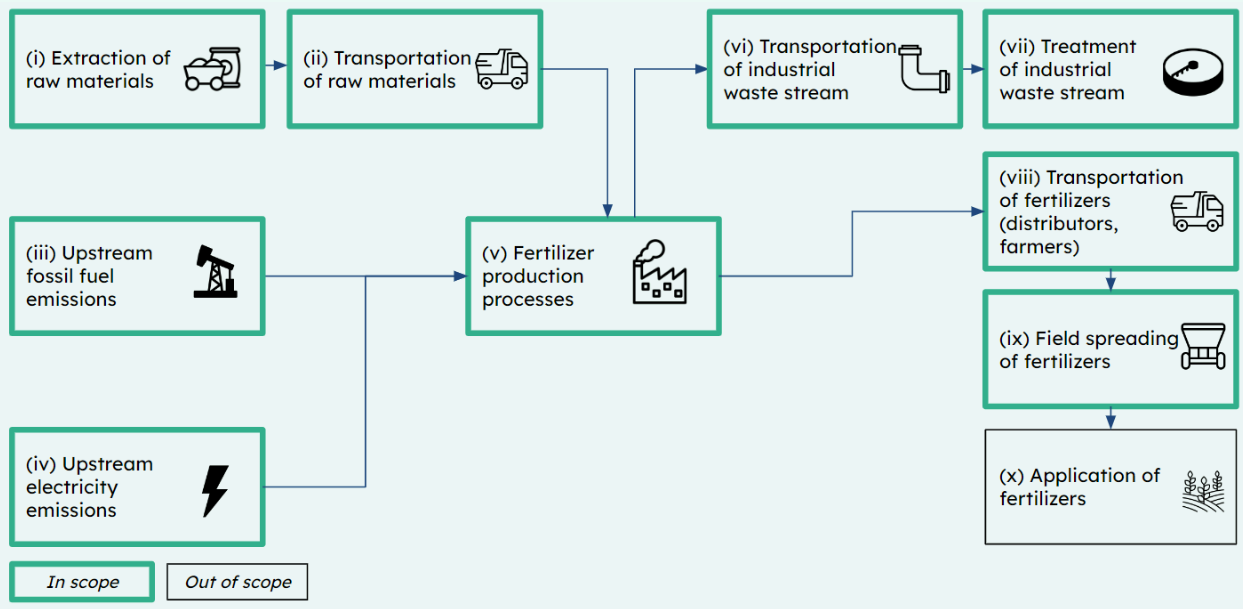

Figure 1: Activities in scope for applicable GHG Projects

This methodology **includes** calculations for the GHG emissions of the following activities:

- **Fertilizer production processes**: The key production processes within a fertilizer factory, such as the ammonia and nitric acid production, are sources of GHG emissions.
- **Energy supply (fossil fuel, electricity):** 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.
- **Transportation of fertilizers to the end-users:** The transportation of fertilizers from production sites to farms or retail centers involves the burning of fossil fuels, leading to CO_2e emissions. This includes emissions from vehicles and machinery used in the distribution process.
- **Other emissions:** This methodology also accounts for possible additional emissions related to fertilizer production. 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 (operational emissions), transportation of raw materials, transportation of industrial waste stream, treatment of industrial waste stream and fertilizer spreading on the fields (in case the spreading process is affected by the produced fertilizer).

Examples of more sustainable activities include, but are not limited to, using electrolysis (such as Alkaline or PEM) of water to produce (green) hydrogen, instead of relying on the Steam Methane Reforming process, and sourcing renewable energy, either directly from the grid or produced onsite at the factory. Additionally, implementing more efficient and less energy-intensive production processes or selling fertilizers locally, can further reduce emissions.

It should be noted that the impact of each activity on the GHG emissions can be positive or negative, when compared to the baseline, but the total net reduction (see section 7. Net GHG emissions reductions) must be positive to be eligible for issuing Carbon Credits.

This methodology **does not include** calculations for the GHG emissions of the following activities:

- **Fertilizer application emissions**: The application of the fertilizers in the field can lead to significant GHG emissions. For instance, when nitrogenous fertilizers are applied to soil, they can undergo nitrification and denitrification processes carried out by soil microbes. These processes can convert nitrogen from fertilizers into nitrous oxide (N_2O), which is then released into the atmosphere. Moreover, ammonia volatilization and the leaching of nitrogen into water bodies can indirectly lead to GHG emissions when these nitrogen forms are transformed into nitrous oxide in the environment. GHG Projects that produce fertilizers, which have an impact on the application emissions, must use an appropriate methodology or framework to quantify them. An example of how such emissions can be quantified based on IPCC guidelines is presented in the Appendix B.
- **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[5]
  - 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.[6] As such this temporary capture of carbon is not included in the methodology's calculations, as it is expected that the produced fertilizer will be applied on the field and the carbon will be converted back to CO_2.

