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Carbon Credits Model and Standard for Farmers

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List of Acronyms

I3 Instrument Programme	Interregional Innovation Investment Instrument
IPCC	Intergovernmental Panel on Climate Change
EU ETS	European Union Emissions Trading System
GHG	Greenhouse gas
GWP	Global Warming Potential
CHP	Combined Heat and Power

1. Executive Summary

This document presents the carbon credits model developed under Task 5.3 of the I3-4-BIOFERTILIZERS project (I3 Instrument Programme). The model provides a standardised methodology for calculating the carbon credit value generated when farmers deliver organic waste and agricultural residues to bio-fertilizer production facilities, instead of disposing of them through conventional practices such as open burning, landfilling, or uncontrolled field decomposition.

The model is designed to be applicable across all seven partner countries (Greece, Portugal, Hungary, Spain, Belgium, Italy, and France) and covers three categories of organic feedstock: crop residues, animal manure, and agro-industrial by-products. It uses internationally accepted emission factors from the IPCC 2006 Guidelines and 2019 Refinement (Tier 1 defaults), ensuring scientific credibility while minimising data requirements for partners.

The carbon credit calculation operates through three complementary pathways: (A) avoided emissions from waste management, including transport; (B) avoided emissions from synthetic fertilizer production that is displaced by the bio-fertilizer; and (C) soil carbon sequestration from compost or digestate applications. The model includes a revenue-sharing mechanism that allocates carbon credit income to farmers in proportion to the type and quantity of feedstock they deliver, with higher-carbon-value feedstocks receiving proportionally higher payments.

The model is implemented as an Excel workbook with automated calculations based on look-up tables of emission factors. Users need only provide basic operational data: feedstock type, quantity, current disposal practice, treatment process, and transport distance. All emission factors and carbon price scenarios are pre-loaded and referenced to their scientific sources.

A key finding from the model development is that carbon credit value varies substantially by feedstock type and baseline scenario. Manure diverted from anaerobic storage and nitrogen-rich agro-industrial by-products generate the highest credit values, while low-nitrogen crop residues diverted from field burning may yield marginal or even negative net credits depending on the treatment process used. This differentiation is built into the revenue-sharing formula, providing transparent and scientifically grounded incentives for farmer participation.

2. Introduction

I3-4-BIOFERTILIZERS is a transformative EU-funded project (2024–2027) that promotes interregional cooperation to scale up, demonstrate, and commercialize innovative biofertilizer solutions across Europe. With a total budget of €9.1 million—€6.9 million co-funded by the EU—the project brings together 18 partners from 12 European regions, including SMEs, research centers, innovation agencies, clusters, and public authorities.
As Europe moves toward more sustainable and resilient agricultural practices, biofertilizers and biostimulants offer a promising alternative to chemical fertilizers. They enhance soil fertility, improve crop productivity, and support climate-resilient farming, all while reducing environmental harm. I3-4-BIOFERTILIZERS aims to position these solutions as key drivers of the circular bioeconomy and sustainable food systems. A cornerstone of the initiative is its

emphasis on interregional collaboration, fostering knowledge exchange, shared innovation strategies, and the creation of regional innovation valleys.

