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Economic assessment of selected CARINA

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ABBREVIATIONS

BEP	Break-even point
BCR	Benefit cost ratio
CBA	Cost benefit analysis
DC	Double cropping
EEI	Economic efficiency of inputs
FU	Functional unit
GM	Gross margin
GT	Gross turnover
GVA	Gross value added
GVAp	Gross value added per person
NM	Net margin
RC	Relay cropping
ROI	Return on Investment
OPEX	Operative cost
SB	System boundaries
VC	Value chain
WP	Work Package

1 Executive Summary

This report presents the methodological foundations of the economic assessment applied to the selected innovative bio-based value chains of the CARINA project, carried out within WP3 (Sustainability Assessment) and specifically linked to T3.2 (Economic assessment of selected CARINA concepts). In this context, a set of economic indicators was defined in T3.1 (Identification of sustainability indicators) as part of the overall project framework. To address these indicators comprehensively and ensure a holistic evaluation, the economic impacts of the selected CARINA value chains were assessed through a Cost-benefit Analysis.

This document reports exclusively on those indicators examined from a life cycle perspective, presenting a first-round assessment. The preliminary results serve a dual purpose: (i) to identify economic hotspots across the different phases of the selected CARINA value chains, thereby providing decision support for developing more sustainable process routes, and (ii) to refine both the data inputs and the methodological framework applied.

A second-round assessment will be presented in a forthcoming deliverable (D3.5), in which the full set of economic indicators will be evaluated as part of a broader Integrated Sustainability Assessment (T3.5). This will be complemented by a social (T3.3) and an environmental assessment (T3.4), ensuring a multidimensional perspective on sustainability performance.

In conclusion, this assessment represents an initial step for the evaluation of the economic sustainability of CARINA concepts. Although results remain preliminary and constrained by data availability, they already provide some insights on economic hotspots and performance within CARINA value chains. Future assessments, incorporating more comprehensive datasets and building on the know-how developed during the first two years of experimental trials, are expected to provide a more robust and consolidated analysis.

2 Economic assessment of the CARINA project

The CARINA project is a four-year, cross-national EU-funded initiative under the Horizon Europe programme. It aims to boost sustainable diversification in agricultural production systems, through the introduction of two novel oilseed crops — camelina and carinata— and their use as feedstocks in bioeconomy value chains (VCs).

To ensure robustness and co-creative approaches, CARINA established a network of 9 Lighthouses, 5 Living Labs, and 9 Policy Innovation Labs across Europe, which play a central role in driving innovation and validating project actions. The project involves a broad consortium of countries, including Bulgaria, France, Germany, Greece, Italy, Morocco, Poland, Serbia, Slovakia, Spain, Switzerland, Tunisia, and the United Kingdom.

Within the project framework, the term “CARINA concepts” refers to innovative VCs based on camelina and carinata, encompassing the entire pathways from crop cultivation to the development of bio-based end products included within the project.

The project includes several case studies involving field trials, seed crushing tests, and industrial trials, designed to cover the full VC from agricultural production to a wide range of potential final bio-products (e.g. bioherbicides, bioplastics, etc). Trials are mainly held in Europe, but also in Morocco and Tunisia. The overarching aim is to contribute to the creation of European VCs with a strong cross-regional dimension. A selection of VCs relevant for the economic sustainability analysis, considering also the data availability was then performed. The economic assessment builds on a simplified life cycle-based methodology covering the three main phases of the VC: farming, seed crushing, and industrial manufacturing. It integrates primary data collected through dedicated templates with secondary datasets, enabling the identification of potential risks and opportunities associated with the CARINA VCs under investigation. This approach is strengthened by a participatory approach, involving stakeholders from the early stages of the project, for example

through the co-selection of relevant economic indicators. Preliminary results suggest potential economic risk at the field phase, whereas opportunities are mainly in the industrial phase. Some economic indicators, such as gross value added per person and income stabilization, could not be fully assessed due to a lack in suitable data and therefore warrant more in-depth analysis.

The economic sustainability assessment of the selected CARINA concepts was carried out through trials conducted in nine countries: Bulgaria, France, Greece, Italy, Morocco, Poland, Serbia, Spain, and Tunisia.

Not in all the countries involved in the trials there are industrial facilities for the crushing and the processing of camelina-based or carinata-based bioproducts, nor consolidated VCs beyond the agricultural production. For these reasons, for countries where only the field phase is established, such as Bulgaria, Greece, Morocco, Poland, Serbia and Tunisia, scenarios ending at the seeds' sales stage are assessed. For the case studies developed in France, Spain and Italy, both the agricultural and industrial phases are well established and supported by infrastructure and companies. Data obtained for a French seed crushing plant (Saipol) was used to model crushing phases in Spain and Italy, as well as data coming from Spain, France and Italy pilot and industrial plants (Kimitec, Terres Inovia, Novamont, and Flanat) were used to model industrial phases in Spain, France and Italy.

2.1 Field Trials

Concerning the field phase, a range of cropping systems was considered in the context of the CARINA project, called with a letter for differentiation purposes:

- Camelina as a cash-cover crop in double cropping.
- Camelina intercropping and relay cropping.
- Camelina on marginal land.
- Carinata as a cash-cover crop in double cropping.
- Carinata intercropping and relay cropping.
- Carinata on marginal land.

A detailed overview of the field phase scenarios is provided in Tab. 1, including information on location, the responsible project partner, and the campaign year. The scenarios are structured around two system types: reference scenarios, and CARINA scenarios. The latter are characterized by the integration of camelina or carinata in different ways: (i) as cash-cover crops in double cropping systems (scenarios A and D), (ii) through intercropping or relay cropping (scenarios B and D), and (iii) on marginal land (scenarios C and F).

Not all scenarios are addressed in this deliverable, due to data availability and data quality considerations. Specifically, the following trials are excluded from this assessment:

- Spain trials: these trials are not included because the available dataset still requires revision. Several values must be redefined, and agreement among partners on the calculation procedures has not yet been reached. Final validation of the data is therefore pending, preventing their reliable use in the current assessment. These trials will be incorporated in the final assessment once validated.
- Intercropping trials: these trials have been excluded due to technical issues observed during implementation, which resulted in inconsistent crop interactions and, ultimately, in non-representative outcomes that cannot be part of the economic evaluation.

- Non-significant trials: trials in which nitrogen fertilisation exceeded the thresholds established by partners and recognised as the common practice are excluded. In particular, trials applying more than 60 kg/ha of N for marginal-land case studies and more than 80 kg/ha of N for double-cropping case studies are not considered, as such input levels alter comparability and affect the robustness of the assessment.

These exclusions ensure methodological consistency and enhance the reliability of the intermediate results presented in this deliverable.

Furthermore, another selection criterion was applied, based on the positive economic performance of the field phase trials. The underlying rationale is that if the field phase proved economically unviable, extending the analysis to the entire VC would also not be meaningful. This approach ensures consistency and enhances the robustness of the results. Following these selection criteria, the case studies selected are listed below:

- In France four case studies were selected: two from scenario A (FR2_Sf-Cm 23 and FR2_Sf-Cm 24 and two from scenario B FR1_B-Cm and FR1_B-Cr)
- In Italy, one case study was selected, from scenario E (IT5_Cp-Cr).
- In Poland, one case study was selected, from scenario C (PL2_CmML).

Table 1: List of the field phase scenarios of the CARINA project.