[5] Aligned with the cut-off date from the European Regulation on Deforestation-free products (EUDR)

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

- **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.

1.3. Co-benefits & no harm principle

This methodology does not prescribe any calculation methods for quantifying additional benefits resulting from low-carbon fertilizer production.

Proba encourages low-carbon fertilizer production project 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). For instance, the SDG Impact Assessment Tool offers a structured approach to help assess and align projects with the SDGs[8]. *Figure 2* illustrates the SDGs related to sustainable fertilizer production, as presented in a report from the International Fertilizer Association (IFA)[9].

Figure 2: Sustainable Development Goals that are in line with sustainable fertilizer production

[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

Project Developers should 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 should be employed to ensure ongoing compliance with this principle throughout the project lifecycle. This process should be clearly defined and explained in the POD.

1.4. Crediting Period

Every GHG Project must define a Crediting Period. The Crediting Period is the timeframe within which the GHG program can issue credits for the project.

The Crediting Period should start at the beginning of the first yield period, but no later than 12 months after validation of the POD.

The Crediting Period can be renewed within the total project duration, providing it complies with the criteria defined in the section *"Crediting Period"* of the Proba Standard[10]. The renewal of the Crediting Period requires that the Project Developer must re-assess the baseline scenario, project additionality (regulatory, financial, prevalence) and project emissions with the new context, and where applicable, update the carbon reduction potential of the GHG Project.

For low-carbon fertilizer production projects, the Crediting Period should cover 5-8 years, depending on the trend in regulatory and industry landscapes toward more sustainable production practices. The selected Crediting Period should be properly justified in the POD.

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

2. Project boundary

2.1 Spatial boundary

The spatial boundary covers the activities that are related to the fertilizer production as presented on Figure 1.

2.2 Temporal boundary

The project Crediting Period must follow the requirements for GHG Projects focusing on emissions reductions of greenhouse gases as set out in the most recent version of the Proba Standard.

2.3 GHG emissions

Greenhouse gases emitted for each activity that are covered under this methodology are presented in *Table 1* below. Baseline emissions that are accounted for are marked with **B** while Project emissions that are accounted for are marked with **P**. It should be noted that all the emissions should be expressed as carbon dioxide equivalents (CO_2e), as described in the Appendix A . Note that the GHG emissions resulting from the activity *(x) Application of the fertilizers* are not directly calculated through this methodology, but can be included through an appropriate methodology or framework (for example based on IPCC the guidelines[11]).

Table 1: Emission sources covered under this methodology for the baseline (B) and project (P) boundaries

	Carbon Dioxide (CO_2)	Methane (CH_4)	Nitrous Oxide (N_2O)
(i) Extraction of raw materials	**B** / **P**		
(ii) Transportation of raw materials	**B** / **P**		
(iii) Upstream fossil fuel emissions	**B** / **P**		

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

	Carbon Dioxide (CO_2)	Methane (CH_4)	Nitrous Oxide (N_2O)
(iv) Upstream electricity emissions	**B** / **P**		
(v) Fertilizer production processes	**B** / **P**	**B** / **P**	**B** / **P**
(vi) Transportation of industrial waste stream	**B** / **P**		
(vii) Treatment of industrial waste stream	**B** / **P**	**B** / **P**	**B** / **P**
(viii) Transportation of fertilizers	**B** / **P**		
(ix) Field spreading of fertilizers	**B** / **P**		

3. Baseline scenario

3.1 Guidelines for baseline estimation

3.1.1 For projects upgrading existing facilities (retrofit)

For existing facilities, the baseline is established based on the normal operations that were happening before the implementation of the GHG Project intervention. Historical information (detailed records) related to the emissions (e.g. raw material sourcing, energy sourcing, production processes, waste management and fertilizer distribution) from at least three years before project implementation shall be used in the baseline calculations.

3.1.2 For projects constructing new fertilizer facilities (greenfield)

For new facilities, the baseline scenario is established based on the sourcing of fertilizers by their (prospective) customers, assuming the GHG Project had not been implemented.

