Project Overview Document (POD)

Agrifirm - low carbon crops

Project ID: *PROBA.2025.0001*

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1. Project description

1.1 Summary of the project

The Agrifirm Low Carbon Crops Project is an insetting initiative aimed at co-creating a more sustainable food chain. Agrifirm, as the primary driver and an influential actor within the agricultural value chain, is using its central position to facilitate verified emission reductions directly at farm level. The project enables food companies and other agri-buyers to access lower-carbon commodities while contributing to real and measurable climate action.

Starting with a 2025 pilot in the Netherlands, the project will engage 10–30 farmers per crop type—winter wheat, barley, and potatoes—ideally with a committed downstream buyer already involved for each commodity. Verified emission reduction certificates will be generated for the GHG reductions achieved and sold to agricultural supply chain actors. This structure ensures that the transition to more sustainable farming practices is co-financed by those sourcing the crops, rather than placing the burden solely on farmers.

The pilot phase is designed not only to demonstrate technical and environmental impact, but to also validate the operational, financial, and organizational feasibility of the model. The outcomes of the pilot phase are expected to provide the necessary evidence and confidence to scale the initiative, enabling a mechanism for decarbonizing agriculture at scale.

1.2 Project Objectives

The objectives of the Agrifirm Low Carbon Crops Project are multi-dimensional:

- Enable verified Scope 3 emissions reductions for food companies and other downstream buyers, in alignment with the Proba Standard, Science Based Targets initiative (SBTi) and the GHG Protocol.
- Support farmers in adopting low-carbon practices that sustain crop productivity and reduce environmental impact.

- Develop a scalable model that fairly shares the costs and benefits of low-carbon farming across the value chain
- Strengthen collaboration by involving agrifood buyers in co-financing on-farm emission reductions within their own supply chains.
- Reduce the carbon footprint of each crop:
    - Winter Wheat: around 40%
    - Summer Barley: around 50%
    - Potatoes around 10%
- Deliver a total GHG reduction of approximately 550 tCO_2e over the course of the pilot

1.3 Project Timelines and Crediting Period

Project Start Date:

The project begins at the start of the 2025 harvest season for winter wheat, barley, and potatoes. This marks the beginning of data collection and intervention implementation. In general the growing season of these crops is:

- Summer Barley February / March 2025 - August 2025
- Winter Wheat October / November 2024 - August 2025
- Potatoes April / May 2025 - September / November 2025

Project Duration:

The project covers one full growing season for every crop.

Crediting Period:

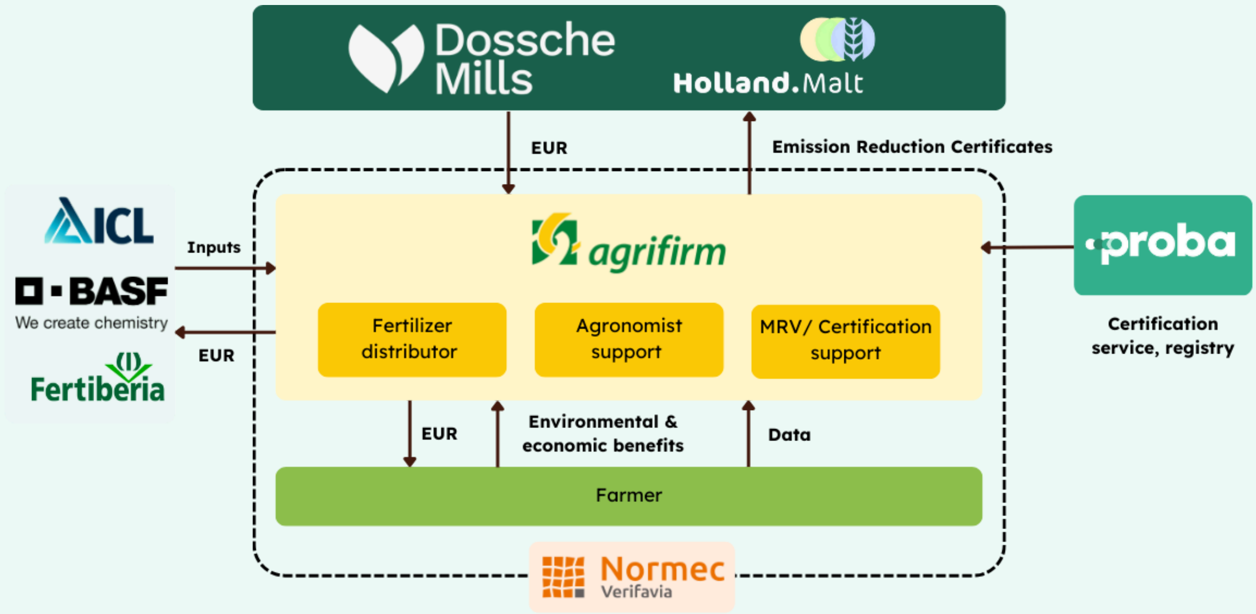
The crediting period is 1 year, aligned with the pilot duration and the seasonal nature of the crops. It covers the full implementation and monitoring cycle for all interventions applied.

Frequency of Monitoring and Verification:

Monitoring and verification will take place after each harvest, once crop yields are reported, intervention data is finalized and emission reduction outcomes can be assessed.

1.4 Project Stakeholders and Roles

The Agrifirm Low Carbon Crops Project is a collaborative effort across multiple actors in the agricultural value chain. Each stakeholder plays a specific and critical role in achieving the project's goals.



The following table provides a detailed overview of all stakeholders involved in the project.

Role	Organization	Responsibilities
Project Developer	Agrifirm	Agrifirm plays a dual role as both the project developer and the aggregator of technical and commercial data. Agrifirm coordinates farmer onboarding, provides technical support, and manages project implementation and reporting.
Agri buyers	Holland Malt (barley) Dossche Mills (wheat)	These companies co-finance the interventions by purchasing verified emission reduction certificates linked to their crop sourcing.
Validation &	Normec Verifavia	Conducts independent validation of the

Verification Body (VVB)		POD and verification of farming activities and the related GHG reductions according to the applied methodologies and the Proba Standard.
Certification Scheme & Methodology Developer	Proba	Proba provides the methodological framework and certification infrastructure. It oversees the issuance and registry of certificates and ensures the project complies with environmental and social safeguards.
Farmers	Participating farmers: 21 farmers Winter Wheat 1 farmer Potatoes 5 + 16 farmers Summer Barley	Farmers implement the on-farm interventions and provide input data for monitoring and verification. Farmers are members of Agrifirm and are supported by the Agrifirm advisory team throughout the growing season.
Fertilizer Input Providers	ICL (CRF), Fertiberia (low-carbon fertilizer), BASF (inhibitors), OCI (low-carbon fertilizer)	Supply low-carbon or enhanced-efficiency fertilizers that enable the interventions and emission reductions.

About Agrifirm

Royal Agrifirm Group is the premier dedicated and experienced specialist for livestock farmers and crop growers, supporting them with innovative products and services so that they can achieve the best results. Agrifirm's activities, products and services are optimally tailored to meet the wishes and requirements of livestock farmers and crop growers. The innovative portfolio is based on years of international scientific research and specific local knowledge and expertise.

Agrifirm seeks to promote a responsible food chain for future generations. We provide measurable, relevant and sustainable value on farms, in fields and for the industrial sector. We do this by supporting our customers with sustainable, innovative and effective products and concepts for optimal results.

Organization details:

Registered name	Agrifirm NWE BV
Address	Landgoedlaan 20 7325 AW Apeldoorn
Country of registration	The Netherlands
Registration number (Chamber of Commerce)	KvK: 16050353
VAT number	NL007611900B01
Main contact persons -name -phone number -email address	 Jan Nammen Jukema / Levi Bin +316-28442139 / +316-52376991 j.jukema@agrifirm.com / l.bin@cebecoagro.nl

2. Project Scope and Boundaries

2.1 Geographical Boundaries

The Agrifirm Low Carbon Crops project will initially be implemented as a pilot across multiple locations within the Netherlands. The participating farms in the 2025 pilot phase are distributed across different provinces. A full list of the plots included in the pilot can be found in the appendix. This will be supplemented with field-level identifiers where possible.

Land Management Units (LMUs) involved in the pilot will be identified using:

- **A unique ID:** Within the project, unique identifiers from the *Boer en Bunder* platform will be used. At present, the Agrifirm farmer management system does not provide publicly recognizable IDs for LMUs. To address this, Agrifirm will make use of their access to the *Boer en Bunder* platform[1] and manually assign these identifiers to the LMUs. Publicly available IDs are required to determine ownership of the plot. These identifiers can be made available upon request for the purpose of project validation.

The project is designed to be scalable, with the potential to add more farms and locations in subsequent phases. Additional farms can be onboarded using the same eligibility and monitoring framework, provided that:

- Field boundaries and input practices are well documented,
- Historical fertilizer use is available, and
- The required crop and intervention data can be linked to specific LMUs.

The full list of participating LMUs and their coordinates or plotidentifiers will be maintained by the project developer and submitted at the time of verification.

2.2 Operational boundaries

[1] https://boerenbunder.nl/

2.2.1 Crop types and land management units

The project targets three crop types: winter wheat, summer barley, and potatoes. Project implementation is structured around Land Management Units (LMUs)[2], which act as the project's primary spatial units. A spatial unit refers to a clearly defined plot or field where a single crop is grown and managed uniformly throughout the season. Each LMU serves as the basis for:

- Assigning applicable interventions,
- Monitoring and data collection,
- Emissions reduction quantification, and
- Certificate issuance.

2.2.2 Land access and legal rights

The participating farmers hold the legal or statutory rights to all cadastral locations (LMUs) where interventions will be implemented. This includes ownership, tenancy, or other recognized land access arrangements. Agrifirm, as the project developer, will collect and provide evidence confirming these rights, which must extend at least through the full project duration or crediting period. Documentation will be made available at validation and verification. Evidence will include data from the Dutch RVO's **Basic Registration of Parcels (BRP)**, a national system that provides a detailed and up-to-date overview of all agricultural parcels in the Netherlands. It registers exactly which farmer manages which plots of land and what crops are grown on them. This ensures transparency, supports agricultural policy and subsidy schemes, and helps monitor land use and crop production at a national scale.