Scenario	Sub-scenario code	Location	CARINA partner	Reference crop system	CARINA crop system	Campaign	Area (ha)
A	FR1_B-Cm	France (Centre-Val de Loire, Bainvilliers)	TI	Barley	Barley & Camelina	2024	1
	FR1_P-Cm			Pea	Pea & Camelina	2024	1
	FR2_Sf-Cm	France (SW)	ARVALIS	Sunflower	Camelina & Sunflower	2023 & 2024	1 (2)
	FR2_So-Cm			Sorghum	Camelina & Sorghum	2024	1
	IT1_Sf-Cm	Italy (experimental site in Bologna)	UNIBO	Sunflower	Camelina & Sunflower	2023 & 2024	0.1314 0.285
	IT1_So-Cm			Sorghum	Camelina & Sorghum	2023 & 2024	0.1314 0.285 0.16
	RS1_Sf-Cm	Serbia (Rimski sancevi)	IFVCNS	Sunflower	Camelina & Sunflower	2024	0.1314
	RS1_So-Cm			Sorghum	Camelina & Sorghum	2024	0.1314
	SP1_Sy-Cm	Spain (Lleida)	CCE	Barley Soy	Camelina & Soy	2024	2.7

Scenario	Sub-scenario code	Location	CARINA partner	Reference crop system	CARINA crop system	Campaign	Area (ha)
B	PL1_B-Cm	Poland (next to Poznan)	PULS	Winter wheat	Barley & Camelina	2023 & 2024	0.35 (2)
	FR1_B-Cr	France (centre, Boigneville)	ARVALIS	Barley	Barley & Carinata	2024	1
	FR1_B-Cm	France (centre, Boigneville)	ARVALIS	Barley	Barley & Camelina	2024	1
	RS2_P-Cm	Serbia (Rimski sancevi)	IFVCNS	Barley	Pea & Camelina	2023	0.1314
C	SP2_WBP-Cm	Spain (Ciudad Real)	CCE	Crop rotation: Wheat, barley & pea (with fallow)	Crop rotation: Wheat, barley & pea (with camelina)	2023	1.38
	SP3_SfBP W-Cm	Spain (Burgos)		Crop rotation: Sunflower, barley, pea & wheat (with fallow)	Crop rotation: Sunflower, barley, pea & wheat (with camelina)	2023	36
	PL2_CmML	Poland (next to Poznan)	PULS	NA (marginal land)	Camelina in marginal land	2023 & 2024	0.35 (2)
	IT2_CmML	Italy (Emilia-Romagna, Ozzano dell'Emilia)	UNIBO	NA (marginal land)	Camelina in marginal land	2023	0.168
	IT2_CmML			NA (marginal land)	Camelina in marginal land	2024	0.24
D	IT3_Cp-Cr	Italy (experimental site in Bologna)	UNIBO	Chickpea, Carinata (0.04)	Chickpea & Carinata	2024	0.076 0.162
	IT4_Cp-Cr	Italy (Lemmo rino)	Novamont	NA	Chickpea & Carinata	2024	1

Scenario	Sub-scenario code	Location	CARINA partner	Reference crop system	CARINA crop system	Campaign	Area (ha)
	PL3_B-Cr	Poland (next to Poznan)	PULS	Barley, Carinata	Barley & Carinata	2023 & 2024	0.35 (2)
E	PL4_CrML	Poland (next to poznan)	PULS	NA (marginal land)	Carinata in marginal land	2023 & 2024	0.35

Case FR2_Sf-Cm: Camelina cash-cover cropping with double cropping in Montesquieu and Juzes (France)

The first case study examines a type A double cropping system conducted in Montesquieu in 2023, where camelina was cultivated as a cash-cover crop in combination with sunflower as a food crop. A second case study of the same type was carried out in 2024, in Juzes, covering 1 ha. They are hereby referred to as FR2_Sf-Cm 23 and FR2_Sf-Cm 24, respectively. In this instance, the reference scenario (sunflower) was compared to the CARINA scenario (sunflower and camelina). The cropping rotation spans approximately one year; the camelina (CARINA scenario) was sown in mid-November, harvested in mid-June, and immediately followed by the sowing and cultivation of sunflower.

Case FR1_Ba-Cr: Carinata in relay cropping with Barley in Boigneville (Centre France)

The third case study consists of a type B relay cropping system (carinata in relay cropping with barley) conducted in Boigneville. Barley is sown in autumn 2023 and carinata is sown in barley a few weeks before being harvested in 2024. Covering 1 ha, the reference scenario is barley.

Case FR1_Ba-Cm: Camelina in relay cropping with Barley in Boigneville (Centre France)

The fourth case study consists of a type B relay cropping system (camelina in relay cropping with barley) conducted in Boigneville. Barley is sown in autumn 2023 and camelina is sown in barley a few weeks before being harvested in 2024. Covering 1 ha, the reference scenario is barley.

Case PL2_CmML: Camelina on marginal land next to Poznan (Poland)

The fifth case study comprises a cropping system type C (camelina on marginal land) performed next to Poznan in 2023 and 2024. Covering 0.7 ha, the reference scenario (fallow land) was compared to the CARINA scenario (camelina in marginal land). The cropping rotations lasted about one year, starting from the fallow (reference scenario) or the camelina crop (from mid-June 2022 until early November 2022), sown in early November 2023 and harvested in early June 2024 / was sown in mid-December 2023 and harvested in mid-June 2024.

Case IT3_Cp-Cr: Carinata intercropping and relay cropping in Cadriano (Bologna, Italy)

The sixth case study is considered a cropping system type E (carinata intercropping and relay cropping) performed in Bologna (Italy) during 2023/24. Covering 0.04 ha, the reference scenario (chickpea) should have been compared to the CARINA scenario (chickpea and carinata), but all the trials in this CS turned out to be not profitable, differently from a carinata monoculture trial which was originally not planned for the assessment. The cropping rotations lasted about one year, starting from the summer fallow (reference scenario), which lasted from mid-June 2024 until early November 2024. In the carinata intercropping system, carinata was initially sown together with chickpea (intercropping). The chickpea continued growing following the carinata harvest, thereby extending

the productive period and optimizing soil coverage and resource use. Positive results were observed only in the monoculture plot.

2.2 Pilot and industrial Trials

Within the project, three main trial phases were conducted: the field phase, the crushing phase, and the industrial phase. During the field phase, camelina and carinata were cultivated in rotation with different food crops, as outlined above, to assess their agronomic performance under diverse conditions. In the crushing and industrial phase, the harvested seeds of both camelina and carinata underwent a crushing process (Saipol – France or Flanat – Italy), yielding two main fractions: oil and protein-rich cake. These intermediates can be further processed into a variety of bio-based products across different European countries, creating distinct VCs.

- Camelina Cake: can be directly used as animal feed (Saipol – France) or can be processed to develop a Carrier formulation designed to increase the bioavailability of food supplements (Flanat – Italy) or to produce Biostimulant (Kimatec – Spain);
- Camelina oil: can be consumed as such since it is edible or can be processed to produce biofuels, but both the final products are out-of-scope for the CARINA project, since they are not innovative VCs;
- Carinata Cake: due to high glucosinolates (GLS) content, it cannot be used directly as animal meal, but a GLS-free meal can be produced (Terres Inovia – France) or can be processed to produce Biostimulant (Kimatec – Spain). From GLS, Biopesticide can be obtained (Kimatec – Spain);
- Carinata oil: can be processed into Bioherbicide or Bioplastic (Novamont – Italy).

This integrated approach highlights the versatility of camelina and carinata as multipurpose crops, enabling the development of innovative, sustainable VCs that combine food, feed, and industrial applications.

As previously anticipated, the industrial VCs and facilities (WP5) for camelina- and carinata-based products are more consolidated only in France, Italy, and Spain, where specific processing routes and final applications were established. For the other countries involved in the project, less consolidated VCs have been identified at this stage.

2.3 Value Chains Co-Selection

Based on the considerations above, and to ensure comparable and realistic assessments across heterogeneous contexts, two distinct evaluation approaches were applied:

1. Crop-based products for countries with less consolidated VCs (Poland, Serbia, Morocco, Bulgaria, Tunisia and Greece);
2. Industrial products for countries with more consolidated VCs (France, Italy and Spain).

For the first assessment, comparisons were on the basis of the total output generated at plot level, irrespective of whether one or multiple crops were cultivated. Each case study was assessed against its specific reference scenario (i.e. business-as-usual, fallow land in the case of marginal areas, or single-crop cultivation in the case of rotations).