Since the Carbon Credits are issued based on the actual customers of the fertilizer factory, the Project Developer should define the prospective customers as accurately as possible.

As such, a market analysis should be made that includes the following steps:

- Assess industry norms, historical purchasing patterns, and market trends to estimate the fertilizers prospective customers would have sourced. This includes analyzing their origins and associated production and transportation emissions.
- Identify the specific fertilizer products that the new fertilizers are replacing, assuming the project had not been implemented. If multiple fertilizers are being replaced, the split should be identified, and the total baseline emissions should be calculated based on the current situation on a pro-rata basis.
    - For example, if the project replaces 60% urea and 40% ammonium nitrate, the baseline emissions should reflect the combined emissions from these products based on their respective proportions.
- Utilize regionally-specific, published data wherever possible. In import markets, rely on documented figures of product imports and usage to establish the baseline. Determine what your products can reasonably displace by analyzing similarities in application or evidence of farmers switching to your product. Providing detailed information that demonstrates the reasonableness of the baseline will help ensure its accuracy and credibility.

Overall, the aim should be to create a realistic picture of the emissions landscape that would exist without the new project. A solid baseline should clearly identify the current situation and provide a quantification of its emissions based on solid evidence. To attain such evidence, it is optimal to use country-specific data and, even better, local data from industry reports and market research.

A greenfield facility might plan to produce a new type of fertilizer, which differs from those commonly used in the industry (baseline fertilizer). For example, a facility might aim to produce and sell low-carbon ammonium nitrate as a substitute for the widely used urea.

- The GHG emissions resulting from the **application** of these fertilizers on the fields might be different compared to the baseline fertilizer.
- The quantities of each fertilizer required to achieve the same **crop yield** may differ. For instance, according to the "*Fertilizer Industry Handbook*"[12] by Yara International, trial

12 https://www.yara.com/siteassets/investors/057-reports-and-presentations/other/2022/fertilizer-industry-handbook-2022-with-notes.pdf

results for arable crops (cereals, UK) show that to maintain the same yield, 14% more nitrogen from urea is needed compared to nitrogen from ammonium nitrate.

Therefore, 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, for example through a field study. This field study needs to be independently verified to increase accuracy and credibility of the claims. More specific information on the quantification of these emissions can be found on step *(x) Application of fertilizers* in section 5. Emission calculations.

If the greenfield facility plans to produce multiple types of fertilizers, and each type affects the GHG emissions and crop yield differently compared to the baseline fertilizer, then the process should be followed separately for each type of fertilizer.

3.2 Dynamic baseline

In regions and markets where regulatory changes and the industry standards are evolving rapidly and have a severe impact on baseline calculations, a dynamic baseline is required. Project Developers should assess and explain if such changes are expected during the Crediting Period, and if so the usage of a flexible dynamic baseline should be used, as described in the Proba standard. For GHG Projects with a dynamic baseline, baseline emissions are recalculated upon every verification event. Moreover, updates which affect additionality (regulatory changes, subsidies, tax incentives, etc.) should be transparently presented in the verification report.

3.3 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 2: 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 should 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 should 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.

4. Additionality

Low-carbon fertilizer production projects that wish to issue Carbon Credits under the Proba Standard and wish to use this methodology, must be able to demonstrate additionality.

Projects must comply with the three additionality aspects (regulatory, financial and prevalence) as explained in the Proba Standard.

In the context of fertilizer production, the Project Developer must pay extra attention to prove specific regulatory additionality in a fast-evolving regulatory landscape that includes regional, national, or sector targets and subsidy funding. 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.

Regulatory additionality can be demonstrated to the VVB by presenting a locally relevant research report that includes an obstacle analysis on the local regulatory context, showing the lack of financial incentive of legal directives to realize the proposed intervention. Should subsidies be available, the Project Developer must show that available funding does not cover the financial gap to realize the intervention.

Should the project fall 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. The Project Developer could utilize the dynamic baseline to provide a more realistic emission reduction during the Crediting Period.

As additionality is highly dependent on the local, national, or regional context, a Project Developer must assess the regional and national regulatory environment on a project-by-project basis.

The Project Developer should be able to prove that the project wouldn't be achievable without the financial support from Carbon Credit finance, solidifying its alignment with the Proba Standard's additionality criteria. To prove it, a financial analysis should 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*"[13] 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.