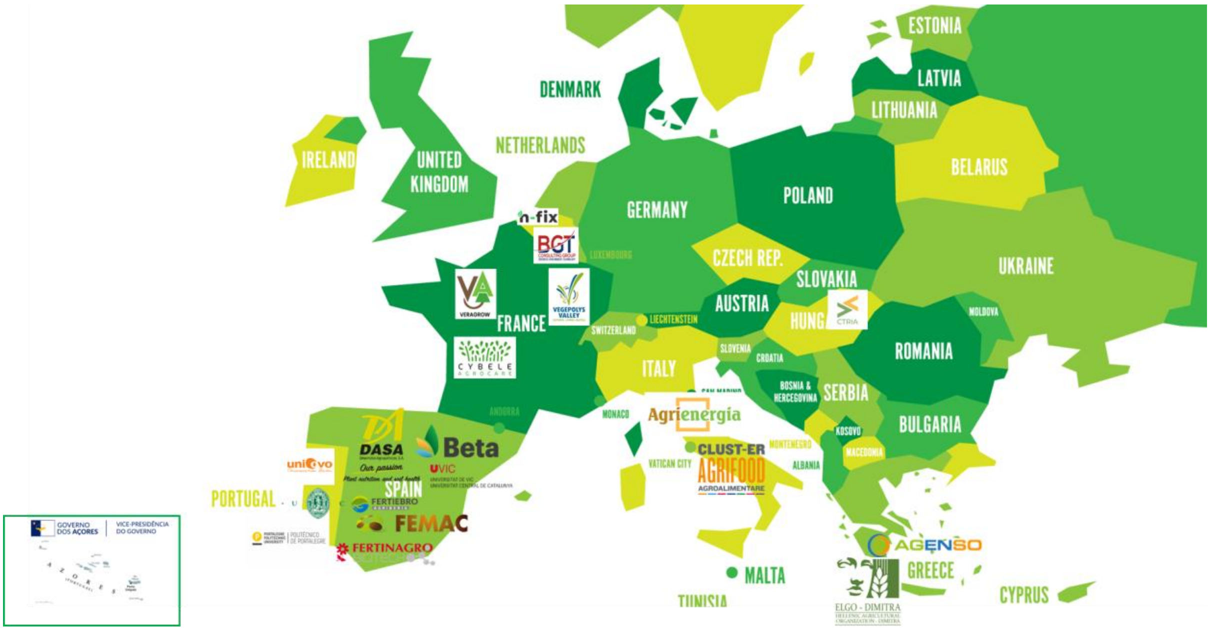

Figure 1 : I3-4-BIOFERTILIZERS consortium

The project identifies high-potential business cases through in-depth needs assessments and provides both technical and financial support to SMEs along the biofertilizer value chain. Over its three-year duration, the consortium will upscale, pilot, and demonstrate 8 distinct investment projects, each focused on developing cutting-edge biofertilizers, including biostimulants, and implementing sustainable agricultural practices. This comprehensive approach not only addresses existing market and technical barriers but also propels the sector towards greater competitiveness and environmental resilience. The investment cases are:

- Organic fertilizers production from poultry manure
- Production of high-quality liquid biofertilizers
- Biofertilizers production from compost of a biogas plant
- Circular and plant-extract based production of natural biostimulants
- High-quality microbials from agricultural biomass residues
- Scale-up production of a vermicompost-based biostimulant
- Agronomic testing for market launch of PGPR-based biostimulants
- Digital decision support systems for optimal biofertilization

A dedicated fund of €1.8 million from the project will support third-party projects, complemented by advisory services to accelerate market uptake.

2.1 Background and Policy Context

The European Green Deal and the EU Farm to Fork Strategy identify the circular use of organic resources as a priority for reducing agricultural emissions and improving soil health. The production of bio-based fertilizers from organic waste streams contributes simultaneously to waste reduction, nutrient recycling, and climate change mitigation. However, the economic viability of collecting small quantities of organic waste from dispersed farming operations remains a significant barrier. Carbon credit mechanisms offer a potential revenue stream that can incentivize farmer participation in feedstock supply chains.

The EU Emissions Trading System (EU ETS) provides a compliance carbon price that has fluctuated between €60 and €85 per tonne of CO_2 equivalent in 2025–2026, with projections reaching €100 or more by 2027. The voluntary carbon market, while offering lower prices (€4–15 per tCO_2e), provides additional monetisation opportunities for emission reductions outside the compliance market. Both price signals are relevant for assessing the economic feasibility of carbon credit schemes for farmers.

2.2 Scope and Objectives

This deliverable responds to Task 5.3 (Design and validation of a model for carbon credits for farmers), which requires the development of a carbon credits model that:

- Establishes a model and standard using carbon credits that provides incentives to farmers to deliver their feedstock to collection points or fertilizer facilities;
- Ensures that part of the earnings goes to farmers according to the feedstock they deliver;
- Includes a database of production, treatment processes, and quantity and quality of by-products or waste of organic origin;
- Is tested and validated through consultation of regional stakeholders.

2.3 Geographical Scope

The model covers seven EU Member States represented in the partnership: Greece (GR), Portugal (PT), Hungary (HU), Spain (ES), Italy (IT), Belgium (BE), and France (FR). The baseline scenarios and feedstock types reflect the agricultural practices and waste management infrastructure typical of each country and region.

3. Methodology

3.1 Overall Approach

The carbon credits model uses a comparative life-cycle emissions approach, calculating the difference in greenhouse gas (GHG) emissions between a baseline scenario (current waste disposal practice) and a project scenario (delivery of feedstock for bio-fertilizer production). The net emission reduction, expressed in kilograms or tonnes of CO_2 equivalent (CO_2e), represents the carbon credit value generated.