For the second assessment, to focus on strategic products in countries with more consolidated VCs, national project partners were asked to select up to three bio-based final products of interest (Fig 1. and Fig. 2). The social sustainability assessment was therefore performed on a maximum of three complete VCs per country (including field phase, crushing phase, and, where applicable, the

industrial phase). The most comparable and consolidated products on the market were identified and used as reference baselines, chosen in close collaboration with industrial stakeholders.

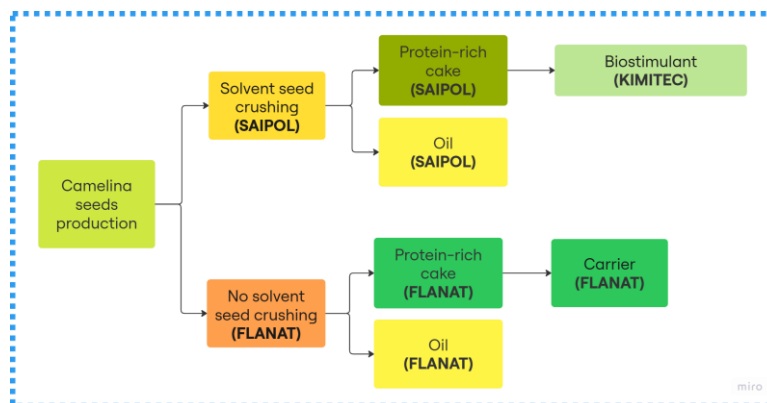


Figure 1: All possible camelina VCs for France, Italy, and Spain.

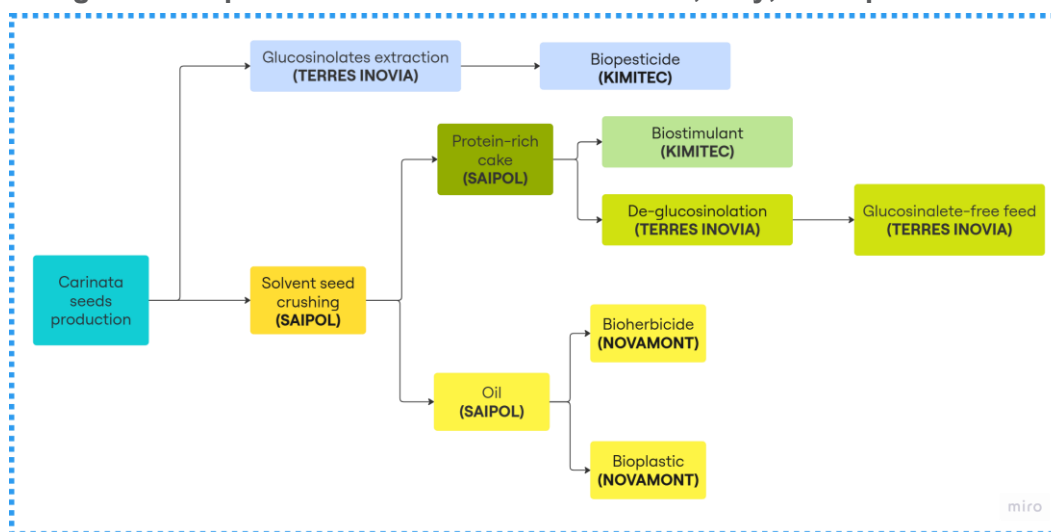
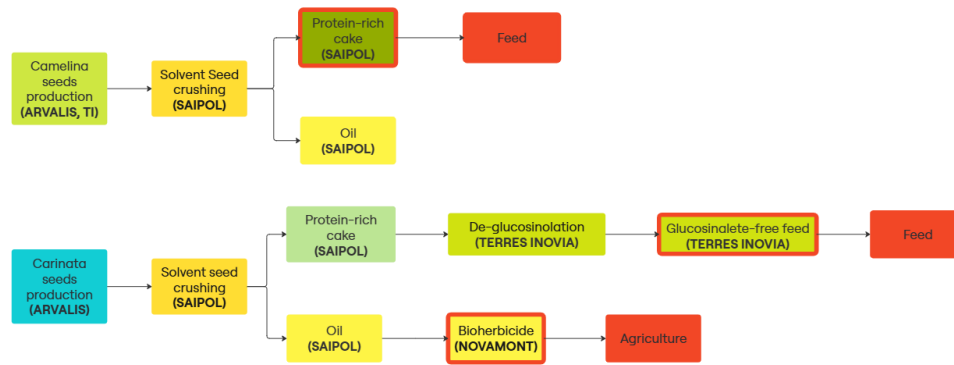


Figure 2: All possible carinata VCs for France, Italy, and Spain.

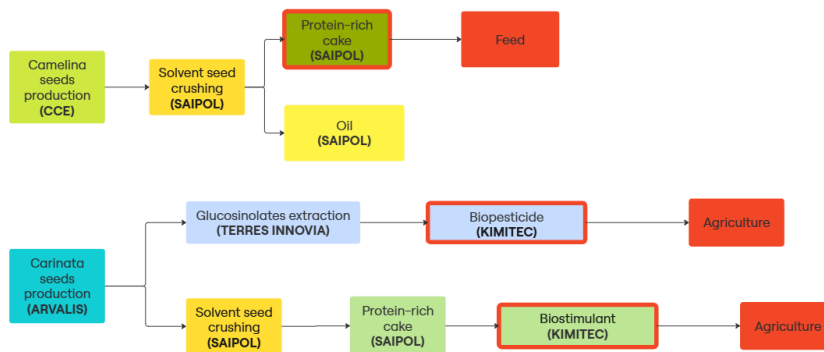
As a result of this joint selection process, three final products per country were defined as follows (and as resumed in Fig. 3):

1. France: Protein-rich Cake from camelina; GLS-free feed from carinata; Bioherbicide from carinata;
2. Italy: Carrier from camelina; Bioherbicide from carinata; Bioplastic from carinata;
3. Spain: Protein-rich Cake from camelina; Biopesticide from carinata; Biostimulant from carinata.

FRANCE



SPAIN



ITALY

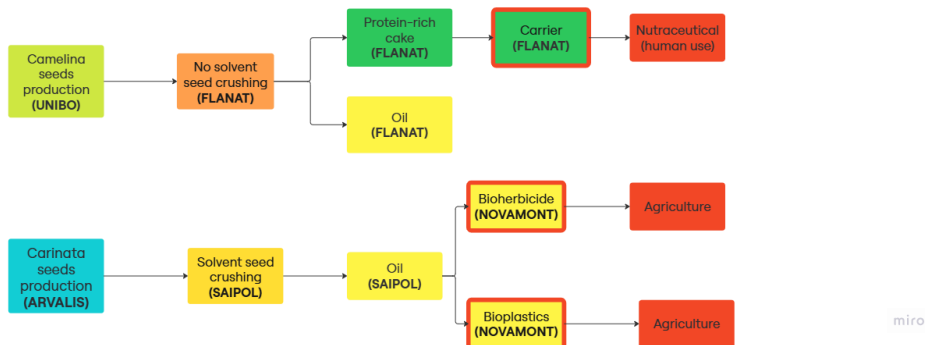


Figure 3: France, Italy, and Spain CS of VC selection (the selected final products are circled in red).

To summarize, the nine scenarios whose final products include the field phase, the crushing phase, and the industrial phase (or the whole VC) are:

1. France Cake
2. France GLS-free feed
3. France Bioherbicide
4. Italy Carrier
5. Italy Bioherbicide
6. Italy Bioplastic
7. Spain Cake
8. Spain Biopesticide
9. Spain Biostimulant

3 Methodology

The methodology to assess the economic sustainability of CARINA case studies, integrates a cost-benefit analysis (CBA) with a life cycle perspective. Traditional CBA provides a structured framework to evaluate the economic feasibility of an intervention by comparing costs and benefits over time (Boardman et al., 2018). When applied to bio-based systems, CBA can be significantly enhanced by incorporating life cycle approach, which captures upstream and downstream processes and accounts for indirect effects often overlooked in conventional analyses (Ness et al., 2007). This combined perspective allows for a more comprehensive evaluation of VCs, linking economic indicators with process-level data and providing insights into trade-offs across different stages of production.