The Project Developer must provide a barrier analysis to identify and document obstacles that prevent the project from being realized without carbon finance. The CDM "*Guidelines for objective demonstration and assessment of barriers*"[14] provide help for identifying and assessing barriers.

[13] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-02-v7.0.pdf
[14] https://cdm.unfccc.int/EB/050/eb50_repan13.pdf

5. Emission calculations

The emissions of both the baseline and the project can be calculated using the same set of equations, which are presented in this section.

For projects upgrading existing facilities (**retrofit**), the activities that have a delta in emissions should first be identified. Based on that, the emissions of the baseline and the project can be calculated through the equations presented in this section. In this case, it is expected that Tier 3 data[15] emission factors will be available, thus increasing the reliability of the calculations.

For projects constructing new fertilizer facilities (**greenfield**), the baseline scenario is established based on the typical sourcing of fertilizers by the prospective customers, assuming the GHG Project had not been implemented. In this case, Tier 2 historical data on the sourcing of fertilizers by the prospective customers should be acquired (or assumed based on standard values: regional/country or sector data). In addition, Tier 2 data (or Tier 1, if Tier 2 are not available) of emission factors of the industrial production of fertilizers should be used for the calculation of the baseline. Similarly, the emissions of the baseline and the project can be calculated based on the equations presented in this section.

The total (baseline or project) emissions can be calculated as the sum of the subsequent activities, which are presented in section 2. Project boundary.

$$E = \sum_{a=i}^{x} (E_a) \tag{1}$$

Where:

E	=	Total (baseline or project) emissions (tCO_2e/year)
E_a	=	Emissions of activity a (tCO_2e/year)

[15] See section 3.3 Data selection for an explanation of Tier 1, 2 and 3 data

Below, a summary of the equations per activity along with the emission factors and activity data is presented. More information on the data and parameters that should be collected by the Project Developer to calculate the project emissions, can be found in the tables presented in section 8. Monitoring, Reporting and Verification.

Table 3: 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 $E_{iv} = \frac{EC}{(1-TDL)} \cdot EF_{u,z}$	Supplier-specific method - Emission factor of the upstream emissions of (purchased) electricity - Transmission & distribution loss rate (%), specific to grid where energy is generated and consumed Average-data method - Grid-region, country, or regional emission factors of the upstream emissions of (purchased) electricity - Country/regional average transmission & distribution loss	- Electricity consumption

Activity	Emission factors needed	Activity data needed
	rate (%)	
(v) Fertilizer production processes $E_{v,a} = \sum_{x} \sum_{p} (EF_{p,x} \cdot Q_{x}) + FE$ *or* $E_{v,b} = \sum_{x} EF_{x} \cdot Q_{x} + FE$	Process-specific method - Emission factors of the production processes of the fertilizers (relevant for existing facility process change) Average-data method - 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
(vi) Transportation of industrial waste stream $E_{vi} = \sum_{tf} \sum_{w} (EF_{m} \cdot Q_{w,tf,m} \cdot D_{w,tf,m})$	- Emission factors for each mode of transportation	- Quantities of different waste streams generated - Distance traveled by each mode of transport for each waste stream
(vii) Treatment of industrial waste stream $E_{vii} = \sum_{tf} \sum_{w} (EF_{w,tf} \cdot Q_{w,tf})$	- Emission factors of the waste treatment method per waste stream	- Quantities of waste streams going to the different waste treatment facilities
(viii) Transportation of fertilizers (distributors, farmers) $E_{viii} = \sum_{c} \sum_{x} (EF_{m} \cdot Q_{x,c,m} \cdot D_{x,c,m})$	- Emission factors for each mode of transportation	- Quantities of different fertilizer products transported to each customer - Distance traveled by each mode of transport for each fertilizer product stream
(ix) Field spreading of fertilizers $E_{ix} = \sum_{cf} \sum_{mf} (EF_{mf} \cdot D_{cf,mf} \cdot N_{f})$	- Emission factors of the vehicle type or the field spreading machinery	- Distance traveled by each vehicle on each field - Number of time the fertilizer is spread per year

(i) Extraction of raw materials

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

$$E_i = \sum_l \sum_r (EF_{r,l} \cdot Q_{r,l}) \quad (2)$$

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:

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

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 [16, 17].

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

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)

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

$EF_{u,z}$	=	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)
- 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):

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

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) [18]

[18] 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

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:

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

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).

(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).

