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WP6- Improving bio-based industry in the biochemicals sector

D6.2 - Report for Stakeholders: Biochemicals sector-wide recommendations

Lead: BTG

Author(s): Marre Porré (OLEON), Jurjen Spekreijse (BTG), Nariê Rinke Dias de Souza (NTNU)

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DELIVERABLE CONTRIBUTORS			
	Name	**Organisation**	**Job title**
Deliverable leader	Marre Porré	OLEON	CSR - LCA Specialist
Contributing Author(s)	Marre Porré	OLEON	CSR - LCA Specialist
	Jurjen Spekreijse	BTG	Consultant
	Nariê Rinke Dias de Souza	NTNU	Postdoctoral Fellow
Reviewer(s)	Dineshkumar Muniyappan	INSAT	Postdoctoral Researcher
	Massimo Pizzol	AAU	Professor

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1 Executive Summary

The European bio-based chemical sector stands at the forefront of the EU's transition to a circular and climate-neutral economy. Yet, its environmental contributions remain undervalued due to persistent gaps in sustainability assessment practices. This report delivers targeted, sector-wide recommendations to enhance the credibility, consistency, and comparability of life cycle assessments (LCAs), with a focus on three critical areas: upstream data quality, methodological harmonization, and end-of-life modelling.

1. **Strengthening Upstream Data Collection and Collaboration**
   The sector continues to struggle with fragmented and inconsistent upstream data, particularly for specialty chemicals. To address this, the report recommends early supplier engagement, harmonized data templates, and the development of shared datasets. These measures aim to reduce reliance on proxy data and improve transparency across the value chain.

2. **Harmonizing LCA Methodologies**
   Methodological fragmentation remains a major barrier to fair and comparable assessments. The report advocates for improved documentation of methodological choices made and alignment with ALIGNED's tiered guidance. Regulatory clarity and interoperability of LCA tools are also emphasized to support consistent application across the sector.

3. **Advancing Cradle-to-Grave Thinking**
   End-of-life modelling is often oversimplified, failing to capture the climate value of temporary carbon storage. The report calls for enhanced downstream data collaboration and development of sector-specific end-of-life datasets.

Together, these recommendations form a coherent strategy to improve data quality, foster methodological alignment, and support science-based decision-making. By implementing them, stakeholders can ensure that the environmental benefits of bio-based chemicals are accurately recognized and fairly represented in sustainability assessments.

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2 Introduction

The bio-based chemical sector is one of Europe's most promising industries for building a more sustainable and circular economy. By using renewable resources like plant oils, sugars, and agricultural residues, this sector offers greener alternatives to fossil-based chemicals in everything from cosmetics and coatings to lubricants and detergents.

But while the potential is clear, the path forward is not without challenges. Companies in this space are navigating complex sustainability questions: how to measure their climate impact fairly, how to collect reliable data from suppliers, and how to account for the full life cycle of their products, including what happens at the end of life of the products.

This document brings together practical recommendations to help address these challenges. It is intended for sustainability managers, LCA practitioners, R&D professionals, academic researchers, and EU policymakers; stakeholders who are actively shaping the future of the bio-based chemical sector. By offering actionable insights and sector-specific guidance, the aim is to support more consistent, transparent, and science-based sustainability assessments that can help the sector grow with confidence and credibility.

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3 Overview of the sector

The European bio-based chemical sector is a dynamic and rapidly evolving industry that plays a pivotal role in the EU's transition toward a circular and climate-neutral economy. By leveraging renewable biological resources; the sector offers sustainable alternatives to fossil-based chemicals across a wide range of applications (EC, 2021a). These include lubricants, coatings, cosmetics, detergents, and advanced polymers. The sector is also a key enabler of green innovation, contributing to the development of biodegradable materials, low-carbon industrial inputs, and safer consumer products. Its alignment with EU policy frameworks such as the Circular Economy Action Plan, the Bioeconomy Strategy, and the Green Deal underscores its strategic importance in achieving long-term environmental and economic resilience (EC, 2020).

One of the sector's greatest strengths lies in its ability to combine environmental performance with industrial functionality. Bio-based chemicals can offer improved biodegradability and lower toxicity compared to fossil-based alternatives (Rosenboom et al., 2022). While they hold high potential for the reduction of greenhouse gas emissions, their actual environmental performance depends on a wide range of factors across the life cycle, including biomass type, conversion technology, and EOL treatment. The sector further supports rural development and agricultural diversification by creating value-added markets for biomass and agricultural residues. Technological advancements in fermentation, enzymatic processing, and green chemistry have further expanded the sector's capabilities, enabling the production of high-performance bio-based molecules with tailored properties (Jong et al., 2020). These innovations are increasingly being adopted by large industrial players and SMEs alike, fostering a vibrant ecosystem of sustainable chemical production across Europe.

Nevertheless, the sector is actively addressing concerns around feedstock competition and sustainability by exploring alternative and circular sourcing strategies. Companies are increasingly turning to non-edible crops, agricultural residues, and industrial by-products to reduce pressure on land and food systems (EC, 2018b). Algae-based feedstocks and waste-derived inputs are gaining traction as scalable, low-impact alternatives (OECD/FAO, 2021). In parallel, many actors are investing in regenerative agriculture practices that enhance soil health, biodiversity, and carbon sequestration (Newton, 2020). These efforts are complemented by circular supply chain initiatives, such as mass balance approaches and closed-loop recycling systems, which aim to valorise waste streams and extend material lifecycles. Together, these strategies reflect the sector's commitment to balancing environmental stewardship with industrial growth and resilience (EC, 2023a).

A concrete example of this commitment is illustrated by the ALIGNED case study of Oleon[1], a leading European producer of oleochemicals. Oleon is specialised in converting natural fats and oils into a wide range of oleochemical products, such as fatty acids, glycerine, esters, dimers, technical oils, specialty oleochemicals and biodiesel. These products are used in a wide range of industries as raw materials, ingredients or additives, enhancing the properties of the final product. Oleon has embedded sustainability into the core of its business strategy. The

[1] Oleon: A Natural Chemistry

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company's approach goes beyond compliance, aiming to actively contribute to climate action, biodiversity protection, and inclusive growth (Oleon, 2025).

Oleon's sustainability strategy is anchored in three core commitments: protecting natural resources and biodiversity, taking action for the climate, and fostering inclusive and collaborative progress (Oleon, 2025). This includes sourcing over 95% of its raw materials from bio-based origins, setting up deforestation-free supply chains, and investing in traceability and satellite monitoring systems to verify sustainable sourcing practices. The company also promotes eco-design principles in product development and engages in joint impact projects with stakeholders to drive positive environmental and social outcomes.

Within the ALIGNED project, Oleon's production of Hydrogenated Dimer Acid (HDA) from rapeseed oil was selected as a representative case for the bio-based chemical sector. The study applied the Life Cycle Assessment (LCA) methods identified in the ALIGNED project to evaluate the environmental performance of HDA, including dynamic carbon accounting and uncertainty analysis.

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4 Identified sustainability assessment challenges

The bio-based chemical sector, while having large potential to offer significant environmental benefits over fossil-based alternatives, faces several complex sustainability assessment challenges that must be addressed through harmonised methodologies and improved data practices to ensure robust and credible life cycle evaluations.

5.1 Main environmental challenges associated with the sector

The sustainability of feedstocks used in bio-based chemical production is a potential area of concern. Many processes still depend on oil crops (e.g. palm, soy, rapeseed), sugar, and starch which can lead to land use conflicts with food production and contribute to deforestation and biodiversity loss (EC, 2018b).

The sector's dependence on biomass introduces sustainability trade-offs, particularly when feedstocks compete with food and energy uses. This competition can intensify land scarcity, drive indirect land use change, and threaten biodiversity. Ensuring the sustainability of biomass sourcing, especially for imported feedstock, requires robust traceability systems, certification schemes (e.g., ISCC, RSPO, RTRS, etc.)[2], and alignment with deforestation-free regulations such as the EU Deforestation Regulation (EUDR[3]).

A substantial share of the bio-based chemical sector's environmental footprint is related to land use, land use change, and forestry. These emissions, categorized as FLAG by the Science-Based Targets initiative (SBTi), include CO_2 from deforestation, CH_4 and N_2O from fertilizer use, and biogenic carbon fluxes (SBTi FLAG Guidance[4], 2025). However, many companies lack the tools, data granularity, or methodological clarity to accurately quantify and report these emissions. The integration of FLAG emissions into corporate GHG inventories is further complicated by the need for spatially explicit land-use data and the absence of harmonized accounting frameworks.

Despite its potential, the bio-based chemical sector currently occupies only a small share of the overall chemical market. This limited market penetration is due to a combination of increased production costs, infrastructure limitations, and policy gaps, which hinder the sector's ability to scale effectively (EC, 2021a; Spekreijse et al., 2019).

End-of-life management and recycling remain challenging. Many bio-based products are not easily recyclable, and the infrastructure to support their proper disposal or reuse is often lacking (EC, 2023). Composite materials and certain insulation products, for example, are difficult to separate and process, complicating efforts to close the loop in a circular economy.

[2] ISCC – International Sustainability & Carbon Certification, RSPO – Roundtable on Sustainable Palm, RTRS – Roud Table on Responsible Soy
[3] EUDR
[4] SBTi FLAG Guidance

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5.2 Challenges which are not properly addressed

In the pursuit of transparency and reliability in sustainability assessments, several persistent challenges remain insufficiently addressed. Below are key issues that continue to hinder the effectiveness of LCAs and GHG inventories in the bio-based chemical sector.

5.2.1 Upstream Data Collection

The collection of high-quality upstream data remains a persistent and multifaceted challenge in the (bio-based) chemical sector. While commodity chemicals are generally well-represented in established LCA databases, specialty chemicals often fall outside the scope of these inventories. As a result, companies are frequently required to develop tailor-made datasets, which are both time-consuming and costly to produce.

Structural and operational challenges further complicate the collection of upstream data. Confidentiality constraints, often formalized through non-disclosure agreements, can restrict transparency and reduce the level of detail available of upstream and downstream data. In addition, suppliers often use different methodologies and data formats, making integration into a consistent LCA framework difficult. This creates a "terminological misalignment" between LCA practitioners, commercial teams, and suppliers, hindering effective data exchange.

Due to these limitations, companies frequently rely on proxy data or secondary datasets. While these can serve as temporary solutions, they often compromise the accuracy, representativeness, and credibility of environmental assessments. This presents a significant challenge, particularly in the context of third-party verification and regulatory compliance, where data quality and methodological transparency are being evaluated more rigorously.

The lack of harmonized data collection protocols and the absence of sector-specific guidance for specialty chemicals further exacerbate the issue. Without coordinated efforts to improve supplier engagement, standardize data formats, and facilitate secure data sharing, upstream assessments will continue to rely on assumptions that undermine their robustness and comparability.

5.2.2 Methodological Fragmentation

A critical and persistent challenge in the (bio-based) chemical sector is the methodological fragmentation in LCA practices. Despite the increasing demand for robust environmental assessments, the sector continues to suffer from a wide array of LCA methodologies and inconsistent application of standards. This fragmentation manifests across several dimensions:

- **Allocation rules**: There is no consensus on whether mass-based, economic, energy-based, or stoichiometric allocation should be applied. Each approach can yield significantly different results. For instance, a comparative analysis of three allocation methods (mass, stoichiometric, and economic) for the same product showed carbon footprint variations of over 50%, depending on the method used (The Product Carbon Footprint Guideline for the Chemical Industry, 2024). This variability undermines the credibility and comparability of LCA studies.

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- **Biogenic carbon accounting**: The treatment of biogenic carbon remains inconsistent. Some assessments apply a 0/0 approach (no credit for uptake, no burden for release), while others use a -1/+1 approach (credit for uptake, burden for release). This discrepancy is particularly problematic for bio-based products, where biogenic carbon flows are central to the environmental profile.

  The implications of this inconsistency become especially pronounced in systems involving recycled bio-based materials. The choice between 0/0 and -1/+1 approaches can lead to substantial differences in both cradle-to-gate and cradle-to-grave carbon footprints. These inconsistencies not only hinder comparability across studies and products but also complicate strategic decision-making related to product design, material selection, circularity, and sustainability communication.

  Moreover, current assessment standards such as ISO 14067 may unintentionally penalize bio-based products by failing to account for delayed or avoided emissions and temporary carbon storage. This regulatory gap undermines the environmental credibility of bio-based solutions and discourages innovation in circular and low-carbon product design.

- **Impact assessment methods**: The coexistence of different life-cycle impact assessment methods – such as IPCC, Environmental Footprint (EF 3.1), EN15804+A2, etc. – further complicates harmonisation. These methods differ in scope, midpoint indicators, and characterisation factors, leading to divergent interpretations of environmental performance.

- **Data integration and software interoperability**: LCA practitioners often face difficulties when combining datasets from different sources. Incompatibilities in methodological assumptions hinder seamless integration and reduce transparency.

This methodological fragmentation not only hampers the comparability of LCA results but also erodes stakeholder trust and limits the utility of LCA as a decision-support tool. It creates barriers for companies aiming to benchmark their performance, for policymakers seeking to design effective regulations, and for customers trying to make informed choices. Without harmonised guidance and sector-specific methodological alignment, the risk of misinterpretation and greenwashing remains high.

5.2.3 End-of-life Uncertainty

Bio-based intermediates are often embedded in complex formulations and dispersed across diverse applications, making cradle-to-grave assessments challenging. Producers typically lack visibility beyond their own operations, and chemical products often end up in numerous final products with varying use patterns and disposal routes. This lack of downstream transparency hinders accurate modeling end-of-life impacts.

End-of-life scenarios vary widely, from long-term storage to incineration or landfill, each with distinct environmental effects. Current LCA practices often oversimplify these dynamics, assuming for example immediate carbon release at end-of-life and ignoring temporary storage

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benefits. Recycling is further complicated by inconsistent infrastructure and methodological constraints.

These limitations are aggravated by the fact that current LCA standards often do not accommodate delayed emissions or temporary carbon storage. This can lead to underestimation of the climate benefits of bio-based products, particularly those with long-lived applications. Revising such standards is critical to ensure that end-of-life modelling reflects the true environmental performance of bio-based materials.

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4 Recommendations

To effectively address the current challenges in sustainability assessments within the bio-based chemical sector, several strategic recommendations are proposed.

5.3 Improving Upstream Data Collection and Collaboration

In response to the challenges outlined earlier, the recommendations below offer practical steps to strengthen the transparency and reliability of sustainability assessments within the bio-based chemical industry.

5.3.1 To chemical producers and LCA practitioners

- **Engage suppliers early and systematically in the data collection process**. Establishing long-term data-sharing agreements and using pre-defined templates can help overcome confidentiality concerns and improve data consistency.
- **Use harmonized data collection formats** and align with the sustainability data guidelines developed in ALIGNED (Pizzol et al., 2024) to ensure compatibility across different actors and tools.
- **Avoid over-reliance on proxy data by investing in primary data collection** where feasible. When proxies are used, clearly document assumptions and uncertainty ranges to improve transparency and comparability.

5.3.2 To industry associations and data providers

- **Facilitate the creation of sector-specific guidance** for upstream data collection, including minimum data requirements and best practices for supplier engagement.
- **Support the development of shared datasets** for common intermediate and processing steps, especially where confidentiality is less of a concern.

5.3.3 To policy makers

- **Promote the harmonization of supplier data reporting practices** by encouraging the uptake of voluntary frameworks or, where appropriate, regulatory incentives. This should be pursued in close consultation with chemical producers and LCA practitioners to ensure both relevance and feasibility. This could include the promotion of digital product passports or mandatory disclosure of environmental data for key chemical inputs.

5.4 Harmonizing LCA Methodologies Across the Sector

Given the methodological fragmentation discussed above, stakeholders are recommended to:

5.4.1 To chemical producers and LCA practitioners

- **Apply harmonized and transparent LCA modelling practices**: Clearly document methodological choices, including allocation rules, impact assessment methods, and biogenic carbon accounting approaches (e.g. 0/0 or –1/+1). This level of transparency enhances comparability across assessments, facilitates third-party verification, and reduces the risk of misinterpretation. Within the ALIGNED project, tiered guidance has been developed to support biogenic and dynamic carbon accounting as well as climate change characterization. By applying ALIGNED methods on the case studies, the

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project advises the –1/+1 approach for biogenic carbon accounting. Further methodological details are available in the project's open repository (Hamelin et al., 2024)

5.4.2 To industry associations and data providers

- **Support the development of harmonized and accessible LCI datasets**: Facilitate the creation of open-access or anonymized datasets for bio-based feedstocks and intermediates. These should specify how carbon uptake and release are treated and follow standardized formats.
- **Promote interoperability of LCA tools and databases**: Encourage software providers to improve compatibility and offer geographically differentiated, process-specific data relevant to the bio-based chemical sector.

5.4.3 To policy makers

- **Promote regulatory alignment of LCA methodologies**: Encourage the adoption of harmonized LCA practices across EU frameworks (e.g. Sustainable Products Initiative, CSRD, DPP) to reduce fragmentation and enhance trust in environmental claims. Inspiration can be drawn from Horizon Europe-funded projects such as ALIGNED, CALIMERO, and LCA4BIO, which have explored sector-specific guidance, dynamic carbon accounting tools, and interoperable data platforms that may support future methodological convergence.
- **Clarify expectations for biogenic carbon treatment**: Ensure that regulatory frameworks and verification schemes explicitly address biogenic carbon accounting to reduce ambiguity and greenwashing risks

5.5 Promoting Cradle-to-Grave Thinking

Enhancing the credibility and rigor of environmental assessments – especially regarding EOL modelling – requires the implementation of the following actions:

5.5.1 To chemical producers and LCA practitioners

- **Enhance downstream data collaboration**: Producers should proactively engage with downstream users to exchange LCI data and improve transparency on EOL scenarios.

5.5.2 To industry associations and data providers

- **Develop sector-specific EOL datasets**: Associations should coordinate the development of representative EOL datasets for common bio-based intermediates and applications.

The recommendations outlined above form a coherent strategy to enhance the credibility, consistency, and comparability of sustainability assessments across the bio-based chemical sector. By fostering methodological alignment, improving data quality, and enhancing collaboration among stakeholders, they lay the groundwork for more transparent and science-based decision-making.

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6 Conclusions

The bio-based chemical sector continues to be a key enabler of Europe's climate and circular economy ambitions. Yet, its environmental contributions are not fully captured in current sustainability assessments due to persistent gaps in upstream data quality, methodological fragmentation, and end-of-life modelling. These limitations hinder comparability, reduce transparency, and risk undermining the credibility of bio-based solutions.

To address these challenges, the report outlines targeted recommendations for producers, LCA practitioners, industry associations, and policymakers. These include improving supplier engagement and harmonizing data formats, fostering methodological alignment across LCA practices, and enhancing downstream collaboration to support cradle-to-grave modelling.

In addition to these core areas, the sector must also prioritize digitalization and data infrastructure. The development of interoperable platforms, digital product passports, and secure data-sharing mechanisms will be essential to streamline reporting and reduce administrative burdens. These tools can also support regulatory compliance and facilitate third-party verification.

Taken together, these actions form a coherent strategy to strengthen the robustness of sustainability assessments and support the responsible scaling of the bio-based chemical industry. By investing in data integrity, methodological clarity, and collaborative infrastructure, stakeholders can reinforce the sector's role as a cornerstone of Europe's sustainable bioeconomy.

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