2.2.3 Scope of the value chain (for each crop type)

The value chain within the scope of the Agrifirm Low Carbon Crops project includes:

- **Tier 1: Farming**
  - Participating farmers, who grow the different crops and implement interventions on identified LMUs;

[2] A Land Management Unit (LMU) is a clearly defined area of land under consistent management, where fertilizer application and nitrogen stabilizer use can be directly monitored and attributed. As defined by GHG Protocol in the Land Sector and Removal Guidance. The LMU level allows GHG emissions and reductions to be accurately measured and linked to specific plots, each with defined boundaries and documented management practices

- **Tier 2: Distribution**
    - Agrifirm in the role of distributor for Wheat and Barley, who collect and handle physical crop volumes and blend outputs;
    - Potatoes are directly distributed to potato processors;
- **Tier 3: Food processors**
    - Milling company that transforms wheat into intermediate or final products;
    - Malting company that transforms barley into intermediate or final products;
    - Potatoes are directly distributed to potato processors;
- **Tier 4: Food companies**
    - Bakeries for wheat that market and sell finished products to end customers
    - Breweries for barley that market and sell finished products to end customers
    - Potato companies for potatoes that market and sell finished products to end customers

	Tier 1: Farming	Tier 2: Distribution	Tier 3: Food Processing	Tier 4: Food companies
Winter Wheat	Farmer ➪	Agrifirm ➪	Milling company ➪	Bakery
Spring Barley	Farmer ➪	Agrifirm ➪	Malting company ➪	Brewery
Potatoes	Farmer ➪		Processing Industry ➪	Potato companies

2.2.4 Chain of Custody and traceability

To ensure that emission reduction certificates are credibly linked to low-carbon crops, the project applies a crop-specific chain of custody (CoC) model. This model establishes a traceable link between interventions implemented at the LMU (field) level and the physical crop volumes (e.g. wheat, barley, potatoes) ultimately delivered to buyers.

A mass balance approach may be used at the crop level (when not all plots managed by the farmer are in scope of the project). It is always ensured that the volume of emission reduction certificates issued does not exceed the volume of crop harvested from LMUs where certified interventions were implemented. Traceability is maintained by linking plot-level monitoring data (e.g. fertilizer use, fuel type, stabilizer application) to LMUs.

Emission reduction certificates are allocated to buyers based on the actual volume of product sourced through the value chain described in Section 2.2.3, ensuring consistency between physical crop flows and credit attribution.

2.3 Crediting Framework

2.3.1 Insetting and emission reduction certificates

The Agrifirm Low Carbon Crops project is designed as an insetting initiative, enabling participating agri-buyers to make credible Scope 3 climate claims. Emission reduction certificates are issued in accordance with the Proba Standard and align with the GHG Protocol and SBTi guidance for purchased goods and services.

Certificates represent verified GHG reductions from interventions applied at the LMU level, calculated using intervention-specific methodologies.

Certificates are attributed to buyers based on their actual sourcing of low-carbon crops from the project, as described in the chain of custody and value chain sections (2.2.3 and 2.2.4). All certificates are initially issued to the project developer (Agrifirm) and are transferred to buyers based on the volume of product sourced. While third-party verification applies to the quantification of emission reductions, eligibility for certificate transfer is determined by the buyer’s sourcing activity, as further detailed in the claiming and attribution section 7.2.

2.3.2 Double Counting and Double Claiming Prevention

To safeguard against double counting and double claiming:

- Each LMU is uniquely identified via plot-level data.
- The Proba platform maintains a central ledger of all issued and retired certificates.
- As the project developer, Agrifirm declares that this project is not registered under any other carbon registry and commits not to submit it elsewhere for crediting during its operational period.
- Agrifirm will also provide documented proof of signed agreements and declarations from all participating farmers, confirming that the associated GHG reductions will not be claimed or sold through any other channel. An example of this farmer agreement is included in an annex on the Proba registry.

2.3.3 Offsetting and scalability

While this project is currently designed for insetting purposes, its structure allows for future expansion to support offsetting use cases as well. If aligned with buyer demand and evolving market standards, the project may be adapted to issue certificates for offsetting in the future. Any such adaptation would require appropriate adjustments to credit labeling, transparency protocols, and use restrictions to ensure environmental integrity. Improved crop emission attributes can no longer be reported and used by the crop buyers. The Proba platform and underlying data model have been designed to accommodate this flexibility while maintaining traceability and accountability.

2.4 Project Additionality

The project meets Proba's additionality requirements across all three dimensions:

- **Regulatory Additionality**:
  The use of low-carbon fertilizers, nitrogen stabilizers, controlled release fertilizers and renewable fuels (HVO) is not mandated by existing legislation or policy in the regions where Agrifirm operates. Although the European Green Deal and EU Climate Law signal increasing climate ambition, they do not require the adoption of these specific practices. All interventions exceed the current legal and policy

requirements and are entirely voluntary.

- **Financial Additionality**:
  All interventions entail higher costs without providing financial returns or agronomic advantages to farmers. For example, Nutramon Novo KAS is 36% more expensive than conventional fertilizers, while nitrogen stabilizers, controlled release fertilizers and HVO fuels significantly increase input costs. Adoption would not occur without the enabling role of carbon finance.

- **Prevalence**:
  The interventions are not common practice in the sector. Adoption of low-carbon fertilizers, controlled release fertilizer and nitrogen stabilizers remains below 25%, limited to pilot projects. HVO use in agricultural machinery is also minimal. Benchmarking confirms that the interventions deliver significantly lower GHG emissions than prevailing practices.

For further detail, refer to the *completed Additionality Assessment Template for Agrifirm (Proba.2025.0001)*, submitted as an annex to this Project Overview Document and available on the Proba Registry.

3. Quantification approach

This chapter sets out how greenhouse gas emission reductions are quantified within the Agrifirm Low Carbon Crops project. It explains how interventions are matched to approved methodologies, including a description of each intervention and the approach that is followed to calculate the GHG impact.

3.1 Interventions in Scope

The table below provides an overview of the methodologies used to quantify the impact of each intervention, the product type, its commercial name as well as the crops that each intervention implemented.

				Crops		
				Wheat	Barley	Potato
Interventions	Product type	Agrifirm product description	Methodology			
Switch from conventional fertilizers to low carbon fertilizer	CAN 27 CAN 24S	Nutramon Novo (low carbon) KAS (Agrifirm product code: 701007810) Impact Zero Nergetic DS+(KAS S) (Agrifirm product code: 700711510)	PM.0002: Adoption of low-carbon fertilizer technologies to transition to Low-Carbon Agriculture	X	X	
Use of inorganic fertilizer in combination with nitrogen stabilizers	CAN 24S +SDCD (NI)	Impact Zero Nergetic DS+(KAS S) (Agrifirm product code: 700711510)	PM.0004: Adoption of Nitrogen Stabilizers to Transition to Low-Carbon Agriculture	X	X	
Use of organic fertilizer in combination with nitrogen stabilizers	Pig slurry +Vizura (NI) Cattle slurry +Vizura (NI)	Vizura (BASF product)	PM.0004: Adoption of Nitrogen Stabilizers to Transition to Low-Carbon Agriculture	X	X	
Switch from conventional fertilizer to Controlled release fertilizers	80% blend of CRF/Urea + 20% CAN27	TopCote Consumptie (Agrifirm product code: 100493610)	PM.0005: Adoption of controlled-release fertilizers			X
Switch to Renewable fuel for machinery usage	Renewable diesel fuel (HVO)	HVO100 and Blauwe Diesel 50 (HVO50)	AMS-III.AK (Version 03.0) - Biofuel production and use for transport applications	X	X	X

Reduction of N application rate of fertilizer			PM.0005: Adoption of controlled-release fertilizers			X

1) **Switch to low-carbon inorganic fertilizer**

This intervention targets upstream GHG emissions associated with the production of mineral fertilizers. It achieves this by replacing conventional mineral fertilizers which are typically produced through energy intensive processes that rely on fossil fuels, with alternatives produced using low-emission technologies. The intervention focuses specifically on mitigating cradle-to-gate emissions.

It uses the Proba methodology “PM.0002: Adoption of low-carbon fertilizer technologies to transition to low-carbon agriculture”

2) **Usage of inorganic and/or organic fertilizers in combination with nitrogen stabilizers**

This intervention focuses on reducing direct and indirect N_2O emissions by incorporating nitrogen stabilizers such as nitrification inhibitors (NI) into fertilization practices. These stabilizers slow down the transformation of nitrogen compounds in soil, enhancing nitrogen use efficiency (NUE) and reducing direct N_2O emissions and indirect N_2O emissions from ammonia volatilization and nitrate leaching processes.

The intervention will be applied to both inorganic and organic fertilizers. It uses the Proba methodology “PM.0004: Adoption of nitrogen stabilizers to transition to low-carbon agriculture”.

3) **Switch from conventional fertilizer to Controlled Release Fertilizers**

This intervention focuses on reducing direct and indirect N_2O emissions by substituting conventional nitrogen fertilizers with a fertilizer formulation in which a defined proportion of the total nitrogen is supplied through controlled-release fertilizer (CRF) technologies. These products slow the nutrient release, aligning with crop uptake patterns and minimizing excess nitrogen in the soil, thus reducing direct N_2O emissions and indirect N_2O emissions from ammonia volatilization and nitrate leaching processes.

It uses the Proba methodology “PM.0005: Adoption of controlled-release fertilizers to transition to low-carbon agriculture”

4) **Switch to biofuel**

This intervention focuses on the quantification of GHG emission reductions resulting from the switch from fossil diesel to HVO50 and/or HVO100 fuels in agricultural machinery and tractors used for farming operations, by the participating farmers in the pilot.

The calculation of emission reductions follows the framework of Clean Development Mechanism: AMS-III.AK (Version 03.0) - Biofuel production and use for transport applications[3]. The intervention uses a tailored application focusing exclusively on fuel consumption rather than biofuel production.

3.2 Quantification of emission reductions

The quantification covers GHG emissions related to the production of fertilizers (PCF), direct and indirect N_2O emissions from fertilizer application, and CO_2 emissions from the use of agricultural vehicles. Other emission sources are not included, as they are expected to remain constant across both baseline and project scenarios. For example, emissions related to pesticide use, seed production, and on-farm energy use (beyond fertilizer application) are considered immaterial in the context of this fertilizer-focused intervention.