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

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)

(viii) Transportation of fertilizers

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

$$E_{viii} = \sum_{c} \sum_{x} (EF_{m} \cdot Q_{x,c,m} \cdot D_{x,c,m}) \tag{10}$$

Where:

E_{viii}	=	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 customer c via the mode of transportation m (t/year)
$D_{f,c,m}$	=	Distance traveled of fertilizer product f to customer c via the mode of transportation m (km). If the customer location is not known, the distance between a regional distributor plus an assumed conservative average distance can be assumed

(ix) Field spreading of fertilizers

When considering the GHG emissions associated with a fertilizer product spreading on the field, it is essential to include emissions 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).

$$E_{ix} = \sum_{cf} \sum_{mf} (EF_{mf} \cdot D_{cf,mf} \cdot N_f) \tag{11}$$

Where:

E_{ix}	=	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

(x) Application of fertilizers

In this methodology, the focus is on the production process of the fertilizers, which is designed to be less emission-intensive, resulting in low-carbon fertilizers.

However, fertilizers emit greenhouse gases (GHGs) when applied to fields, with nitrogen-based (N) 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)[19]. 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)[20].
- In contrast, phosphorus-based (P) and potassium-based (K) fertilizers typically do not emit substantial quantities of GHGs emissions[21]. However, if the project produces a P or K-based fertilizer that emits significant GHGs compared to the baseline, those emissions should be accounted for, and the method for calculating and verifying these emissions should be provided.

As mentioned in section 3.1. Guidelines for the baseline estimation, 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 should 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 B, which is based on the IPCC guidelines.

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

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[19] https://doi.org/10.1038/s41598-022-18773-w
[20] https://doi.org/10.1016/j.soilbio.2017.10.008
[21] https://doi.org/10.1186/s13021-019-0133-9

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 measurements. If the impact is estimated to be minimal, it should be approached conservatively, and such reductions should 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 be quantified. If the emissions are substantial enough to offset the positive impacts of all other phases, the project should 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. Increased emissions due to fertilizer usage should be accounted for as potential **leakage** (see Section 6. Leakage), as they currently fall outside the Project boundary.

6. Leakage

For both existing and greenfield facilities, it is crucial to identify any potential displacement (or increase) of emissions that might result from project activities. This displacement, often referred to as *"leakage"* occurs when emission reductions in one area cause an increase in emissions elsewhere.

The Project Developer is responsible for identifying and quantifying leakage sources relevant to the project. Examples of leakage sources could be the following:

Indirect increase of gray electricity production: by sourcing large amounts of renewable electricity for fertilizer production, there is a risk that the production of gray electricity increases to compensate for a lower amount of renewable energy available on the grid. As such, Project Developers sourcing green electricity must prove that the sourced electricity comes from additional production capacity or low-emissions electricity grids. If that is not the case, the leakage from the indirect increase of gray electricity production should be calculated, based on data given by the electricity provider or grid operator.

Indirect increase of fertilizer demand in the region as a result of the Project: The project may indirectly increase fertilizer demand in the region, potentially leading to higher overall nitrogen usage, when compared to the historical fertilizer demand. To demonstrate that the project is displacing imports rather than simply adding to regional demand, the Project Developer should use available data on imported fertilizer volumes once production begins.

Negative GHG impact related to the application of fertilizers: As described in section 3. Baseline scenario, fertilizers can emit GHGs when applied. If the produced fertilizer differs from the one used in the baseline, the Project Developer should research and present findings on the emissions of the new fertilizer compared to the baseline for the same application. The quantification of these emissions should be done through an appropriate methodology as explained in section 5. Emission calculations If the new fertilizer **emits more** GHGs than the baseline, this difference should be quantified and included as leakage. Due to the high uncertainty and difficulty in predicting application emissions, actual field studies should be conducted after the fertilizer is applied to confirm the leakage predictions. If the emissions are lower than estimated, the previously subtracted leakage delta can be reclaimed.

To effectively manage and measure the impact of these displacements, an ongoing evaluation system must be established to assess leakage effects. Additionally, a mitigation plan of the leakage risks should be developed. This system should also evaluate the effectiveness of any mitigation measures implemented to counteract the displacement effects.

7. Net GHG emissions reductions

The emission reduction achieved by the project activity shall be determined as the difference between the baseline emissions and the project emissions and leakage.