The methodology uses IPCC (Intergovernmental Panel of Climate Change) Tier 1 default emission factors from the 2006 Guidelines for National Greenhouse Gas Inventories and the 2019 Refinement. This choice is deliberate: Tier 1 provides internationally accepted, conservative values that require minimal site-specific data, making the model feasible for application across seven countries with diverse conditions. All Global Warming Potential (GWP) values follow the IPCC Fifth Assessment Report (AR5): 28 for CH_4 and 265 for N_2O.

3.2 Three-Pathway Framework

The model calculates carbon credits through three complementary pathways, each capturing a distinct emission reduction mechanism:

3.2.1 Pathway A: Waste Management Emissions Balance

Pathway A quantifies the net change in GHG emissions from redirecting organic waste from the baseline disposal method to a bio-fertilizer production facility. It has three sub-components:

A1 — Avoided baseline emissions: The GHG emissions that would have occurred under the current disposal practice (open burning, landfilling, lagoon storage, field decomposition, etc.). These represent the positive credit (emissions saved).

A2 — Treatment process emissions: The GHG emissions generated during the bio-fertilizer production process (composting, anaerobic digestion, etc.). These represent a deduction from the credit.

A3 — Transport emissions: The GHG emissions from transporting feedstock from farm to facility. Calculated as: vehicle emission factor (kg CO_2e/km) × one-way distance (km) × 2 (round trip) × number of trips per year. These represent a further deduction.

Net Pathway A = A1 − A2 − A3

An important finding from the model is that Pathway A can yield negative values for certain feedstock-treatment combinations, particularly when low-emission baselines (e.g., field decomposition of crop residues) are combined with relatively emission-intensive treatment processes (e.g., open windrow composting). This is scientifically correct and reflects the physical reality that not all waste diversion pathways reduce GHG emissions.

3.2.2 Pathway B: Avoided Synthetic Fertilizer Production

Pathway B captures the emission reductions achieved when bio-fertilizer products displace synthetic fertilizers. The production of synthetic nitrogen fertilizers via the Haber-Bosch process is highly energy-intensive, generating approximately 6.6 kg CO_2e per kg of nitrogen produced in Europe. Phosphate and potassium fertilizer production generates approximately 1.0 and 0.6 kg CO_2e per kg of nutrient, respectively.

The available nutrient content in the bio-fertilizer is calculated from the feedstock's nutrient composition (N, P_2O_5, K_2O content as percentage of dry matter), adjusted by the nutrient retention efficiency of the treatment process.

Pathway B = (Available N × EF_N) + (Available P_2O_5 × EF_P) + (Available K_2O × EF_K)

3.2.3 Pathway C: Soil Carbon Sequestration

Pathway C accounts for the long-term stabilisation of organic carbon in soils when compost or digestate is applied to agricultural land. During the treatment process, a portion of the feedstock's organic carbon is lost as CO_2 (aerobic decomposition) or captured as biogas (anaerobic digestion). The remaining carbon in the end product, when applied to soil, undergoes further decomposition, but a fraction becomes stabilised as recalcitrant soil organic carbon.

The model uses a simplified approach based on the percentage of remaining carbon that is expected to persist for more than 100 years (long-term sequestration fraction), converted from carbon mass to CO_2 equivalents using the molecular weight ratio of 3.67 (44/12).

Pathway C = Feedstock mass × DM × Organic C% × (1 − C loss%) × Sequestration% × 3.67

3.3 Baseline Scenarios

The model defines seven baseline scenarios representing current waste disposal practices across the partner countries. Each scenario is characterised by CH_4 and N_2O emission factors expressed per kilogram of dry matter managed or burned. The baseline scenario must be selected by each partner based on what actually happens to the feedstock in the absence of the bio-fertilizer scheme.

Baseline Scenario	CH_4 EF (g/kg DM)	N_2O EF (g/kg DM)	Applicability
Open field burning	2.7	0.07	Crop residues (GR, PT, ES, FR)
Field decomposition	0.0	0.01	All feedstocks
Landfill (no gas capture)	50.0	0.0	All (common in HU, some GR)
Landfill (gas capture)	25.0	0.0	Modern facilities (BE, FR)
Liquid storage / lagoon	15.0	0.0	Manure (all countries)
Solid storage / pit	4.0	0.02	Manure (all countries)
Direct land spreading	0.0	0.02	Untreated manure

Source: IPCC 2006 Guidelines, Volumes 4 and 5.