To assess the GHG impact of the project activities, quantification was performed for both baseline and intervention scenarios, as required under the developed Proba methodologies. The detailed scenarios and the methodologies that were used to quantify the impact for each crop in scope can be seen in ***Table 1***. This quantification follows principles and equations that are presented in Proba methodologies PM002, PM004, PM005, and the Proba approved CDM methodology AMS-III.AK (Version 03.0) . The emissions are then quantified based on:

- Product Carbon Footprint (PCF) values for fertilizer and stabilizer manufacturing and transportation
- N application rate (kg N/ha)
- Emission Factors (EFs) for direct and indirect GHG emissions associated with fertilizer application

[3] https://cdm.unfccc.int/methodologies/DB/LNFDO5DUYAJHKH8DJCRNHTZB9E7P1C

- Fuel consumption and machinery used

All calculations have been implemented within the Proba platform and are presented in detail in the accompanying quantification tool (see annex spreadsheet: Agrifirm Intervention Calculator), which also includes all the related information referenced above. For the avoidance of doubt, the calculations in the platform are leading. The quantification tool is used for validation and verification purposes and for simulation of plot level scenarios. A full breakdown of emissions calculations per scenario is included in the tool. The calculation logic can be verified with the logic presented in the spreadsheet in the tab “Intervention calculator". Representative equations are provided in Appendix B1.

PCF (cradle-to-gate) and transportation of fertilizers:

Emissions associated with the production and transport of fertilizers and stabilizers (cradle-to-gate) were quantified using PCF data. The applied PCFs followed these requirements:

- Based on Life Cycle Assessment (LCA) in accordance with ISO 14040/14044 or ISO 14067
- Include emissions from raw material extraction, synthesis, production, and transport to the farm gate
- Verified by qualified third parties to ensure accuracy and credibility
- Consistent methodologies used for both baseline and intervention products

Where a PCF for a specific product was unavailable, an available PCF was selected to reflect similar characteristics. In addition to the PCF calculations, emissions related to the transportation of fertilizers are also quantified based on the Proba methodologies. A comprehensive table with all the PCF values used for each baseline and intervention scenario is provided in the Appendix A.1

Nitrogen application rate (kg N/ha):

The N rate is a critical input parameter for quantifying direct and indirect N_2O emissions, as it determines the magnitude of reactive nitrogen entering the soil system. In accordance with the methodology guidelines, the N application rate is defined based on farmer-logs, supported where necessary by regional agronomic data. The detailed collection and reporting of N application rates is described in the MRV table (see Section 6) of this document

Emission factors:

Standardized emission factors are used to estimate reductions at the field level. Emission factors are applied to both the baseline and the project scenario to determine the net impact of each intervention. EFs for direct and indirect emissions were selected according to the guidelines outlined in the Proba methodologies. In summary these include:

- Alignment with environmental and management conditions, including climate, soil type, crop, fertilizer formulation, and stabilizer category.
- Use of meta-analyses and national GHG inventories where direct matches were unavailable, ensuring that conservative and representative values were chosen.
- Conservative selection from intersecting emission reduction ranges across multiple sub-groups (e.g., soil and crop types) when partial alignment was observed.
- Adherence to quality standards for experimental design of underlying scientific studies (e.g., replication, controls, field-based measurements) as presented in PM004 and PM005

In some cases for indirect emissions, EFs from the 2019 Refinement to the IPCC Guidelines for National Greenhouse Gas Inventories were used. A comprehensive table with direct and indirect N_2O EF values used for each baseline and intervention scenario is provided in the Appendix A.2

Fuel consumption and machinery use:

Each fuel type is assigned a PCF value, which represents the total greenhouse gas emissions associated with its full life cycle, expressed per unit of fuel. The quantification of emissions from fuel usage follows the guidelines of the approved methodology AMS-III.AK (Version 03.0). Operational data on fuel types is collected, while activity data such as distances traveled and frequency of field operations are based on market-standard average values rather than project-specific measurements. These inputs are used to calculate emissions and assess reductions achieved through fuel-saving interventions, such as switching to low-carbon fuels or reducing machinery passes, and are documented in the MRV table (see MRV section). A comprehensive table with fuel related PCF values used for baseline and intervention scenario is provided in the Appendix A.3

In contrast to the original AMS-III.AK framework, which determines emission reductions based on biofuel production volumes and their eligible quantities for crediting (BFy), this project:

- Excludes production-side parameters (PBF_y, $PBF_{on\text{-}site,y}$, $PBF_{other,y}$).
- Calculates emission reductions directly based on the actual consumption of HVO fuels by agricultural vehicles.

Thus, only the quantity of HVO50 and HVO100 consumed (CBF_y) is the basis for emission reduction calculations.

The project will apply the following adapted formula:

$$ER_y = (CBF_y \cdot NCV_{BF,y} \cdot EF_{CO2,FF,y}) - (CBF_y \cdot NCV_{BF,y} \cdot EF_{CO2,BF,y}) \quad (1)$$

Where:

ER_y	=	Emission reductions in year y (tCO2e)
CBF_y	=	Quantity of biofuel consumed in year y (tonnes)
$NCV_{BF,y}$	=	Net calorific value of the biofuel (GJ/tonne)
$EF_{CO2,FF,y}$	=	Emission factor of the fossil diesel (tCO2/GJ)
$EF_{CO2,BF,y}$	=	Emission factor of the biofuel (HVO) (tCO2/GJ)

4. Leakage & Permanence

4.1 Leakage

This project considers two types of leakage, meaning unintended increases in GHG emissions outside the project boundary resulting from project activities:

4.1.1 Market Leakage (Displacement of conventional fertilizer use):

This project involves the substitution of conventional nitrogen fertilizers, specifically CAN24S, CAN27, and NK fertilizers, with enhanced efficiency fertilizer technologies, implemented across a cultivated area of 650 hectares. In theory, this could lead to market leakage, where displaced conventional fertilizers are redistributed and used outside the project boundary by non-participating actors.

However, according to the Proba methodologies (see table from methodologies below), projects below 1,000 hectares are considered small-scale, with negligible market influence and traceability challenges that are minimal. The Agrifirm Low Carbon Crops project falls well within this small-scale category, and therefore qualifies for a 0% market leakage deduction.

Market leakage deduction for different scenarios

Project scale[4]	Scenario	Traceability of the displacement	Deduction
<1.000 ha	A	Leakage risk is considered negligible.	0%
1,000 - 10,000 ha	B	Project shows displaced fertilizer was not used outside the project (e.g. supplier confirmation, farm data, or market data)	1%
	C	Fate of displaced fertilizer unknown or unconfirmed (no evidence)	5%
>10.000 ha	D	Project shows displaced fertilizer was not used outside the project (e.g. supplier confirmation, farm data, or market data).	2%
	E	Displaced fertilizer may have been used outside the project (uncertain or evidence of redirection). No evidence, or indications of redistribution in trade/sales data.	10%

4.1.2 Market Leakage (Displacement of conventional fuel use):

The likelihood of leakage resulting from the fuel switch intervention is negligible. Participating farmers replace fossil diesel with certified HVO biodiesel, which is sourced through existing commercial fuel supply chains. There is no evidence that this shift displaces emissions to other actors or regions.

4.1.3 Yield-Related Leakage (Production shifting):

The project involves the replacement of conventional nitrogen fertilizers with enhanced efficiency fertilizer technologies that are expected to maintain or enhance crop yield performance. The main intervention types and their expected effects on crop yield and nitrogen use efficiency are outlined below:

- *Low carbon footprint fertilizers:* These fertilizers are formulated to deliver the same amount of plant available nitrogen as conventional products. They are

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

expected to support similar yield levels while they are produced with a reduced PCF.

- *Nitrogen stabilizers:* Their use improves the timing and duration of nitrogen availability in the root zone, which supports stable or improved crop yields through better synchronization with crop nutrient demand.
- *Controlled release fertilizers (CRF):* These products release nutrients gradually throughout the crop growth cycle, aligning nutrient availability with plant uptake patterns. CRF applications are expected to maintain or even increase yield levels under typical field conditions.

Although these technologies are expected to preserve or improve crop productivity, the Proba methodologies require that the project assess whether any yield reduction has occurred that could trigger production shifting and related emissions. This will be evaluated by comparing project area data on crop yield and nitrogen use efficiency with historical farm records or regional benchmarks, allowing for a tolerance of up to 10%. Years impacted by extreme (weather) events will be excluded from this assessment. The data that needs to be collected is presented in the MRV table in section 6.1 and results of the assessment will be reported in the monitoring report (see section 6.2).

4.2 Permanence

The interventions in scope for this project result in reduced emissions, not carbon storage. As such, there is no risk of reversal, and permanence is ensured through monitoring of actual Enhanced efficiency fertilizers and HVO fuel use within the crediting year.

5. Estimated GHG impact

The figures presented in this section are high-level estimates derived from aggregated pilot data and the quantification approaches described in Section 3. They are intended to provide an indicative view of the potential greenhouse gas (GHG) reductions achievable through the interventions implemented across the participating plots.

It is important to note that the final estimated impact at the asset level, as reported on the Proba platform, will differ from these figures.

Metric	Crop	Baseline	Project	Reduction
Fertilizer emissions (per ha)	Winter wheat	0,88 $tCO2e$	0,6 tCO_2e	0,28 tCO_2e
	Summer Barley	0,41 $tCO2e$	0,22 tCO_2e	0,19 tCO_2e
	Potato	tCO_2e	tCO_2e	tCO_2e
Fertilizer emissions (per tonne of crop)	Winter wheat	0,10 tCO_2e	0,07 tCO_2e	0,03 tCO_2e
	Summer Barley	0,082 tCO_2e	0,044 tCO_2e	0,038 tCO_2e
	Potato	tCO_2e	tCO_2e	tCO_2e
Fuel emissions (per ha)	Winter wheat	0,5 tCO_2e	0,05 tCO_2e	0,45 tCO_2e
	Summer Barley	0,37 tCO_2e	0,04 tCO_2e	0,33 tCO_2e
	Potato			
Fuel emissions (per tonne of crop)	Winter wheat	0,06 tCO_2e	0,006 tCO_2e	0,05 tCO_2e
	Summer Barley	0,074 tCO_2e	0,008 tCO_2e	0,066 tCO_2e
	Potato			
Total GHG emissions reduced (tCO_2e)	Winter wheat			500 tCO_2e
	Summer Barley			40 tCO_2e
	Potato			10 tCO_2e

6. Monitoring, reporting and verification

6.1 Monitoring, reporting and verification framework

To ensure consistent and transparent data collection across all interventions, the following table consolidates the monitoring, reporting, and verification (MRV) requirements for all methodologies applied in the project. It outlines the key parameters, data sources, and reporting frequencies used to support emission reduction quantification and verification.

Table 2: Project scoping

Index	*Name*	*Description*	*Background from this methodology*	*Evidence required*	*Frequency of reporting*
A1	Scope of activities	The list of interventions can be seen in ***Table 1***	Section 2.1	POD section 3.1	Once during POD validation or update during verification if they change during the crediting period
A2	GHG sources	**The GHG sources in scope are**: - GHG emissions related to the production of fertilizers (PCF) - Direct and indirect N_2O emissions from fertilizer application - CO_2 emissions from the use of agricultural vehicles **GHG sources not in scope** - Other GHG sources are expected to remain constant across both baseline and project scenarios. For example, emissions related to pesticide use, seed production, on farm energy use (beyond fertilizer application) considered immaterial in the context of the fertilizer-focused intervention	Section 2.2	POD section 3.2	
A3	Spatial boundary and size (hectares or similar)	Present coordinates delineating the: • locations of the field (for Land Management Unit level boundary)	Section 2.3	POD section 2.1 and table xx	
A4	Temporal boundary (for monitoring)	Define the temporary boundary for the project	Section 2.4	POD section 1.3	

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

Index	Category name	Subcategory name	Description	Evidence required for baseline	Evidence required for project	Frequency of reporting
B1.1	Crop types	-	Type of crop being cultivated	Farmer log or market based information	JSON file containing (input) data for all LMUs	Reconfirmed or updated for every verification
B1.2	Fertilizer	Fertilizer PCF	Cradle-to-gate emissions Appendix A1.	• Third party verified manufacturer's PCF report • Credible database e.g. National/regional PCF datasets	POD Appendix A1 with supported documentation like: • Third party verified manufacturer's PCF report • Credible database e.g. National/regional PCF datasets	
		Type	CAN 27 Manure …	Farmer log or market based information	JSON file containing (input) data for all LMUs • Proof of purchase and product label (upon request)	
		N rate	Can 27/potato =200kg of N CAN27/wheat= 180 kg N	Farmer log or market based information	POD Appendix A2	
		Application rate & method	Application rate of the fertilizer & method, timing, splitting	Farmer log or market based information	JSON file containing (input) data for all LMUs	
B1.3	Nitrogen stabilizer	Nitrogen stabilizer PCF	Cradle-to-gate emissions	-	POD Appendix A1 • Third party verified manufacturer's PCF report • Credible database e.g. National/regional PCF datasets	

Index	Category name	Subcategory name	Description	Evidence required for baseline	Evidence required for project	Frequency of reporting
		Type	Type of nitrogen stabilizer being applied	-	JSON file containing (input) data for all LMUs • Proof of purchase (or sale from the distributor), product label & regulatory eligibility	
		Application rate & method	Application rate of the nitrogen stabilizer & method, timing, splitting	-	• JSON file containing (input) data for all LMUs	
B1.4	Crop yield (Y)	-	Amount of crops harvested	Farmer log or market based information	JSON file containing (input) data for all LMUs	Reconfirmed or updated for every verification
B1.5	Reference crop yield		Historical amount of crop harvested	Farmer log or market based information	• Average yield of project • Average yield of benchmark • Average yield in time based on CBS Statline information.	
B1.6	NUE	Project NUE	Nitrogen use efficiency, which must be compared to historical or regional benchmark NUE values to verify that the baseline practices are following the region's guidelines.	Farmer log	The actual NUE will be compared to the region's guidelines based on the thresholds of Dutch nitrogen legislation	
		Regional or historical NUE	Regional or historical NUE	Regional database (or similar) or farmer logs (for the historical NUE).	-	
B1.7	Transportation emissions	Distance	Average distance between the production location and	Data from distributor	Data from distributor	

Index	Category name	Subcategory name	Description	Evidence required for baseline	Evidence required for project	Frequency of reporting
			the use location of the fertilizer			
		Vehicle type	Type of vehicle(s) used to transport the fertilizer	Data from distributor, industry reports	Data from distributor, industry reports	
B1.8	Field spreading emissions	Machinery type	Type of vehicle(s) used to spread the fertilizer	Farmer log	Farmer logs related to days of application	
		Distance traveled per field spread	Distance that the machinery (e.g. tractor) travels to spread the fertilizer	Farmer log	Farmer logs related to days of application	
		Number of field spreading events per cropping cycle	Based on the type of fertilizer, spreading method, etc. different number of field spreading events might happen.	Farmer log	Farmer logs related to days of application	
		Fuel type	Fuel type that was used (e.g. biofuel)	Fuel purchase invoice	Fuel purchase invoice	
B1.9	(Optional) Additional management practices	-	Optional only if additional management practices are implemented, along with the nitrogen stabilizer introduction, which lead to an extra reduction of GHG emissions.	-	• 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)	
B1.10	(Optional) Additional data for more detailed EF	Influential environmental and/or management	Optional. In case more detailed EF are selected, then additional information are required	Farmer log or market based information	For each additional data point, sufficient evidence is required	

Index	Category name	Subcategory name	Description	Evidence required for baseline	Evidence required for project	Frequency of reporting
		practices				
B1.11	Emission factors	-	List of EFs selected for each activity in scope	Relevant evidence depending on the approach selected (see Appendix A2)		

Table 4: MRV data for fuel switch consumption

Index	Category Name	Subcategory Name	Description	Evidence Required for Baseline	Evidence Required for Project	Frequency of Reporting
FS-1	Fuel Use	Baseline Diesel Usage	Volume of fossil diesel that would have been used in absence of the intervention	Historical fuel purchase records OR regional average fuel use per hectare per crop	N/A	Once (initial setup or per crop season)
FS-2	Fuel Use	HVO Usage	Volume and blend type (HVO50 or HVO100) used in farm operations	N/A	Fuel purchase receipts OR supplier delivery statements	Per crop cycle (after harvest)

FS-3	Emission Factors	Baseline Emission Factor	CO_2e emission factor for fossil diesel (kg CO_2e per liter)	National or IPCC default values OR supplier documentation	N/A	Once, unless emission factors are updated
FS-4	Emission Factors	Project Emission Factor	CO_2e emission factor for HVO50/HVO100 used	N/A	Verified life cycle analysis (LCA) documentation from supplier	Once, unless feedstock or supplier changes
FS-5	Crop Area	Area Under Intervention	Number of hectares where the fuel switch is applied (linked to crop and machinery activity)	Field records, GPS data, or IACS data	Same	Per crop season
FS-6	Adoption Confirmation	Fuel Type Confirmatio n	Confirmation that HVO was used for farm operations, not for unrelated uses	N/A	Farmer declaration or spot-check audit OR telemetry data (if available)	Per crop cycle

6.2 Monitoring report

Before verification, Agrifirm will prepare and submit all relevant input data for each LMU. The following elements will be included:

1. **Input Data per LMU**
    - Agrifirm will compile all input data at the LMU level in a structured JSON file.
    - This file will be imported directly into the Proba platform to quantify the impact.
    - The input data will also be attached to the monitoring report that will be used for verification and published on the registry.
2. **Yield Leakage Assessment**
    - A yield-related leakage assessment (as described in section 4.1.3) will be conducted to account for potential indirect effects.
    - This assessment will be based on historical and/or reference crop yield data.
    - The results of this analysis will be documented in the monitoring report to support the verification.

6.3 Managing data quality

As a project developer, Agrifirm is responsible for the collection, preparation, and quality assurance of all MRV data used in this project. This data forms the basis for the quantification of GHG emission reductions and the issuance of emission reduction certificates on the Proba platform.

6.3.1 Data exchange and processing

The MRV data, Agrifirm provides, includes all data required under the applicable methodologies:

- LMU identifiers and field sizes
- Inputs used in both the baseline and project scenarios (fertilizers, stabilizers, and fuels)
- Crop types and associated yields
- Fertilizer application rates
- Fuel types and use rates

This data is sourced from a combination of centralized systems within Agrifirm and structured data collection from participating farmers. To ensure consistency and compatibility, all data is compiled using Proba's standardized JSON template prior to submission to the Proba platform. The template contains all MRV data required for the quantification of the estimated and realized impact.

6.3.2 Data quality assurance

Agrifirm applies a structured internal process to safeguard the quality of all submitted MRV data:

- **Four-eyes principle**: Data entered manually into the JSON template are reviewed by a second team member.
- **Traceability**: Each dataset is linked to a specific LMU and crop season, ensuring clear auditability from field-level data to certificate issuance.
- **Averages of the output:** based on the manual entered data, averages are calculated and compared to the averages of the original data sources (Farmer input, the Agrifirm ERP system and the Agrifirm CRM systems). Outliers are marked.
- **Four-eyes principle 2**: These outliers entered manually into the JSON template are double checked by a second team member.

7. Certificate issuance, attribution and claiming

7.1 Issuance of emission reduction certificates

Emission reduction certificates are issued by Agrifirm through the Proba platform once quantification and verification has been completed.

Each certificate corresponds to a verified emission reduction of one tonne CO_2e, and is uniquely linked to:

- The Land Management Unit where the reduction occurred
- The crop type involved (winter wheat, barley, or potatoes)
- The intervention(s) applied (referenced via metadata)
- The growing season
- A full audit trail of input and output values used in the quantification

Each certificate carries metadata that includes the following available metrics:

- Total GHG emissions reduced (tCO_2e)
- GHG emissions per hectare (baseline vs. project scenario)
- GHG emissions per tonne of crop produced (emission intensity)
- Cradle-to-gate emissions of applied inputs (e.g., fertilizer, stabilizers, fuel)
- Crop yield (tonnes/ha)
- Date of issuance and verification entity

Certificates are registered on the Proba platform registry, and can subsequently be transferred or claimed and retired.

7.2 Attribution of certificates

Attribution is about assigning rights to emission reduction certificates and is the act of designating who enabled the emission reduction based on causality and proof of sourcing. Attribution is only available to buyers who are linked to the crop specific value chains and are positioned upstream to demonstrate sourcing of the relevant crops. Certificates cannot be claimed by downstream parties who are not in a position to demonstrate causality or sourcing at the commodity level.

7.2.1 Causality

To maintain environmental and accounting integrity of the project, causality must be demonstrated before a buyer can claim certificates as part of their Scope 3 emission reductions. This ensures that buyers only claim reductions they have genuinely enabled—and that no free-riding or double claiming occurs.

In this project, causality is established by the presence of an offtake certificate agreement between the project developer and each buyer. This agreement confirms that the buyer intended to source from the project area and financially supported the implementation directly.

The Proba platform performs a causality eligibility check as a supporting mechanism for the buyer's auditor. The full demonstration and verification of causality, however, remains the responsibility of the buyer's auditor when validating claims in Scope 3 reporting. To illustrate the operation of the causality eligibility check, the transfer process from certificate issuance to retirement is summarized below.

1. Project developer can issue verified emission reduction certificates after the VVB has completed the verification;
2. Project developer initiates a certificate transfer to a designated buyer;
   - Part of this process is a causality eligibility check, where the project developer is asked to upload an offtake agreement with the designated buyer and confirm that this buyer supported the project.
3. The offtake agreement is not published on the public registry but is stored securely on the Proba platform for audit and compliance purposes.
4. Buyer receives the certificates

7.2.2 Proof of sourcing

In parallel with causality, proof of sourcing is required before a buyer can claim and retire certificates. As physical traceability of each crop unit is not feasible, the project applies a mass balance approach.

1. **Step 1: Buyer initiates retirement of certificates**
2. **Step 2: Buyer adds procurement records and volume declaration**

- **Procurement records:** The buyer uploads procurement documents (e.g. purchase records, contracts, invoices) for the relevant crop. Two traceability scenarios are supported:
  i. Direct traceability: The buyer provides procurement records showing that the purchased crop originated directly from the Agrifirm supply chain during the relevant season.
  ii. Indirect traceability: The buyer provides procurement records demonstrating that the purchased crop originated from the geographic and operational sourcing area linked to the project.
- **Volume declaration:** Alongside the document upload, the platform requires the buyer to manually enter the total quantity of crop purchased, expressed in tonnes

3. **Step 3: Platform reconciliation check** The platform automatically compares the following data points:
   - The total amount of crop produced in the project from LMUs linked to emission reduction certificates.
   - The crop volumes entered by the buyer.
   - The volume of certificates the buyer is attempting to claim.

If both causality and proof of sourcing checks are passed, the buyer's attribution is finalized. The certificates will be retired and may then be included in GHG reporting.

7.3 Reporting of emission reduction certificates

Each buyer who is attributed emission reduction certificates may report them in the context of their Scope 3 GHG emissions, particularly under Category 1: Purchased Goods and Services.

There are two primary reporting options, depending on the buyer's preference and existing accounting framework:

1. **Absolute Emission Reductions**:
   Buyers may report the total volume of CO_2-equivalent reductions achieved through the project (i.e. the total number of emission reduction certificates attributed to them) as a standalone contribution to supply chain decarbonization.

2. **Updated Emission Factors**:
   Alternatively, buyers may choose to integrate the effects of the intervention into their corporate inventory by adopting **improved emission factors** (EFs) for the relevant crops and sourcing regions. This approach reflects a lower average footprint per unit of purchased product and can be integrated directly into Scope 3 emissions calculations.

8. Social and Environmental Safeguards

8.1 Do No Harm Assessment

The Agrifirm Low Carbon Crops Project complies with the “Do No Harm” principle required for GHG mitigation activities under the Proba Standard. This principle ensures that climate action does not cause unintended negative social or environmental consequences.

To demonstrate compliance, Agrifirm has completed a review using the *Proba Sustainable Development Benefits and Safeguards* framework. This includes assessing whether the project activities may introduce any environmental or social risks and identifying mitigation measures where relevant.

The completed safeguard assessment is included in Appendix C of this document.

8.2 SDG Contributions (Co-Benefits)

The Agrifirm low carbon crops project aims to contribute to the following SDGs.

SDG	**Contribution**
SDG 2 – Zero Hunger	Maintaining yields while limiting (the carbon footprint of) inputs.
SDG 9 - Industry, Innovation and Infrastructure	Stimulating decarbonization of fertilizer production
SDG 12 – Responsible Consumption and Production	Increasing input use efficiency in Agricultural systems.
SDG 13 – Climate Action	Reducing GHG emissions in crop cultivation.

SDG 15 – Life on Land	Decreasing Nitrogen losses to the environment.

9. Stakeholder Engagement

9.1 Stakeholders

The Agrifirm Low Carbon Crops Project involves a range of stakeholders from across the agricultural value chain, each with a direct or indirect role in enabling the implementation of low-carbon interventions and the generation of verified emission reductions. Section 1.4 identified the key stakeholders in the project already.

9.2 Stakeholder consultation method

Stakeholder consultation was conducted by Agrifirm during project development and onboarding. The methods used included:

- **Direct outreach to farmers** via Agrifirm advisors and commercial teams, supported by informational materials on the goals, interventions, and participation model of the project.
- **Individual advisory sessions and onboarding calls**, offering farmers the opportunity to ask questions and raise concerns.
- **Engagement with agri-buyers** through structured meetings and bilateral discussions, aligning project goals with buyers' Scope 3 emission reduction targets.
- **Supplier coordination** through meetings and discussions to confirm input specifications and alignment with Proba's requirements for product carbon footprints.
- **Documentation of agreements** including offtake letters and farmer participation agreements to formalize stakeholder roles and secure mutual understanding.

- **Public consultation** by publishing the Project Overview Document (POD) on the Proba website, providing an opportunity for any interested stakeholders to review the project design and submit comments before final validation.

9.3 Summary of feedback

Farmers point out that the risks of “decarbonization” are largely placed on them: while the higher costs are clear upfront, the returns remain uncertain. A second risk they face is the still limited and inconsistent availability of low-carbon products within short timeframes, which causes strong fluctuations in the price gap with standard products—again leaving growers exposed to financial uncertainty.

9.4 Impact on project

Agrifirm agreed with the fuel supplier a constant price difference between standard and low carbon products during the season. For the Low Carbon Fertilizers Agrifirm connected the price difference of the low carbon fertilizers to the pricelist of the traditional products. This reduced the risk for the farmer but increased the risk for Agrifirm. For the short term this is a way to reduced risk, Agrifirm is looking for new solutions which work for a further scaled project.

9.5 Ongoing stakeholder engagement

Stakeholder engagement continues throughout the implementation phase of the project to ensure transparency, responsiveness, and continuous improvement. Ongoing engagement mechanisms include:

- **Seasonal check-ins with farmers**, conducted by Agrifirm’s field advisors to provide technical support, collect monitoring data, and review progress.
- **Feedback loops with agri-buyers**, allowing for coordination around procurement volumes, certificate attribution, and reporting needs. Buyers are informed about verification status and credit issuance timelines via the Proba platform.
- **Platform data uploads**, enabling stakeholders to access project data and monitor emissions reductions.

- **Grievance and support mechanisms** available to farmers and buyers through Agrifirm and Proba, with clear escalation paths for unresolved issues.

10. Risk assessment

10.1 Identified risks and mitigation measures

The following table provides an overview of project-specific risks, their potential impact, and the corresponding mitigation measures designed to minimize their likelihood and/or impact.

Project specific Risk name/type	**Potential negative impact**	**Mitigation Measure(s)**
Risk of (willingful) wrong reporting by project participant	- Reversal of credits and negative impact on credibility of the project - Buyers need to update their Scope 3 inventories with the reversals	- Regular communication with farmer (POD section 9.5) - Buffer pool (POD section 10.2)
Risk of underperforming yield vs benchmark	- Not eligible for emission reductions - Negative financial impact for farmers - Bad publicity	- Conservative yield estimates - Small scale start, - Field trials for inputs,
Risk of errors in data processing	- Incorrect quantification of impact - Reversal of credits and negative impact on credibility of the project - Buyers need to update their Scope 3 inventories with the reversals	- Section Data Quality Management (POD section 6.3) - Buffer pool (POD section 10.2)

Risks of unreliable PCF data	- Incorrect quantification of impact - Reversal of credits and negative impact on credibility of the project - Buyers need to update their Scope 3 inventories with the reversals	- Small scale start - Preferred usage of certified PCFs otherwise double check on reliability of PCF is executed - Buffer pool (POD section 10.2)
Risk that the crop will not be sold according to the original "market shed"	- Before issuance: Not eligible for emission reductions - After issuance: Reversal of credits and negative impact on credibility of the project	- For two of the three crops distribution is guaranteed by Agrifirm - Most crops are contracted up front (contract farming)

10.2 Buffer pool

In accordance with the Proba Standard (sections 3.8 and 3.9), the project will contribute 10% of all issued credits to the Proba Buffer Pool. This contribution covers residual risks identified in Section 10.1 (e.g. underperforming yields, data errors, and reporting risks) that could lead to reversal.

The 10% rate is applied as it reflects the Proba Standard's default contribution level, deemed sufficient to insure against the risks relevant for this project. Buyers of the inset credits remain directly accountable for reporting and managing reversals in their Scope 3 inventories.

Appendix A: Emission parameters and inputs

A.1 Product Carbon Footprints of fertilizer products

	Type of fertilizer product	Product carbon footprint [kg CO2eq / kg product]	Source	Documentation/Justification
1	CAN27 (conventional)	0.951	International Fertilizer Society report (Hoxha et al., 2018)	The IFS report presents regional reference values for greenhouse gas emissions associated with fertilizer production, based on data collected from fertilizer producers. These reference values are intended to provide representative benchmarks for fertilizer carbon footprints. For CAN 27, a PCF of 0.951 kg CO_2eq/kg product is applied. This value reflects the EU average for CAN 27 Document: Hoxha, A., Christensen, B., & International Fertiliser Society. (2018). *The carbon footprint of fertilizer production : regional reference values.* International Fertiliser Society.
2	CAN27 (low-carbon)	x.xxx	OCI, verified	This value is derived from third-party verified PCF data provided by OCI, a producer of low-carbon fertilizers. The value is calculated on a cradle-to-gate basis according to ISO 14067.
3	CAN24 + S (conventional)	0.845	International Fertilizer Society report (Hoxha et al., 2018)	The PCF for CAN 24 + S is derived from the IFS reference value for CAN 27 (0.951 kg CO_2eq/kg), scaled according to the relative nutrient content (24% vs. 27% nitrogen). This approach is consistent with the methodology outlined in the IFS report, where carbon footprints are closely linked to nutrient composition and production intensity. The resulting value of 0.845 kg CO_2eq/kg product thus reflects a proportionally adjusted EU benchmark Document: Hoxha, A., Christensen, B., & International Fertiliser Society. (2018). *The carbon footprint of fertilizer production : regional reference values.* International Fertiliser Society.
4	CAN24 + S (Fertiberia Impact Zero DS+)	x.xxx	Fertiberia, verified	This value is derived from third-party verified PCF data provided by Fertiberia, a producer of low-carbon fertilizers.

5	NK (13%, 0%, 25%)	0.55	International Fertilizer Society report (Hoxha et al., 2018) Fertilizers Europe. (2011)	The PCF for NK 13-0-25 is derived using the EU reference value for CAN 27 (0.951 kg CO_2eq/kg product) to quantify the nitrogen contribution (since the origin of N is CAN) and the EU plant-gate reference for Muriate of Pottasium (KCl, 60% K_2O) (0.25 kg CO_2eq/kg product) to quantify the potassium contribution. The mass of CAN required to deliver 13% N (0.13/0.27) and the mass of MOP required to deliver 25% K_2O (0.25/0.60) are applied to the respective reference PCFs and summed. The resulting value of ~0.56 kg CO_2eq per kg product thus reflects a proportionally adjusted EU benchmark for this NK formulation Document: Hoxha, A., Christensen, B., & International Fertiliser Society. (2018). *The carbon footprint of fertilizer production : regional reference values.* International Fertiliser Society. Fertilizers Europe. (2011). *Mineral fertiliser carbon footprint reference values: 2011.* Validated by European Commission methodology.
6	Ammonium sulfate (8% N)	0.215	Carbon Footprint Calculator for Fertilizer Products (https://app.calcfert.com/)	The PCF for Ammonium sulfate (8% N) is derived from the reference value for standard Ammonium sulfate (21% N, 24S) of 0.564 kg CO_2eq/kg product, scaled according to the relative nitrogen content (8% vs. 21% nitrogen). This approach is consistent with the methodology outlined in the IFS report, where carbon footprints are closely linked to nutrient composition and production intensity. The resulting value of 0.215 kg CO_2eq/kg product thus reflects a proportionally adjusted EU benchmark
7	Toptrace N Allround (Methylene urea)	x.xxx	Biron calculation	This value is derived from third-party verified PCF data provided by Biron, a distributor of fertilizer products.
8	CRF urea (part of Topcote)	x.xxx	ICL	This value is derived from third-party verified PCF data provided by ICL, a producer of controlled release fertilizers.
9	DMPP (Vizura)	x.xxx (per liter of product)	BASF	This value is derived from third-party verified PCF data provided by BASF, a producer of nitrogen stabilizers.

A.2 Emission Factors from direct and indirect N_2O emissions

	Information	Type of emissions	Emission factor %, [kgN2O-N / kgN]	Study/Source	Justification
			Organic fertilizers		
1	Winter wheat, Slurry, Clay soil	Direct N_2O-N	0.115	https://doi.org/10.1016/j.eti.2024.103952	This EF is selected due to the alignment in crop type, soil type, fertilization method, and climate characteristics, fulfilling Tier 2 quality criteria defined in methodology PM.0004
		Indirect due to NH_3 volatilization	0.131	• IPCC 2019 • https://doi.org/10.1016/j.geoderma.2015.10.007	To estimate indirect N_2O emissions originating from ammonia volatilization, the project uses the manure-type-specific volatilization fraction provided by Bell et al. (2016). This fraction number is considered representative due to the alignment in fertilizer type, application method, and regional climate (temperate). This volatilization fraction was combined with the IPCC 2019 default EF4 to calculate the final indirect N_2O–N emission factor. fulfilling Tier 2 quality criteria defined in methodology PM.0004
		Indirect due to NO_3^- leaching	0.264	IPCC 2019	Due to the limited availability of Tier 2 emission factors for indirect N_2O emissions originating from nitrate leaching, the approach follows the guidance of the IPCC 2019 Refinement report. Tier 1 default values, disaggregated according to fertilizer type and environmental conditions were used.
2	Winter wheat, Slurry, Clay soil, DMPP (Vizura)	Direct N_2O-N	0.023	https://doi.org/10.1016/j.eti.2024.103952	This EF is selected due to the alignment in crop type, soil type, fertilization method, inhibitor product/type and climate characteristics, fulfilling Tier 2 quality criteria defined in methodology PM.0004. According to the cited study, the application of DMPP resulted in substantial reductions in N_2O emissions, with observed emission factor reductions ranging from 76% to 100% when compared to untreated organic nitrogen inputs (specifically, pig slurry, PS). To ensure methodological conservativeness and avoid over-crediting, this project adopts an 80% reduction
		Indirect due to NH_3 volatilization	0.131	https://doi.org/10.1016/j.geoderma.2015.10.007	In line with findings from the meta-analysis by Fan et al. (2022), nitrification inhibitors are not expected to significantly affect ammonia volatilization rates. Therefore, no reduction is applied to this indirect emission pathway.

					No impact is claimed. Therefore the same EF with the baseline scenario is used.
		Indirect due to NO_3^- leaching	0.158	• IPCC 2019 • https://doi.org/10.1088/1748-9326/acb833	In order to quantify the efficiency of nitrogen stabilizers in reducing indirect emissions, a 40% reduction was applied to this EF, based on the meta-analysis by Chen et al. (2023). As shown in Table 2 of the study, nitrification inhibitors applied with fertilizers in similar conditions result in median nitrate leaching/run-off reductions of 48%. The 40% reduction was selected as a conservative value to avoid overestimating mitigation based on the guidelines of the methodology PM.0004
3	Barley, Slurry, Clay soil	Direct N_2O-N	0.439	https://doi.org/10.1016/j.eti.2024.103952	This EF is selected due to the alignment in crop type, soil type, fertilization method, and climate characteristics, fulfilling Tier 2 quality criteria defined in methodology PM.0004
		Indirect due to NH_3 volatilization	0.131	• IPCC 2019 • https://doi.org/10.1016/j.geoderma.2015.10.007	To estimate indirect N_2O emissions originating from ammonia volatilization, the project uses the manure-type-specific volatilization fraction provided by Bell et al. (2016). This fraction number is considered representative due to the alignment in fertilizer type, application method, and regional climate (temperate). This volatilization fraction was combined with the IPCC 2019 default EF4 to calculate the final indirect N_2O–N emission factor. fulfilling Tier 2 quality criteria defined in methodology PM.0004
		Indirect due to NO_3^- leaching	0.264	IPCC 2019	Due to the limited availability of Tier 2 emission factors for indirect N_2O emissions originating from nitrate leaching, the approach follows the guidance of the IPCC 2019 Refinement report. Tier 1 default values, disaggregated according to fertilizer type and environmental conditions were used.
4	Barley, Slurry, Clay soil, DMPP (Vizura)	Direct N_2O-N	0.246	https://doi.org/10.1016/j.eti.2024.103952	This EF is selected due to the alignment in crop type, soil type, fertilization method, inhibitor product/type and climate characteristics, fulfilling Tier 2 quality criteria defined in methodology PM.0004
		Indirect due to NH_3 volatilization	0.131	• IPCC 2019 • https://doi.org/10.1016/j.geoderma.2015.10.007 • https://doi.org/10.1111/gcb.16294	In line with findings from the meta-analysis by Fan et al. (2022), nitrification inhibitors are not expected to significantly affect ammonia volatilization rates. Therefore, no reduction is applied to this indirect emission pathway. No impact is claimed. Therefore the same EF with the baseline scenario is used.
		Indirect due to NO_3^- leaching	0.158	• IPCC 2019 • https://doi.org/10.1088/1748-9326/	In order to estimate the efficiency of nitrogen stabilizers in reducing indirect emissions, a 40% reduction was applied to this EF, based on the meta-analysis by Chen et al. (2023). As shown in Table 2 of the study, nitrification inhibitors applied with fertilizers in similar conditions result in median nitrate leaching/run-off reductions of 48%. The 40%

				acb833	reduction was selected as a conservative value to avoid overestimating mitigation based on the guidelines of the methodology PM.0004
5	Potato, Slurry, Clay soil	Direct N_2O-N	1.103*	https://doi.org/10.1016/j.soilbio.2006.04.040	This EF is selected due to the alignment in crop type, soil type, fertilization method, fulfilling Tier 2 quality criteria defined in methodology PM.0004
		Indirect due to NH_3 volatilization	0.131	• IPCC 2019 • https://doi.org/10.1016/j.geoderma.2015.10.007	To estimate indirect N_2O emissions originating from ammonia volatilization, the project uses the manure-type-specific volatilization fraction provided by Bell et al. (2016). This fraction number is considered representative due to the alignment in fertilizer type, application method, and regional climate (temperate). This volatilization fraction was combined with the IPCC 2019 default EF4 to calculate the final indirect N_2O–N emission factor. fulfilling Tier 2 quality criteria defined in methodology PM.0004
		Indirect due to NO_3^- leaching	0.264	IPCC 2019	Due to the limited availability of Tier 2 emission factors for indirect N_2O emissions originating from nitrate leaching, the approach follows the guidance of the IPCC 2019 Refinement report. Tier 1 default values, disaggregated according to fertilizer type and environmental conditions were used.
Inorganic fertilizers					
6	Winter wheat, CAN27 (conventional), Clay	Direct N_2O-N	0.653*	https://doi.org/10.3389/fenvs.2023.1231767	This EF is selected due to the alignment in crop type (winter wheat), soil type (clay), fertilization method (CAN), and climate (temperate EU), fulfilling Tier 2 quality criteria defined in methodology PM.0002
		Indirect due to NH_3 volatilization	0.05	IPCC 2019	Due to the limited availability of Tier 2 emission factors for indirect N_2O emissions originating from ammonia volatilization, the approach follows the guidance of the IPCC 2019 Refinement. Tier 1 default values, disaggregated according to fertilizer type and environmental conditions were used.
		Indirect due to NO_3^- leaching	0.396	• IPCC 2019 • https://edepot.wur.nl/169366	Due to the limited availability of site-specific measurements on nitrate leaching and indirect N_2O emissions for CAN-based fertilizers, this project applies a combination of values from authoritative sources. The leaching fraction for arable land on clay soils is taken as 0.36, based on the methodology of Wageningen University and Research, Alterra (Report 2151), which provides regionally validated estimates for the Netherlands. For the emission factor associated with indirect N_2O emissions from nitrate leaching, the default framework of the IPCC 2019 Refinement report is applied
7	Potato, CAN27 (conventional), Clay	Direct N_2O-N	0.7	https://edepot.wur.nl/169366	This EF is selected due to the alignment in crop type (generic: arable crop), soil type, fertilizer type, and regional climate, fulfilling Tier 2 quality criteria defined in methodology PM.0002. The EF originates from field-based measurements conducted in the Netherlands.

		Indirect due to NH_3 volatilization	0.05	IPCC 2019	Due to the limited availability of crop- and region-specific studies on indirect N_2O emissions from ammonia volatilization following the application of CAN-based fertilizers, this project applies the default emission factor framework provided in the IPCC 2019 Refinement (Table 11.3). CAN is categorized under ammonium nitrate-based fertilizers
		Indirect due to NO_3^- leaching	0.396	• IPCC 2019 • https://edepot.wur.nl/169366	Due to the limited availability of site-specific measurements on nitrate leaching and indirect N_2O emissions for CAN-based fertilizers, this project applies a combination of values from authoritative sources. The leaching fraction for arable land on clay soils is taken as 0.36, based on the methodology of Wageningen University and Research, Alterra (Report 2151), which provides regionally validated estimates for the Netherlands. For the emission factor associated with indirect N_2O emissions from nitrate leaching, the default framework of the IPCC 2019 Refinement report is applied.
8	Barley, CAN24 + S**** (conventional), Mostly sandy (or clay)	Direct N_2O-N	0.63	https://doi.org/10.1007/s10705-009-9273-8	This EF is selected due to the alignment in crop type, soil texture, climate, and fertilizer type (CAN), fulfilling Tier 2 quality criteria defined in methodology PM.0004. Therefore, the use of the conservative EF for CAN is scientifically justified and ensures no overestimation of mitigation potential
		Indirect due to NH_3 volatilization	0.05	IPCC 2019	Due to the limited availability of crop- and region-specific studies on indirect N_2O emissions from ammonia volatilization following the application of CAN-based fertilizers, this project applies the default emission factor framework provided in the IPCC 2019 Refinement (Table 11.3). CAN is categorized under ammonium nitrate-based fertilizers
		Indirect due to NO_3^- leaching	0.396	• IPCC 2019 • https://edepot.wur.nl/169366	Due to the limited availability of site-specific measurements on nitrate leaching and indirect N_2O emissions for CAN-based fertilizers, this EF is selected based on a combination of values from authoritative sources. The leaching fraction for arable land on clay soils is taken as 0.36, based on the methodology of Wageningen University and Research, Alterra (Report 2151), which provides regionally validated estimates for the Netherlands. For the emission factor associated with indirect N_2O emissions from nitrate leaching, the default framework of the IPCC 2019 Refinement report is applied.
9	Barley, CAN24 + S**** (with DMPSA, NI), Mostly sandy (or clay)	Direct N_2O-N	0.46*	• https://doi.org/10.1007/s10705-009-9273-8 • https://doi.org/10.1111/gcb.16294	Due to the limited availability of Tier 2 emission factors for direct N_2O emissions, the EF is selected based on the study by Abdalla et al. (2010), which reported a direct N_2O emission factor from CAN application to spring barley (see row 8). In order to estimate the efficiency of nitrogen stabilizers in reducing emissions, a 26% reduction was applied to this EF, based on the meta-analysis by Fan et al. (2022). As shown in Figure 3b of the study (cereal crops), nitrification inhibitors applied with synthetic fertilizers in similar conditions result in median N_2O reductions of ~30%. The 26% reduction was selected as a conservative value to avoid overestimating mitigation based on the guidelines of the methodology PM.0004

		Indirect due to NH_3 volatilization	0.05	• IPCC 2019 • https://doi.org/10.1111/gcb.16294	Due to the limited availability of crop- and region-specific studies on indirect N_2O emissions from ammonia volatilization following the application of CAN-based fertilizers, this project applies the default emission factor framework provided in the IPCC 2019 Refinement (Table 11.3). CAN is categorized under ammonium nitrate-based fertilizers. In line with findings from the meta-analysis by Fan et al. (2022), nitrification inhibitors are not expected to significantly affect ammonia volatilization rates. No impact is claimed. Therefore the same EF with the baseline scenario is used.
		Indirect due to NO_3^- leaching	0.238	• IPCC 2019 • https://edepot.wur.nl/169366 • https://doi.org/10.1088/1748-9326/acb833	Due to the limited availability of site-specific measurements on nitrate leaching and indirect N_2O emissions for CAN-based fertilizers, this EF is selected based on a combination of values from authoritative sources. The leaching fraction for arable land on clay soils is taken as 0.36, based on the methodology of Wageningen University and Research, Alterra (Report 2151), which provides regionally validated estimates for the Netherlands. For the emission factor associated with indirect N_2O emissions from nitrate leaching, the default framework of the IPCC 2019 Refinement report is applied. In order to estimate the efficiency of nitrogen stabilizers in reducing indirect emissions, a 40% reduction was applied to this EF, based on the meta-analysis by Chen et al. (2023). As shown in Table 2 of the study, nitrification inhibitors applied with fertilizers in similar conditions result in median nitrate leaching/run-off reductions of 48%. The 40% reduction was selected as a conservative value to avoid overestimating mitigation based on the guidelines of the methodology PM.000
10	Wheat, CAN24 + S**** (conventional), Clay	Direct N_2O-N	0.849*	https://doi.org/10.1007/s10705-022-10211-7	This EF is selected due to the alignment in crop type (winter wheat), soil type (loamy/clay), fertilizer type (CAN), and temperate climate, fulfilling Tier 2 quality criteria defined in methodology PM.0005. While the formulation used was CAN without sulfur, the addition of sulfate in CAN+S is not expected to increase N_2O emissions and may slightly reduce them through improved N uptake, making this a conservative and appropriate choice.
		Indirect due to NH_3 volatilization	0.05	IPCC 2019	Due to the limited availability of crop- and region-specific studies on indirect N_2O emissions from ammonia volatilization following the application of CAN-based fertilizers, this project applies the default emission factor framework provided in the IPCC 2019 Refinement (Table 11.3). CAN is categorized under ammonium nitrate-based fertilizers
		Indirect due to NO_3^- leaching	0.396	• IPCC 2019 • https://edepot.wur.nl/169366	Due to the limited availability of site-specific measurements on nitrate leaching and indirect N_2O emissions for CAN-based fertilizers, this EF is selected based on a combination of values from authoritative sources. The leaching fraction for arable land on clay soils is taken as 0.36, based on the methodology of Wageningen University and

					Research, Alterra (Report 2151), which provides regionally validated estimates for the Netherlands. For the emission factor associated with indirect N_2O emissions from nitrate leaching, the default framework of the IPCC 2019 Refinement report is applied.
11	Wheat, CAN24 + S**** (with DMPSA, NI), Clay	Direct N_2O-N	0.441*	https://doi.org/10.1007/s10705-022-10211-7	This EF is considered representative due to the alignment in crop type (winter wheat), soil type (loamy/clay), fertilizer form (CAN + NI), and temperate climate, fulfilling Tier 2 quality criteria defined in methodology PM.0004. Since DMPSA and DMPP share the same active compound (DMP), and CAN+S behaves similarly to regular CAN in microbial pathways, the same reduction can conservatively apply to CAN+S with DMPP under similar field conditions
		Indirect due to NH_3 volatilization	0.05	• IPCC 2019 • https://doi.org/10.1111/gcb.16294	Due to the limited availability of crop- and region-specific studies on indirect N_2O emissions from ammonia volatilization following the application of CAN-based fertilizers, this project applies the default emission factor framework provided in the IPCC 2019 Refinement (Table 11.3). CAN is categorized under ammonium nitrate-based fertilizers. In line with findings from the meta-analysis by Fan et al. (2022), nitrification inhibitors are not expected to significantly affect ammonia volatilization rates. Therefore, no reduction is applied to this indirect emission pathway.
		Indirect due to NO_3^- leaching	0.238	• IPCC 2019 • https://edepot.wur.nl/169366 • https://doi.org/10.1088/1748-9326/acb833	Due to the limited availability of site-specific measurements on nitrate leaching and indirect N_2O emissions for CAN-based fertilizers, this EF is selected based on a combination of values from authoritative sources. The leaching fraction for arable land on clay soils is taken as 0.36, based on the methodology of Wageningen University and Research, Alterra (Report 2151), which provides regionally validated estimates for the Netherlands. For the emission factor associated with indirect N_2O emissions from nitrate leaching, the default framework of the IPCC 2019 Refinement report is applied. In order to estimate the efficiency of nitrogen stabilizers in reducing indirect emissions, a 40% reduction was applied to this EF, based on the meta-analysis by Chen et al. (2023). As shown in Table 2 of the study, nitrification inhibitors applied with fertilizers in similar conditions result in median nitrate leaching/run-off reductions of 48%. The 40% reduction was selected as a conservative value to avoid overestimating mitigation based on the guidelines of the methodology PM.000
12	Potato, NK (13%, 0%, 25%), Clay	Direct N_2O-N	1.05	https://doi.org/10.1002/agj2.21720	This emission factor is selected due to the alignment in crop type (potato), soil type (clay), fertilization method (synthetic N), and regional climate (temperate, Northwestern Europe), fulfilling Tier 2 quality criteria as defined in methodology PM.0005. The EF was derived from a study that applied 120 kg N/ha as mineral fertilizer and reported cumulative N_2O emissions for both fertilized and unfertilized control treatments. To isolate the emissions attributable to nitrogen input, we used the control-subtracted approach, in which background N_2O emissions (1.45 kg N_2O–N/ha) were subtracted from total emissions under fertilization (2.71 kg N_2O–N/ha). This results in a direct emission factor of 1.05% of applied N, expressed as N_2O–N.

		Indirect due to NH_3 volatilization	0.05	IPCC 2019	Due to the limited availability of crop- and region-specific studies on indirect N_2O emissions from ammonia volatilization following the application of N -based fertilizers, this project applies the default emission factor framework provided in the IPCC 2019 Refinement (Table 11.3). The source of N is CAN and this fertilizer type is categorized under ammonium nitrate-based fertilizers
		Indirect due to NO_3^- leaching	0.396	• IPCC 2019 • https://edepot.wur.nl/169366	Due to the limited availability of site-specific measurements on nitrate leaching and indirect N_2O emissions for CAN-based fertilizers (the source of N is CAN), this EF is selected based on a combination of values from authoritative sources. The leaching fraction for arable land on clay soils is taken as 0.36, based on the methodology of Wageningen University and Research, Alterra (Report 2151), which provides regionally validated estimates for the Netherlands. For the emission factor associated with indirect N_2O emissions from nitrate leaching, the default framework of the IPCC 2019 Refinement report is applied.
13	Barley Ammonium sulfate (8% N) Mostly sandy (or clay)	Direct N_2O-N	0.340	http://dx.doi.org/10.1016/j.agee.2015.12.015	The study was conducted across two consecutive years on winter wheat and spring barley, and at two sites with sandy loam and loam soils in Germany (similar condition to NL). To determine a representative EF, we focused on results for: barley cultivation on loamy soil. A conservative average EF of 0.34% was selected by taking the mean of those values. The alignment in fertilizer type (ammonium sulfate), application method (injection), crop type (barley), and soil textures (sandy and clay/loamy soils) ensures compliance with Tier 2 quality criteria as defined in methodology PM.0004.
		Indirect due to NH_3 volatilization	0.08	IPCC 2019	Due to the limited availability of crop- and region-specific studies on indirect N_2O emissions from ammonia volatilization following the application of Ammonium sulfate fertilizers, this project applies the default emission factor framework provided in the IPCC 2019 Refinement (Table 11.3). Ammonium sulfate is categorized under ammonium-based fertilizers
		Indirect due to NO_3^- leaching	0.264	IPCC 2019	Due to the limited availability of Tier 2 emission factors for indirect N_2O emissions originating from nitrate leaching, the approach follows the guidance of the IPCC 2019 Refinement report. Tier 1 default values, disaggregated according to fertilizer type and environmental conditions were used.
14	Barley Ammonium sulfate + Inhibitor (Vizura BASF 3L), Mostly sandy (or clay)	Direct N_2O-N	0.252	• http://dx.doi.org/10.1016/j.agee.2015.12.015 • https://doi.org/10.1111/gcb.16294	Due to the limited availability of Tier 2 emission factors for direct N_2O emissions, the EF is based on the study by Deppe et al. (2016), which reported a direct N_2O emission factor from Ammonium sulfate application to spring barley. In order to estimate the efficiency of nitrogen stabilizers in reducing emissions, a 26% reduction was applied to this EF, based on the meta-analysis by Fan et al. (2022). As shown in Figure 3b of the study (cereal crops), nitrification inhibitors applied with synthetic fertilizers in similar conditions result in median N_2O reductions of ~30%. The 26% reduction was selected as a conservative value to avoid overestimating mitigation based on the guidelines of the methodology PM.0004