An Uncertainty Factor (UF) is applied to enhance conservativeness and reliability in the calculations. It includes the potential variability in the emission factors, input data, measurements and assumptions used in the project. To calculate the Uncertainty Factor, the tool [22] developed by

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

the GHG Protocol Initiative can be used. This Excel-based tool automates the aggregation steps for developing a basic uncertainty assessment for GHG inventory data, following the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National GHG Inventories. The tool is supplemented by a guidance document [23], which describes the functionality of the tool and gives a better understanding of how to prepare, interpret, and utilize uncertainty assessments. The Project Developer must quantify and document all uncertainties concerning assumptions, data measured, tooling involved for both static and dynamic baselines. Moreover, the Project Developer must ensure to use conservative standard data and document the choice for the data used. Should data come as a bandwidth or vary, the lower value should be chosen.

$$ER = (BE - PE - LE) \cdot (1 - UF) \tag{13}$$

Where:

ER	=	Net GHG emissions reductions (tCO_2e/year)
BE	=	Baseline emissions (tCO_2e/year)
PE	=	Project emissions (tCO_2e/year)
LE	=	Leakage emissions (tCO_2e/year)
UF	=	Uncertainty Factor (%)

Important note: Typically, a Buffer Pool is applied in GHG projects. This acts as a reserve of Carbon Credits established to cover potential losses in GHG Projects, ensuring the integrity of emissions reductions or removals over time. The size of the Buffer Pool is aligned with the level of reversal risks associated with the GHG Project. Since, the production of low carbon fertilizers does not include carbon sequestration efforts, which can be reversed, there is typically no need for a Buffer Pool. The Project Developer should, however, identify any such potential reversal risks, and if they are sufficient, then include them as part of the Project in the form of a Buffer Pool.

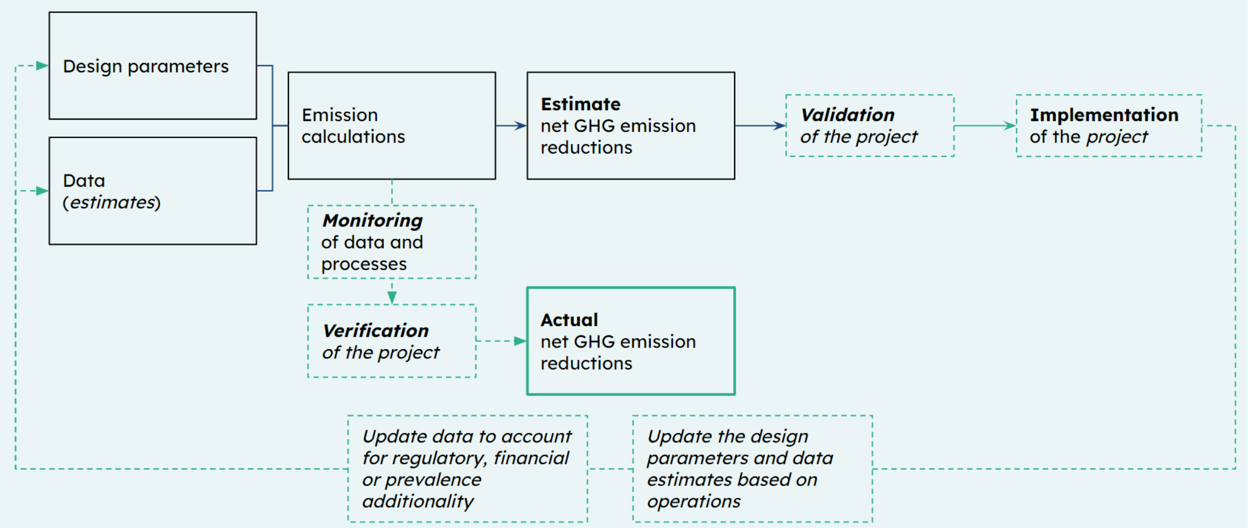
[23] https://ghgprotocol.org/sites/default/files/2023-03/ghg-uncertainty.pdf

8. Monitoring, Reporting and Verification

The Project Developers must follow the monitoring, reporting and verification procedures of the latest version of the Proba Standard.

An overview of the process is presented below:

Figure 3: Flowchart showing the activities involved in the MRV process related to calculating net GHG emissions reductions



The GHG Project must undergo verification once the fertilizer factory is constructed or retrofitted.

The Project Developer should prepare a monitoring report to submit to the VVB during the verification events. To support this, a process should be established to ensure that all relevant data are accurately measured using appropriate equipment, in compliance with the requirements outlined in the POD.