In this approach, every step of the carinata and camelina products' VCs is considered, from the field phase to the end product (be it the crushing phase or the industrial phase, depending on the final product). Hotspots and trade-offs between inputs and outputs though out the VCs are captured and highlighted.

3.1 Goal and Scope definition

The FU of this study is all the economic costs and benefits associated with the production of one ton of final product to be further processed or finally send to be sold into the market (which will vary depending on the scenario considered).

A purely monetary FU might fail to capture the complexity of the systems, given the differences in monetary value, growth periods, transport routes, and times associated with the various products, and market price fluctuations. Consequently, a money-based FU (€/ha and €/ton) was preferred to ensure consistency across the VCs.

For the assessments, system boundaries (SB) were defined for both the reference scenarios and the CARINA scenarios. The SB of the studies were as "cradle-to-gate", where the various countries and sectors potentially involved in the VC are considered.

For countries with less consolidated VCs only the field phase was considered; while, for those with more consolidated VCs, the field and crushing phases were considered, and in some cases also an industrial phase, depending on the final product.

This choice reflects the extent, or the end-of-life of the two scenarios, which occur either at product consumption or with field testing and consumer use (Fig. 4-6).

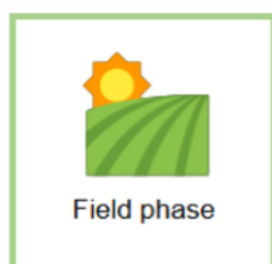


Figure 4: Cradle-to-(farm)gate SB for countries with less consolidated VCs.



Figure 5: Cradle-to-(seed crushing)gate as SB for protein-rich Cake from camelina.



Figure 6: Cradle-to-(industrial)gate SB for all other CARINA final products.

Concerning the selection of relevant impact categories and sustainability indicators, stakeholder engagement was included to ensure context-relevant economic impact assessment. The involvement of relevant stakeholders is described in detail in D3.1, while Tab. 2 presents the final indicators list from the co-selection process (see Task 3.1.2 Bottom-Up). For the economic dimension, the description of the indicators is further explained with an equation. Being that CBA addresses the business level and not the whole life cycle of the analysed bio-based products, indicators are assessed at each stage of the VC, and the resulting metrics are aggregated in a comprehensive evaluation to assess the benefit/cost ratio (BCR) on a defined FU.

Some minor changes have been made to the formulas reported in D3.1:

- For the calculation of the Economic Efficiency of inputs (EEI), the inputs were considered as variable costs. This is the definitive formula: $(\text{Total Gross Revenues} - \text{Variable Costs}) / \text{Variable Cost} (\%)$;
- Net Revenues were considered as “Benefits” in the original formula (see D3.1), thus the Return on Investment (ROI) was calculated as $(\text{Total Net Revenues} - \text{Total cost}) / \text{Total cost} (\%)$; and the Benefit Cost Ratio (BCR) as $\text{Total Net Revenues} / \text{Total Costs} (\%)$;
- To assess the Break-even point (BEP), Fixed costs were divided by the difference between product’s selling price and variable costs.

Table 2: Set of final co-selected indicators for the economic dimension. GM = Gross Margin, NM = Net Margin, GT = Gross Turnover, GVAp = Gross Value Added per person, GVA = Gross Value Added, OPEX = Operative Cost, EEI = Economic Efficiency of Inputs, ROI = Return on Investment, BEP = Break-even Point, BCR = Benefit Cost Ratio.

Indicator	Short description	Unit
GM	Total Gross Revenue - Total Cost / Total Gross Revenue	%
NM	Total Net Revenue - Total Cost / Total Net Revenue	%
GT	Total sales	€

GVAp	Total Net Revenue - Total Cost / n of employees	€
GVA	Total Net Revenue - Total Cost	€
OPEX	Total Operative Cost	€
EEl	(Total Gross Revenues - Variable Costs)/Variable Cost (%)	%
ROI	(Total Net Revenues - Total Costs)/Total Cost (%)	%
BEP	BEP = Fixed Costs/(Selling Price - Variable Costs)	%
BCR	BCR = Total Net Revenue/ Total Costs (%)	%

3.2 Data collection

For both CARINA VCs, primary data was collected with the contribution of project partners. Inventories covering economic aspects, in the form of an Excel-based template, were developed and filled by partners. This template included a general information sheet, requesting details about the company (e.g. location, stage of implementation, subsidies received) and the product (e.g. type of product and sub-product, total production, etc.). A separate sheet was dedicated to cost-related data, including acquisition, operation, maintenance, and disposal costs. Since most relied on existing plants and facilities, acquisition costs were not relevant. Prior to distributing the template, bilateral meetings were organized with partners, to validate the information requested and to establish alternative approaches for when specific data could not be provided. These datasets enabled a comprehensive assessment of the economic impacts of each baseline and case study. In instances where primary data was unavailable, secondary and proxy data from databases and the literature was used.

3.2.1 Field phase data collection

For the analysis, the following costs collected or calculated by Arvalis in the Systerre database were used:

Table 3: Share of primary and secondary data used for the assessment of the field phase

Item	Data type	Source
Seed costs (€/ha)	Primary	CARINA project
Land rent (€/ha)	Secondary	FADN
Maintenance / Rental (€/ha)	Primary	CARINA project
Herbicide costs (€/ha)	Primary	CARINA project
Fungicide costs (€/ha)	Primary	CARINA project
Insecticide costs (€/ha)	Primary	CARINA project
Molluscicide costs (€/ha)	Primary	CARINA project
Adjuvant costs (€/ha)	Primary	CARINA project

Item	Data type	Source
Total fertilizer costs (€/ha)	Primary	CARINA project
Fuel (€/ha)	Primary	CARINA project
Growth regulator costs (€/ha)	Primary	CARINA project
Irrigation input costs (€/ha)	Primary	CARINA project
Crop insurance (€/ha)	Primary	CARINA project
Working hours per year (hours/y)	Primary	CARINA project
Wage (€/y)	Secondary	PSILCA
Total wage costs (€/ha)	Secondary	PSILCA
Mechanization and irrigation charges (€/ha)	Secondary	Systerre
Machinery depreciation (€/ha)	Secondary	Systerre
Other mechanization/labour costs (€/ha)	Secondary	Systerre
Uncoupled support (€/ha)	Secondary	FADN
Diverse costs (€/ha)	Secondary	FADN
Mechanization excluding irrigation charges (€/ha)	Secondary	Systerre
Other input costs (€/ha)	Primary	CARINA project
Sales price (€/t)	Primary	CARINA project, Systerre
Yield (t/ha)	Primary	CARINA project

A limitation of the analysis is linked to the number of employees, necessary to calculate the indicator GVAp, and not always known. In fact, sector and nation-specific wages and weekly working hours from PSILCA were taken as secondary data for the trials.

3.2.2 Crushing phase data collection

In this phase, three different processes are considered: the seed crushing of carinata and camelina, and of rapeseed, as a benchmark.

For the analysis, the following data was collected:

1. Primary data: Biomass cost, Oil yield with solvent, Protein-rich Cake yield with solvent, Oil price, Cake price for the benchmark;
2. Secondary data: Production costs, Oil yield without solvent, Protein-rich Cake yield without solvent, Oil price, Cake price, and Taxes on revenues.

A limitation of the analysis is linked to the number of employees, necessary to calculate the indicator GVAp. In fact, Saipol biggest plant's annual production was taken as proxy for these three processes.

Table 4: Primary and secondary data used for the crushing phase assessment

Item	Data type	Source
Biomass cost (€/ton)	Primary, secondary	CARINA project, TESEO
Oil yield with solvent (€)	Primary	CARINA project
Protein-rich Cake yield with solvent (%)	Primary	CARINA project
Oil price (€/ton)	Primary	CARINA project
Cake price (€/ton)	Primary, secondary	CARINA project, TESEO
Production cost (€/ton)	Secondary, proxy	IEA Bioenergy Task 42 Report on Biorefineries (2021); EC – Impact of Oilseeds Processing on Biofuel Market (2022); FAO – Oilseed Processing Report (2023); USDA – Oil Extraction Technologies for Rapeseed (2021); IEA Bioenergy Task 39 – Biofuels Production from Oilseeds (2022); Ecoinvent
Taxes on revenues (%)	Secondary	Service Public – Impôt sur les sociétés (IS)

It must be noted that for the final assessment (D3.5), instead of these sources, energy data from the Ecoinvent process included in D3.4 will be considered as source.

3.2.3 Industrial phase data collection

For the analysis, data on Biostimulant, Bioplastic, Bioherbicide and their benchmarks (Megafol and Isabion, polypropylene and glyphosate) was collected. For these products, mainly secondary and proxy data was possible to obtain for Production costs, Tax cost, and Product price. In addition, for the Biostimulant assessment, primary data from Kimitec was provided; however, this refers to an existing industrial-scale biostimulant rather than to the lab-scale product developed within the project. This choice is aligned with the objective of conducting an industrial-scale VC analysis, and reflects the company’s intention to scale up the new product to the same production level as the proxy used in the assessment.

Since Kimitec suggested two products — Megafol and Isabion — as benchmarks for the Biostimulant, a single reference product was created by averaging the data of the two. This combined benchmark will hereafter be referred to as Megafol–Isabion.

Choosing Polypropylene as benchmark for Novamont’s Bioplastics was in light of Novamont’s aim to formulate flexible materials. Being Polypropylene a flexible plastic, more flexible than other possible benchmarks, it was selected as Baseline.

Concerning Glyphosate, a limit in the comparison must be noted: instead of carrying out an efficiency analysis, the assessment was performed by considering 1 ton as FU for data availability purposes.

Further limits of the analyses are linked to the number of employees, necessary to calculate the indicator GVAp. In fact, for Bioplastic and Bioherbicide, this data was calculated considering Novamont’s “Mater-Bi” bioplastic annual production and Novamont’s “Ager-Bi” bioherbicide annual production as proxies.

Table 5: Data used for the industrial phase Biostimulant assessment.

Item	Data type	Source
Production cost (€/ton)	Primary, secondary	CARINA project; Ecoinvent
Taxes (%)	Secondary	Impuesto sobre Sociedades
Product price (€/ton)	Primary	CARINA project

Table 6: Data used for the industrial phase Bioplastic assessment.

Item	Data type	Source
Production cost (€/ton)	Secondary, proxy	Wellenreuther and Zander, 2022; CARINA project
Taxes (%)	Secondary	IRES – Normativa sull’imposta sul reddito delle società in Italia

Product price (€/ton)	Secondary	https://gianeco.com ; https://europlas.com.vn
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Table 7: Data used for the industrial phase Bioherbicide assessment.

Item	Data type	Source
Production cost (€/ton)	Proxy	Assumptions made by authors, CARINA project
Taxes (%)	Secondary	IRES – Normativa sull'imposta sul reddito delle società in Italia
Product price (€/ton)	Proxy	De Leon Izeppi et al., 2020; Imarc Group; PricePedia; Procurement Resource

Table 8: Data used for the industrial phase Megafol-Isabion assessment.

Item	Data type	Source
Production cost (€/ton)	Proxy	Ainoa Morillas-España et al., 2022
Taxes (%)	Secondary	Impuesto sobre Sociedades
Product price (€/ton)	Secondary	teknoagri.it

Table 9: Data used for the industrial phase Polypropylene assessment.

Item	Data type	Source
Production cost (€/ton)	Secondary	Horvat et al., 2018
Taxes (%)	Secondary	IRES – Normativa sull'imposta sul reddito delle società in Italia
Product price (€/ton)	Secondary	https://it.tradingeconomics.com

Table 10: Data used for the industrial phase Glyphosate assessment.

Item	Data type	Source
Production cost (€/ton)	Secondary	https://echemi.com
Taxes (%)	Secondary	IRES – Normativa sull'imposta sul reddito delle società in Italia
Product price (€/ton)	Secondary	Agropages (2021-2025); https://echemi.com

3.3 Impact assessment

From a methodological perspective, each phase of the VCs was assessed using standardised FUs, rather than case-specific dimensions or yields of individual scenarios. Ensuring comparability of results across different trials and VCs.

Specifically:

- for the field phase, 1 hectare (ha) of cultivated land;
- for the crushing phase, 1 tonne (ton) of processed raw material (camelina or carinata seeds);
- for the industrial phase, 1 tonne (ton) of processed intermediate product (camelina or carinata oil or protein-rich Cake).

For all CARINA VCs, the economic assessments were performed accordingly. This methodological consistency facilitated the integration of results within the overall sustainability assessment framework.

At this stage, the analysis relies on the data from prior experimental years, with results from two additional years of field trials in each geographical location still being collected. Once available, this data will allow to calculate multi-annual averages and to perform a more robust, VC-specific assessment for each rotation and site (D3.5).

For the calculation of net indicators, country-specific proxies were applied to apply taxes on gross revenue and gross margin. Number of employees, was calculated based on both primary and secondary data, as working hours per hectare was among the data collected during the field phase. Multiplying PSILCA's national- and sector-specific data on average working hours per week, this value yielded annual working hours. Total working hours per hectare were divided by this figure, to obtain workers per hectare. For some crushing phase and industrial phase trials, total production costs, the percentage of labour costs on the total and the average wage for the company when data was primary, for the nation and sector when it was secondary from PSILCA, were available. From this information, it was possible to obtain the total number of workers per ton.

It should be noted that it was not possible to compute all indicators across the different VCs and phases, due to data limitations. Specifically:

- GVAp: the conversion of GVA into GVAp could not be always performed because of missing information on labour input. In fact, in some cases no data on working hours per hectare was available, while in others the information on percentage of labour cost per ton was lacking.

- BEP: for certain processes, no detailed data on fixed and variable costs was provided, leading to the calculation of the indicator as zero.

3.4 Interpretation

Within the CARINA project, the interpretation of results aims to derive meaningful insights into the potential social risks and opportunities associated with the VCs based on carinata and camelina crops. The findings of this economic assessment will be integrated with the social and environmental assessments in a dedicated project task (Task 3.5), enabling a comprehensive evaluation of potential trade-offs and synergies solutions across VCs. These integrated results will inform and support the development of policy recommendations, complementing the outcomes of WP4.

4 Results

The analysis conducted within CARINA adopts a multi-level comparative approach, designed to evaluate the performance of innovative VCs against reference systems, alternative products, and across different geographical or temporal contexts. Four main types of comparisons are carried out:

- a. Intra-phase comparison
 1. Field phase: comparisons are made between two double-cropping (DC) and two relay-cropping (RC) trials in France, each assessed against its reference (sunflower and barley monocultures);
 2. Crushing phase: camelina, carinata, and rapeseed (as the benchmark) crushing processes are compared, while at the product level, camelina Cake is evaluated against rapeseed Cake;
 3. Industrial phase: the comparisons include Biostimulant vs Megafol-Isabion, Bioherbicide vs Glyphosate (benchmark), Bioplastic vs Polypropylene (benchmark), and Bioplastic vs Bioherbicide.
- b. Intra-country comparison between different VCs
 1. In Italy: Bioplastic vs Bioherbicide;
 2. In France: camelina Cake vs Bioherbicide.
- c. Inter-country comparison for the same VC
 1. Bioherbicide in Italy vs Bioherbicide in France.
- d. Intra-country comparison under different crop rotations
 1. Camelina–sunflower 2023 - FR2_Sf-Cm 23;
 2. Camelina–sunflower 2024 - FR2_Sf-Cm 24;
 3. Barley-camelina 2024 – FR1_B-Cm.
 4. Barley-carinata 2024 – FR_1B-Cr 24

This structured framework allows for a robust evaluation of performance at different stages of the VCs, across products, and both with spatial and temporal variability.

4.1 Intra-phase comparison

4.1.1 Field phase

The economic assessment of the field phase is constrained by the fact that many trials were excluded from the evaluation, given their low representativeness and/or the exceeding levels of fertilization. Most of the examined trials are not currently profitable, due to the following factors:

1. null or insufficient yields, mainly due to the cropping system currently under adjustment by partners;
2. acceptable yields for food crops but very low market prices (notably for sorghum and barley);
3. unexpectedly high production costs even for low-input crops;
4. climate-related events such as the 2024 drought in Poland;
5. intercropping failures. For example, in Italy one crop outcompeted the other (carinata outcompeted chickpea in 2023/2024, while the opposite happened in 2024/2025).

These factors reveal a combination of structural and context-specific limitations that undermine the economic viability of the tested trials. Moreover, the exclusion of agricultural subsidies – apart from uncoupled supports - which are known to play a crucial role in the economic viability of European agriculture, is another important factor affecting the economic outcomes. To address these challenges, a set of policy instruments observed in WP4 (D4.3) could be adopted to improve the profitability and attractiveness of such innovative value chains:

- Common Agricultural Policy (CAP): CAP remains a key framework to support farmers adopting innovative crops through eco-schemes, agri-environmental measures, and rural development programmes. Including camelina and carinata within specific CAP measures additional to uncoupled supports could provide direct income support and help compensate for initial low yields or high operative costs;
- Inclusion in the Renewable Energy Directive (RED): recognizing camelina and carinata as eligible feedstocks would provide an incentive for their uptake as sustainable raw materials for advanced bio-based applications, ensuring a stable demand and market value;
- Carbon farming and certification: from 2026, practices that contribute to carbon sequestration will be certifiable under the EU's Carbon Removal Certification Framework (CRCF). Rotations involving camelina and carinata could benefit by monetizing their environmental services, thereby offsetting the negative cost-benefit balance;
- Multi-annual payments and targeted subsidies: dedicated schemes compensating the high costs and risks of introducing innovative crops could reduce the economic pressure of low-performing trials and provide the financial space needed for technical optimization;
- R&D and innovation funding: public investment in seed improvement, agronomic practices (e.g. intercropping design, drought resilience), and process optimization (e.g. crushing and pre-treatment) would help overcome the technical bottlenecks behind low yields and high costs.
- Local VC development: cooperative-based supply chains and local market infrastructures, as observed in the Moroccan case, could reduce dependence on volatile international prices for rapeseed or soy and provide stable outlets for camelina- and carinata-based products.

- Market and consumer instruments: measures such as public procurement for bio-based products, labelling, and awareness campaigns would help create stronger market pull for innovative bio-products derived from these rotations.

Among all the field trials showing positive economic performance, only the DC and the RC trials in France are worth commenting in detail. The positive trial in Italy concerns a carinata monoculture, which was designed as a reference trial; the one in Poland concerns camelina on marginal land, and since it is the only positive case it cannot be compared with other Polish trials. The remaining positive trials involve monocultures of sunflower and barley, both used as references for the comparisons of the DC and RC profitable trials.

Regarding the French DC trials, the ranking from best to least performing (Tab. 11) is as follows: FR2_Sf-Cm 24 and FR2_Sf-Cm 23. The reasons behind these results are further discussed in Subchapter 4.4.1.

Table 11 – Comparison of camelina DC trials in France. GM = Gross Margin, NM = Net Margin, GT = Gross Turnover, GVAp = Gross Value Added per person, GVA = Gross Value Added, OPEX = Operative Cost, EEI = Economic Efficiency of Inputs, ROI = Return on Investment, BEP = Break-even Point, BCR = Benefit Cost Ratio.

Indicator	FR2_Sf-Cm 23	FR2_Sf-Cm 24
GM	6%	52%
NM	4%	35%
GT	2007€	1395€
GVAp	46982€	n.a.
GVA	125€	663€
OPEX	1804€	543€
EEI	-85%	267%
ROI	-17%	59%
BEP	-25%	-44%
BCR	83%	159%

FR2_Sf-Cm 23 has no reference available. The other comparison is presented in Tab. 12, and FR2_Sf-Cm 24 performs more profitably than its monocultural reference.

Table 12 – Comparison of camelina DC trial and its reference in France. GM = Gross Margin, NM = Net Margin, GT = Gross Turnover, GVAp = Gross Value Added per person, GVA = Gross Value Added, OPEX = Operative Cost, EEI = Economic Efficiency of Inputs, ROI = Return on Investment, BEP = Break-even Point, BCR = Benefit Cost Ratio.

Indicator	FR2_Sf-Cm 24	ref FR2_Sf-Cm 24
GM	52%	45%
NM	35%	31%
GT	1395€	1,400 €
GVAp	n.a.	551,327 €
GVA	663€	503 €
OPEX	543€	438 €
EEI	267%	149%
ROI	59%	32%
BEP	-44%	-53%
BCR	159%	52%

For the French RC trials, the performance ranking (Tab. 13) from best to lowest is FR1_B-Cm followed by FR1_B-Cr. This outcome is mainly explained by the higher management costs associated with carinata relative to camelina. Although both trials generated comparable revenues due to similar overall yields, the difference in OPEX resulted in a lower economic performance for the carinata RC trial.

Table 13 – Comparison of camelina RC trials in France. GM = Gross Margin, NM = Net Margin, GT = Gross Turnover, GVAp = Gross Value Added per person, GVA = Gross Value Added, OPEX = Operative Cost, EEI = Economic Efficiency of Inputs, ROI = Return on Investment, BEP = Break-even Point, BCR = Benefit Cost Ratio.

Indicator	FR1_B-Cr	FR1_B-Cm
GM	26%	36%
NM	18%	24%
GT	1005€	1005€
GVAp	n.a.	n.a.
GVA	329€	450€
OPEX	807€	627€
EEI	-15%	69%
ROI	12%	29%
BEP	-21%	-25%
BCR	112%	129%

The comparisons of each RC trial with its benchmark, which for both is represented by a barley monoculture, are resumed in Tab. 14 and Tab. 15. Both perform less profitably than the monocultural reference.

Table 14 – Comparison of camelina RC trial and its reference in France. GM = Gross Margin, NM = Net Margin, GT = Gross Turnover, GVAp = Gross Value Added per person, GVA = Gross Value Added, OPEX = Operative Cost, EEI = Economic Efficiency of Inputs, ROI = Return on Investment, BEP = Break-even Point, BCR = Benefit Cost Ratio.

Indicator	FR1_B-Cr	ref FR1_B-Cr
GM	26%	40%
NM	18%	27%
GT	1005€	1287€
GVAp	n.a.	n.a.
GVA	329€	458€
OPEX	807€	440€
EEI	-15%	229%
ROI	12%	25%
BEP	-21%	-37%
BCR	112%	26%

Table 15 – Comparison of camelina RC trial and its reference in France. GM = Gross Margin, NM = Net Margin, GT = Gross Turnover, GVAp = Gross Value Added per person, GVA = Gross Value Added, OPEX = Operative Cost, EEI = Economic Efficiency of Inputs, ROI = Return on Investment, BEP = Break-even Point, BCR = Benefit Cost Ratio.

Indicator	FR1_B-Cm	ref FR1_B-Cm
GM	36%	40%

NM	24%	27%
GT	1005€	1287€
GVAp	n.a.	n.a.
GVA	450€	458€
OPEX	627€	440€
EEl	69%	229%
ROI	29%	25%
BEP	-25%	-37%
BCR	129%	36%

These results can be attributed to the fact that if from one hand there was a lower investment in terms of costs on RC than on the monoculture, from the other hand the yield of barley decreased in the RC trials by 28%, and the revenues from camelina and carinata were insufficient to compensate for this loss in revenues, ultimately reducing the overall profitability of the RC trials.

4.1.2 Crushing phase

The comparison evaluates the performance of camelina and carinata crushing processes against rapeseed, which serves as the benchmark (Tab. 16). Results confirm that rapeseed outperforms both alternative feedstocks. This finding is expected, as benchmark products typically represent more well-established and economically sustainable VCs.

Table 16 – Crushing phase comparison. GM = Gross Margin, NM = Net Margin, GT = Gross Turnover, GVAp = Gross Value Added per person, GVA = Gross Value Added, OPEX = Operative Cost, EEI = Economic Efficiency of Inputs, ROI = Return on Investment, BEP = Break-even Point, BCR = Benefit Cost Ratio.

Indicator	Carinata crushing	Camelina crushing	Rapeseed crushing
GM	7%	4%	19%
NM	5%	3%	14%
GT	723 €	697 €	646 €
GVAp	180 €	93 €	432 €
GVA	39 €	20 €	94 €
OPEX	671 €	670 €	521 €
EEI	9%	5%	25%
ROI	-19%	-22%	-7%
BEP	9%	16%	4%
BCR	81%	78%	93%

At the product level, camelina Cake is compared with rapeseed Cake (Tab. 17). Once again, rapeseed Cake proves more competitive. For camelina Cake, the main economic hotspot is the higher OPEX, which adversely affects several other indicators.

Table 17 – Crushing phase comparison. GM = Gross Margin, NM = Net Margin, GT = Gross Turnover, GVAp = Gross Value Added per person, GVA = Gross Value Added, OPEX = Operative Cost, EEI = Economic Efficiency of Inputs, ROI = Return on Investment, BEP = Break-even Point, BCR = Benefit Cost Ratio.

Indicator	Camelina Cake	Rapeseed Cake
GM	8%	33%
NM	6%	25%
GT	450 €	375 €
GVAp	121 €	431 €

GVA	26 €	93 €
OPEX	415 €	292 €
E EI	9%	30%
ROI	-18%	-2%
BEP	8%	3%
BCR	82%	98%

4.1.3 Industrial phase

Four sets of comparisons were performed: Biostimulant vs Megafol-Isabionng (Tab. 18), Bioherbicide vs Glyphosate (Tab. 19), Bioplastic vs Polypropylene (Tab. 20); and Bioplastic vs Bioherbicide (Tab. 21). It must be noted once again that data used for these comparisons are not Novamont's. For the first three comparisons, the indicator GVAp could not be applied, due to the limitations previously discussed.

Table 18 – Industrial phase comparison. GM = Gross Margin, NM = Net Margin, GT = Gross Turnover, GVAp = Gross Value Added per person, GVA = Gross Value Added, OPEX = Operative Cost, EEI = Economic Efficiency of Inputs, ROI = Return on Investment, BEP = Break-even Point, BCR = Benefit Cost Ratio.

Indicator	Biostimulant	Megafol-Isabion
GM	80%	80%
NM	60%	61%
GT	14,931 €	10,068 €
GVAp	2,240 €	n.a.
GVA	8,212 €	6,132 €
OPEX	2,927 €	2,000 €
EEI	476%	403%
ROI	275%	278%
BEP	3%	0%
BCR	375%	378%

Table 19 – Industrial phase comparison. GM = Gross Margin, NM = Net Margin, GT = Gross Turnover, GVAp = Gross Value Added per person, GVA = Gross Value Added, OPEX = Operative Cost, EEI = Economic Efficiency of Inputs, ROI = Return on Investment, BEP = Break-even Point, BCR = Benefit Cost Ratio.

Indicator	Bioherbicide	Glyphosate
GM	38%	50%
NM	29%	38%
GT	6,500 €	5,000 €
GVAp	1,895 €	n.a.
GVA	1,900 €	1,900 €
OPEX	2,900 €	2,500 €
EEI	73%	100%
ROI	24%	52%
BEP	9%	0%
BCR	124%	152%

Table 20 – Industrial phase comparison. GM = Gross Margin, NM = Net Margin, GT = Gross Turnover, GVAp = Gross Value Added per person, GVA = Gross Value Added, OPEX = Operative Cost, EEI = Economic Efficiency of Inputs, ROI = Return on Investment, BEP = Break-even Point, BCR = Benefit Cost Ratio.

Indicator	Bioplastic	Polypropilene
GM	12%	29%
NM	9%	22%
GT	2,850 €	1,400 €
GVAp	265 €	n.a.
GVA	266 €	304 €
OPEX	2,063 €	1,000 €
EEI	15%	40%
ROI	-13%	6%
BEP	7%	0%
BCR	87%	106%

In both comparisons the benchmark products prove more economically sustainable, as expected. However, the Bioherbicide shows a smaller performance gap relative to its benchmark. This trend is also confirmed in the direct comparison between the two CARINA products.

Table 21 – Industrial phase comparison. GM = Gross Margin, NM = Net Margin, GT = Gross Turnover, GVAp = Gross Value Added per person, GVA = Gross Value Added, OPEX = Operative Cost, EEI = Economic Efficiency of Inputs, ROI = Return on Investment, BEP = Break-even Point, BCR = Benefit Cost Ratio.

Indicator	Bioplastic	Bioherbicide
GM	12%	38%
NM	9%	29%
GT	2,850 €	6,500 €
GVAp	265 €	1,895 €
GVA	266 €	1,900 €
OPEX	2,063 €	2,900 €
EEI	15%	73%
ROI	-13%	24%
BEP	7%	9%
BCR	87%	124%

Although the OPEX for Bioherbicide are significantly higher than for Bioplastic (+29%), all other indicators perform better for Bioherbicide. The higher selling price is a key driver of these results.

Furthermore, the industrial partner Novamont provided a breakdown of cost contributions, which highlights relevant differences between the two production systems:

- Depreciation costs are considerably lower for Bioplastic (1%) than for Bioherbicide (13%). This suggests that Bioherbicide production is more capital-intensive, due to higher investments in equipment and facilities, whereas Bioplastic production involves comparatively lower fixed asset depreciation;
- Raw material costs represent the largest expense category in both cases but are significantly higher for Bioplastic (60%) than for Bioherbicide (42%). This suggests a stronger dependence on feedstock supply for Bioplastic production, making it more sensitive to fluctuations in raw material prices;

- Operating labour costs also differ markedly: 1% for Bioplastic vs 6% for Bioherbicide. This suggests that Bioherbicide production is more labour-intensive, potentially due to greater reliance on specialised or manual operations.

Overall, the analysis points to two distinct cost structures: Bioplastic production is mainly driven by raw material expenses, whereas Bioherbicide production is more affected by depreciation and labour costs.

4.2 Intra-country comparison – Different value chains

4.2.1 Italy

The comparison focuses on Bioplastic and Bioherbicide (Tab. 22), to evaluate the relative advantages of two innovative VCs developed within the same national context.

Table 22 – Italy's VCs comparison. GM = Gross Margin, NM = Net Margin, GT = Gross Turnover, GVAp = Gross Value Added per person, GVA = Gross Value Added, OPEX = Operative Cost, EEI = Economic Efficiency of Inputs, ROI = Return on Investment, BEP = Break-even Point, BCR = Benefit Cost Ratio.

Indicator	Bioplastic - Italy	Bioherbicide - Italy
GM	14.8%	32.3%
NM	9.6%	23.6%
GT	5,526 €	9176 €
GVAp	837,701 €	838,244 €
GVA	532 €	2,166 €
OPEX	2,867 €	3,705 €
EEI	30%	30%
ROI	20%	18%
BEP	109%	110%
BCR	132%	177%

Bioherbicide shows better performances, consistent with prior findings. Since both VCs share identical outcomes for the agricultural and crushing phases, the observed difference stems from the industrial phase, where the Bioherbicide chain has already proven more profitable.

4.2.2 France

In this case, camelina Cake is compared with Bioherbicide (Tab. 23), offering insights into the performance of different bio-based products under the same geographical conditions.

Table 23 – France's VCs comparison. GM = Gross Margin, NM = Net Margin, GT = Gross Turnover, GVAp = Gross Value Added per person, GVA = Gross Value Added, OPEX = Operative Cost, EEI = Economic Efficiency of Inputs, ROI = Return on Investment, BEP = Break-even Point, BCR = Benefit Cost Ratio.

Indicator	Bioherbicide - France (B-Cr)	Cake - France (Sf-Cm average)	Cake – France (B-Cm)
GM	33.5%	22.6%	27.5%
NM	25%	15%	18.7%
GT	8,228€	2,385€	1,689€
GVAp	n.a.	n.a.	n.a.
GVA	2,268€	416€	471€
OPEX	4,378€	1,829€	1,282€

EI	-130%	64%	59%
ROI	16%	4%	11%
BEP	113%	-16%	-27%
BCR	160%	139%	158%

It should be noted that the Bioherbicide VC includes an additional industrial phase, whereas the Cake VC does not. For the Cake, average values from all the sunflower-camelina rotations considered so far were used, as well as the barley-camelina RC previously analysed, separately. For all the chains, GVAp could not be calculated at this stage due to missing data.

From an economic perspective, the Bioherbicide VC appears more favourable than the camelina Cake.

4.3 Inter-country comparison – Same value chains

4.3.1 Bioherbicide

The comparison between Italy and France is intended to assess how geographical, agronomic, and contextual differences influence the performance of the same VC (Tab. 24). A key limitation arises from differences in the field phase: the Italian case is based on a carinata monoculture, whereas the French case follows a RC system (barley-carinata). This discrepancy affects the sales component, since the French chain also generates additional revenue from the food crop (barley), alongside the Bioherbicide crop.

Table 24 – Bioherbicide VCs comparison. GM = Gross Margin, NM = Net Margin, GT = Gross Turnover, GVAp = Gross Value Added per person, GVA = Gross Value Added, OPEX = Operative Cost, EEI = Economic Efficiency of Inputs, ROI = Return on Investment, BEP = Break-even Point, BCR = Benefit Cost Ratio.

Indicator	Bioherbicide - Italy	Bioherbicide - France
GM	32.3%	33.5%
NM	23.6%	25%
GT	9,176 €	8,228€
GVAp	838,244 €	n.a.
GVA	2,166 €	2,268€
OPEX	3,705 €	4,378€
EEI	30%	-130%
ROI	18%	16%
BEP	110%	113%
BCR	177%	160%

This additional revenue from food crop partly explains the better performance of the French chain. Nevertheless, further analyses using more comparable cultivation systems are required before drawing conclusions.

4.4 Intra-country comparison – Same value chains

4.4.1 France

Several VCs considering the previously discussed crop rotations as field phase are compared (Tab. 25), including camelina–sunflower (2023), camelina–sunflower (2024) and barley-camelina (2024). This analysis allows the assessment of how different rotational schemes influence the performance of the same VC over time and under varying agronomic conditions.

Table 25 – Camelina Cake in France VCs comparison. GM = Gross Margin, NM = Net Margin, GT = Gross Turnover, GVAp = Gross Value Added per person, GVA = Gross Value Added, OPEX = Operative Cost, EEI = Economic Efficiency of Inputs, ROI = Return on Investment, BEP = Break-even Point, BCR = Benefit Cost Ratio.

Indicator	Cake - France (Sf-Cm 23)	Cake - France (Sf-Cm 24)	Cake – France (B-Cm 24)
GM	5.8%	39.4%	27.5%
NM	4%	26.7%	18.7%
GT	2,691€	2,079€	1,689€
GVAp	55,207€	n.a.	n.a.
GVA	147€	685€	471€
OPEX	2,459€	1,198€	1,282€
EEI	27%	101%	59%
ROI	-18%	25%	11%
BEP	39%	-70%	-27%
BCR	115%	162%	158%

GVAp could only be calculated for the camelina–sunflower 2023 VC. For the remaining rotations, the available indicators suggest that the camelina–sunflower 2024 VC performs best. This result is primarily driven by its yield of 6 t/ha, which is the second highest among the food crops analysed in this scenario, following barley–camelina (6.4 t/ha). However, despite the higher yield of the barley–camelina rotation, camelina–sunflower 2024 achieves superior economic performance due to the substantially higher selling price of sunflower (450 €/t) compared to barley (157 €/t). This price difference more than compensates for the yield gap, resulting in higher revenues and therefore greater profitability.

Camelina–sunflower 2024 also outperforms the sunflower–camelina 2023 rotation. This advantage is mainly driven by its lower OPEX relative to the 2023 rotation. Although the 2023 trial recorded higher yields for both crops, its cost structure prevented it from achieving comparable economic performance.

4.5 Key messages

The main outcomes of this Deliverable can be summarized as follows:

- The co-selection process facilitated broader consensus among stakeholders; however, it provided only partial coverage of overall impacts.
- Data availability remains a key challenge. Much of the current analysis relies on secondary data, which often lacks granularity and carries limited significance.
- Primary data for the field phase is at trial level, affecting the robustness of results, while secondary field phase data from the PSILCA database is of limited significance for the study.
- Company-specific data was used as proxy for other countries with more consolidated VCs. This approach further limits the significance of conclusions drawn.
- This issue is particularly evident for innovative VCs, where reliable and detailed datasets are scarce. The absence of established VCs introduces additional uncertainty in economic data and innovative bio-based product prices estimations. Market research and demonstrative actions are needed to understand and boost the market.

- Most of field trials showed negative economic performance, but CAP subsidies were not included in the analysis. This result confirms that many European agricultural systems are not economically sustainable without public interventions. Another main reason was the initial lack of experience growing camelina and carinata in some countries, leading to higher input utilisation, more technical issues and lower yields
- For industrial development, research priorities emerge clearly: Bioplastic production research should focus on ways to reduce raw material costs, while Bioherbicide production research should seek ways to lower initial infrastructure investments.
- Overall, the results represent an intermediate assessment, which will be progressively refined and consolidated as additional data and evidence become available.

5 Concluding remarks

The current assessment must be interpreted strictly as the result of an intermediate assessment, as it remains constrained by limited data availability across the field, crushing and industrial phases. Preliminary results indicate that rotations involving camelina and carinata are, in most cases, not yet economically profitable under the present analytical assumptions, especially the exclusion of the coupled support from the CAP, which is vital in most for most of the EU agricultural production activities.

In the field phase, agronomic and economic barriers still limit the profitability of most trials. Nonetheless, a coherent mix of RED incentives, carbon-certification schemes, targeted subsidies, R&D support and market-development policies could improve the long-term competitiveness of camelina- and carinata-based systems within the European bioeconomy. Independently from policy incentives, it will also be important to verify whether—thanks to the experience and know-how gathered during the first two years of experimentation—improved yields and more economically favourable results can be achieved in the forthcoming trial seasons. In the meantime, additional primary data will be collected and the secondary data used so far will be further validated. To date, sunflower-camelina seems the most promising rotation for the double cropping, while barley is the only crop which showed positive results grown with both camelina and carinata in RC. Nonetheless, the number of trials supporting these findings remains limited, and additional evidence is required before drawing definitive conclusions.

In the crushing phase, camelina and carinata do not yet reach the performance levels of rapeseed. However, this finding should be interpreted with caution, as both crops lack a consolidated European market, and several assumptions were required to complete the assessment. These assumptions will be refined and updated in the final Deliverable.

In the industrial phase, Biostimulant production already demonstrates a relatively high degree of competitiveness when compared with its benchmarks, performing better than both Bioherbicide and Bioplastic relative to their respective reference products. Bioherbicide production also appears more profitable than Bioplastic for carinata-based VCs. However, for both camelina- and carinata-based end products, more definitive conclusions will only be possible once the existing data gaps are addressed.

- From a national value chain perspective, the most viable options identified at this stage are in Italy, the production of Bioherbicides from carinata;
- in France, the production of Bioherbicides from carinata rather than Protein-rich Cake from camelina.

Given the preliminary nature of this assessment, the final results may evolve considerably as new data are integrated. In particular, the methodological framework might be refined by revisiting the selection criteria for field trials. Since profitability calculations exclude CAP subsidies—which are crucial for the economic viability of European agriculture—future final assessments may rely on productivity and/or yield performance rather than profitability alone when selecting field trials to be included in the analyses. Moreover, it should be noted that the project is investigating innovative VCs, which obviously lack the level of technical know-how and market development that characterise more consolidated crops and related VCs.

Overall, the results presented in this Deliverable constitute a first analytical step and provide a basis for further data collection, methodological refinement and partner discussion. A more comprehensive and consolidated assessment will be delivered in D3.5, planned for Month 46 of the CARINA project.

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