		Indirect due to NH_3 volatilization	0.08	• IPCC 2019 • https://doi.org/10.1111/gcb.16294	Due to the limited availability of crop- and region-specific studies on indirect N_2O emissions from ammonia volatilization following the application of CAN-based fertilizers, this project applies the default emission factor framework provided in the IPCC 2019 Refinement (Table 11.3). CAN is categorized under ammonium nitrate-based fertilizers. In line with findings from the meta-analysis by Fan et al. (2022), nitrification inhibitors are not expected to significantly affect ammonia volatilization rates.Therefore, no reduction is applied to this indirect emission pathway.
		Indirect due to NO_3^- leaching	0.158	• IPCC 2019 • https://doi.org/10.1088/1748-9326/acb833	In order to estimate the efficiency of nitrogen stabilizers in reducing emissions, a 40% reduction was applied to this EF, based on the meta-analysis by Chen et al. (2023). As shown in Table 2 of the study, nitrification inhibitors applied with fertilizers in similar conditions result in median N leaching/run-off reductions of 48%. The 40% reduction was selected as a conservative value to avoid overestimating mitigation based on the guidelines of the methodology PM.0004
15	Potato, Topcote CRF (80% blend of CRF-urea + 20% CAN27), Clay	Direct N_2O-N	0.574	• https://edepot.wur.nl/169366 • https://doi.org/10.1016/j.agee.2023.108416	This EF is selected due to the alignment in crop type (generic: arable crop), soil type, fertilizer type, and regional climate, fulfilling Tier 2 quality criteria defined in methodology PM.0002. The EF originates from field-based measurements conducted in the Netherlands. A reduction of 18% (conservative) was applied based on the study of Pan et al., (2023)
		Indirect due to NH_3 volatilization	0.025	• IPCC 2019 • https://doi.org/10.1016/j.agee.2023.108416	Due to the limited availability of crop- and region-specific studies on indirect N_2O emissions from ammonia volatilization following the application of CAN-based fertilizers, this project applies the default emission factor framework provided in the IPCC 2019 Refinement (Table 11.3). CAN is categorized under ammonium nitrate-based fertilizers. A reduction of 50% (conservative) was applied based on the study of Pan et al., (2023)
		Indirect due to NO_3^- leaching	0.356	• IPCC 2019 • https://edepot.wur.nl/169366 • https://doi.org/10.1016/j.agee.2023.108416	Due to the limited availability of site-specific measurements on nitrate leaching and indirect N_2O emissions for CAN-based fertilizers, this project applies a combination of values from authoritative sources. The leaching fraction for arable land on clay soils is taken as 0.36, based on the methodology of Wageningen University and Research, Alterra (Report 2151), which provides regionally validated estimates for the Netherlands. For the emission factor associated with indirect N_2O emissions from nitrate leaching, the default framework of the IPCC 2019 Refinement report is applied. A reduction of 10% (conservative) was applied based on the study of Pan et al., (2023)

Notes:

*Manually calculated, because the study provided annual or seasonal cumulative emissions or an emission reduction % was applied based on a meta-analyses study

**The baseline is quantified based on IPCC 2019. IPCC 2019 is referring to the report: “2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories”

***The project’s emissions is calculated based on an emission reduction percentage (on top of the IPCC baseline) from a meta analyses

**** CAN+S contains the same nitrogen forms as CAN (≈50% NO_3^- / 50% NH_4^+); the sulfur additive (gypsum) does not alter microbial N dynamics under aerobic arable conditions. Evidence on sulfur's role in N_2O emissions is limited, and any effect would likely reduce emissions via improved nitrogen uptake.

A.3 Product Carbon Footprint of fuels

Fuels							
	Type of fuel	**Emission factor [kg CO2e / L]**	**Source**	**Fuel use rate per crop (Source KWIN AGV 2022)***		
				Winter Wheat	Barley	Potato
	Diesel B7	3.2	http://co2emissiefactoren.nl	145	113	262
	Biofuel HVO50	1.8	http://co2emissiefactoren.nl	145	113	262
	Biofuel HVO100	0.35	http://co2emissiefactoren.nl	145	113	262

* KWIN AGV 2022: The KWIN AGV 2022 (Kwantiwatieve Informatie Akkerbouw en Vollegrondsgroenten) is a reference document that provides detailed technical and economic data for arable and open-field vegetable crops in the Netherlands. It contains standardized figures on costs, yields, and resource use, making it a reliable benchmark for the sector. Because it includes representative averages for input use, such as fuel consumption per hectare, the KWIN can be used as a credible source to derive the average fuel use/ha across different crops and production systems.

Appendix B: Equations

B.1 Example of calculation methods

This section presents a representative example of the calculation method used to estimate direct N_2O emissions from nitrogen fertilizer application. The approach is based on the methodology PM.0004 “Adoption of nitrogen stabilizers to transition to low-carbon agriculture”. This equation is used for both baseline and intervention scenarios, ensuring that emissions are quantified in a consistent and comparable manner. The only varying inputs are the N fertilizer types, their application rates, and the associated EFs, which are scenario-specific and justified according to the methodology PM.0004. The same approach is in every Proba methodology that was used for this project.

Direct N_2O emissions

This approach is based on equations provided by the IPCC[5].

$$E_{4a} = (F_{in} \cdot EF_{in,direct\_N2O}) + (F_{org} \cdot EF_{org,direct\_N2O}) \cdot 44/28 \cdot A \cdot GWP_{N_2O} \tag{1}$$

Where:

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

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

GWP_{N_2O}	=	Global warming potential of nitrous oxide (kg CO_2e / kg N_2O) [Based on IPCC AR6, the 100-year GWP for N_2O is 273]

Once baseline and project (intervention) emissions are quantified using the applicable methodologies and corresponding equations, the GHG emission reduction resulting from the intervention is calculated by using the below equation:

$$ER = (BE - PE) \cdot (1 - LP) \cdot (1 - UP) \tag{2}$$

Where:

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

This equation and its logic apply uniformly across all interventions in the project. Each intervention, whether it involves product substitution, application rate adjustment, stabilizer use, or fuel switching, is evaluated using this same principle: comparing emissions under business-as-usual (baseline) versus improved practice (project), Appropriate deductions for leakage will be applied to the final quantified emission reduction value that can be seen in section 4.1 Leakage

Uncertainty was addressed in line with the Proba methodologies guidance. Specifically, we incorporated uncertainty into the quantification process through the selection of conservative emission factors and applying appropriate reductions. See EF table in the Appendix A.2

Appendix C: Sustainable Development Criteria

Criteria	Risk relevant to the project (Yes/No)	Response to safeguard requirements (incl POD references)
1. Assessment and management of environmental and social risks	Yes	- The project complies with national and EU laws. All farmers hold valid legal rights to land use (Section 2.2.2). - The project uses a biodegradable CRF product. - Stakeholder consultations were conducted (Section 9), and no vulnerable groups are affected. - Potential negative impacts from the interventions (e.g., fertilizer runoff, air emissions) have been assessed and mitigated through practical guidance of Agrifirm. A grievance mechanism is available via Agrifirm
2. Labour rights and working conditions	No	The project does not employ or subcontract workers; farmers are independent actors operating under existing labor laws in the Netherlands. No activities involve unsafe conditions, discrimination, or forced/child labor. Risk is considered negligible.
3. Resource efficiency and pollution prevention	Yes	Emissions from fertilizers and fuel are minimized through low-carbon products (Section 3.1–3.2). Nitrogen stabilizers and controlled release fertilizers reduce nitrate leaching and ammonia volatilization. Fuel interventions use renewable diesel to lower air pollutants. No hazardous waste or pesticide overuse occurs.
4. Land acquisition and involuntary resettlement	No	All participating landowners are verified to have legal ownership or tenancy rights (Section 2.2.2). The project does not result in any land acquisition.
5. Biodiversity conservation and sustainable management of	Yes	The project avoids any land-use change or conversion of natural ecosystems. Interventions are implemented on existing arable land.

living natural resources		
6. Indigenous Peoples, Local Communities, and cultural heritage	No	The project is located in the Netherlands and does not affect any Indigenous Peoples or culturally significant sites.
7. Respect for human rights, stakeholder engagement	Yes	The project respects all applicable human rights standards. Stakeholder engagement was conducted during project design via Agrifirm's farmer network and supply chain partners (Section 9). Their feedback informed intervention planning, and a grievance mechanism has been included.
8. Gender equality	No	Participation in the project is open to all qualifying farmers regardless of gender.
9. Robust benefit-sharing	Yes	Benefits are shared through the co-financing model for interventions and attribution of verified emission reductions to participating agri-buyers (Section 7.2). Farmers incur no net additional cost. The value chain structure ensures upstream actors fund and claim the reductions.
10. Ensuring positive SDG impacts	Yes	The project contributes to SDGs 2 (sustainable agriculture), 12 (sustainable production), 13 (climate action), and 15 (ecosystem protection). These contributions are detailed in Section 8.2. Impacts are assessed using qualitative and methodological alignment with national and UN goals.