After this initial verification of GHG reductions, the issuance of Carbon Credits can begin without requiring a new verification cycle for each production batch. However, during subsequent verification events, GHG reductions from previous years must be verified.

After the first verification, periodic verification and reporting (typically every 2-4 years) must also be followed, to ensure the accuracy and credibility of the reported GHG emissions reductions. The frequency of the periodic verification depends on the specific intervention and should be clearly presented and explained in the POD. The Project Developer should be transparent related to changes in additionality (regulatory changes, tax incentives, subsidies, etc.) during verification events.

A monitoring plan must be created that systematically tracks and records GHG emissions data throughout the project's operational phase using calibrated instruments and predefined methodologies. These reports must be reviewed by VVBs during the periodic verification to ensure compliance with the monitoring plan and to document any deviations or corrective actions taken. If the Project Developer has established monitoring procedures related to the processes and emissions (such as continuous monitoring through proper instrumentation) of the fertilizer production, then these can be used as part of the monitoring plan of the GHG project.

For instance, the Project Developer must provide documentation of the fertilizer's selling locations, verify the sourcing and usage of (green) energy, confirm the appropriate field spreading and application of the fertilizer products, and regularly update and verify assumptions made during baseline emissions calculations to ensure the emission reductions are genuine.

If discrepancies or deviations from the planned methodology are identified, corrective actions must be implemented promptly to address these issues.

The following design parameters[24] and data[25] are included in this methodology and must be monitored by the Project Developer:

[24] The **design parameters** refer to the design requirements or assumptions of the GHG Project. They are known prior to validation but must be updated in case of any process changes

[25] The **data** include emission factors, and for electricity the transmission and distribution loss rates of the grid for all activities, including the baseline scenario and the GHG Project. These factors should be obtained from credible sources, and be updated regularly to maintain project additionality (regulatory, financial and prevalence). For example, if the fertilizer production industry adopts more sustainable practices, the baseline emission factors will decrease, thus reducing the net GHG emissions reductions of the project. Relevant data also include quantities of raw materials

Table 4: Design parameters

Design Parameter	Description	Activity	Data correlation	Proof required for reporting & verification
r	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

c	List of customer locations for shipping the fertilizer products	(viii)	Specify which fertilizer products (x) are transported to each customer location (c)	Proof of purchase from the customers, including customer location. If the fertilizers are sold to a distributor, then further proof of where the fertilizers are re-sold is needed.
mf	List of vehicle type or fertilizer application machinery	(ix)	-	Documentation from fertilizer users
cf	List of fields where the fertilizers are applied	(ix)	Specify which types of vehicles and machinery (mf) are used on each field (cf)	Documentation from fertilizer users

Table 5: Data (A)

Data	Description	Unit	Activity	Example Sources	Proof required for reporting & 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.

Data	Description	Unit	Activity	Example Sources	Proof required for reporting & verification
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, expressed for the amount of produced fertilizer x	tCO_2e/t of product (or input) x	(v)	• Estimated (based on industry averages or existing processes) and then measured for the GHG Project 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	Documentation verifying the processes included and their emission factors
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/1	-

Data	Description	Unit	Activity	Example Sources	Proof required for reporting & verification
				0.1186/s13021-019-0133-9	
$EF_{w,tf}$	Emission factor of treating the waste stream w via the treatment process in the waste treatment facility tf	tCO_2e/t of waste w	(vii)	• https://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch6ref2.pdf	Documentation from the waste treatment facilities
EF_{mf}	Emission factor of the vehicle type or fertilizer application machinery mf	tCO2e/tonne-km	(ix)	• https://www.researchgate.net/figure/Emission-factors-of-farm-tractors_tbl1_357346706	Documentation types of vehicles used and their emission factors
EF_1	Emission factor for direct N_2O emissions from N inputs	kg N2O–N/(kg N)	(x)	• https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch11_Soils_N2O_CO2.pdf	Documentation from verified field study
EF_4	Emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces	kg N2O–N/(kg NH3–N + NOx–N volatilised)	(x)	• https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch11_Soils_N2O_CO2.pdf	Documentation from verified field study
EF_5	Emission factor for N_2O emissions from N leaching and runoff	kg N2O–N/(kg N leaching/runoff)	(x)	• https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch11_Soils_N2O_CO2.pdf	Documentation from verified field study

Table 6: 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.)

Data	Description	Unit	Activity	Measurement method
$Q_{w, tf, m}$	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 process in the waste treatment facility tf	t of waste/year	(vii)	Documentation from the waste treatment facilities
$Q_{x, c, m}$	Quantity of fertilizer product x sent to customer c via the mode of transportation m	t/year	(viii)	Documentation from the transportation service
$D_{x, c, m}$	Distance traveled of fertilizer product x to customer c via the mode of transportation m	km	(viii)	Documentation from the transportation service
$D_{cf, mf}$	Distance traveled by the fertilizer application machinery (mf) within the field (cf)	km	(ix)	Documentation from the farmer or agricultural cooperative
N_f	Number of times the field is spread per year	-	(ix)	Documentation from the farmer or agricultural cooperative
FSN	Quantity of synthetic fertilizer product x applied on crop c	kg N $yr^{-1}ha^{-1}$	(x)	Documentation from the farmer or agricultural cooperative / Cross-check with purchase records and application logs
FON	Quantity of organic fertilizer product applied on crop c	kg N $yr^{-1}ha^{-1}$	(x)	Documentation from the farmer or agricultural cooperative / Cross-check with application logs
MSN	Mass of N containing synthetic fertilizer product x applied on crop	kg $yr^{-1}ha^{-1}$	(x)	Use supplier-provided data on the label, calculate the nitrogen mass using the

Data	Description	Unit	Activity	Measurement method
	c			nitrogen content percentage
MON	Mass of N containing organic fertilizer applied on crop c	kg $yr^{-1}ha^{-1}$	(x)	Use supplier-provided data on the label (if available)
$NCSN$	N content of synthetic fertilizer applied	g N (100g fertilizer)$^{-1}$	(x)	Use supplier-provided data on the label
$NCON$	N content of organic fertilizer applied	g N (100g fertilizer)$^{-1}$	(x)	Use supplier-provided data on the label
Nha	Total amount of hectares	Hectares	(x)	Use GPS devices, traditional surveying tools, aerial/satellite imagery, farm records/maps, or online mapping tools to measure and calculate the total area of the field
$Dapp$	Date of fertilizer application on crop c in season s	Date	(x)	Date recorded

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Appendix A: Additional information

Carbon dioxide equivalents CO_2e

CO_2e stands for carbon dioxide equivalent, a standard unit used to measure and compare the impact of different greenhouse gases (GHGs) based on their Global Warming Potential (GWP) relative to carbon dioxide. GWP reflects each gas's ability to trap heat in the atmosphere over a specific time frame, typically 100 years.

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

Table 7: Carbon dioxide equivalents per GHG [26]

Greenhouse Gas	Chemical Formula	Global Warming Potential (GWP)
Carbon Dioxide	CO_2	1
Methane	CH_4	28
Nitrous Oxide	N_2O	265

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

$$E_{CO_2e} = E_{GHG} \cdot GWP \quad (14)$$

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)

[26] https://ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf

Appendix B: 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[27]. 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.

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

Table 8: Emission factors for fertilizer application based on the IPCC report

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 synthetic 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 [28])	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.

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

Direct emissions

$$E_{N2O\_Direct} = (FSN + FON) \cdot EF_1 \cdot MWN_2O \cdot GWPN_2O \quad (15)$$

$$FSN = MSN \cdot NCSN \quad (16)$$

$$FON = MON \cdot NCON \quad (17)$$

Where:

E_{N2O_Direct}	=	Annual direct N_2O-N emissions from managed soils (kg N_2O-N $yr^{-1}ha^{-1}$)
FSN	=	Synthetic 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 synthetic fertilizer applied, kg $yr^{-1}ha^{-1}$
MON	=	Mass of N containing organic fertilizer applied, kg $yr^{-1}ha^{-1}$
$NCSN$	=	N content of synthetic 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):

$$E_{N2O\_ATD} = (FSN \cdot FracGASF + FON \cdot FracGASM) \cdot EF_4 \cdot MWN_2O \cdot GWPN_2O \quad (18)$$

Where:

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

$$E_{N2O\_L} = (FSN + FON) \cdot FracLEACH(H) \cdot EF_5 \cdot MWN_2O \cdot GWPN_2O \quad (19)$$

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)

$$E_x = E_{N2O\_Total} = (E_{N2O\_Direct} + E_{N2O\_ATD} + E_{N2O\_L}) \cdot Nha \quad (20)$$

Where:

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