3.4 Feedstock Database

The model includes a database of 16 feedstock types across three categories: crop residues (wheat straw, maize stover, rice straw, olive prunings, vine prunings, fruit tree prunings, sunflower stalks), animal manure (cattle, pig, poultry, sheep/goat), and agro-industrial by-products (olive pomace, grape marc, citrus pulp, sugar beet pulp, brewery/distillery grain). Each feedstock is characterised by dry matter fraction, organic carbon content, nitrogen content, P_2O_5 and K_2O content, and combustion factor.

The database can be extended by partners who wish to include additional feedstock types specific to their region. Any additions should include source references for the characteristic values used.

3.5 Carbon Price Scenarios

The model provides three carbon price scenarios for monetising the calculated carbon credits:

Voluntary market (conservative): €7.50/tCO_2e — Based on average voluntary carbon market prices in 2024, reflecting the price range achievable through standard voluntary offset registries.

EU ETS reference (2025–2026): €72.00/tCO_2e — Based on the EUA price range observed during the project period, representing a policy-relevant benchmark.

EU ETS projected (2027–2030): €100.00/tCO_2e — Based on consensus forecasts for the EU ETS price trajectory, representing the medium-term policy signal.

Users can modify these values in the Carbon_Price sheet of the Excel model to reflect updated market conditions.

4. Revenue Sharing Standard

4.1 Principle: Differentiated Payment by Carbon Value

In accordance with the Grant Agreement requirement that "part of the earnings will go to farmers according to the feedstock they deliver," the model implements a differentiated revenue-sharing formula. Farmers receive payment proportional to the net carbon credit value of their specific feedstock delivery, not a flat rate per tonne.

This means that a farmer delivering high-nitrogen manure (which generates higher credits through avoided fertilizer displacement and avoided methane from storage) receives a higher payment per tonne than a farmer delivering low-nitrogen crop residues. This differentiation is scientifically grounded and creates correct incentive signals.

4.2 Formula

Farmer Payment = Net Carbon Credits (tCO_2e) × Carbon Price (€/tCO_2e) × Farmer Share (%)

The default farmer share is set at 60%, with the remaining 40% allocated to the facility operator to cover collection logistics, processing costs, and administration. This split is adjustable in the model and should be negotiated between stakeholders during the forthcoming validation workshops.

4.3 Worked Example

Consider two farmers delivering to the same composting facility in Greece:

Farmer A: Delivers 10 tonnes of cattle manure currently stored in an open lagoon. The model calculates a net credit of approximately 3.2 tCO_2e, yielding a farmer payment of €138 per year at the EU ETS reference price (60% of 3.2 × €72).

Farmer B: Delivers 10 tonnes of olive prunings currently burned in the field. Due to the high composting emissions relative to open burning, the net credit is near zero or slightly negative. Under the model, this farmer would receive a minimal or no carbon credit payment, though they may still benefit from waste removal services.

This differentiation is a feature, not a bug: it directs the strongest economic incentives toward the feedstocks that generate the greatest climate benefit.

5. Data Requirements for Partners

Each partner is required to fill in one row per feedstock-facility combination in the Partner_Input sheet of the Excel workbook. The required data fields are:

Data Field	Description	How to Obtain
Partner Country & Organisation	Identifying information	Pre-filled

Feedstock Type	Select from dropdown (16 types)	Local knowledge
Annual Quantity (tonnes wet)	Estimated annual feedstock available	Farm records or estimates
Baseline Scenario	Current disposal practice	Local knowledge
Treatment Process	Bio-fertilizer production method	Facility specification
Vehicle Type	Transport vehicle used	Select from dropdown
Coordinates (farm & facility)	Decimal degrees from Google Earth	Google Earth / Maps
Number of trips per year	How often feedstock is delivered	Operational estimate

No laboratory measurements, field sampling, or specialised equipment is required. All emission factors are provided by the model from IPCC default databases.

6. Implementation and Tools

The model is delivered as an Excel workbook (D5.4_Carbon_Credits_Model.xlsx) containing 10 interconnected sheets. The workbook uses standard Excel formulas (VLOOKUP, IFERROR, SUM) with no macros or external dependencies, ensuring compatibility with Microsoft Excel, LibreOffice Calc, and Google Sheets.

The workbook contains 1,070 formulas with zero errors after validation. All calculations are fully transparent: every emission factor can be traced to its source in the lookup tables, and every formula can be inspected by the user.

A companion web-based viewer will be developed under WP7 to disseminate the model results in an accessible GIS-based format, displaying the carbon credit potential across the partnership regions.

7. Stakeholder Validation

As required by the Grant Agreement, the proposed carbon credits model will be tested and validated through consultation of regional stakeholders. The validation process will consists of:

1. Presentation of the model methodology and preliminary results to regional stakeholder groups in each partner country;
2. Collection of structured feedback via a standardised questionnaire covering model assumptions, baseline scenarios, data feasibility, revenue-sharing acceptability, and implementation barriers;
3. Incorporation of stakeholder feedback into the final version of the model and this report.

8. Limitations and Caveats

The model uses IPCC Tier 1 default emission factors, which represent global or regional averages. Site-specific conditions (soil type, climate, management practices) may produce different actual emission rates. Partners with access to country-specific emission factors (Tier 2) are encouraged to substitute these in the lookup tables.

Soil carbon sequestration estimates (Pathway C) carry the highest uncertainty, as long-term carbon stability depends on soil type, climate, management practices, and compost maturity. The default sequestration percentages are conservative estimates from the literature.

The model does not account for potential co-benefits such as improved soil water retention, reduced erosion, or biodiversity enhancement, nor does it include energy credits from biogas utilisation (CHP). These could be incorporated in future versions.

Carbon credit value is sensitive to the choice of carbon price scenario. The voluntary market price and EU ETS price represent different market realities; users should select the scenario most relevant to their intended monetisation pathway.

9. References

IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4: Agriculture, Forestry and Other Land Use. Volume 5: Waste.

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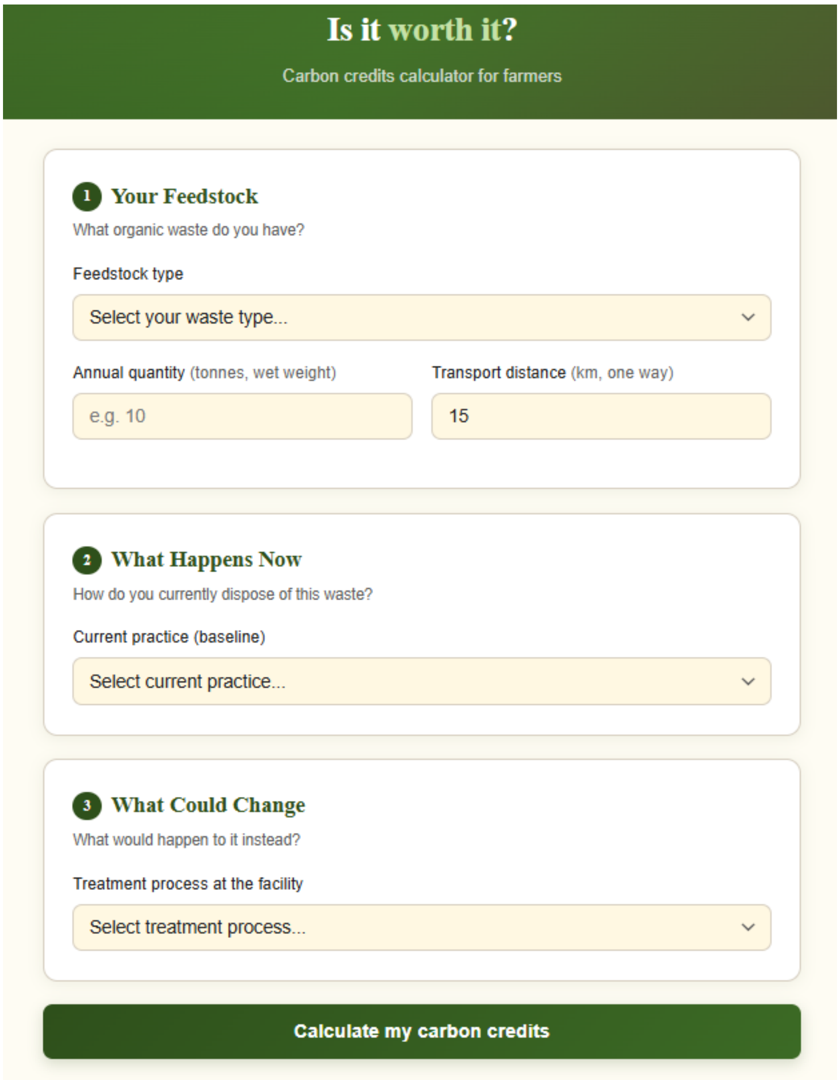
Annex I: Carbon Credits Calculator

This is the tool developed and to be validated with future users.



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A specific example: