HARMONITOR

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REPORT

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CONTENTS

1. EXECUTIVE SUMMARY

The HARMONITOR project aims to enhance the credibility, effectiveness, and harmonisation of Certification Schemes and Labels (CSLs) across the EU bioeconomy by establishing a monitoring platform and shared methodologies. This report, Deliverable D2.4, consolidates the methodologies developed across five core work packages (WP2–WP6) to analyse, benchmark, monitor, and assess the costs, benefits, and societal value of CSLs. It also details the coordination between these WPs and the exchange of data with external projects and stakeholders.

WP2 established the methodological foundation for the entire project, including a CSL and bio-based value chain inventory, a large-scale stakeholder consultation, and the creation of a multi-stakeholder platform that coordinated inputs for all subsequent WPs.

WP3 analysed global and EU trade flows of certified and uncertified bio-based products, compiling value chain data that informed certification mapping, economic feasibility modelling, and monitoring system development.

WP4 developed a Comparative Benchmark Tool to evaluate 22 CSLs based on sustainability, governance, and assurance criteria. It assessed their strengths and weaknesses, supported by scheme owner feedback and updated EU legislation (e.g., EUDR).

WP5 co-developed the BiobasedCert Monitoring Tool (BMT) together with sister projects STAR4BBS and SUSTCERT4BIOBASED. It tested outcome-level indicators with nine CSLs, focusing on measurable sustainability impacts, and finalised a harmonised, three-tier assessment framework.

WP6 assessed the direct and indirect costs, benefits, and externalities of CSL adoption through literature reviews, case studies, stakeholder consultations, and economic modelling.

Information exchange with projects like STAR4BBS, SUSTCERT4BIOBASED, and 3-CO, and coordination with CSL owners and policymakers, ensured methodological coherence, robust validation, and wide relevance. The outputs support improved policy integration, stakeholder trust, and continued methodological development beyond the project's duration.

2. INTRODUCTION

The HARMONITOR project aims to enhance the performance of certification schemes and labels (CSLs) in various sectors of the EU Bioeconomy, making them more effective and strengthening their role as a co-regulation instrument. CSLs can address challenges faced by public regulations and fill policy gaps. The project intends to establish a participative review platform that enables CSLs to collaborate and find common ground within bio-based value chains across EU borders. This platform builds upon the innovative 'Sustainability Certification Tools' proposed by the STAR-ProBio project. The specific objectives of HARMONITOR include establishing a review platform, providing transparent data on bio-based value chains, comparing performance requirements of CSLs, developing a monitoring system, and improving the understanding of CSLs in co-regulation. The expected outcomes of the project include enhanced transparency and traceability in value chains, increased effectiveness, and robustness of CSLs through systematic monitoring, awareness of trade flows and their impacts, and potential use of CSLs as part of the EU Bioeconomy policy framework.

Deliverable 2.3 (D2.3) 'Project methodology handbook for benchmarking and monitoring' is the second of two deliverables of Task 2.3 'Project methodology hub' of Work package 2 (WP2): 'Final documentation of concepts, methodologies, and tools'. The first deliverable of Task 2.3 (D2.3; Concepts and methodologies for the HARMONITOR platform') was finalized in July 2023.

1.1 Task 2.3 description

To ensure consistent and comprehensive results in analysing CSLs, cross-Work Package (WP) coordination is necessary. To facilitate this coordination, Task 2.3 in WP2 functioned as a methodology hub to facilitate the analysis of bio-based value chains and CSLs and ensure consistency and compatibility of results and data flows. The hub, made through the contribution of all the project partners, coordinated the selection of methodologies that were used across different project WPs. Its tasks were to coordinating data collection, discussing methodologies development and selection, preparing coherent results, data transferring and exchanging information with other projects with similar objectives under the ZERO POLLUTION call. The hub served as a platform for identifying connections between tasks and interdisciplinary project activities. Additionally, the hub enabled partners to collectively identify data sources and define methodologies for reviewing, monitoring, and assessing selected CSLs.

The methodologies used in WP1 and WP7 are excluded from this report due to the practical non-academic component that the coordination and dissemination tasks require. Therefore, the focus of this methodological handbook is on theoretical methodological research aspects.

This report (D2.4 'Project methodology handbook for benchmarking and monitoring') is the final report. With the exception of the final methodology of the BMT, all methodologies of all work packages have been finalized.

1.2 Connection between and description of HARMONITOR work packages

This section summarizes the connections between the seven HARMONITOR work packages (WPs) and the expected results of each WP according to the project proposal. An overview of the WP structure is provided in Figure 1.

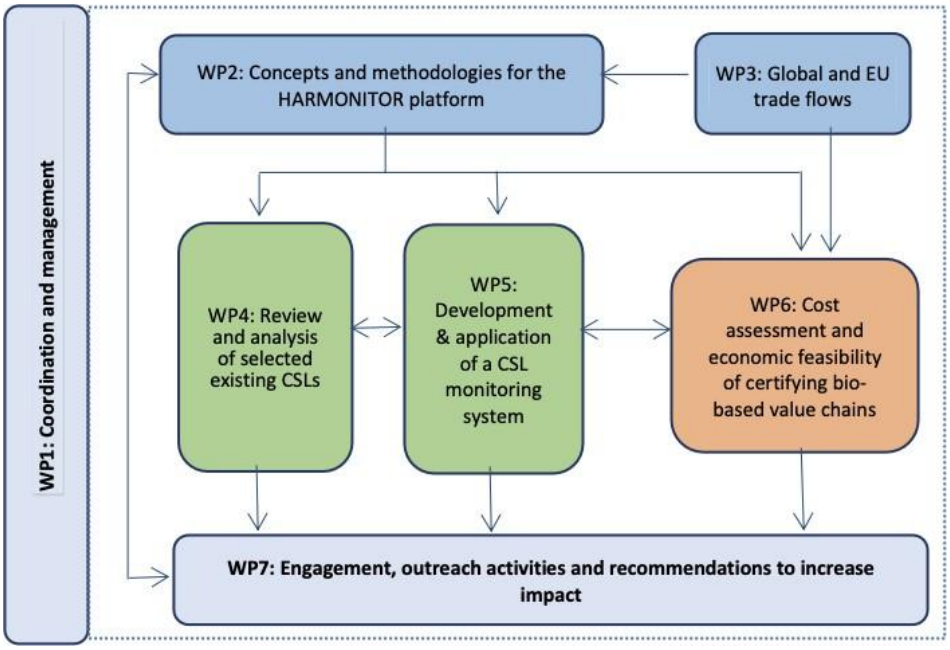

Figure 1. Overall structure of the work plan as represented in the HARMONITOR proposal.

The HARMONITOR WPs are interconnected to facilitate the collaborative development of various project products. This deliverable primarily aims to bolster this collaborative effort by providing a comprehensive description of the individual tasks and methodologies within each WP. It highlights the collaboration among WPs to collectively achieve the overarching objectives of developing a monitoring system and a CSL platform. Below, the aims and activities of each work package are briefly summarized.

WP2: Concepts and methodologies for the HARMONITOR platform

WP2 aimed to define common starting points for analysing bio-based value chains and CSLs. In Task 2.1, an inventory overview of existing CSLs and value chains was prepared, covering relevant biological resources used in bio-based value chains and materials/products. A final selection of CSLs was made in collaboration with the Commission and the project's Advisory Board. Subsequently, a concept of essential elements for the HARMONITOR platform was developed. Task 2.2 included an open public consultation that was conducted to gather input on critical issues affecting existing CSLs. The consultation contributed to initiating the participative and review HARMONITOR platform, allowing CSLs to find commonalities and cooperation when operating in bio-based value chains within and across EU borders. The consultation also contributed to defining starting points for subsequent tasks.

Task 2.3 established a methodology hub to coordinate data collection and methodologies across the project. This was important to ensure coherence within the WPs and to exchange information with other projects that had similar objectives. Task 2.4 established a conceptual approach, structure, and essential elements to develop the HARMONITOR platform, also using information from the other project tasks. Subtasks 2.4.1, 2.4.2, 2.4.3, and 2.4.4 coordinated the involvement of the selected CSLs in the HARMONITOR platform. The focus was on the development of the platform's concept and system elements (including governance options and funding for long-term operations), feedback-based testing and refinement of the conceptual basis of the platform, and the creation of a first version of the HARMONITOR platform. The active participation of CSLs ensured its continuous operation and improvement beyond the project's duration.

WP3: Global and EU trade flows of biological resources, bio-based materials, and products

WP3 aimed to collect and analyse data on the volumes and trade flows of biological resources and bio-based materials and products. The tasks focussed on distinguishing between certified and uncertified resources, materials and products by determining the scope and selection of resources (Task 3.1), assessing trade flows (Task 3.2), evaluating the level of certification and labelling (Task 3.3), and synthesizing the collected data into a report (Task 3.4). The goal of the WP was to provide insights into global trade patterns and promote sustainable practices in the bio-based industry.

WP4: Review and analysis of selected existing CSLs for biological resources, bio-based materials, and products

The objective of WP4 is to conduct a comparative analysis of selected CSLs that focuses on the environmental, social, and economic impacts of bio-based products. The analysis assessed the effectiveness and robustness of the assurance and governance systems of each scheme in achieving their intended impacts. The tasks included developing an inventory of key aspects of CSLs through literature review and documentation analysis (Task 4.1), conducting a comparative analysis of each scheme's impacts, assurance systems, and governance systems (Task 4.2), and validating the findings through stakeholder consultation (Task 4.3). The final comparison study provided a comprehensive overview of the performance of the selected CSLs and offer recommendations.

WP5: Development and application of a CSL monitoring system

WP5 aimed to develop and implement a monitoring system for CSLs related to bio-based products. In Task 5.1, the monitoring system will be developed, including requirements, indicators, and verification tools to assess environmental, social, and economic sustainability aspects of CSLs. The system will be collaboratively developed by academic and market partners with input from the European Commission and other stakeholders. In Task 5.2, the monitoring system will be applied to selected CSLs to test its effectiveness and optimize its methodology. Task 5.3 involves validating the monitoring system based on the test results and making necessary improvements. The monitoring system will be continuously updated and developed under the project, and collaboration with ISEAL will be sought for further harmonization.

WP6: Costs, benefits, and economic feasibility of CSLs

WP6 outlined the objectives and tasks related to quantifying the costs and benefits of adopting CSLs in industrial bio-based value chains. The objective was to assess the direct and indirect costs and

benefits of adopting CSLs in selected industrial bio-based value chains, including externalized environmental and social costs, and to identify governance options for increasing certified production. Task 6.1 aimed at quantifying the direct costs of obtaining certification from selected CSLs. To achieve this, direct costs were estimated based on certification bodies' experience (see Deliverable 6.1). Task 6.2 assessed costs and benefits of meeting sustainability criteria by conducting a systematic literature review (see Deliverable 6.1 and Rossi et al. 2024)[1]. Task 6.3 used economic modelling to quantify the environmental externalities of selected biological resources and bio-based products at EU member state and EU levels (see Deliverable 6.2). The monetary value of externalities, here GHG emissions, was determined using existing valuation methods. The impacts of internalizing the costs of these emissions were further assessed taking the case of the Netherlands.. Finally, Task 6.4 evaluated i) the overall economic feasibility by conducting three case studies and ii) the use of verification instruments and particularly certification in EU bioeconomy policies (see Deliverable 6.3). Cost-benefit analysis and net present value analysis were conducted, considering direct and indirect costs and benefits. Literature reviews, interviews, and surveys with experts and stakeholders were conducted to identify governance options for increasing the feasibility and effectiveness of certification.

[1] Rossi, C., Shen, L., Junginger, M., & Wicke, B. (2024). Sustainability certification of bio-based products: Systematic literature review of socio-economic impacts along the supply chain. Journal of Cleaner Production (Vol. 468). https://doi.org/10.1016/j.jclepro.2024.143079

3. DESCRIPTION OF THE METHODOLOGIES PER WORK PACKAGE

In this chapter, the methodologies developed in the different work packages over the runtime of the HARMONITOR are explained and summarized. Where appropriate, more elaborate methodological information for WPs 2-6 can be found in Appendixes A to E.

For each work package, we also describe (i) which information was from other HARMONITOR WP's was used as input, (ii) which information was forwarded to other WP's within HARMONITOR, (iii) which information was forwarded to the other SISTER projects SUSTCERT4BIOBASED and STAR4BBS and iv) which information/results were actively disseminated to other projects and stakeholders, e.g. through webinars, workshops or project deliverables. This was also part of Work Package 7 . However, as we did not develop a designated methodology for dissemination, we refrained from including it here, and simply summarized the dissemination efforts.

An overview of all work package and sub-task leads covered in this report is provided in Table 1 below.

Table 1 Overview of all WP and subtask leads.

	Lead	Organisation
WP2	Stefan Majer	DBFZ
Task 2.1	Stefan Majer	DBFZ
Task 2.2	Martin Junginger	Utrecht University
Task 2.3	Martin Junginger	Utrecht University
Task 2.4	Stefan Majer	DBFZ
WP3	Martijn Vis	BTG
Task 3.1	Martijn Vis	BTG
Task 3.2	Martijn Vis	BTG
Task 3.3	Martijn Vis	BTG
Task 3.4	Martijn Vis	BTG
WP4	Simon Windfeld Møller	Preferred by Nature
Task 4.1	Simon Windfeld Møller	Preferred by Nature
Task 4.2	Simon Windfeld Møller	Preferred by Nature
Task 4.3	Ana Gabriela López Camey de Schrader	Preferred by Nature
WP5	Martin Junginger	Utrecht University
Task 5.1	Martin Junginger	Utrecht University
Task 5.2	Martin Junginger	Utrecht University
Task 5.3	Martin Junginger	Utrecht University
WP6	Birka Wicke	Radboud University
Task 6.1	Simon Windfeld Møller	Preferred by Nature
Task 6.2	Birka Wicke	Radboud University
Task 6.3	Birka Wicke	Radboud University
Task 6.4	Birka Wicke	Radboud University

WP2: Concepts and methodologies for the HARMONITOR platform

Task 2.1: Definition of common starting points (Month 12) – completed

An initial inventory of existing CSLs in the EU biobased economy was generated through a comprehensive review of scientific literature and available databases. The initially identified 100 CSLs were further assessed based on their specific characteristics and filtered according to the needs of each specific WP. An internal questionnaire was developed to match the identified schemes with the requirements and expectations of the project partners. The relevance and applicability of the CSLs to the selected biobased value chains under WP2 were also considered. The result of this process was an internal longlist of approximately 50 CSLs for further analysis in the project.

To shorten the longlist, a preselection of 35 biobased value chains, including feedstock categories, intermediates, and potential products, was made. A questionnaire was used to gather additional parameters and preferences for the selection of value chains from the project partners involved in relevant WPs. Feedstock groups were clustered with appropriate intermediate and final products to facilitate the selection process. Additional selection criteria, such as the inclusion of intermediate products for downstream processing and the availability of CSLs, were applied. The elements of the value chain clusters were matched with the selected CSLs to assess their potential coverage. Based on these steps, a final selection of biobased value chains for further analysis in the HARMONITOR project was compiled. Overall, the methodology involved a comprehensive review, questionnaire-based assessments, and matching exercises to identify a range of certification schemes, labels, and biobased value chains for analysis and work within the HARMONITOR project.

Task 2.2: Open public consultation (Month 12) - completed

The public consultation for the survey was conducted online and developed by Utrecht and Radboud University scholars. The survey received feedback and advice from the HARMONITOR project partners, as well as from the sister projects STAR4BBS and SUSTCERT4BIOBASED, ISEAL, and ECOS, particularly regarding the application of the 10 ISEAL credibility principles. These principles define the core values of credible and effective sustainability systems and were selected since they help organizations develop standards and sustainability tools by identifying critical attributes that enhance credibility.

The survey consisted of four parts. The first part focused on respondents' background, including their stakeholder group affiliation and geographical location. The second part gathered respondents' general opinions on the advantages and disadvantages of CSLs, as well as their familiarity with EU legislation on the sustainability of biobased products, which often utilize CSLs. The third part was the central section of the questionnaire, where respondents were asked to assess the strengths and weaknesses of CSLs based on the 10 ISEAL credibility principles. They had the option to evaluate CSLs in general or specific ones, ranking them from weak to strong. In cases where weaknesses were identified, respondents were asked to provide explanations and motivations. If respondents mentioned specific CSLs, these CSLs were anonymized in the results. The final part of the survey offered respondents the choice to provide their name and contact details for follow-up interviews and to request the survey results.

The survey was disseminated through project partners, advisory board members, social media platforms like LinkedIn and Twitter, and targeted outreach to individuals and organizations involved in critically reviewing CSLs. Data collection for the report took place starting early March 2023 and is still

ongoing. Preliminary results presented at the workshop in Bologna at the EUBCE side event were based until May 7th, 2023. By that time, 68 respondents had started the survey, and 33 had completed it. As some stakeholder groups were underrepresented, the survey remained open until 16 July 2023. At this time of writing, we received 95 respondents that started the survey and 42 that completed it. The aim will be to have at least 100 survey respondents starting the survey and 50 finishing it, with ideally all stakeholder groups being covered.

After the survey is finalized, Utrecht University will follow up with in-depth interviews with a limited number of selected key stakeholders. The results of the consultation, the interviews and other activities (e.g., the HARMONITOR and its sister project workshop held in Bologna in June 2023 as side event of the EU Biomass Conference and Exhibition EUBCE 2023) will then be summarized and forwarded to the JMS working groups. In addition, the ambition is to condense the findings and publish them as a paper in a peer-reviewed open access scientific journal for further dissemination.

Task 2.3: Project methodology hub (Month 36) – this deliverable

The final deliverables (D2.4) of this task builds on D2.3 and contains the full set of final methodologies developed within the HARMONITOR project. It consists of a short introduction of each WP and sub-task, a methodological part that summarizes the specific methodologies used for each task, and a final reflection section that connects the methodologies across tasks and WPs. The introductory part was based on the HARMONITOR base documents with task descriptions. The methodological part was developed from documents provided by each task coordinator, which outlined the methods used for achieving the deliverables. These were then shortened and summarized. The final flowchart connects the different methodologies across tasks and WPs to visualize the exchange of information throughout the project.

Task 2.4: Development of the HARMONITOR platform (Month 36) – finalized

Task 2.4 has developed a collaborative platform for certification schemes and labels as well as certification bodies and different additional stakeholder groups. The platform included two main elements: i) a series of different communication/dissemination events for the BIOBASEDCERT cluster and ii) a roundtable for CSLs.

The roundtable has been a forum to discuss elements of the developed Monitoring Tool (i.e. the BMT), such as its criteria and indicators as well as general trends and relevant topics in the bio-based industries and sustainability certification. It has facilitated informal discussions on the design, market implementation, and uptake of CSLs. The platform, which includes around 12 certification schemes as well as different certification bodies and other entities organised different meetings, each of them dedicated a specific topic. The content of these meetings was driven by the interests and inputs of the roundtable participants. Highlights included sessions on emerging trends in policy and industry relevant to CSLs, as well as an in-person event with representatives from DG GROW, DG RTD, DG Environment, and DG CLIMA to discuss the role of certification in future policy frameworks.

Throughout the project, the roundtable organised five meetings to discuss:

1. the general interest and focus points of the participating CSLs and certification bodies,
2. new trends and upcoming demand for certification in the bioeconomy. With keynotes from DG Climate, BASF and the advisory board,
3. upcoming regulations and lessons learned regarding the use of sustainability certification as a co-regulation instrument. A meeting in Brussels with representatives of 14 CSLs and DG GROW, DG RTD, DG Environment, DG CLIMA,
4. the developed BMT and how the BMT might support the future development of CSLs and

5. the future of the roundtable after the end of HARMONITOR.

The following figure gives an overview of the roundtable meetings.

The successful development of the collaborative platform for CSLs was acknowledged by the roundtable members who expressed their willingness to support a continuation of the roundtable after the end of the BIOBASEDCERT cluster projects. Currently, different options and concepts for the continuation of the roundtable, with a co-ownership model of CSLs are being discussed with the roundtable members.

Information and data exchange between WP2 and other WPs and projects

The Platform developed in WP 2.4 was used as to collect input and feedback from external stakeholders which was then supporting the work in HARMONITOR WPs 2, 3, 4, 5 and 6. This included: the development of the concept for the roundtable, the presentation of intermediate results from the BMT development, the presentation of trade flow results, etc.

WP3: Global and EU trade flows of biological resources, bio-based materials, and products

Task 3.1: Determining scope and selection of resources, materials, and products (Month 6) – completed

The goal of the selection was to have a representative mix of bio-based products, using various feedstocks, covering a broad range of sectors, and relevant for EU policy making and sustainability certification analysis. Overall, the methodologies involved compiling lists of bio-based materials, pre-selecting dedicated, and drop-in products based on trade volumes, identifying main biological

resources, and making the final selection based on various criteria and policy relevance. These are summarized in 5 main methodological steps:

1. Step 1: An extensive list of 350 bio-based materials and products, supplemented with wood products and other bio-based products, was created. It indicated whether the products are drop-in or dedicated bio-based materials.

2. Step 2: All dedicated bio-based materials and products for which statistical trade information is readily available, including wood-based products, were pre-selected.

3. Step 3: The 40 drop-in bio-based materials and products with the highest bio-based production volumes were selected for further assessment.

4. Step 4: The main biological resources used for the production of the selected bio-based materials and products were identified through a quick assessment of their value chains.

5. Step 5: The final selection of bio-based value chains was made considering several criteria and considerations, including market size, representative distribution between sectors, inclusion of innovative and traditional products, use of residues and wastes, inclusion of both EU and imported feedstocks, environmental and social challenges, coverage by sustainability certification schemes and labels, and relevance to EU bioeconomy policies.

For more information on what each precise step is used in this task check Appendix B.

Task 3.2: Assessing trade flows of biological resources, bio-based materials and products (Month 18) – finalized

Task 3.2 involved assessing the trade flows of biological resources, bio-based materials, and products. The approach included mapping trade flows using existing market databases and combining statistical information with estimated percentages of bio-based production for drop-in bio-based products. The trade flows of biogenic feedstock were mapped using existing databases, with other sources used if statistical information was unavailable. The data collection process included describing the value chain, collecting statistical data, and collecting data in cases where no statistical information was available. The results aim at showing production, market, import, and export of major global regions, with a more detailed mapping of trade between EU member states where available. The deliverables included an initial assessment of trade flows at month 12 (May 2023) and the trade flows report at month 27 (August 2024). The work was divided between the Biomass Technology Group (BTG) and Utrecht University, with BTG assessing value chains with chemicals, sugar/starch, and oil crops as biomass resources, and Utrecht University handling other value chains such as wood, paper, and textiles. An uncertainty indicator was used to rank the quality of information sources, considering factors like reliability, data source, and adjustments based on circumstances.

Task 3.3: Assessing level of certification and labelling of biological resources, bio-based materials and products (Month 27) – completed

Task 3.3 involves assessing the level of certification and labelling of biological resources, bio-based materials and products. Data on the level of sustainability certification of specified bio-based products is generally difficult to obtain. Statistics do not disclose any data on flows of certified versus uncertified bio-based products. For biological resources and a number of wooden products and fibre-based products, country level data may be available from certification schemes or literature. For many bio-

based chemicals, this type of information is not available, meaning that the level of sustainability certification has to be determined using company data. We identified three situations and developed suitable approaches:

- If possible and available, the level of certification is determined at country level by using literature, summary reports by certification schemes, and scientific research (approach A).
- In case country level data is not available and there are a limited number of producers (for example in case of bio-based chemicals), it is possible to identify the producers, their production locations and capacities and whether they have a sustainability certificate. This way at least the share of certified producers versus total producers can be identified (Approach B)
- In case country level data is not available and there are many producers (for example in the wood sector) the number of chain-of-custody (CoC) certificates of the main certification schemes of the product could be counted per country, providing insight into which countries have relatively more or less certificates compared to the total production of the product in each country as found in statistics (approach C).

The results are described in Deliverable D3.4 Level of certification and labelling of biological resources, bio-based products and materials, submitted on 29 November 2024. The work was performed by BTG (approach 1 and 2) and DBFZ (approach 3).

Task 3.4: Trade flows synthesis (Month 33) – completed

The goal of Task 3.4 is to synthesize, visualise and make accessible all collected data on trade in certified/uncertified biological resources and bio-based products and materials. Moreover, the main findings, including information on data gaps and practical solutions have been summarised. The trade flows have been visualised in an online trade flow tool and a pivot table. Using the combined data from Comext and the UN Comtrade databases, a comprehensive dataset was created for EU trade data of the selected bio-based value chains. This dataset is presented in a pivot table format, offering enhanced filtering options for products, import and export data, and intra- and extra-EU trade. To visualize the trade flows, the data was entered into the 'FlowmapBlue' tool[2]. This tool gives the possibility to filter between the different value chains, to see the individual trade flows between countries; and the total imports and exports of a specific country. The results are found in D3.5 Trade flows synthesis, of 28 February 2025.

Information and data exchange between WP3 and other WPs and projects

The 35 value chains as selected in Task 3.1 and described in D3.1 Selection of bio-based value chains (M6), have been input to Task 2.1 Definition of common starting points, resulting in a refined list of value chains (found in D2.1 (M12), that became the focus of research of Task 3.3 on the level of certification of bio-based value chains. Moreover, result of Task 3.3 has provided background information for the case studies on cost and benefits of certification in Task 6.2 and the overall feasibility of certification in Task.6.4.

On a regular basis, we have exchanged our ideas, approaches, and intermediary results with the two sister projects STAR4BBS and SUSTCERT4BIOBASED, especially with the colleagues from nova Institute and Wageningen University, the partners doing the trade flow assessments within these

[2] https://flowmap.blue/1VWZpdRU-Gk8kWX2NQEtnaq3UvDH3tqZjWErpI2AfEzg/d34f5c2

projects. Five sister project meetings have taken place in which the selection of value chains and trade flows played a role (16 June 2022, 28 Oct 2022, 12 Nov 2022, 18 July 2023 and 13 March 2024). Moreover, BTG has provided input to a joint presentation on trade flows during a dedicated workshop with the three sister projects as part of the EUBCE conference in Bologna, in June 2023. On 13 June 2024, the three sister projects organized a joint workshop at the Renewable Materials Conference in Siegburg, in which Harmonitor WP3 has presented the trade flow assessment and tools. A similar presentation was held at the online BioBasedCert meeting of 27 September 2024.

WP4: Review and analysis of selected existing CSLs for biological resources, bio-based materials, and products

Task 4.1: Literature review and inventory of key aspects of each selected CSL (Month 12) – completed

Task 4.1 consists of several subtasks, including subtask 4.1.1 which comprises a literature review on sustainability CSLs. This was originally planned to be carried out by the German Biomass Research Centre (DBFZ) and RINA CONSULTING, but was taken up by Utrecht University. A meta-review was carried out based on scientific, peer-reviewed articles and studies that discussed the functioning of CSLs for biobased products from various angles. The literature review was conducted on Google Scholar by using the terms ‘meta-analysis’, ‘critical discussion’, ‘analyzing key aspects’, ‘review’, and ‘sustainability assessment’ to identify articles published during the past 6 years on critical aspects of CSLs. A particular attention was given to aspects of the governance system based on the ISEAL credibility principles (Sustainability Impacts, Collaboration, Value Creation, Measurable Progress, Stakeholder Engagement, Transparency, Impartiality, Reliability, Truthfulness and Continual Improvement) through different categories of bio-based products (e.g., consumer goods, biomass, bioplastics, etc.) or aspects of certifications, such as best practices or market mechanisms. The identified and assessed included amongst other studies that assessed the use of CSLs for demonstrating compliance with legislation, the benefits of CSLs for smallholders, the effectiveness and economic viability of forest certification (several articles) and the impact of other CSLs for specific feedstocks (e.g., palm oil), transparency of CSLs focusing on textiles, and many more topics.

Subtasks 4.1.2 to 4.1.5 focused on establishing specific inventories based on the following brief:

- Subtask 4.1.2: Inventory of certifiable biological resources, bio-based material and products covered by selected CSLs. (DBFZ, RINA CONSULTING)
- Subtask 4.1.3: Inventory of environmental, social, and economic requirements, including control points examined during audit assessments. (Preferred by Nature, RINA CONSULTING)
- Subtask 4.1.4: Inventory of assurance system requirements, relating to how compliance with the scheme requirements is ensured. This includes protocols that are meant to ensure effectiveness, robustness, and other aspects of how the scheme operates. (Preferred by Nature)
- Subtask 4.1.5: Inventory of governance system requirements, including aspects such as impartiality, transparency, stakeholder engagement, impact measurement, etc., determining overall CSL credibility. (Utrecht University)

The general overview of the selected CSLs is based on a review of the CSLs' system documentation (e.g., CSLs' websites, ITC Standards Map). To provide a broad overview of the different CSLs, different topics were covered: market relevance, available documentation, certification procedure, communication options, recognition of other schemes, potential geographic application, value chain elements, etc.

First, information available on the CSLs' websites related to the selected topics was reviewed. Information on the topics that could not be identified in the first step was gathered from other sources, such as the ITC Standards Map. Based on this approach, the collected information was inventoried for each CSL and transferred to tables to provide a schematic representation of the results and to facilitate the comparison among the different CSLs. A summary and key conclusions were written for each table, highlighting the main common points and the main differences among the analysed CSLs. The CSLs' websites and the main CSLs' standards represented the main reference for the review of the environmental, social, and economic requirements, which have been presented in this document. The analysis was complemented by a comparative analysis of the assurance systems implemented by various certification schemes, as well as by a thorough review of the governance system requirements for the 22 selected CSLs. The relevant data was gathered from the CSLs official website and documents as well as ITC Standards Map. Based on this analysis, a complete inventory of key aspects of the selected CSLs have been developed.

The CSLs reviewed under WP4.1 were derived from the list of CSLs provided by WP2. This comprehensive list also designates the CSLs according to the commodity it covers. The WP4 partners shortlisted 22 CSLs from the list provided by WP2. The selection followed the aim to cover a representative mix of relevant and innovative CSLs and bio-based products focusing on various feedstocks (including residues and wastes) and a broad range of bioeconomy sectors relevant to EU policymaking, variety in feedstock type to cover as many industries as possible, partners individual experience with the CSL, and if it was covered by the Standards Map developed by the International Trade Centre. Then followed the review that completed the inventory by verifying and covering the partners' individual subtask through document review of each selected CSL.

Please note WP4.1 was due to be completed by project month 12 (May 2023), but received an extension as this deadline was not beneficial since the selection of CSLs in WP2 had not been completed prior to project month 12. Deliverable 4.1 was postponed and delivered in Month 16 (September 2023), as approved by the project officer. The main insights from this analysis were used both for task 4.2 and for WP5, which informs the development of the BMT.

Task 4.2: A detailed comparative analysis of each selected CSL (Month 21) – completed

An assessment framework was created based on appendix C (a methodology developed by Preferred by Nature to assess certification schemes) and the inventory of key aspects of each scheme (D4.1), which is used as the basis for identifying requirements on certificate holders, certificate bodies and the certificate system. The inventory of 22 CSLs, as detailed in D4.1 Literature review and inventory of certification schemes and labels requirements contributed to the comprehensive selection of indicators to create the Comparative Benchmark Tool (CBT).

A collaborative online workshop was conducted with partners to complete the formulation of the CBT in September 2023. It involved key stakeholders, including experts in sustainability, assurance, and governance, who actively contributed to identifying crucial indicators for evaluation. The CBT was designed to comprehensively cover the domains of sustainability, assurance, and governance for a holistic assessment.

This task conducted a comparative analysis of each selected CSL, including the extent to which each scheme assesses and certifies values regarding:

- Subtask 4.2.1: Environmental, social, and economic impacts and trade-offs. (Preferred by Nature, RINA CONSULTING, agroVet)
- Subtask 4.2.2: Assurance system requirements. (Preferred by Nature, agroVet)
- Subtask 4.2.3: Governance system requirements. (Utrecht University)

The formulated CBT was translated into structured Excel sheets to facilitate indicator by indicator systematic data analysis. Each sustainability scheme was assigned a dedicated section in the Excel sheets. The final evaluation of a CSL in the excel ultimately includes:

- A description (or summary) of the scheme's normative requirements
- A discussion of findings, including an overview of issues and risks (based on referenced sources) relevant to the indicator.
- Conclusion & Justification which shall be clearly formulated as Covered, Partly Covered, Not covered or Not Applicable at indicator level; including a summary justification of the designation to provide the rationale behind the final conclusion. E.g., "based on findings x, y and z, it is concluded that the indicator is PARTIALLY COVERED".

Notable gaps across the CSLs were also analyzed, where expected contributions to social or environmental impacts were not realized. The benchmarking conclusions for the CBT and CSLs are presented at the criteria level, using the colors as explained in Table 1, below.

Table 1. Classification of the benchmark results

Colour	Definition used by the Comparative Benchmark Tool (CBT)
Fully covered, dark green	The contents and intention of all indicators in the CBT are addressed. Differences may still exist in the wording and structure of how topics are presented. In conclusion, it is considered to be covered by the benchmarked standard.
Intent covered, light green	The intention of the criterion is covered in general. There may be differences or gaps in individual indicators within a criterion, but the overall intent of the relevant criterion is addressed in the benchmarked standard. In conclusion, it is considered to be covered by the benchmarked standard.

Partly covered, yellow	Some aspects are not covered which are regarded as important for the overall intent of the criteria. These aspects need to be considered in addition to the scheme requirements.
Missing, red	None of the indicators are covered. The core topic of the criteria is not addressed in the benchmarked standard.
Not applicable, grey	The criterion is considered not applicable to the sector or commodity of the benchmarked standard. In some cases, the topic may be applicable in rare cases only, in which case we may still conclude that it is not applicable.

As a general note, the benchmark exercise seeks to evaluate if the overall intention of applicable criteria in the CBT has been considered in the benchmark standards rather than detailing the individual indicator level differences. The WP4.2 partners would like to specify that in the assessment conducted, the analysis is done at the indicator or the control point level. This implies that a control point from the CBT is considered covered when an explicit requirement is stated in the certification scheme documents. In some cases, the scheme mentions them on the website and in this case, we have added them in the remarks column but marked the indicator as partly covered. We acknowledge that schemes may have requirements to comply with all applicable laws and regulations of the country in which the operation occurs, as well as with relevant international laws and agreements. For more specific indicators, such as the requirement to have a list of all relevant international conventions ratified by the country and holding legal force, the indicator coverage was dependent on whether this additional specificity was present or not.

The analysis results were compiled to generate a summary table, providing a concise overview of the key findings for each scheme. The summary table highlighted both strengths and identified gaps, focusing on specific indicators and domains where improvements could be made.

Quality checks were implemented throughout the process to ensure the accuracy and reliability of the data through internal review processes. In many cases, a scheme expert and auditor also reviewed the results. While our aim is to evaluate all schemes and criteria uniformly, and we have consistently discussed the coverage of specific indicators and criteria, we recognise that conclusions may be subject to interpretation by individual evaluators. Future stakeholder consultations in Task 4.3 intend not only to verify results but also to enhance the overall consistency of outcomes

This methodology ensured a thorough and standardised evaluation of the ten sustainability verification schemes. The transparent process, from the collaborative workshop to the final summary table, aimed to provide interested stakeholders with actionable insights for improving sustainability practices within each scheme. Given this is a step before stakeholder consultation, please note the authors of his deliverable bear a limited responsibility for the preliminary nature of the presented results. We can state that to the best of our abilities during the execution of WP4.1 and WP4.2 based on the described methodology, the use of the CBT and publicly available information this report accurately represents the subject matter.

Task 4.3: Validation and final comparison study (Month 31) – completed

The methodology used in this task was tailored specifically to meet the objectives of assessing and benchmarking Certification Schemes and Labels (CSLs) related to sustainability assurance and governance of the schemes. The core approach involved developing the Comparative Benchmark Tool (CBT), which was based on principles outlined in appendix C. This framework was designed to ensure

that the assessment captured not only the technical compliance aspects of sustainability but also incorporated a holistic evaluation of assurance and governance standards. To ensure a comprehensive and balanced evaluation, feedback from scheme owners was obtained through a structured and transparent process. Each scheme owner was presented with a benchmarking analysis and given a clear opportunity to review and comment on the conclusions. The feedback window, opened in April 2024, allowed several months for careful consideration and closed in December 2024. Of the ten scheme owners contacted, five responded to this first call and provided feedback on specific indicators.

The feedback from scheme owners primarily focused on indicators initially classified as "partly" met or "missing." They often challenged these conclusions by referencing documentation, revised standards, or other clarifying materials. Where appropriate, these new insights led to adjustments in the indicator classifications. In some cases, indicators previously marked as "partly" met were upgraded to "intent covered" or even "fully covered" once the supporting evidence was verified. Conversely, if the additional documentation did not substantively change the initial assessment, the original classification remained.

In addition to requesting reclassifications, scheme owners also sought further explanation for certain outcomes. This prompted the evaluation team to clarify the thresholds and criteria used to determine whether an indicator was considered "partly," "missing," or otherwise.

Some of the feedback from schemes pointed to new standards or requirements in system documentation developed in response to the EU Deforestation Regulation (EUDR) and called for a consistency check across results from the schemes. We saw this as an opportunity to reopen the benchmarks and incorporate all of the updates that schemes have implemented in response to the EUDR, conduct a calibration in key consistency areas, and initiate a second call for schemes to provide feedback. The second call for feedback allowed us to receive comments from two more schemes. The resubmission of D4.3 was approved for February 2025. This integration and calibration process required the evaluation of updated documentation, cross-reference new information with previous assessments, and compare results across all schemes.

Compared to the earlier results in report D4.2—which relied solely on documentation available at that time—this process integrated the latest information, including scheme updates influenced by the European Union's Deforestation Regulation (EUDR). The inclusion of scheme owner feedback and recent developments allowed for a more accurate and nuanced final evaluation. The review process ensured that each scheme's performance was represented as fairly and accurately as possible.

It is important to note that this analysis evaluates certification schemes based on their documented standards and frameworks. This analysis does not assess actual compliance or impact. Stakeholders with concerns about specific practices should engage directly with the relevant certification bodies, which typically maintain grievance mechanisms and compliance reporting channels. Independent verification of claims and direct communication with certification schemes remain essential for addressing potential violations of standards.

As these certification schemes continue to evolve, dialogues like these will remain essential. They help clarify criteria, encourage continuous improvement, and ensure that sustainability certifications reflect best practices considering emerging legislation and market expectations.

Information and data exchange between WP4 and other WPs and projects

Task 4.1 created an inventory of 22 selected CSLs, documenting their requirements and systems, which was used in Task 4.2 as the basis for developing the Comparative Benchmark Tool. Task 4.2 analyzed

these CSLs using the inventory data, producing preliminary classifications for each indicator. Task 4.3 then used these initial results to engage scheme owners for feedback, leading to adjusted classifications and a more accurate final assessment that incorporated recent regulatory-related changes.

WP4 received input from WP2, which provided the comprehensive list of CSLs from which WP4 partners shortlisted 22 schemes for review. The selection process for benchmarking 10 CSLs was guided by value chains identified in WP2, focusing on various feedstocks and bioeconomy sectors.

The comparison methodology and its implementation were communicated to coordinators and relevant topic groups of the BIOBASEDCLUSTER, with the purpose of making the three BMT levels available for their use as needed. Processes and results related to D4.1 and preliminary results in D4.2 and D4.3 were detailed in our Midterm Review Report, which was shared with STAR4BBS upon request.

Information sharing with sister projects SUSTCERT4BIOBASED and STAR4BBS also happened on a BMT call on February 18 regarding benchmarking results and methodologies, particularly regarding sustainability verification schemes and their alignment with EUDR requirements.

Based on the framework developed in D4.1, Preferred by Nature provided feedback on the BMT content level – led by SUSTCERT4BIOBASED, which influenced the addition of criteria on legal land rights and forest degradation and detailed requirements on no deforestation.

Dissemination of results to other projects and stakeholders

- "How can certification help you comply with EUDR" webinar held on April 24, 2025, presenting benchmarking results to 157 participants representing stakeholders including operators, traders, NGO/Civil society, non-EU Supplier, Certification Bodies, CSLs and Academia, and covering different sectors, like timber, rubber, palm oil and soy. The webinar was co-hosted by ISEAL, a partner in STAR4BBS.
- Blog post sharing insights from benchmarking CSLs against sustainability, robustness, and EUDR requirements published on the HARMONITOR website on April 18, 2025
- Findings promoted through social media campaigns on LinkedIn, Facebook, and X on March 19, 2025

Direct engagement with certification scheme owners through a structured feedback process from April 2024 to February 2025. Five schemes responded to the first call (April to December 2025) for feedback, and two more provided input during a second call (January to February 2025). Feedback process led to adjustments in indicator classifications and improved consistency in evaluation results

WP5: Development and application of a CSL monitoring system

Between September 2022 and February 2023, the three ZEROPOL sister projects HARMONITOR, SUSTCERT4BIOBASED AND STAR4BBS jointly developed a proposal for a joint monitoring system, now referred to as the BiobasedCert Monitoring Tool (BMT). The rationale for a joint BMT was to avoid internal competition and external fatigue and confusion of stakeholders. The proposal was submitted to the project officer in February 2023 and approved at the end of May 2023.

Task 5.1: Develop a monitoring system for all CSLs reviewed (Month 24) – Completed

The BiobasedCert Monitoring Tool (BMT) for biobased CSLs aims to reduce confusion and mistrust among stakeholders by harmonizing the existing systems and providing clarity for policymakers in the

transition to a bioeconomy. The benefits of a BMT include improved trust, resource optimization, and long-term funding prospects. Its purpose is to evaluate the potential of CSLs to contribute to sustainability goals and objectives set by EU policies while harmonizing existing schemes and increasing the understanding of their effectiveness and robustness. The BMT aims to assess sustainability criteria, provide a baseline for evaluation, and drive continuous improvement. The primary users of the BMT are the European Commission/policymakers and certification scheme owners, with potential access for industry users, NGOs, practitioners, and the general public.

The structure of the BMT consists of three levels, each coordinated by a different ZEROPOL sister project:

- **System Level** (led by STAR4BBS), focusing on governance and standards;
- **Content Level** (led by SUSTCERT4BIOBASED), focusing on the sustainability requirements of CSLs;
- **Outcome Level** (led by HARMONITOR), capturing the actual impacts of CSLs.

While the development of each level was coordinated by a different project, the three levels were jointly developed and are considered equally important. The indicators developed for each level were tested with selected CSLs during the testing phase in Task 5.2 to refine and optimize the methodology.

The development of the BMT was a collaborative effort across the three sister projects, building on existing tools, databases, and insights from earlier initiatives. Specifically for the outcome-level methodology, the draft was informed by an extensive review of existing studies, including scientific articles, grey literature, and outputs from initiatives such as the Delta Framework, to better understand current approaches and challenges in monitoring the outcomes of CSLs. Coordination involved a series of joint meetings and was informed by stakeholder input gathered through consultations (e.g., Task 2.2) and workshops, including the EUBCE side event held in June 2023. For more information on this methodology, check Appendix D.

Task 5.2: Apply the proposed monitoring system and indicators on CSLs reviewed (Month 33) – Completed

Task 5.2 aimed to test the outcome-level methodology developed earlier in Task 5.1 for monitoring the measurable progress of certification schemes and labels (CSLs) towards sustainability goals. The objective of the testing was to refine the comprehensiveness, transparency, and operational feasibility of the proposed framework. A two-stage testing process was conducted between February 2024 and January 2025. The testing involved nine CSLs covering a range of sectors and communication scopes: Better Biomass, Better Cotton, Bonsucro, EU Ecolabel, FSC, ISCC, Nordic Swan Ecolabel, RSB, and SBP.

The first testing round, carried out with FSC, Nordic Swan Ecolabel, and RSB, assessed the feasibility of the initial methodology through in-depth interviews with CSL owners and a literature review. Insights from this phase informed the development of an extended outcome-level framework, which was then tested in the second round with the remaining six CSLs. The second round also included in-depth interviews with scheme owners, in addition to desk research using publicly available scheme documentation and scientific literature.

The revised outcome level framework comprises five principles, nine criteria, and 25 indicators, capturing performance of CSLs on both measurable progress at the certificate holder level and at the scheme level. Each CSL was evaluated using a qualitative scoring system (Fully, Partly, Missing, or Not Applicable), based on the collected evidence.

The testing of the outcome level methodology was conducted in parallel and in close coordination with the testing of the system and content levels carried out by sister projects SUSTCERT4BIOBASED and STAR4BBS. The testing process was supported by various stakeholder engagement, i.e. through interviews, Q&A sessions, and validation workshops, which played a central role in informing methodology refinements and validating testing results. Further details on the methodology and results of Task 5.2 can be found in Deliverable 5.2.

Task 5.3: Validation of the monitoring system (Month 36) – Finalized

Task 5.3 focuses on validating the BiobasedCert Monitoring Tool (BMT) and implementing necessary improvements to ensure an effective and robust monitoring system, along with its associated indicators. The validation builds on the results of the testing phase conducted under Task 5.2. During this final phase, each CSL are evaluated to determine how far it fulfils the requirements established by the BMT.

The final methodology was submitted end of May 2025 as deliverable D5.3. Below, we summarize the main elements of outcome level of the methodology, which was developed within the HARMONITOR project.

The outcome level methodology is the third and final tier of the BIOBASEDCERT Monitoring Tool (BMT), developed collaboratively by the HARMONITOR, STAR4BBS, and SUSTCERT4BIOBASED projects. It focuses on evaluating the effectiveness of certification schemes and labels (CSLs) in terms of their measurable impacts and outcomes. The methodology was developed through an iterative process involving literature review, expert consultations, interviews with CSL representatives, stakeholder workshops, and validation rounds.for a summary of the method, we refer to appendix D.

Information and data exchange between WP5 and other WPs and projects

Task 5.1 developed a draft monitoring system, which served as the foundation for Task 5.2 in designing a monitoring framework. This framework will be finalized and delivered under Task 5.3. In Task 5.2, the draft methodology was tested on nine CSLs to assess its operational feasibility and comprehensiveness. Based on these findings, Task 5.3 is refining and validating the final methodology, which will then be applied to the participating CSLs.

WP5 received valuable input from WP2, particularly from Task 2.2, which conducted a public consultation. This consultation gathered extensive stakeholder feedback on factors influencing the credibility of CSLs. One key insight was that stakeholders perceived CSLs to be weakest on the "measurable progress" principle—one of the ten ISEAL credibility principles. This directly informed the outcome-level methodology in WP5, which focused specifically on addressing this principle.

Throughout the duration of WP5, close collaboration was maintained with the BIOBASEDCERT cluster, which includes the sister projects STAR4BBS and SUSTCERT4BIOBASED. The coordination involved regular exchange of information, including testing results, feedback on potential methodological

improvements, and alignment of framework content to ensure overall coherence in the BMT, scheduled for delivery in May 2025.

Additionally, results from Task 5.2—including both findings and the methodological approach—were presented to the BIOBASEDCERT roundtable members (Task 2.4). A draft of the outcome-level monitoring framework, along with the system and content level of the BMT, was also shared with the sister project 3-CO. These inputs contributed to their Task 1.4, which focuses on assessing the robustness and effectiveness of B2C-focused CSLs.

Dissemination of Results to Other Projects and Stakeholders

- **Workshops**
    - BIOBASEDCERT Cluster online co-creation event: *"Robust and Effective Sustainability Certification for Bio-based Systems",* held on December 11, 2024.
    - EUBCE 2024 side event "*BIOBASEDCERT Monitoring System methodology and preliminary results*", held on June 26, 2024, in collaboration with STAR4BBS and SUSTCERT4BIOBASED
    - A closed workshop with participating CSL owners, held on May 29, 2024, in collaboration with STAR4BBS and SUSTCERT4BIOBASED
    - A closed workshop with the BIOBASEDCERT roundtable members and policymakers in Brussels, held on December 4, 2024
- **Presentations**
    - BIOBASEDCERT Roundtable Meeting: Online presentation of the BMT methodology and results, held on April 2, 2025
    - EUBCE 2024 conference: Oral presentation titled *"Methodological Approach to Monitor Outcomes of Certification Schemes and Labels for Bio-based Products"*
    - Life Cycle Management Conference 2025 (Planned for September 2025): Oral presentation titled *"Methodological Approach to Monitor Outcomes of Certification Schemes and Labels for Bio-based Products"*
- **Scientific Publication**

  A scientific article is currently under preparation: *"Methodology for Monitoring Outcomes of Sustainability Certification Schemes and Labels in the Bio-based Sector"*, based on Tasks 5.1, 5.2, and 5.3.

WP6: Costs, benefits, and economic feasibility of CSLs

Task 6.1: Quantifying direct cost of certification (Month 24) - completed

Task 6.1 focuses on direct costs of CSLs. The *direct costs* identified include fees charged by the Certification Bodies (CBs) for conducting audits, fees charged by certification scheme owners, and any

fees for trademark usage related to participating in the CSL. Additional costs such as travel and accreditation fees charged by the CBs are not considered due to limited resources and large variability (travel fees depend on the location and infrastructure, accreditation fees depend on CSL). To collect the required information, the WP6.1 group combined two approaches. They identified partners within the HARMONITOR project who have access to direct cost data through their organizations, particularly accredited CBs like RINA SERVICES, Preferred by Nature, and Agrovet. Furthermore, they consulted academic literature for any relevant direct cost estimates.

Details of the methods as well as results were presented in Deliverable D6.1.

Task 6.2: Quantifying cost and benefits of achieving sustainability criteria (Month 30) - completed

In Task 6.2, *indirect costs and benefits* associated with meeting the sustainability criteria established by CSLs were assessed. The approach involved conducting a systematic literature review on the costs and benefits of certification. The literature review focussed on agricultural and forestry products, with specific attention given to underrepresented and relevant feedstocks such as palm oil, natural rubber, soybean, sugar cane, wood, and raw cotton. Besides agricultural and forestry products, the review also looked for cost and benefit estimates of certifying other supply chain elements. The review followed a systematic approach based on the PRISMA guidelines for systematic reviews[3]. Relevant studies were identified by scanning different databases and assessed based on inclusion and exclusion criteria. Both qualitative and quantitative studies were included, with data on certification costs and benefits extracted. The collected data included information on location, feedstocks, certifications, year of certifications, farm size, certification area, number of employees, gender composition, family size, education levels, income, expenditures, certification and auditing fees, indirect costs of meeting sustainability requirements, production volume, yield, price of certified products, gross return, and profit. Constraints in CSL adoption and factors related to child school attendance, educational facilities, health facilities, and child mortality were also considered. The data helped determine the direct and indirect costs of certification and was collected at different levels, including farm and household. The review also included gathering information on the methodologies used in previous studies, along with their limitations, to guide the analysis process. Details of the methods as well as results were presented in Deliverable D6.1.

In addition to the literature review, three case studies were selected to examine the impact of meeting sustainability criteria on costs and benefits obtained by market actors. The case studies aimed to represent the diversity of the bio-based economy and focussed on palm oil, wood and cotton. A preliminary list of data to be collected was created based on the information gathered from the literature review. Data was collected from literature and processed in Task 6.4 to calculate benefit-cost ratios and net present value. The results were presented in Deliverable 6.3.

Task 6.3: Modelling environmental and social externalities (Month 35) – completed

The research approach for this task involves using environmentally extended multi-regional input-output (EE MRIO) analysis[11] to quantify impacts domestically and abroad of consuming bio-based commodities in European countries. The research steps are as follows:

[3] http://prisma-statement.org/?AspxAutoDetectCookieSupport=1

1. Defining and disaggregating relevant sectors: Sectors related to the bioeconomy were categorized as fully bio-based, partially bio-based, or non-bio-based. Seven partially bio-based sectors were identified that were disaggregated into their bio-based and non-bio-based components. Depending on data availability, the sector's disaggregation was based either on the market share of its bio- versus non-bio components or on its average bio-based trade share (imports or exports) with all other regions combined.
2. Quantifying environmental impacts: An EE-MRIO model was constructed to estimate the direct and indirect impacts associated with the consumption of bio-based commodities in the EU 27 member states. The Leontief equation was used to calculate the GHG emission footprint, land use footprint and scarcity-weighted water use footprint of each region. The environmental extensions in the model are the region-sector-wise GHG emission intensities, land use intensities and scarce water use intensities, respectively.
3. Estimating the monetary value of impacts: The environmental costs of GHG emissions linked to the EU-27's consumption of bio-based commodities were estimated by applying a carbon price based on the True Price Foundation's methodology. This price reflects the cost of limiting global warming to 2°C, including restoration and prevention measures. To illustrate the economic impact of internalizing production-based GHG emission costs, we apply our approach to the Netherlands, where sector-specific operating surplus data are readily available. While not fully representative of the EU bioeconomy, this case study serves to test the method and can be extended to other countries in future research.

Details of the methods as well as results were presented in Deliverable D6.2.

Task 6.4: Evaluating overall economic feasibility and governance options (Month 36) – completed

This research task synthesized and expanded on the outcomes of Tasks 6.1 and 6.2. This research task estimated benefit-cost ratios and net present values, using data collected in tasks 6.1- 6.2. The goal was twofold. First, the analysis focussed on evaluating the economic feasibility of certification, defining non-financial barriers, and identifying strategies to overcome barriers and increase feasibility of certification. The methods for this research involved conducting a literature review and processing data from literature to determine benefit-cost ratios and net present values in three case studies (wood, palm oil, cotton). To better evaluate the overall feasibility of certification, we also focussed on determining the main barriers to certification as well as methods to overcome them. For this, we collected information from literature as well as in-depth interviews with different stakeholders and an open public consultation.

Second, this task analyzed how verification instruments and particularly certification are currently used in EU policies relevant for the bioeconomy. Together with the first part of this task as well as with WP2, two public consultations were conducted to measure stakeholder understanding of CSLs as co-regulation instruments for the EU bioeconomy as well as identify barriers of certification and strategies to overcome them.

Details of the methods as well as results were presented in Deliverable D6.3.

Information and data exchange between WP6 and other WPs and projects

Tasks 6.1 and 6.2 were joint activities to assess direct and indirect costs and benefits of certification. While these tasks focused on biological resource production, the tasks collaborated with the Horizon Europe 3CO project, where also other supply chain elements were investigated.

Task 6.3 used data on international trade of biological resources and biobased materials and products from WP3 to disaggregate some bio-based sectors in the EE-MRIO database.

Task 6.4 integrated findings and expanded the case study analysis from Tasks 6.1 and 6.2 to determine the overall feasibility of certification, as well as adding an analysis of current use of certification and other verification instruments in EU policies linked to the bioeconomy. The latter used input from Task 4.3 to compare assurance requirements by policies and CSLs. The first public consultation was done jointly with WP2 (Task 2.2) where WP6 questions focused on stakeholders' opinions on CSLs use as co-regulation instrument and their familiarity with certification in different EU policies. These questions were repeated in the second public consultation, where additional questions were added on financial and non-financial barriers of certification and how to overcome them. Interviews were conducted as a joint effort with the Horizon Europe 3CO project in order to avoid stakeholder fatigue.

Use of WP6 results in other WPs

The results from WP6 deliverables will be integrated in D1.2 (HARMONITOR final policy brief), which will be submitted by the end of May 2025.

Data exchange with sister projects

In total, 13 so-called sister project meetings on the topic of economic feasibility were held online between HARMONITOR, SUSTCERT4BIOBASED and STAR4BBS. The meetings were used to exchange information and learn about each other's methods and data, showing the diversity of approaches and topics as part of studying the economic feasibility of certification. The meetings were also used for jointly planning the co-creation event in November 2024 and the session at the final conference in May 2025 (see also below).

Dissemination of results to other projects and stakeholders

1. Co-creation event - Driving Sustainability through Certification: Unveiling the costs and benefits of Certification Schemes in bio-based industries and products, 11 November 2024 online.
2. Session at the final conference of the three projects - Assessing the feasibility of voluntary sustainability certification: costs, benefits, challenges and ways forward, 13 May 205.
3. Blogpost on barriers and challenges of certification
4. Blogpost environmental externalities of the EU bioeconomy

Conference presentations:

5. EUBCE 2023 – Oral presentation: Economic feasibility of certification schemes and labels for biobased products
6. EUBCE 2024 - Poster presentation: Economic costs and benefits of sustainability certification across biobased value chain
7. Scientific paper published in a peer-reviewed journal (Rossi et al, 2024)[1].

4. SUMMARY AND CONCLUSIONS

3.1 Summary of methodological information exchange within HARMONITOR Work Packages (WP2-WP6)

The HARMONITOR project is built upon a deeply integrated structure that encourages intensive methodological, data-driven, and conceptual interaction among five key research work packages: WP2 through WP6. Each of these work packages is interconnected by design and an iterative exchange of knowledge and feedback loops. This summary details the nature of these internal interactions as they have occurred between June 2022 and April 2025, highlighting the flow of information, mutual dependencies, and collaborative development processes that shaped the project's outcomes.

WP2: Coordinating Methodological Consistency and Framework Integration WP2 served as the backbone of the HARMONITOR project's methodology, orchestrating the alignment of frameworks across all WPs. WP2.1 identified relevant CSLs and bio-based value chains through internal coordination and stakeholder mapping. These were passed on to WP3 (for value chain structuring), WP4 (for benchmarking), WP5 (BMT development), and WP6 (economic feasibility).

WP2.2 designed and executed a stakeholder survey with over 100 participants, offering critical input for WP4's benchmarking structure and WP5's indicators related to measurable outcomes. WP2.3 supported the harmonization of methodological tools, capturing common data structures and performance criteria. WP2.4 ensured that CSL involvement and stakeholder consultations were structured as part of the platform activities.

WP3: Delivering Data on Value Chains and Certification Volumes WP3 provided a data-rich foundation for multiple WPs. WP 3.1 identified 35 value chains, directly aligned with the CSL selection framework from WP2. WP 3.2 and WP 3.3 offered disaggregated data on global trade flows and certification volumes, which WP 6.3 used to model environmental externalities through MRIO analysis. WP6.4 further relied on WP3 outputs to conduct economic feasibility and policy impact assessments.

WP3.4 presented a visualization of trade and certification dynamics that was shared with WP2 for platform design and with WP5 to contextualize certification coverage in monitoring system design. WP3 also hosted several knowledge exchange workshops with WP6 and WP2, aligning methodologies and results formatting.

WP4: Benchmarking CSLs and Structuring Governance Analysis WP4 was responsible for adapting and using the Comparative Benchmark Tool (CBT) on the CSLs selected in WP2. Tasks 4.1–4.3 conducted detailed reviews of 10 CSLs, using both stakeholder interviews and survey data from WP2. The benchmarking outputs were forwarded to WP5 to help structure especially the outcome level and content level of the BiobasedCert Monitoring Tool (BMT).

Moreover, WP4 and WP6 collaborated on aligning scheme-level benchmark scores with broader policy assurance frameworks (e.g., the EUDR). WP4's governance findings also informed WP5's design of feedback mechanisms and stakeholder validation.

WP5: Outcome-Level Monitoring Tool Design and Testing WP5 developed the BMT's outcome-level methodology. It relied partly on WP4's benchmarking and on the WP2's survey results. WP5 also coordinated validation exercises, developing the outcome level methodology in an iterative manner, focussing on the tool's usability, clarity, and practical applicability. Joint workshops and two testing rounds tests with in total 9 different CSLs yielded feedback that WP5 also shared back with WP2 (the CSL platform).

WP5 played a central role in aligning BMT outputs with the work done by STAR4BBS and SUSTCERT4BIOBASED, ensuring its outcome-level layer fit logically under the three-tiered structure (system, content, outcome, see also section 3.2).

WP6: Economic Analysis, Policy Coherence, and Impact Modelling WP6 assessed economic feasibility, social cost, and policy impact of CSL adoption. WP6.1 and WP6.2 used trade and certification data from WP3 and benchmarking data from WP4 to model cost gaps and potential premiums.

Task 6.3's MRIO analysis was based on WP3's data and considered feedback from WP2 consultations. WP6.4 incorporated public consultation insights collected via WP2, and used WP4 data to compare CSL robustness against EU policy demands.

The iterative feedback loop culminated in WP6 feeding results into WP5 for incorporation into the BMT and into WP2 for inclusion in the HARMONITOR platform.

3.2 Summary of data and methodological information exchange between HARMONITOR and other projects and stakeholders

HARMONITOR closely collaborated with three key external stakeholder groups: the sister projects STAR4BBS and SUSTCERT4BIOBASED (both funded under the ZERO POLLUTION call alongside HARMONITOR), the Horizon Europe project 3-CO, and a broad stakeholder platform composed of CSL owners, NGOs, academics, and policymakers.

The collaboration between **HARMONITOR and the two sister Projects: STAR4BBS and SUSTCERT4BIOBASED** can be described as outstanding. The three projects jointly took the initiative early on to collaborate intensively, and to developed the BiobasedCert Monitoring Tool (BMT), a joint harmonized assessment framework for CSLs:

- STAR4BBS led the "system level" methodology (focusing on governance).
- SUSTCERT4BIOBASED developed the "content level" (criteria and requirements).
- HARMONITOR focused on the "outcome level" (actual performance impacts).

Regular coordination meetings (e.g., during the EUBCE 2023, and monthly technical exchanges) ensured alignment. Shared methodological principles (e.g. ISEAL credibility principles) and two well-coordinated and thorough testing rounds with CSLs helped validate tool robustness.

In addition to the intensive collaboration with SUSTCERT4BIOBASED and STAR4BBS, HARMONITOR collaborated with **3-CO** on two items:

- WP6 (HARMONITOR) and Task 1.5 (3-CO) shared interview results and cost-benefit data for certification case studies. The projects coordinated public consultation efforts to reduce stakeholder fatigue and aligned their policy analysis frameworks.
- HARMONITOR's WP5 Task 5.2. and 5.3 also contributed insights to 3-CO's assessment of scheme robustness (3-CO task 1.4).

Last but not least the **Stakeholder Platform** offered a means of both obtaining input and methodological validation and a means of disseminating project results.

This multi-layered exchange ensured that HARMONITOR methodologies were both scientifically robust and practically relevant. Stakeholder insights directly shaped CSL benchmarking, BMT indicator design, and platform governance recommendations, increasing the likelihood of further adoption post-project.

3.3 Conclusions and outlook beyond the HARMONITOR project

During the runtime of the HARMONITOR project, a large amount of methodologies has been developed and applied both within the HARMONITOR project between work packages and with other Horizon Europe project partners and external stakeholders. Based on the fact that the feedback received by external stakeholders (such as CSL owners and policy makers) has overall been positive and constructive, and the fact that this work has led to already one published scientific article and two more in preparation, we conclude that the methodology development has been very successful. This was enabled by a frequent exchange both between work package leaders and contributors within the HARMONITOR project as well as close interproject coordination.

Looking ahead, the methodologies and results of the HARMONITOR project will surely be further developed. Many of the methods and results of the HARMONITOR projects are likely to be intensively used (e.g. the novel work on mapping certified biomass trade flows developed in WP3, or the WP6 assessed economic feasibility, social cost, and policy impact of CSL adoption).

We foresee two opportunities to continue the methodology development initiated by HARMONITOR:

1. The BiobasedCert Monitoring Tool (BMT) will be presented at the final conference in Brussels in May 2025. While it is still unclear at the time of writing whether this tool will be used by e.g. EC or national EU policy makers, and/or bio CSL's themselves as a (self-)assessment tool for further improvement, it is evident that the BMT has an unprecedent comprehensiveness as a tool to monitor CSLs. Moreover, two PhD students at Utrecht University will continue methodology development and application along two lines: (1) measuring and quantifying the impact over time of CSL's (Maulidia Khairani) and (2) the socio-economic impact of CSL's for biobased products (Costanza Rossi).
2. The CSL platform has proven to be very useful as a means of information exchange and dissemination between CLS's, the three sister projects and other stakeholders (e.g. industry and policy makers). A continuation of the platform beyond the runtime of HARMONITOR is currently discussed with the platform participants.

5. APPENDICES

Appendix A. Methodologies of WP2

Task 2.1: Inventory and characterisation of identified CSLs and selection of bio-based value chains

This section describes the methodological approach for the identification and selection of certification schemes and labels as well as bio-based value chains for the further analysis in the different Work packages of the HARMONITOR project. Furthermore, the selection will be an input to Task 2.4 for the development of the platform for continuous improvement of CSLs.

The selection of both elements was organised in subsequent steps, starting with the development of a broader inventory of existing CSLs which were then matched with the value chains for HARMONITOR, selected under Deliverable 3.1. The two following subchapters summarise the different steps, which led to a longlist of CSLs and value chains which are presented in chapter 4.

Developing a CSL inventory for the HARMONITOR project

Our review and selection of CSLs included a wide range of existing elements, which we summarise under the following terms:

Labels: Labels are used for the communication of certain product characteristics to consumer and customers. A certification process can be a precondition for the labeling of a product. However, there are also products self-labeled by the producer. Further types are labels of testing organisations, testing for example products from different manufacturers in order to label the ones with the best results.

Sustainability initiatives: Sustainability initiatives are herein referred to as initiatives compiling sets of sustainability criteria and indicators for a particular purpose, e.g., the analysis of the sustainability of specific biogenic feedstocks. They might be organised as a heterogeneous group of people or institutions with different background and with different interests. The goal of this type of initiative is to reach a consensus between the different parties. In the resulting set of criteria, the different interests are covered equally. This type of initiative is often called “multi-stakeholder initiative” or “roundtable”.

The second type of initiative included in this context shall be an initiative consisting of a group of people belonging to one party. They can have a background in science and academics, governmental agencies, enterprises or NGOs. The one object, quality sustainability initiatives have in common is the outcome/product, which is a set of criteria for further unspecified or specified use. The outcome can be used internally, e.g., for the sustainability strategy of an organisation or may be picked up by other organisations in case the outcome is open source.

Certification schemes: Certification schemes are based on a normative framework, e.g., a standard or a set of criteria and indicators. The output of sustainability initiatives may be used as the basis for a certification scheme. Sustainability initiatives therefore sometimes turn into a certification scheme holder over time as it happened with different roundtables. The most important characteristic of a certification scheme, as it is understood in this context, is that it includes a third-party verification of the sustainability requirements, stipulated in the system documents. Also, the whole certification process is usually based on accreditation standards (e.g., ISO 19011 or ISO 17065), in which the separation of evaluation and certification is an important feature. As a result of the certification process, a label on a product shows compliance with the requirements set by the respective certification scheme. Certificate holders mostly participate voluntarily in a certification scheme. However, there are industries, in which holding certificate facilitates market access, which is, for instance, the case with liquid biofuels sold in European Union markets.

Process for the selection of CSLs

The process of selecting CSLs for HARMONITOR was organised in a threefold approach (compare Figure 1).

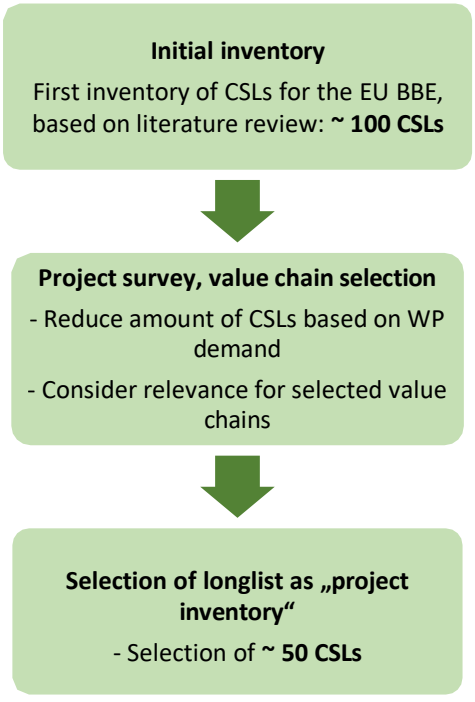

Figure 1 Process steps for the selection of the CSLs inventory in HARMONITOR. own figure.

As first step towards the development of CSL inventory, which can serve the specific needs of the different tasks within the HARMONITOR project, an **initial inventory** on the certification landscape in the EU bio-based economy was generated.

This step was based on a comprehensive review, involving literature desktop research, as well as available databases such as the ITC Standards Map (International Trade Centre 2021) and Label

Online (Label online 2023). This step revealed a list of ~ 100 certification schemes as a first, preliminary result.

To understand and assess the potential relevance of the identified schemes for the work in HARMONITOR, further desktop research was conducted on the sustainability requirements and sustainability topics included in these CSLs (compare Annex I). This step allowed to introduce filters for further selection and differentiation according to the specific needs of the different HARMONITOR WPs in a subsequent working step.

Secondly, the identified CSLs have been assessed against the specific expectations and the demand formulated by HARMONITOR partners, involved specifically in WPs 3, 4, 5 and 6. For this purpose, a comprehensive, **project internal questionnaire** was developed, including the following questions:

- Which elements of the CSLs are important for your analysis/work (e.g., the sustainability requirements, the verification procedures, risk assessment, etc.)?
- How many CSLs are you planning to analyse in your task or work package?
- To define the parameters for the selection of CSLs. Please indicate which aspects are important for you and the work in your task regarding the CSL selection (e.g., geographical focus, feedstock focus, specific market sectors in the EU bio-based economy, business-to-business focus or business-to-focus, the “ambition” of the CSL regarding the comprehensiveness of the sustainability requirements).
- Do you already have recommendations or made a pre-selection of CSLs? If yes, which CSLs should be selected from your perspective (and why)?

The results of the survey are documented in Annex II of D2.1.

Another important aspect is the relevance and applicability of the CSLs for the value chains selected under WP2. HARMONITOR will use value chains for relevant and/or innovative bio-based products to assess specific parameters (e.g., costs) regarding the effectiveness of the CSLs within certain product environments and value chains. For this purpose, the developed inventory of CSLs was matched with the specific value chain elements (compare section 0).

As a result of this activity, an internal longlist of ~ 50 CSLs, which will be used as a starting point for the subsequent activities in other work packages of HARMONITOR has been produced.

Selecting value chains as starting points for HARMONITOR

In addition to the CSL inventory, Task 2.1 selects a minimum of 5 to 10 value chains (according to the description of work in the Grand Agreement of the project) as starting points for the subsequent HARMONITOR WPs.

The identification of relevant value chains and products, which shall support the assessment and monitoring of CSLs was part of a comprehensive process under WP 3. As a result, D3.1 presents a preselection of 35 bio-based value chains, including a description of feedstock categories (e.g., starch or sugar), intermediates (e.g., sawn wooden products), potential products (e.g., bioplastics) to be produced in downstream processes as well as a characterisation of these chains regarding their markets, levels of innovation, etc. The full methodology of WP3 / D3.1 is given in Appendix B below.

Task 2.2: Summary of public consultation inputs

The public consultation was carried out based on an online survey. This survey was developed by Michele Mutchek, Li Shen and Martin Junginger (Utrecht University), Costanza Rossi (SQ Consult) and Birka Wicke (Radboud University Nijmegen), in close collaboration with project partners from the HARMONITOR project, as well as from the sister projects STAR4BBS and SUSTCERT4BIOBASED. In particular, partners from TU Berlin, Wageningen University, ISEAL and ECOS provided detailed feedback and advice on earlier drafts of the survey (especially on the application of the ISEAL credibility principles).

The survey consists of 4 parts:

- In the first part, respondents needed to provide their background (to which of the 10 defined stakeholder groups they belonged) and where they were based geographically.
- In the second part, respondents were asked to provide their general view on the possible advantages and disadvantages of CSLs, and a number of questions of how familiar they were with legislation covering the sustainability of biobased products in the EU (of which a number make use of CSLs to demonstrate compliance).
- Next, as central part of the questionnaire, respondents were asked to indicate the strength and weaknesses of CSLs for each of the ten ISEAL credibility principles. Respondents could indicate up front whether they wanted to answer these questions for CSLs in general, or with a specific CSL in mind. Respondents could rank CSLs for each principle from (very) weak to (very) strong. In case the selected weak or very weak, they were also asked to provide an explanation and motivation for this choice. In case respondents mentioned a specific CSL explicitly, this was anonymized in the results section.
- Last, respondents were asked if they were willing to provide their name and contact details to follow up with in depth interviews, and whether they would like to receive the survey results.

The central framework on which this consultation was based the ten 2021 ISEAL credibility principles: Sustainability impacts, Collaboration, Value creation, Measurable progress, Stakeholder engagement, Transparency, Impartiality, Reliability, Truthfulness, and Continual improvement.

The Credibility Principles define the core values of credible and effective sustainability systems. They provide the foundations for systems to deliver greater impact. The 2021 version of the credibility principles was based on an extensive global consultation. The principles help organizations develop standards and similar sustainability tools to understand which attributes of their system are critical to the credibility of their approach, and why these matters for improving sustainability performance and delivering impacts. The principles also help businesses, governments, and civil society to identify systems that can be effective partners in delivering against shared sustainability objectives. As such, they were deemed highly relevant and suitable as the basis for this consultation.

The survey was disseminated through a number of different channels:

- All project partners from HARMONITOR, STAR4BBS and SUSTCERT4BIOBASED were requested several times to disseminate the invitation for the survey through their networks to relevant stakeholders. In particular, ISEAL and ECOS also encouraged their members to fill in the survey.

- The members of the joint advisory board of the three projects were also requested to disseminate the request through their networks.
- The survey was advertised through repeated posts on LinkedIn and Twitter and other social media.
- Last but not least, a search was carried out through amongst others social and traditional online media for recent initiatives that critically reviewed and the role of CSLs for demonstrating the sustainability of biobased products. The authors of these critical studies and initiatives were then directly contacted by Silvia Seixas Lopes and invited to fill in the survey.

The data used for this report was collected from early March 2023 until 7 May 2023. At this point in time, a total of 68 respondents had started the survey, and 33 respondents had finished the entire survey. As some stakeholder groups were underrepresented, it was decided to leave the survey open to allow for additional responses. All results presented in D2.2 are based on the input received until May 7th, 2023.

Appendix B. Methodologies of WP3

Task 3.1: Selection of Bio-Based Value Chains

Executive summary

The HARMONITOR project aims to improve the effectiveness of certification schemes and labels (CSLs) in different sectors of the EU Bioeconomy and therewith strengthen their use as a co-regulation instrument. As part of this project, production and trade data will be collected on bio-based value chains and their levels of sustainability certification. As a first step, 35 value chains from biomass to bio-based products or materials needed to be selected for further assessment. Furthermore, this selection will be used for work to be performed in other tasks within the HARMONITOR project, i.e., the selection and assessment of certification schemes and labels (in short CSLs), and the assessment of costs, benefits, and economic feasibility of CSLs. The selection of 35 value chains has been performed in 5 steps:

Step 1: Starting point was an extensive list of 350 bio-based materials and products (NACE[a] 20, 21 and 22) supplemented with 188 wood products and other bio-based products (NACE 13, 16, 17), resulting in a long list of 538 bio-based products. It was indicated whether these are drop-in (identical to their fossil alternative) or dedicated (chemically unique) bio-based materials or products.

Step 2: All dedicated bio-based materials and products (...) were pre-selected.

Step 3: The 40 drop-in bio-based materials and products with the highest bio-based production volumes were pre-selected for further assessment.

Step 4: For all bio-based materials and products selected in step 1 – 3, the main biological resources used for their production were identified by a quick assessment of their value chains. Step 5: Final selection taking into account several criteria and considerations.

After a pre-screening on the representativeness of the PRODCOM and CN codes, 226 dedicated bio-based materials and products were pre-selected as well as a list of 101 drop-in bio-based products. Their biological sources were identified and, based on the production (PRODCOM) and, if needed, trade (CN) volumes, an initial selection was made. As a result of several project meetings, including a three-hour workshop on the 2nd of November in Berlin, and exchanges with sister projects, the final selection of bio-based value chains was made considering:

- Market size of value chains & coverage by existing statistics (focus of steps 1-4)
- Representative distribution between bio-based sectors
- Inclusion of both innovative and traditional bio-based products
- Inclusion of value chains using residues and wastes
- Inclusion of both EU and imported feedstocks and products
- Value chains with environmental and social challenges (where CSL play an important role)
- Coverage by sustainability certification schemes and labels
- Relevance for EU bioeconomy policies such as the CAP reform, Taxonomy Regulation, Farm to Fork strategy, EU Forest Strategy, Circular Economy Action Plan, European Regulation on Sustainable products, recast of RED, and the EU Strategy for Sustainable and Circular Textiles.

The final selection aims to be a representative mix of bio-based products, using various feedstocks (including residues and wastes), covering a broad range of sectors, relevant for EU policy making,

currently traded, and relevant for further analysis of sustainability certification schemes. The 35 selected bio-based value chains are presented in Table 1.

Table 1: Overview of selected bio-based value chains

#	Intermediary chemical	Sector	biomass type in	Products out	Intermediary included in statistics?	Feedstock: EU, import, or both?	Existing bio-based market?	Innovative bio-based product?	Feedstock: waste/ residue?
1	Acetic acid	Chemicals	Sugar/starch	PTA, VAM, acetic anhydride, acetate esters	n	both	y	y	n
2	Ethylene glycol	Chemicals	Sugar/starch	PET	n	import	y	y	n
3	Ethylene	Chemicals	Sugar/starch	Polyethylene (PE), HDPE	n	import	y	y	n
4	Butanediol (1,4)	Chemicals	Sugar/starch	Solvent, production of polyurethanes	n	both	y	y	n
5	Lactic acid	Chemicals	Sugar/starch (cane sugar)	PLA	y	import	y	y	n
6	Lactic acid	Chemicals	Sugar/starch (cane sugar)	Salts and esters	y	both	y	n	n
7	Starch polymers	Chemicals	Starch (potatoes), corn	Plastic utensils	y	both	y	n	n
8	Palmitic acid with its salts and esters	Chemicals	Palm oil	Cosmetics, surfactants	y	import	y	n	n
9	Propylene glycol	Chemicals	Oil crop (glycerol)	Propylene glycol	n	both	y	y	both
10	Poly(urethane) PUR	Chemicals	Vegetable oil - soybeans	PUR	n	import	y	y	n
11	Epichlorohydrin	Chemicals	Vegetable oil, glycerol	Solvent in resin, paints	n	both	y	y	both
12	Rayon	Chemicals	Wood	Tarn	y	EU	y	y	n
13	PHA	Chemicals	wastewater	Plastics	n	EU	n	y	y
14	(Poly)propylene	Chemicals	UCO	Plastics	n	both	n	y	y
15	Algal fatty acids	Chemicals	Algae	Cosmetic ingredient	n	both	n	y	n
16	Sawn wooden products	Wood	Wood	Several	y	both	y	n	n
17	Fibreboard (particle, MDF, etc)	Wood	Wood, waste wood	MDF, Particle board	y	both	y	n	y
18	Oriented strand board	Wood	Wood	OSB	y	both	y	n	n
19	Wooden packaging	Wood	Wood	Cases, boxes, drums	y	both	y	n	n
20	Wooden pallets	Wood	Wood	Pallets	y	both	y	n	n
21	Wood wool, wood flour	Wood	Wood	Panels, fibre cement, insulation, filler	y	both	y	n	n
22	Lignin based products	Wood	Wood	Binders and aromatic chemicals, asphalt/bitumen	n	both	n	y	y
23	Tall oil	Wood	Wood	Chemicals	n	both	y	y	y
24	Pulp	Paper	Wood, wastepaper	Graphic paper	y	both	y	n	y
25	Pulp	Paper	Wood, wastepaper	Paper board	y	both	y	n	y
26	Pulp	Paper	Wood, wastepaper	Toilet paper	y	both	y	n	y
27	Cotton fabrics	Textile	Cotton	Woven fabrics, table and bed linen, sacks and bags	y	import	y	n	n
28	Wool fabrics	Textile	Wool	Textile	y	both	y	n	n
29	Jute	Textile	Jute	Textile	y	import	y	n	n
30	Flax	Textile	Flax	Textile, table linen	y	EU	y	n	n
31	Hemp	Textile	Hemp	Textile, insulation materials	n	EU	y	n	n
32	Straw	Building	Straw	building materials	n	EU	y	y	y
33	Biowaste	Waste	Biowaste	Compost	y	EU	y	n	y
34	Leather	Textile	Animal skin	Clothing, textiles	y	import	y	n	n
35	Natural rubber	Chemicals	Natural rubber	Tyres, various products	y	import	y	n	n

1 Introduction

1.1 Background

The project *"harmonisation and monitoring platform for certification schemes and labels to advance the sustainability of bio-based systems"* (HARMONITOR) will improve the effectiveness of certification schemes and labels (CSLs) in different sectors of the EU Bioeconomy and therewith strengthen their use as a co-regulation instrument. As part of this project, production and trade data on bio-based value chains and their levels of sustainability certification will be collected. As a first step, about 35 value chains from biomass to bio-based product or materials needed to be selected for further assessment within the HARMONITOR project.

1.2 Goal

The objective of this task was to select 35 relevant value chains from biomass to a specific (group of) bio-based products or materials that will be subject to the assessment of global and EU trade flows and their level of certification. Furthermore, this selection will be used for work to be performed in other tasks within the HARMONITOR project, i.e., the selection and assessment of certification schemes and labels (in short CSLs) in Work Package 4 (WP4), and the assessment of their costs, benefits, and economic feasibility (WP6).

1.3 Scope

According to CEN EN 16575, *"Bio-based"* simply means *"derived from biomass".* In the frame of the HARMONIOR project, the focus is on industrial bio-based systems excluding food/feed, biofuels, bioenergy and cultural/recreational sectors. This allows for a better focus on the existing and emerging bio-based sectors within the larger bioeconomy. Given the relevance for the bio-based economy and the prominent role of sustainability certification in forestry, trade flows of certified and non-certified wood and forestry-based products are within the scope of the project. Primary biomass resources, bio-waste and residues intended for bio-based industrial value-chains, bio-based materials and products are included in the scope of the project. In case of resources with multiple applications, e.g., food, feed, materials and energy, for example palm oil, they will be regarded as within the scope of the assessment.

1.4 Approach

The selection of 35 value chains was performed in 5 steps:

- Step 1: Starting point is an extensive list of 350 bio-based materials and products (...) supplemented with wood products and other bio-based products (NACE 13, 16, 17)
- Step 2: All dedicated bio-based materials and products (...) will be pre-selected
- Step 3: The 40 drop-in bio-based materials and products with the highest bio-based production volumes will be pre-selected for further assessment
- Step 4: For all bio-based materials and products selected in step 1 – 3, the main biological resources used for their production will be identified by a quick assessment of their value chains 6
- Step 5: Final selection taking into account several criteria and considerations. In chapter 2 each step of this approach has been described in further detail. Chapter 3 shows which bio-based products have been selected as a result of this step wise approach.

2. Selection of bio-based materials and products

2.1 Step 1: Extensive list of bio-based materials and products

Approach

Starting point was an extensive list of 350 bio-based materials and products - mostly chemicals, pharmaceuticals and plastics, NACE 20, 21, 22, as presented in Spekreijse et al. (2019) - supplemented with wood products and other bio-based products (NACE 13, 16, 17). This list was used to provide an overview of:

1. (i) bio-based materials and products for which statistical trade information is available, and
2. (ii) bio-based materials and products for which statistical trade information is not readily available.

Next, it was indicated whether these are drop-in (identical to their fossil alternative) or dedicated (chemically unique) bio-based materials or products.

Drop-in bio-based chemicals appear in the same statistical category as their chemically identical fossil-based counterparts, making it impossible to determine the volumes of the bio-based chemical using only statistics. Although considerable effort is performed to improve statistics of bio-based materials (e.g., the BioMonitor project), additional sources are needed to determine trade flows of drop-in bio-based products. Therefore, drop-in bio-based materials were assessed in a separate step.

Result

A long list of 538 product was established including the following NACE categories:

- NACE 13: Manufacture of textiles
- NACE 16: Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
- NACE 17: Manufacture of paper and paper products
- NACE 20: Manufacture of chemicals and chemical products
- NACE 21: Manufacture of basic pharmaceutical products and pharmaceutical preparations
- NACE 22: Manufacture of rubber and plastic products.

Figure 1: Excerpt from the longlist of 538 bio-based materials and products

	A	B	C	D	G	H	U	V	X	Y	Z
1	Product	NACE	CPA	Prodcom	characteristic	type	PRODCOM text	Specific PRODCOM code?	CN Code	CN text	Specific CN code?
2	Carboxymethyl cellulose and salts	20.16	201659	20165950	polysaccharide	dedicated	Cellulose and its chemici	no	3912 31 00	carboxymethylcellulose a	y
3	Cellulose esters	20.16	201659	20165950	polyether	dedicated	Cellulose and its chemici	no	3912 90 10	cellulose esters	y
4	Cellulose ethers	20.16	201659	20165950	polyether	dedicated	Cellulose and its chemici	no	3912 39	other cellulose ethers	y
5	Alginate with salts and esters	20.16	201659	20165950	polyether	dedicated	Cellulose and its chemici	no	3913 10 00	alginic acid polymer	y
6	Pure glycerol	20.41	204110	20411000	polyol	dedicated	Glycerol (glycerine), crude	no	2905 45 00	Glycerol	y
7	Fructose	Other	106213	10621320	polyol	dedicated	Chemically pure fructose	no	1702 50 00	pure fructose	y
8	Ethanol	20.14	201474	20147400	alcohol	dedicated	Undenatured ethyl alcoh	no	2207 20 00	denatured ethanol	y
9	Mannitol	20.14	201423	20142337	polyol	dedicated	Diols and polyhydric alco	no	2905 43 00	mannitol	y
10	Coenzyme Q10 (ubiquinone)	20.14	201462	20146260	alkene	dedicated	Quinones	no	2914 62 00	coenzyme Q10	y
11	Palmitic acid with salts and esters (aka hexadecanoic acid)	20.14	201432	20143235	organic acid	dedicated	Palmitic acid, stearic acic	no	2915 70 40	palmitic acid with salts a	y
12	Stearic acid with salts and esters (aka octadecanoic acid)	20.14	201432	20143235	organic acid	dedicated	Palmitic acid, stearic acic	no	2915 70 50	stearic acid with salts an	y
13	Lauric acid with salts and esters (aka dodecanoic acid)	20.14	201432	20143280	organic acid	dedicated	Lauric acid and others; sa	no	2915 90 30	lauric acid with salts and	y
14	Azelaic acid (aka nonanedioic acid) with salts and esters	20.14	201433	20143381	organic acid	dedicated	Oxalic, azelaic, malonic, (	no	2917 13 90	azeleic acid with salts ar	y
15	Sebacic acid (aka decanedioic acid)	20.14	201433	20143381	organic acid	dedicated	Oxalic, azelaic, malonic, (	no	2917 13 10	sebacic acid	y
16	Tartaric acid	20.14	201433	20143381	organic acid	dedicated	Oxalic, azelaic, malonic, (	no	2918 12 00	tartaric acid	y
17	Lactic acid with salts and esters	20.14	201434	20143475	organic acid	dedicated	Carboxylic acid with alcol	no	2918 11 00	lactic acid with salts and	y
18	Citric acid	20.14	201434	20143473	organic acid	dedicated	Citric acid and its salts ai	combined	2918 14 00	citric acid	y
19	Lecithin and phophoaminolipids	2110	211020	21102040	phosphate	dedicated	Quaternary ammonium si	no	2923 20 00	lecithins and other phos	y
20	Methionine	20.14	201451	20145133	amino acid	dedicated	Thiocarbamates and dith	no	2930 40 10	Methionine	y

The longlist contains the product description, NACE, CPA, PRODCOM and CN code, as well as the PRODCOM and CN text. It is indicated whether the products have a specific PRODCOM and CN code. If this is not the case, the product is part of a group of products. Moreover, for all products it was determined whether it is a “dedicated” or “drop-in”. product. In case of chemicals, the type of chemical was characterized. See Figure 1.

2.2 Step 2: Pre-selection of dedicated bio-based materials and products

Approach

All dedicated bio-based materials and products for which statistical trade information is readily available (usually requiring to be identifiable at 6-digit CN code level), including wood-based products, were pre-selected.

Result

All dedicated products were taken from the longlist for further assessment. In some cases, sub-categories were combined to get a group for which statistical data is available. For example, no data is available for “lactic acid”, but data is available for “lactic acid, its salts and esters”. Not all products are well described by single PRODCOM and/or CN code. For example, “furan” falls in the category “20145225; Heterocyclic compounds with oxygen only hetero-atom(s)” containing a range of compounds including furan. In this case the bio-based product was not preselected. Given that usually compounds with smaller production or trade volumes are grouped, this approach can be justified. This

first screening resulted **in 226 dedicated bio-based materials and products** that have at least a unique PRODCOM or CN code (226).

In order to get a first impression of the size of the production and trade flows, for each dedicated product of which a unique PRODCOM is available, the highest production volume of the last three years has been obtained from Eurostat, via COMEXT. For all the other products the import to and export from the EU, as well as the import and export within the EU was obtained, via the CN codes. The list was ordered from highest to lowest production and or trade volumes.

2.3 Step 3: Pre-selection of drop-in bio-based materials and products

Approach

The 40 drop-in bio-based materials and products with the highest bio-based production volumes were selected for further assessment. Production volumes are not readily accessible from trade statistics but can be obtained from bio-based market studies and reports.

The level of detail of CN, which is used by the customs to obtain import/export tax, is generally higher than PRODCOM. Therefore, if the PRODCOM code is known, this usually means that production data (PRODCOM) and trade data (CN) is available in statistics. However, in many other cases no PRODCOM code is known, but the CN code is known, meaning that only trade data is available in statistics.

Result

Like in the case of the dedicated products, some aggregation of categories was performed, and drop-in bio- based products without unique PRODCOM or CN code removed, resulting in a list of 101 drop-in bio-based products.

Based on earlier work, especially Spekreijse et al (2019)[d] and Spekreijse et al (2021)[e], and an initial assessment of bio-based products that are currently allowed for certification under ISCC PLUS, a shortlist of about **40 drop- in bio-based products** was drawn. It was decided not to further reduce the shortlist, but to make the final selection in step 5 for the dedicated and drop-in bio-based materials and products together.

[d] Spekreijse, J, T. Lammens, C. Parisi, T. Ronzon, M. Vis (2019) Insights into the European market for bio-based chemicals, analysis based on 10 key product categories, JRC science for policy report, EUR 29851 EN, Publications office of the European Union, Luxembourg, 2019, ISBN 978-92-79-985419-8, doi:10.2760/673071, JRC112989.

[e] Spekreijse, J., K. Vikla, M. Vis, K. Boysen-Urban, G. Philippidis, R. M'barek (2021) Bio-based value chains for chemicals, plastics and pharmaceuticals, a comparison of bio-based and fossil-based value chains, EUR 30653 EN, Publications office of the European Union, Luxembourg, 2021m ISBN 978-92-76-32459-1, doi: 10.2760/712499, JRC124141.

Table 2: overview of pre-selected drop-in bio-based materials and products

Pre-selection of 40 bio-based drop-in materials and products			
Acetaldehyde	Formic acid	Poly (methyl methacrylate) - PMMA	Cyclohexanone
Acetic acid	Isoprene	Poly (vinyl acetate) - PVA	Ethane
Acetone	Poly (ethylene terephthalate) - PET*	Acrylic acid with salts	Ethylene dichloride
Adipic acid	Poly(ethylene) - PE*	Methanol	Ethylene Propylene Diene Monomer (EPDM) rubber
Butadiene	Poly(urethane) - PUR	Styrene	Methane
Butanediol (1,4-)	Propylene oxide	Acetylene	Phenol (and its salts)
Butanol (n-)	Caprolactam	Acrylamide	Poly (vinyl chloride) - PVC
Epichlorohydrin	Cyclohexane	Acrylonitrile	Propane
Ethylene*	Methyl methacrylate (MMA)	Benzene	Propylene
Ethylene oxide*	Poly (butylene terephthalate) - PBT	Cyclohexanol	Toluene

* Several drop-in bio-based products can be present in the same value chain. This is for example the case with ethylene, ethylene oxide and poly(ethylene).

2.4 Step 4: Identification of main biological resources

For all bio-based materials and products selected in step 1 – 3, the main biological resources used for their production were identified by a quick assessment of their value chains. Typical resources include wood, sugar/starch, and oil crops. Residues and biowaste streams were also selected, even if they are currently not used, in case they form suitable resources for the selected bio-based materials and products.

2.5 Step 5: Additional considerations

The final selection of value chains for further analysis should be a representative mix of bio-based products, using various feedstocks (including residues and wastes), covering a broad range of sectors, relevant for EU policy making, currently traded, and relevant for further analysis of sustainability certification schemes.

EU Policies and bio-based value chains

A Broad range of relevant EU legislation and policy expresses directly or indirectly sustainability requirements for bio-based value chains. Examples include the CAP reform, Taxonomy Regulation, Farm to Fork strategy, EU Forest Strategy, Circular Economy Action Plan, European Regulation on Sustainable products, recast of RED, and the EU Strategy for Sustainable and Circular Textiles. In the assessment of CSL and the setup of the monitoring system for assessing the sustainability of bio-based value chain within HARMONITOR, these policies will be assessed in detail. For the selection of bio-based value chains, we would like to highlight that the selected bio- based value chains should contribute to the main objectives of the European Bioeconomy Strategy:

- Ensure food and nutrition security
- Manage natural resources sustainably

- Reduce dependence on non-renewable, unsustainable resources
- Limit and adapt to climate change
- Strengthen European competitiveness and create jobs.

We have taken these objectives as follows in the selection of value chains. If bio-based value chains should ensure food and nutrition security, it makes sense to select value chains that are based on residues and wastes, which do not require additional land. *Managing natural resources sustainably*, can mean that value chains with high sustainability risks should be selected (for example cotton products), as CSLs can make the difference between sustainable and unsustainable practices. On the other hand, sustainable value chains could be selected, as CSLs gives them a platform to present their sustainability benefits (for example hemp). *Reduce dependence on non-renewable, unsustainable resources* and *limit and adapt to climate change* means that value chains with considerable production and trade volumes should be selected, as these value chains have generally more impact on use of unsustainable sources and climate change. The objective to *strengthen European competitiveness and create jobs* means that innovative bio-based value chains should be selected that create economic activity such as research, scale up and new commercial activities within the EU.

Relevance of bio-value chains for assessment of CSLs

The *Study of the environmental sustainability requirements of bio-based value chains and supply chains for bio- based industry in future EU funded R&I demonstration and flagship projects* (not published yet), identified five overarching environmental principles for bio-based value chains, i.e., mitigate global warming, conserve and protect biodiversity, conserve and protect water resources, protect soil quality and productivity, and promote good air quality. It has been assessed whether environmental or social concerns exist regarding the selected bio- based value chains, which is the case for the vast majority of selected value chains, and whether CSLs covering these concerns exist (see Table 7 on page 18).

Final selection approach

BTG has made a draft final selection of bio-based value chains considering:

- Market size of value chains & coverage by existing statistics (focus of steps 1-4)
- Representative distribution between bio-based sectors
- Inclusion of both innovative and traditional bio-based products
- Inclusion of value chains using residues and wastes
- Inclusion of both EU and imported feedstocks and products
- Value chains with environmental and social challenges (where CSL play an important role)
- Coverage by sustainability certification schemes and labels
- Compatibility with environmental requirements from EU bioeconomy policies (CBE, EU Bioeconomy Strategy).

Several meetings were organised to discussion the approach and the selection of value chains:

- On the 14th of October 2022, BTG presented the value chain selection approach in an online meeting with the two sister projects STAR4BBS and SUSTCERT4BIO-BASED.
- On the 24th of October 2022, the results of step 1 – 3 of the value chain selection procedure was presented and discussed with the HARMONITOR consortium in an online meeting.
- On the 28th of October 2022, the HARMONITOR value chain selection approach and results of step 1 – 3 were discussed with the sister projects. The sister projects will select the value chains at a later stage. Therefore, it was not possible to discuss or divide certain value chains with the sister projects. On the one hand, some overlap between the selection could support the

presentation of differences in approach between the sister projects. On the other hand, it would be worthwhile that the three projects together cover a broad range of different value chains.

- On the 2nd of November, as part of the hybrid HARMONITOR progress meeting in Berlin, the first draft of the final selection of value chains (step 1 – 5) were discussed in detail, during a three-hour workshop fully dedicated to the selection of value chains. Several suggestions for inclusion of additional value chains were made based on the final selection criteria presented above.
- On the 9th of November, based on the outputs of the workshop, BTG has sent the draft of the final selection of value chains to the consortium partners, for their final comments or approval.
- On the 14th of November, the draft final selection was presented during an online meeting with the sister projects and the EU project offers of the three projects. During this meeting, some remarks were made, for example whether value chains with import of the bio-based product were included in the selection, which is indeed the case.
- On the 18th of November, the final selection was made after having processed some final remarks from HARMONITOR consortium partners.

In the next chapter the resulting selection of bio-based value chain is further described and discussed.

3 Description of selected bio-based materials and products

3.1 Bio-based chemicals

From the list of drop-in chemicals (step 3), six significant ones were selected. All these chemicals show significant bio-based production in Europe and a large potential market (Table 3).

Table 3: Bio-based chemicals

	EU Bio-based production (kt/y)	EU Fossil-based production (kt/y)
1,4-butanediol	30[f]	n.a.
Acetic acid	24.5[g]	968[d]
Epichlorohydrin	36[d]	265[d]
Ethylene glycol	220[h]	1180[d]
Propylene glycol	20[d]	633[d]
PUR	39[d]	3500[d]

The selection was further expanded by the largest volume of dedicated bio-based chemicals (step 2). The largest PRODCOM categories are those involving starch (maize starch, modified starch, wheat starch, and potato starch, each with over 1400 kt/y produced). These categories were taken into the selection as 'starch polymers. The next largest produced dedicated bio-based chemical is glycerol (20411000, Glycerol (glycerine), crude; glycerol waters and glycerol lyes) with an EU production of 730 kt/y. However, glycerol is not a final product and can be seen as a feedstock. This feedstock is already included in the value chain for propylene glycol. The next chemical in the list is citric acid (20143473, Citric acid and its salts and esters). However, citric acid was excluded since it finds its main application in food. The next entry, Tall Oil (20147130, Tall oil; whether or not refined, 480 kt/y) was included. This results in the addition of starch polymers and tall oil to the final selection.

From the chemicals from which only the CN data can be used, ethanol scores the highest trade statistics with 1252.4 kt/y[i] traded within and across the EU borders. However, it is expected that the bulk of the bio-based ethanol will be used as fuel and is excluded from the selection. The next three groups (CN

29232000, lecithins and other phosphoaminolipids; CN 391239, other cellulose ethers; and 29181100, lactic acid with salts and esters) all show trade values between 250 and 500 kt/y. Due to its interest for CSLs, the lactic acid into PLA value chain was selected from these.

Table 4: Selected bio-based value chain in the chemical sector

Intermediary chemical	Biomass type in	Products out
Acetic acid (see tab 1)	Sugar/starch	PTA, VAM, acetic anhydride, acetate esters
Ethylene glycol (see tab 2)	Sugar/starch	PET, PE
Butanediol (1,4)	Sugar/starch	Solvent, production of polyurethanes
Lactic acid	Sugar/starch (cane sugar)	PLA (USA, Thailand)
Lactic acid	Sugar/starch (cane sugar)	Salts and esters
Starch polymers	Starch (potatoes), corn	Plastic utensils
Palmitic acid with its salts and esters	Palm oil	Cosmetics, surfactants
Propylene glycol	Oil crop (glycerol)	Propylene glycol
Poly(urethane)	Vegetable oil - soybeans	PUR
Epichlorohydrin	Vegetable oil, glycerol	Solvent in resins, paints
Rayon	Wood	Tarn
Tall oil	Wood	Chemicals

[f] Spekreijse, J., K. Vikla, M. Vis, K. Boysen-Urban, G. Philippidis, R. M'barek (2021) Bio-based value chains for chemicals, plastics and pharmaceuticals, a comparison of bio-based and fossil-based value chains, EUR 30653 EN, Publications office of the European Union, Luxembourg, 2021m ISBN 978-92-76-32459-1, doi: 10.2760/712499, JRC124141.

[g] Spekreijse, J, T. Lammens, C. Parisi, T. Ronzon, M. Vis (2019) Insights into the European market for bio-based chemicals, analysis based on 10 key product categories, JRC science for policy report, EUR 29851 EN, Publications office of the European Union, Luxembourg, 2019, ISBN 978-92-79-985419-8, doi:10.2760/673071, JRC112989.

[h] Green Chemicals Blog, https://greenchemicalsblog.com/2022/08/25/upm-gears-up-for-bio-meg-commercialization/

[i] The highest trade volumes: extra EU import, extra EU export, plus intra EU trade of the period 2019-2021 was taken using COMEXT.

3.2 Wood sector

For the wood sector (NACE 16), a similar approach was taken as for the dedicated chemicals. Since in this sector nearly all products are bio-based, and all those products are dedicated, only a list with dedicated bio-based products exists. The nine PRODCOM categories with the highest production numbers within the EU27 are presented in Table 5.

Table 5: overview of the nine PRODCOM categories from the wood sector with the highest production volumes within the EU27

PRODCOM	PRODCOM text	Production (kt/y)[a)]	Included as
16102503	Coniferous wood in chips or particles	36,000	*Excluded (fuel)*
16291500	Pellets and briquettes of pressed and agglomerated wood and of wood waste and scrap	17,926	*Excluded (fuel)*
16231900	Builders joinery and carpentry of wood (excluding windows, French windows and doors, their frames and thresholds, parquet panels, shuttering for concrete constructional work, shingles and shakes)	6,300	Sawn wooden products
16102505	Non-coniferous wood in chips or particles	5,639	*Excluded (fuel)*
16102110	Coniferous wood continuously shaped (including strips and friezes for parquet flooring, not assembled)	3,063	Sawn wooden products
16241320	Cases, boxes, crates, drums and similar packings of wood (excluding cable drums)	2,687	Wooden packaging
16102400	Wood wool; wood flour	2,080	Wood wool, wood flour
16211543	Fibreboard (excluding medium density fibreboard [MDF]), of wood or other ligneous materials, whether or not bonded with resins or other organic substances, of a density exceeding 0.8 g/cm³	900	Fibreboard (particle, MDF, etc.)
16241133	Flat pallets and pallet collars of wood	824	Wooden pallets

[a)] For each PRODCOM category the highest production volume of the period 2019, 2020 and 2021 was taken from COMEXT.

Three of the nine PRODCOM categories with highest production numbers (16102503, 16291500, and 16102505) were excluded due to their high use in fuel applications, which is out of the scope of the HARMONITOR project. The remaining products were all taken up in the selection, although with some modifications. For clarity, some categories were taken wider than the PRODCOM classification. For example, in the category fibreboard, also MDF of different sizes (16211529, 16211523 and 16211526 and particle board of wood (16211200), is included, whereas our final selection simply included all fibreboard as one product entry.

Finally, the selection of wooden products was completed with the inclusion of Oriented Strand Board (OSB) (16211316), as to provide a rather complete picture of the wooden panel sector.

3.3 Paper products

The PRODCOM classification of paper products has several PRODCOM product entries that have a high production value due to their generic description. For example, fluting (17123400) and corrugated paper (17211100) have high production volumes of 11,051 kt/y and 10,821 kt/y[j], respectively. In this selection, we gave priority to well defined products. The well-defined products with the highest production values are graphic paper, paperboard (17121439 and 17121425) with a total EU production of 9,015 kt/y and toilet paper (17221120), at a production of 4,651 kt/y. These groups were included in the HARMONITOR selection as three separate entries: graphic paper, paperboard, and toilet paper.

3.4 Textiles

The PRODCOM classification for textiles is fragmented into several categories that focus on functionality rather than material. For example, next to 'woven fabrics of cotton' (132020), cotton products can be found in, amongst others, 'Bed linen of cotton' (13921253), 'sacks and bags, of cotton' (13922130), and 'table linen of cotton' (13921353). To prevent the selection of several cotton products and to maximise the diversity in feedstocks, six textiles from different feedstocks were selected. These are cotton, wool, jute, flax, hemp, and leather.

3.5 Other additions

To adhere to all the additional considerations (step 5), several other products were added to the selection. Moreover, a selection purely based on currently large production numbers would omit important and innovative.

In order to include both EU and imported feedstocks & products, two value chains for lactic acid were selected. On one hand the production of PLA from lactic acid, which mostly takes place in the USA and Thailand. On the other hand, the production of lactic acetate salts and esters, which also takes place within the EU. Moreover, ethylene, which is mainly produced outside of the EU, was included with the value chain towards bio-based polyethylene.

The use of straw as a building material was included as innovative bio-based value chain in the construction sector. Compost from kitchen and garden waste, the production of PHA from wastewater and the production of polypropylene from used cooking oil were selected in order to increase the number of value chains that rely on rest streams. Natural rubber and leather were selected, since they were not identified in the initial list of 350 chemicals and polymers even though it is an important bio-based product, and finally, algal fatty acids were added to represent the upcoming blue economy.

3.6 Final selection

Table 6 on page 17 presents the selected 35 value chains, starting with the main intermediary chemical, sector, typical biomass resource used and outgoing products. Furthermore, it is indicated if the intermediary chemical is readily available in EU statistics. This is not the case for drop-in bio-based chemicals, and some more innovative and waste-based value chains. The next column shows whether the feedstock for the bio-based product as sold in the EU is mainly grown in the EU, imported or both. During trade flow analysis, more information will be collected on this aspect. The next columns show whether an existing bio-based market has been established, and if the product can be regarded as new/innovative bio-based product. The next column shows whether the product is a waste or residue.

Table 7 and Table 8 show whether possible major environmental and social concerns exist for the selected value chains. This does not mean that these value chains are unsustainable, but it does indicate a certain need for CSLs. Next, it is indicated whether the value chains are covered by existing CSLs. Further research is needed to investigate if and to what degree CLS are applied in these value chains. Moreover, a number of relevant CSLs are mentioned. This list may not be complete, during the project a more detailed assessment of CSLs will be performed.

Table 6: Overview of selected bio-based value chains

#	Intermediary chemical	Sector	biomass type in	Products out	Intermediary included in statistics?	Feedstock: EU, import, or both?	Existing bio-based market?	Innovative bio-based product?	Feedstock: waste/ residue?
1	Acetic acid	Chemicals	Sugar/starch	PTA, VAM, acetic anhydride, acetate esters	n	both	y	y	n
2	Ethylene glycol	Chemicals	Sugar/starch	PET	n	import	y	y	n
3	Ethylene	Chemicals	Sugar/starch	Polyethylene (PE), HDPE	n	import	y	y	n
4	Butanediol (1,4)	Chemicals	Sugar/starch	Solvent, production of polyurethanes	n	both	y	y	n
5	Lactic acid	Chemicals	Sugar/starch (cane sugar)	PLA	y	import	y	y	n
6	Lactic acid	Chemicals	Sugar/starch (cane sugar)	Salts and esters	y	both	y	n	n
7	Starch polymers	Chemicals	Starch (potatoes), corn	Plastic utensils	y	both	y	n	n
8	Palmitic acid with its salts and esters	Chemicals	Palm oil	Cosmetics, surfactants	y	import	y	n	n
9	Propylene glycol	Chemicals	Oil crop (glycerol)	Propylene glycol	n	both	y	y	both
10	Poly(urethane) PUR	Chemicals	Vegetable oil - soybeans	PUR	n	import	y	y	n
11	Epichlorohydrin	Chemicals	Vegetable oil, glycerol	Solvent in resin, paints	n	both	y	y	both
12	Rayon	Chemicals	Wood	Tarn	y	EU	y	y	n
13	PHA	Chemicals	wastewater	Plastics	n	EU	n	y	y
14	(Poly)propylene	Chemicals	UCO	Plastics	n	both	n	y	y
15	Algal fatty acids	Chemicals	Algae	Cosmetic ingredient	n	both	n	y	n
16	Sawn wooden products	Wood	Wood	Several	y	both	y	n	n
17	Fibreboard (particle, MDF, etc)	Wood	Wood, waste wood	MDF, Particle board	y	both	y	n	y
18	Oriented strand board	Wood	Wood	OSB	y	both	y	n	n
19	Wooden packaging	Wood	Wood	Cases, boxes, drums	y	both	y	n	n
20	Wooden pallets	Wood	Wood	Pallets	y	both	y	n	n
21	Wood wool, wood flour	Wood	Wood	Panels, fibre cement, insulation, filler	y	both	y	n	n
22	Lignin based products	Wood	Wood	Binders and aromatic chemicals, asphalt/bitumen	n	both	n	y	y
23	Tall oil	Wood	Wood	Chemicals	n	both	y	y	y
24	Pulp	Paper	Wood, wastepaper	Graphic paper	y	both	y	n	y
25	Pulp	Paper	Wood, wastepaper	Paper board	y	both	y	n	y
26	Pulp	Paper	Wood, wastepaper	Toilet paper	y	both	y	n	y
27	Cotton fabrics	Textile	Cotton	Woven fabrics, table and bed linen, sacks and bags	y	import	y	n	n
28	Wool fabrics	Textile	Wool	Textile	y	both	y	n	n
29	Jute	Textile	Jute	Textile	y	import	y	n	n
30	Flax	Textile	Flax	Textile, table linen	y	EU	y	n	n
31	Hemp	Textile	Hemp	Textile, insulation materials	n	EU	y	n	n
32	Straw	Building	Straw	building materials	n	EU	y	y	y
33	Biowaste	Waste	Biowaste	Compost	y	EU	y	n	y
34	Leather	Textile	Animal skin	Clothing, textiles	y	import	y	n	n
35	Natural rubber	Chemicals	Natural rubber	Tyres, various products	y	import	y	n	n

Table 7: Selected value chains – initial assessment of applicable CSLs

#	Intermediary chemical	biomass type in	Products out	Possible major environ-mental concerns	Possible major social concerns	ISCC PLUS	Better Biomass	RSB	REDCert	Bonsucro	SAI	Alliance Water	Fairtrade Int.	VCS	Nature Care Products	Recognised	SGE 21	OK biobased	TFS	ZNU	FSC	PEFC	SBP	ARSO	EU Ecolabel - textiles	Textile exchange	FAIR Rubber	GPSNR	Total # CSLs
1	Acetic acid	Sugar/starch	PTA, VAM, acetic anhydride,	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y									15
2	Ethylene glycol	Sugar/starch	PET	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y									15
3	Ethylene	Sugar/starch	Polyethylene (PE), HDPE	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y									15
4	Butanediol (1,4)	Sugar/starch	Solvent, polyurethanes	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y									15
5	Lactic acid	Sugar/starch (cane sugar)	PLA	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y									15
6	Lactic acid	Sugar/starch (cane sugar)	Salts and esters	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y	y									15
7	Starch polymers	Starch (potatoes), corn	Plastic utensils	y	y	y	y	y	y		y	y	y		y	y	y	y	y	y									13
8	Palmitic acid & salts and esters	Palm oil	Cosmetics, surfactants	y	y	y	y			y	y	y	y	y	y	y	y	y	y	y									13
9	Proplyene glycol	Oil crop (glycerol)	Propylene glycol	y	y	y	y		y		y	y	y	y	y	y	y	y	y	y									13
10	Poly(urethane) PUR	Veg oil, soybeans	PUR	y	y	y	y		y		y	y	y		y	y	y	y	y	y									12
11	Epichlorohydrin	Vegetable oil, glycerol	Solvent in resins, paints	y	n	y	y		y		y	y	y	y	y	y	y	y	y	y									13
12	Rayon	Wood	Tarn	y	n	y	y	y											y	y	y	y	y						8
13	PHA	wastewater	Plastics	n	n	y	y	y	y										y	y									6
14	(Poly)propylene	UCO	Plastics	n	n	y	y	y	y										y	y									6
15	Algal fatty acids	Algae	Cosmetic ingredient	y	n	y		y				y	y	y						y									6
16	Sawn wooden products	Wood	Several	y	y	y	y	y				y		y				y	y	y	y	y							10
17	Fibreboard (particle, MDF)	Wood, waste wood	MDF, Particle board	y	n	y	y	y				y		y				y	y	y	y	y							10
18	Oriented strand board	Wood	OSB	y	n	y	y	y				y		y				y	y	y	y	y							10

Table 8: Selected value chains – initial assessment of applicable CSLs (continued)

#	Intermediary chemical	biomass type in	Products out	Possible major environ-mental concerns	Possible major social concerns	ISCC PLUS	Better Biomass	RSB	REDCert	Bonsucro	SAI	Alliance Water Stewardship	Fairtrade Int.	VCS	Nature Care Products	Recognised	SGE 21	OK biobased	TFS	ZNU	FSC	PEFC	SBP	ARSO	EU Ecolabel - textiles	Textile exchange	FAIR Rubber	GPSNR	Total # CSLs
19	Wooden packaging	Wood	Cases, boxes, drums	y	n	y	y	y				y		y					y	y	y	y	y						10
20	Wooden pallets	Wood	Pallets	y	n	y	y	y				y		y					y	y	y	y	y						10
21	Wood wool, wood flour	Wood	Panels, fibre cement, insulation, filler	y	n	y	y	y				y		y					y	y	y	y	y						10
22	Lignin based products	Wood	Binders and aromatic chemicals, asphalt/bitumen	y	n	y	y	y				y		y					y	y	y	y	y						10
23	Tall oil	Wood	Chemicals	y	n	y	y	y				y		y					y	y	y	y	y						10
24	Pulp	Wood, wastepaper	Graphic paper	y	n	y	y	y				y		y					y	y	y	y	y						10
25	Pulp	Wood, wastepaper	Paper board	y	n	y	y	y				y		y					y	y	y	y	y						10
26	Pulp	Wood, wastepaper	Toilet paper	y	n	y	y	y				y		y					y	y	y	y	y						10
27	Cotton fabrics	Cotton	Woven fabrics, table and bed linen, sacks and bags	y	y	y	y	y				y		y						y				y	y	y			9
28	Wool fabrics	Wool	Textile	y	y	y	y	y				y		y						y				y	y	y			9
29	Jute	Jute	Textile	y	n	y	y	y				y		y						y				y	y	y			9
30	Flax	Flax	Textile, table linnen	y	n	y	y	y				y		y						y				y	y	y			9
31	Hemp	Hemp	Textile, insulation materials	y	n	y	y	y				y		y						y				y	y	y			9
32	Straw	Straw	building materials	y	n	y		y	y																				3
33	Biowaste	Biowaste	Compost	n	n	y					y																		2
34	Leather	Animal skin	Clothing, textiles	y	y	y						y		y						y				y	y	y			7
35	Natural rubber	Natural rubber	Tyres, various products	y	y	y															y	y					y	y	5

4 CONCLUSIONS

35 bio-based of value chains were selected for further assessment within the HARMONITOR project. A systematic five step approach was applied, starting with a longlist of 538 products from NACE 13, 16, 17, 20, 21 and 22. After a pre-screening on the representativeness of the PRODCOM and CN codes of the bio-based product, 226 dedicated bio-based materials and products were pre-selected as well as a list of 101 drop-in biobased products. Their biological sources were identified and based on the production (PRODCOM) and, if/needed, trade (CN) volumes, an initial selection was made. During several online meetings and a workshop in Berlin, a further screening was applied taking into account considerations such as representative distribution between bio-based sectors, inclusion of both innovative and traditional bio-based products, inclusion of value chains using residues and wastes, inclusion of both EU and imported feedstocks and products, coverage by sustainability certification schemes and labels, relevance for EU bioeconomy policies such as the CAP reform, Taxonomy Regulation, Farm to Fork strategy, EU Forest Strategy, Circular Economy Action Plan, European Regulation on Sustainable products, recast of RED, and the EU Strategy for Sustainable and Circular Textiles.

The final selection aimed to be a representative mix of bio-based products, using various feedstocks (including residues and wastes), covering a broad range of sectors, relevant for EU policy making, currently traded, and relevant for further analysis of sustainability certification schemes.

Task 3.2: Assessing Trade Flows of Biological Resources, Bio-based Materials and Products

Task 3.2 description

A mapping of the trade flows of the selected chemically unique bio-based products will be performed, primarily using existing and consolidated market databases (e.g., Eurostat, Comext, STIX, FAOSTAT). In case of drop-in bio-based products, statistical information will be combined with estimated percentages of bio-based production using databases and market studies. Associated biological resources will be obtained from statistics, sector data, existing resource assessments, etc. (Months 7 – 27).

Methodology

Within the HARMONITOR project, 35 value chains from biomass to bio-based product or materials have been selected for further assessment (D3.1). An initial assessment of the trade flows and imports of these 35 value chains with focus on statistical data collection has been performed and described in milestone report (M3) *"Initial assessment of trade flows"*, submitted on 31 May 2023. Several choices were made towards the selection of statistical data. These are as follows

- Statistical data will be collected separately for the biogenic feedstock, the different intermediary chemicals/products and the outgoing chemicals/products. Later these will be linked to each other.
- Data will be collected and presented at least for one base year, namely 2021. Eurostat trade data on 2022 is at the time of writing not expected to be complete yet.
- If statistical information is available for a series of years, data on the last 10 years will be collected. It is to be decided how this information will be presented, given the number of value chains.
- Data collection will focus on trade volumes (in tonnes) (CN), and production volumes if available in Prodcom.
- As a minimum, the trade flows between the EU and non-EU countries/regions will be shown.
- If available, the following data will be collected.
  - Import to EU countries from EU countries;
  - Import to EU countries from non-EU countries;
  - Export from EU countries to EU countries (is often slightly and in some cases very different, even if volumes are used)
  - Export from EU countries to non-EU countries.
- The focus lies on obtaining a big picture overview of the 35 value chains. Therefore, no substantial effort will be put in explaining outliers, data gaps and omissions of trade between EU countries.
- If no statistical information is available, other sources will be used, preferably sources that are regularly updated, from e.g., sector organisations.
- The quality of information sources will be ranked with an uncertainty indicator. This methodology has been developed and used in two JRC studies executed by BTG (Spekreijse et al 2019, 2021).
- The resulting trade flows will show production, market, import and export of the major global regions.
- Where available, a more detailed mapping of trade with and between EU Member States will be presented. The statistical information will be checked on obvious errors; where possible data

gaps in trade between EU and non-EU countries will be identified and filled with data from FIGARO or commercial free available trade databases (e.g., Abrams Wiki).
- The data will be presented in a comprehensive manner using tables, graphs, and highlighting the highest importing/exporting countries to obtain insights from the collected data.

Statistical data collection of (bio-based) chemicals

The two main databases used for the statistical data collection are Comext, also known as Easy Comext; and the UN Comtrade database. Comext is Eurostat's statistical database on the trade of goods and uses data from the EU Member States' national statistical administration. The United Nations Comtrade database uses trade data collected from approximately 200 countries. The Comtrade database regards the EU as one entity and does thereby not take intra-EU trade into account[4]. As such, in order to get the most desirable data, Eurostat's Easy Comext database was used for intra-EU data, while the UN Comtrade database was used for extra-EU data.

As certain products are not included in the UN Comtrade database, but are available in the Comext database, mirror data was used for certain value chains. This mirror data is derived from the declarations of the partner country. For example, for certain value chains, extra-EU imports were deduced from EU Member States' declarations of extra-EU exports and vice versa.

Differences between import and export data between the declaring countries were observed. In general, imports are usually recorded with more accuracy as these generate tariff revenues, while exports do not. The quality of the data collection can also vary among countries[5]. Data from 2021 was used, as this is the most recent year with the full data available for all value chains.

In general, the import data appears to be more complete and as mentioned above, it is often more accurate due to tariff revenues. As such, import data was used for the mapping of intra-EU trade, rather than intra-EU exports. The mapping of trade flows also includes both the extra-EU imports and extra-EU exports, as only the flows to and originating from the EU are taken into account in the data collection, giving no issues with repeated data for extra-EU countries. For the mapping, the tool 'FlowmapBlue' was used, an online flow map visualization tool, which shows the quantity of trade of the selected value chains between countries. FlowmapBlue is free to be used in non-commercial projects.

Two of the selected value chains, polyhydroxyalkanoates (PHA) and algal fatty acids were not available in either the Comext, UN Comtrade or other databases. As such, information on their trade flows and bio-based content will be derived from literature.

The trade data collected for the chemical value chains is presented below. Table 1 shows the CN code and official name of the chosen value chains, whether they are a drop-in or dedicated bio-based chemical and the database source of its intra- and extra-EU trade data. As mentioned before, for some value chains, the CN code was not included in the UN Comtrade database. Mirrored data from Comext was then used for extra-EU data.

[4] https://unstats.un.org/wiki/display/comtrade/EU+in+UN+Comtrade
[5] https://wits.worldbank.org/wits/wits/witshelp/content/data_retrieval/T/Intro/B2.Imports_Exports_and_Mirror.htm

Table 2, CN code, type and data source of chosen value chains.

Value chain and CN code	Type	Trade flow	Database
*291521 - **Acetic acid***	Drop-in	Intra	Easy Comext
		Extra	UN Comtrade
*290531 - Ethylene glycol "**ethanediol**"*	Drop-in	Intra	Easy Comext
		Extra	UN Comtrade
*290121 - **Ethylene***	Drop-in	Intra	Easy Comext
		Extra	UN Comtrade
*29053926 - Butane-1,4-diol or tetramethylene glycol [**1,4-butanediol**] having a bio-based carbon content of 100% by mass*	Drop-in/bio-based	Intra	Easy Comext
		Extra	Easy Comext
*390770 - **Poly"lactic acid"**, in primary forms*	Dedicated	Intra	Easy Comext
		Extra	UN Comtrade
*291811 - **Lactic acid**, its salts and esters (excl. inorganic or organic compounds of mercury)*	Dedicated	Intra	Easy Comext
		Extra	UN Comtrade
*35051050 - **Starches**, etherified or esterified (excl. dextrins)*	Dedicated	Intra	Easy Comext
		Extra	Easy Comext
*29157040 - **Palmitic acid** and its salts and esters*	Dedicated	Intra	Easy Comext
		Extra	Easy Comext
*290532 - **Propylene glycol** "propane-1,2-diol"*	Drop-in	Intra	Easy Comext
		Extra	UN Comtrade
*39095090 - **Polyurethanes** in primary forms (excl. polyurethane of 2,2'-"tert-butylimino"diethanol and 4,4'-methylenedicyclohexyl diisocyanate, in the form of a solution in N,N-dimethylacetamide)*	Drop-in	Intra	Easy Comext
		Extra	Easy Comext
*291030 - 1-Chloro-2,3-epoxypropane "**epichlorohydrin**"*	Drop-in	Intra	Easy Comext
		Extra	UN Comtrade
*540310 - High-tenacity yarn of viscose **rayon** filament (excl. sewing thread and yarn put up for retail sale)*	Dedicated	Intra	Easy Comext
		Extra	UN Comtrade
*390210 - **Polypropylene**, in primary forms*	Drop-in	Intra	Easy Comext
		Extra	UN Comtrade

Statistical data collection of wood and textile products

Similar to (bio-based) chemicals, statistical data for wood and textile products on intra-EU trade was collected from Comext and extra-EU trade was collected from the UN Comtrade database for the year 2021. Trade data in both databases are subject to variations in data quality and discrepancies. Some of these are prominent in wood product trade including inconsistencies or errors in conversion in quantities and differences in methods in assessing trade data between reporting countries. Additional data sources, such as EFI's Forest Products Trade Flow database and UNECE's Joint Forest Sector Questionnaire will be helpful in further analysis and improving data quality.

The compilation of data was based on commodity codes of the Harmonized System Nomenclature (HS) without the additional digits of the CN system (8 digit code). The present selection of product classification varies between value chains. Cotton fabrics are presented at HS heading level (2 digit code), but should be further refined. Straw and organic waste are not included in the present dataset.

Table 3, HS code, type and data source of chosen value chains for wood and textile products.

Value chain and HS codes	*Type and products out*
4407 - Wood sawn or chipped lengthwise, sliced or peeled, whether or not planed, sanded or end-jointed, of a thickness exceeding 6 mm	Sawn wooden products (Several)
4411 - Fibreboard of wood or other ligneous materials, whether or not bonded with resins or other organic substances	Fibreboard (particle, MDF, etc) (MDF, Particle board)
4410 - Particle board, oriented strand board (OSB) and similar board (for example, waferboard) of wood or other ligneous materials, whether or not agglomerated with resins or other organic binding substances.	Oriented strand board (OSB)
441510 - Cases, boxes, crates, drums and similar packings; cable-drums	Wooden packaging (Cases, boxes, drums)
441520 - Pallets, box pallets and other load boards; pallet collars	Wooden pallets (Pallets)
440500 - Wood wool; wood flour.	Wood wool, wood flour (Panels, fibre cement, insulation, filler)
380400 - Residual lyes from the manufacture of wood pulp, whether or not concentrated, desugared or chemically treated, including lignin sulphonates, but excluding tall oil of heading 38.03.	Lignin based products (Binders and aromatic chemicals, asphalt/bitumen)
380300 - Tall oil, whether or not refined	Tall oil (Chemicals)
4802 - Uncoated paper and paperboard, of a kind used for writing, printing or other graphic purposes, and non perforated punchcards and punch tape paper, in rolls or rectangular (including square) sheets, of any size, other than paper of heading 48.01 or 48.03; hand-made paper and paperboard.	Pulp (Graphic paper)
4804 - Uncoated kraft paper and paperboard, in rolls or sheets, other than that of heading No 4802 or 4803	Pulp (Paper board)
4818 - Toilet paper and similar paper, cellulose wadding or webs of cellulose fibres, of a kind used for household or sanitary purposes, in rolls of a width not exceeding 36 cm, or cut to size or shape; handkerchiefs, cleansing tissues, towels, tablecloths, serviettes, bed sheets and similar household, sanitary or hospital articles, articles of apparel and clothing accessories, of paper pulp, paper, cellulose wadding or webs of cellulose fibres	Pulp (Toilet paper)
52 - Cotton.	Cotton fabrics (Woven fabrics, table and bed linen, sacks and bags)
5105 - Wool and fine or coarse animal hair, carded or combed (including combed wool in fragments)	Wool fabrics (Textile)
530310 - Jute and other textile bast fibres, raw or retted	Jute (Textile)
5306 - Flax yarn	Flax (Textile, table linnen)
5302 - True hemp (Cannabis sativa L.), raw or processed but not spun; tow and waste of true hemp (including yarn waste and garnetted stock)	Hemp (Textile, insulation materials)
4107, 4112, 4113, 4114 - Leather further prepared after tanning or crusting, including parchment-dressed leather, of bovine (including buffalo) or equine animals (4107), sheep or lamb	Leather (Clothing, textiles)

(4112), other animals (4113) without hair on, whether or not split, Chamois (including combination chamois) leather; patent leather and patent laminated leather; metallised leather (4114)	
4001 - Natural rubber, balata, gutta-percha, guayule, chicle and similar natural gums, in primary forms or in plates, sheets or strip	Natural rubber (Tyres, various products)

1.2.1 Task 3.3 Level of certification and labelling of biological resources, bio-based products and materials

Introduction

The goal of Task 3.3 is to provide insight in the level of sustainability certification and labelling of a selection of biological resources, bio-based chemicals, wooden products and fibre-based products, using best available data sources, and best possible estimations in case of low data availability. Secondly, it showcases three different approaches to of data collection on the level of certification and introduces a method to indicate the level of uncertainty of the results.

Challenges

This task aims to determine the level of sustainability certification and labelling for a selection of the feedstocks and bio-based products. Data on the level of sustainability certification of specified bio-based products is scarce. Statistics do not disclose any data on flows of certified versus uncertified bio-based products. For biological resources and some wooden products and fibre-based products, country level data is available from certification schemes or literature. For many bio-based chemicals, this type of information is not available, meaning that the level of sustainability certification has to be determined using company level data, for example by checking whether the company has a sustainability certificate. However, most certification schemes publish only company names & certified products, and do not disclose amounts of certified product nor their destinations. Similarly, companies usually do not disclose amounts of certified bio-based products as this is competition sensitive information. Moreover, each value chain consists of various products with different trade flows. Therefore, it is very complex and labour intensive to determine the level of certification of each intermediary chemical. Finally, two issues add up to uncertainty: companies with a certificate may certify only part of their bio-based production volume; and given that for drop-in bio-based products, statistical data is generally not available, this makes any statement on level of certification even more uncertain.

Determination of the level of certification

As a first step, the value chain of each product is briefly described and visualised using a blockchain diagram. Next, the main producing countries or producers of the targeted bio-based chemicals and materials are identified. Depending on the targeted chemical or material and available information, main producers are identified on country or company level. Initially, we focus on intra-EU production, though in case of no or very little intra-EU production, the major extra-EU producers are targeted. Production data available from Harmonitor Deliverable D3.3 *"Trade flows of biological resources, bio-based materials and products*"[6] is utilized for this step, as well as information from, amongst others, FAOStat. Depending on data availability, the challenge of identification of the level of certification is taken up, by using three approaches for three different situations:

[6] Groenestege, M., A. Ebbers-Sustronk, J. Spekreijse, R. Hoefnagels, K. Osman, M. Vis (2024) Trade flows of biological resources, bio-based materials and products, HARMONITOR deliverable D3.3, https://www.harmonitor.eu/_files/ugd/e39b13_a44339606c684250980aa7f11fb668e9.pdf

- Approach A: country level data on sustainability certified volumes available
- Approach B: country level data not available, limited number of producers
- Approach C: country level data not available, many producers.

Approach A: country level data on sustainability certified volumes available

If possible and available, the level of certification is determined at country level by using literature, summary reports by certification schemes, scientific research, institutes, etc. This results in a statement on the level of sustainability certification of biological resource or product x as produced in county y.

Approach B: country level data not available, limited number of producers

In case approach A is not applicable due to lack of data, while the number of producers of the product is limited - which is the case for several bio-based chemicals – an effort is made to identify the producers, their production locations and capacities, building on HARMONITOR Deliverable D3.3 *Trade flows of biological resources, bio-based materials and products*[6], complemented by additional search of various sources, such as reports, company websites, press releases, etc. After that, for each company it is checked whether it has a sustainability certificate for its product(s), by visiting the company websites and checking the certificate databases of the relevant sustainability schemes for both the feedstock and product. For example, in case of bio-based chemicals ISCC PLUS is very relevant, and several feedstocks, such as palm oil, cotton, sugar, and wood have specific schemes. This way at least the share of certified produces versus total producers can be identified, resulting in a statement that x out of y producers have a sustainability certificate. In case the production capacities are known, the level of certification can be calculated, by dividing the capacities of companies holding a sustainability certificate, by the total production capacity of all companies producing the product, giving an indication of the level of certification. Please note that we assume that, if a company is certified, we assume that the whole production volume is certified, unless we find other indications. This can potentially lead to an over estimation of the level of certification of bio-based products. In cases where it is very likely that the whole volume of at least the feedstock is certified, for example, if glycerine is used as byproduct of biodiesel production, which needs to be certified to count to EU transport targets, this is indicated in the text.

Approach C: country level data not available, many producers

If approach A and B are not possible, e.g. no literature on the level of certification is available while there are many producers of the biological resource or product, the number of chain-of-custody (CoC) certificates of the main certification schemes of the product are counted per country, providing insight into which countries have relatively more or less certificates compared to the total production of the product in overall countries as found in statistics. The databases of certification schemes (e.g. FSC, PEFC, GOTS) are used to check how many CoC certificates have been issued for the product in the respective countries. The number of CoC certificates per country is then compared to the total number of certificates. Only certificates within the EU27 are taken into account. This means that the basic represents the number of certificates within the European Union per product category. Additionally, the share of European certificates in the total number of certificates issued worldwide is also given. These relations serve as an indicator of the scale of issued certificates within European countries. In order to guarantee the reproducibility of the results, the databases were filtered according to the following criteria:

FSC

- Certificate status = valid
- Certificate type = Chain of Custody (CoC)
- Role = “no filter”

PEFC

- Site/member status = valid
- Certificate type = Chain of Custody (CoC)
- Certificate subtype = Any (“no filter”)
- Activity = Any (“no filter”)
- Licence type = Any (“no filter”)

The access date and the specific product category are stated. Furthermore, a comparison is made between the proportion of production in the five leading European countries and the proportion of CoC certificates. The final tables present data on the share of CoC in each country, with colours indicating whether this share is above the share of production within that country. The following explanations refer to the colours used:

- | red | Production share above share of CoC certificates
- |orange | Production and CoC certificate share are nearly equal
- | green | Share of CoC certificates is higher than the share of production volume

The presence of green colouring could be an indication of the increased importance of certification in these countries. However, this should only be seen as a rough indicator, as there are no associated market volumes and it is uncertain whether the certified products are intended for export. This indicator therefore only represents the production side and does not allow any conclusions to be drawn about the market share on the consumption side.

Uncertainty indicator

The data on the level of sustainability certification of biological resources and bio-based products has been obtained from a variety of sources with different levels of reliability. To enable the reader to distinguish between reliable and less reliable data sources, an uncertainty indicator was developed, ranging from 1 for very reliable data to 5 for the least reliable data. The uncertainty indicator is determined by (a) data availability and (b) quality of the data source, which also both range from 1 to 5. The highest rank of both aspects determines the resulting uncertainty indicator value.

Data availability

Data availability is determined by the following criteria.

Criteria to determine data availability	Score	Meaning
Actual total production of certified + non-certified material known	1	very good
Production volumes of certified product known	2	good
Production capacities known	3	satisfying
Production locations or sustainability certificates identified	4	uncertain
No data found	5	highly uncertain

Quality of the data source

The quality of the data sources is determined as follows:

Criteria to determine the quality of the data source	Score	Meaning
directly obtained from companies	1	Very high quality
scientific peer-reviewed literature, statistical data, data from market data specialists	2	High quality
Data from other reports and websites	3	Moderate quality
Authors' estimates	4	Low quality

The quality of data depended not only on the data source but on several additional factors. The base scores as defined above were adjusted (up to a maximum score of 5) when any of the following circumstances applied:

- For every 5 years that have passed since the publication of the data: +1.
- For every calculation performed with the data: +1[7].
- When multiple different data sources independently included similar data: −1.
- When multiple different data sources included different data: +1.

After assessing the two indicators, data availability and data source, we combine them into an overall uncertainty indicator. The overall indicator is determined by the highest values within the individual indicators.

[7] Not applied in case of conversions with low loss of reliability

Appendix C. Methodologies of WP4

Introduction

This document contains the methodology for developing and implementing the Comparative Benchmark Tool (CBT), which will be used to conduct the comparative analysis of Certification Schemes and Labels (CSLs), as defined in WP 4.2.

This methodology was developed by Preferred by Nature.

General description of objectives

WP4: Review and analysis of selected existing CSLs for biological resources, bio-based materials and products.

This document outline of the methodology for benchmarking used in Work Package 4 (WP4).

The lead beneficiary of WP4 is Preferred by Nature (formerly NEPCon). The objective of WP 4 is to "conduct a comparative analysis of the selected CSLs regarding certified environmental, social, and economic impacts including trade-offs, as well as the robustness and effectiveness of the assurance and governance systems that support each scheme in achieving those intended impacts."

The Scheme Evaluation Framework will be used to assess the scope of normative requirements, as well as the robustness and effectiveness of selected CSLs. This deliverable is produced from the

Summary of WP 4

The methodology contained in this document forms part of WP 4, summarised below.

WP 4 consists of 3 tasks as detailed here; (I) Task 4.1 Develop an inventory of key aspects of CSLs, (II) Conduct a comparative analysis of selected CSLs and, (III) Validation and final comparison study.

Task 4.1 - Develop inventory of key aspects of CSLs. (Preferred by Nature, DBFZ, Utrecht University, RINA CONSULTING).

A scientific and other literature review will be conducted regarding sustainability of CSLs, focusing on schemes for bio-based products. This will include insights from recent studies reviewing individual value chains etc., tools and practices that focus on measuring the effectiveness and robustness of CSLs. The review will focus on quantitative aspects (how long has the certification scheme existed, number of certificates, etc.) and qualitative (e.g., easiness of certification procedures, communication effectiveness, etc.). Desktop research will review system documentation available for selected CSLs, serving as a basis for producing an inventory of key aspects for the CSL comparative analysis (task 4.2). Implications about the transparency of CSLs will be derived, as key gaps in available documentation will also be identified. (Months 5-12).

3. **Subtask 4.1.1:** Literature review of sustainability CSLs. (DBFZ, RINA CONSULTING)
4. **Subtask 4.1.2:** Inventory of certifiable biological resources, bio-based material and products covered by selected CSLs. (DBFZ, RINA CONSULTING)
5. **Subtask 4.1.3:** Inventory of environmental, social, and economic requirements, including control points examined during audit assessments. (Preferred by Nature, RINA CONSULTING)
6. **Subtask 4.1.4:** Inventory of assurance system requirements, relating to how compliance with the scheme requirements is ensured. This includes protocols that are meant to ensure effectiveness, robustness, and other aspects of how the scheme operates. (Preferred by Nature)
7. **Subtask 4.1.5:** Inventory of governance system requirements, including aspects such as impartiality, transparency, stakeholder engagement, impact measurement, etc., determining overall CSL credibility. (Utrecht University)

Task 4.2 - Conduct comparative analysis of selected CSLs. (Preferred by Nature, Utrecht University, agroVet, RINA CONSULTING).

Using this methodology defined in Task 2.3 (this document), and inventory of key aspects of each scheme (D 4.1), this task will conduct a comparative analysis of each selected CSL, including the extent to which each scheme assesses and certifies values regarding:

- **Subtask 4.2.1:** Environmental, social, and economic impacts and trade-offs. (Preferred by Nature, RINA CONSULTING, agroVet)

8. **Subtask 4.2.2**: Assurance system requirements. (Preferred by Nature, agroVet)
9. **Subtask 4.2.3**: Governance system requirements. (Utrecht University, agroVet)

Notable gaps across the CSLs will also be analysed, where expected contributions to social or environmental impacts are not being realised (Months 10 - 21).

Task 4.3 - Validation and final comparison study. (Preferred by Nature, Utrecht University, DBFZ).

Draft results of the comparative analysis will be open for consultation with stakeholders, including scheme owners. This activity is closely coordinated with tasks 2.2 and 7.1, where CSLs are engaged to ensure proof of concept. This step is crucial to avoid misunderstandings, follows best practices, promotes transparency, and adds to the overall credibility and sustainability of results. The findings will become an important part of the HARMONITOR Platform (task 2.4). After consultation, the final comparison study will include:

(i) description of the methodology used (based on outputs from task 2.4);
(ii) results of comparison analysis of each selected CSL;
(iii) results of the stakeholder consultation process;
(iv) synthesis on how selected CSLs perform as a group; and
(v) overall conclusions and recommendations. (Months 21-31),

Preparation of the Scheme Evaluation Framework

The Scheme Evaluation Framework (SEF) is the Framework that forms the base of the Comparative Benchmark Tool (CBT). The CBT is the tool that is going to be developed in order to conduct the comparative analysis of each of the selected CSLs in WP4.

The SEF has been developed with the objective of reviewing and analysing sustainability certification schemes and labels using a systematic and comprehensive approach to assess the credibility and effectiveness of the schemes.

Below are the key steps that were followed in the development of the SEF itself:

1. Define the objectives: The formulation of the criteria and indicators of the SEF was based on Specific Objective 3: "*To review and compare performance requirements (criteria and indicators) and assurance and governance systems for comprehensive sustainability coverage of international and EU CSLs for bio-based systems*."
2. Review existing frameworks: Certification systems typically consist of three key components: the requirements placed on certificate holders, certification bodies, and the certification scheme itself. Here is a brief overview of each:
    a. Requirements placed on certificate holders: Certification systems establish certain criteria and standards that certificate holders, such as companies or organisations, must meet to obtain and maintain certification. These requirements vary depending on the certification system's specific sustainability goals and objectives. They may include compliance with environmental regulations, adherence to social responsibility standards, implementation of sustainable practices, and transparency in reporting.
    b. Certification bodies: Certification bodies are independent entities responsible for evaluating and verifying the compliance of certificate holders with the certification scheme's requirements. They play a crucial role in assessing and certifying the sustainability performance of organisations. Certification bodies should be accredited, meaning an accreditation body has formally recognised them for their competence and impartiality. They follow specific protocols and procedures to ensure consistent and reliable evaluations.
    c. Certification scheme: The certification scheme encompasses the overall framework, guidelines, and rules governing the certification process. It defines the specific requirements, criteria, and indicators used to analyse and assess the sustainability performance of certificate holders. The scheme may include documentation requirements, on-site inspections, data collection, verification processes, and periodic audits. It also establishes the terms and conditions for obtaining, maintaining, and displaying the certification and any fees or costs associated with the certification process.

    It's important to note that certification systems' structure and specific details can vary significantly depending on the specific sustainability domain, such as organic farming, energy efficiency, or fair trade. Different sectors and industries may have their own unique certification requirements and schemes tailored to their specific needs and challenges.
3. Identify key criteria: The criteria that will form the basis of evaluation are aligned with internationally recognised sustainability principles and cover various dimensions, such as environmental impact, social responsibility, economic viability, and governance, as well as the

qualitative aspects of scheme implementation and oversight. The indicators covering sustainability requirements are derived from the Preferred by Nature Sustainability Framework.

Based on the objectives, literature review, and stakeholder engagement, develop specific evaluation criteria for each stakeholder group. Consider the following aspects:

a. Certificate holders: Criteria that assess the sustainability performance of the organisations seeking certification. This includes their environmental impact, social responsibility, governance practices, supply chain management, stakeholder engagement, and transparency in reporting.

b. Certification bodies: Criteria that analyse the competence, independence, and integrity of the certification bodies. This may include their accreditation status, adherence to recognised evaluation methodologies, training and qualifications of evaluators, quality assurance mechanisms, and ethical conduct.

c. Scheme owners: Criteria that assess the robustness and effectiveness of the certification scheme itself. This may include the clarity and transparency of the scheme's guidelines, accessibility to different stakeholders, management of conflicts of interest, stakeholder engagement in decision-making, continuous improvement mechanisms, and monitoring and enforcement procedures.

Establish evaluation indicators: The criteria have been translated into measurable indicators or metrics. Indicators are developed to be clear and specific. They allow for quantitative or qualitative assessment of the performance of each CSL.

Overview of the Scheme Evaluation Framework requirements

As described above, the SEF consists of criteria and indicators applicable to certificate holders, certification bodies and the scheme owners themselves, aiming at addressing a) performance requirements; b) assurance system; and c) governance system.

The SEF is developed in an excel worksheet with different tabs, dividing the evaluation requirements in different sections.

The CSLs reviewed under WP4.1 shall be based on the list of CSLs provided by WP2. This comprehensive list also designates the CSLs according to the commodity it covers. The WP4 partners selected the CSLs for WP4.1 based on; presence in the EU, variety in feedstock type to cover as many industries as possible, partners individual experience with the CSL, and if it was covered by the Standards Map developed by the International Trade Centre.

A: Certificate holder requirements

This component corresponds to subtask *"4.1.2 Inventory of environmental, social, and economic requirements, including control points examined during audit assessments"*

The certificate holder requirements shall be used to analyse the normative requirements of the specific CSL, relevant for the certificate holders.

The Certificate Holder requirements are labelled A1 through A5 in the Excel sheet and include the following sections:

A1: Land-Use Requirements

This list contains the SEF requirements for CSLs' sustainability – the objective is to analyse the scope of how the CLSLs define sustainability issues and how well their normative requirements are defined.

These requirements are derived from the Sustainability Framework and cover the following sustainability aspects:

1. Management and business practices are responsible.
2. People's well-being and human rights are respected.
3. Nature and the environment are protected.
4. Climate impacts are reduced and mitigated.

A2: Supply chain requirements

These requirements include fundamental sustainability requirements for CSLs, aimed at the supply chain entities. The objective is to analyse how well the standards of the Schemes include subjects particularly related to human rights issues in processing, trade and manufacturing.

The key question the evaluation of these requirements should answer is if the scheme includes a complete and comprehensive set of requirements enabling the evaluation of compliance with applicable sustainability issues by the certificate holder?

A3 Requirements for material control

Does the scheme include requirements to ensure that material from unknown sources is not mixed into the product flow included in the scope of the certification? This may be via a CoC system using different forms of physical separation or risk-based supply chain management approaches. It should be underlined that it is not a requirement of the SEF that schemes have a specific type of CoC system, but there does need to be performance requirements that assure the absence of mixing.

A4 General requirements for Certificate Holders

These requirements relate to evaluating how the CSLs include measures to control potential conflicts and manage corruption risks within the Certificate Holder's operations.

A5 Quality and procedural requirements for Certificate Holders

The SEF contains criteria that shall be used to assess how the scheme ensures that Certificate Holders have in place systems, capacity and qualifications to continually meet the Scheme requirements.

B: Certification body requirements

This component corresponds to the following subtask: "*4.1.3 Inventory of assurance system requirements, relating to how compliance with the scheme requirements is ensured. This includes protocols that are meant to ensure effectiveness, robustness, and other aspects of how the scheme operates.*"

- General Certification Body requirements
- Certification Body requirements for auditing and certification

These criteria are formulated to assess the system of the Scheme that should be in place to manage processes like accreditation, oversight, competence and resources in relation to Certification Bodies.

C: Scheme requirements

This component corresponds to the following subtask: "*4.1.4 Inventory of governance system requirements, including aspects such as impartiality, transparency, stakeholder engagement, impact measurement, etc., determining overall CSL credibility.*"

The criteria are defined as follows:

- Transparency
- Standard setting
- Accreditation
- Certification process

These criteria are formulated to assess the system of the Scheme that should be in place to manage Standard setting and revision, as well as ongoing scheme maintenance and development, including scheme transparency, managing complaints etc.

Template tools

Assessment of certification schemes shall follow *this procedure*, and use the following documents:

- Certification Scheme Evaluation Framework (SEF);
- Certification Scheme Benchmarking template (Scheme specific version of the SEF)
- Certification Scheme Evaluation Report (SER) template;
  - SER shall be in excel
  - A summary of SER shall be developed in Word and provided with a narrative describing the project and short intro to the scheme.

Steps of the Evaluation process

The Scheme Evaluation process has a number of distinct steps that shall be followed. These comprise, in the following approximate order and are discussed in turn:

1. Application of the SEF by experts (*Evaluators*),
2. Quality review,
3. Consultation – including scheme owners

1.2.2 Step 1: Application of the Scheme Evaluation Framework

This step shall include communication with the Scheme owners/managers to inform them of the evaluation, as well as to ensure that the Evaluators have access to the correct and sufficient information about the scheme functioning.

The application of the Evaluation Framework shall be applied on two levels:

- Evaluation of the Scheme at the overall (international) level
- Consideration of how the Scheme will be implemented at the local (national) level. The purpose is that national-level evaluation is to provide data and findings that feed in as evidence into the central-level evaluation.

Following the methodology described below, the draft evaluation report shall be developed. The evaluation shall be done in the excel based SEF template, and the result shall be presented in a separate Word report based on the Excel SEF.

1.2.3 Step 2: Quality review

The Evaluator (Preferred by Nature team responsible for the application of the Evaluation Framework) shall ensure quality checks of draft scheme assessments before the report is shared with the Scheme owner.

The objective of the quality review is to ensure:

- the assessments have complied the method described in this document;
- the rigour of the evaluation process, as well as;
- the consistency of the evaluation approach across all Scheme evaluations.

The results of the review shall be provided by reviewers in writing to the Evaluators, who shall make sure to store all comments, as well as integrating the comments into the Evaluation itself.

1.2.4 Step 3: Consultation – including scheme owner

Stakeholder consultation shall be implemented, using the draft evaluation of each scheme. This activity is closely coordinated with tasks 2.2 and 7.1.

Scheme owners shall be directly contacted and supplied with the draft evaluations and have the time (minimum three weeks) to review and provide comments. Also, one (or more, where necessary) call with scheme owners shall be arranged to present the draft findings and allow the scheme owners to ask questions and provide feedback. It shall be underlined that direct and clear communication with the scheme owners is paramount to the evaluation process.

Evaluation Methodology

The main step in this process is the evaluation of how the Scheme is aligned with the requirements of the Framework. This consists of a desk review of documentation about the Scheme's requirements, systems, and operations. Also, additional sources of information will be used beyond what can be provided by the Scheme owner itself.

This section describes the evaluation methodology that will be employed:

In the process of scheme evaluation, the performance requirements of the existing sustainability schemes are benchmarked against the generic the individual requirements of the SEF. The comparison is made **on the indicator level**.

For the scheme standard, we aim to use the **most granular level of auditable requirements**. Often these would be indicators, but the term varies between schemes.

The following outlines the method to be used in the evaluation:

Information gathering

The assessment of each indicator should be conducted primarily using these sources of information:

- Publicly available information from the scheme itself
- Direct interviews and discussions with relevant Scheme personnel
- Stakeholder input via the Stakeholder Consultation

These are addressed in turn below:

1.2.5 Publicly available information from the scheme itself

Identify a clear description of the Scheme normative requirement(s) or other core documents[8] that are considered to cover a corresponding SEF indicator, and record these in the report template.

Note: The Evaluator may contact the Scheme owner and ask them to support filling in relevant information. However, the evaluator has ownership and remains responsible for the content and quality of the input. To this end, all information completed by others shall be checked by the Evaluator.

For each indicator, the following shall be considered by Evaluators, using a systematic approach, to ensure complete coverage of the Scheme in the analysis:

- Relevant types of certification standard
- Models of certification
- The use of approved temporary or interim standards
- Approved final versions of standards/guidance, where the new document has not come into force or is still in a transitional phase

Identify a clear description of the Scheme GUIDANCE or other tools or resources that describe how requirements should be interpreted, which are considered most relevant to the SEF indicator.

Sources referenced in the Scheme Evaluation Report (SAR), shall be described in the following way: i) Certification Scheme (if not indicated in the Standard Code); ii) Standard Code or name; iii) Version; iv) relevant criterion or Indicator; iii) link on the Scheme website. Example:

PEFC ST 2002:2013 2015-12-07 Second Edition, criterion 5.4.1: https://cdn.pefc.org/pefc.org/media/2019-02/023fae13-c278-4104-93e0-bf48b123bc8b/5aa3f8bc-30c3-5f99-951e-e6a8f6d1d01b.pdf

Provide a description (or summary) of the normative requirements and guidance/interpretations.

Other sources of public information will also be considered. This will include insights from recent studies reviewing individual value chains etc., tools and practices that focus on measuring the effectiveness and robustness of CSLs.

The literature review should focus on key aspects of bio-based Certification Schemes and Labels (CSLs). The review is conducted on Google Scholar using specific terms and criteria to find articles published within the past six years. The terms included in the search are: 'meta-analysis', 'critical discussion', 'analysing key aspects', 'review', and 'sustainability assessment'. The governance system of CSLs based on the ISEAL credibility principles is explored, with attention given to different categories of bio-based products and aspects of certifications, such as best practices and market mechanisms.

We will also include conclusions and information available on schemes publicly and on international databases such as the UN Standards Map.

1.2.6 Direct interviews and discussions with relevant Scheme personnel

Interviews with Scheme personnel (and, where relevant, related bodies such as assurance providers, accreditation bodies and certificate holders) are expected to provide the assessment team with information about the intended functioning of schemes and deepen the understanding of the activities of the scheme participants.

[8] These may be Scheme guides, interpretations, directives, policies, procedures or advice notes

At the outset of each Scheme assessment, an 'initial list' of information required from the Scheme may be elaborated, to be presented as soon as possible to Scheme personnel.

The subject matter for future interviews with Scheme personnel, shall vary according to the questions that remain or gaps that require filling in the assessment.

Questions should be formulated by email and written responses with evidence (additional data, information, guidance or normative documents…) requested in return. This will reduce the time for notetaking and ensure accurate records of the Scheme response are recorded.

If necessary, follow-up interviews or calls can be conducted by either phone or online, to clarify questions or responses in the email exchange. Where possible, they should be carried out in the language of the interviewee.

Returned written responses (and/or interview notes) should be saved (with a systematic file name) in the relevant file.

Sources referenced in the Scheme Evaluation Report (SER), shall be described in the following way: i) Certification Scheme; ii) Interview/email date; iii) Interviewee (position).

E.g., BV call-14/10/2020-Head of Accreditation.

E.g., FSC email responsel-09/12/2020-Head of Accreditation.

Evaluation of coverage

The **objective of the analysis** is to understand how well a Scheme is aligned to meet requirements of the SEF.

Sections A1 to A3 may be relatively straightforward to analyse, as they mostly address performance requirements and coverage of the definition of timber legality as far as the EUDR is concerned.

However, sections A4, A5, B and C address issues of quality. As a result, it may not necessarily be the case that a gap (*Partially Covered* or *Not Covered* conclusion) in relation to a single criterion may not necessarily always result in the need to report a significant deficiency or gap in the Scheme as a whole, but rather just point to a potential vulnerability in relation to the Scheme's robustness or potential weakness.

Provide an **appropriate justification** for coverage by the Scheme of the specific indicator in the SEF, as necessary. This will follow the following approximate format:

- Description (or summary) of the normative requirements
- Discussion of findings, including an overview of issues and risks (based on referenced sources) relevant to the indicator. Include any Outcomes or impacts data or information (as per 8.6 above).
- Conclusion & Justification which shall be clearly formulated as **Covered**, **Partly Covered** or **Not covered**. Include a summary justification of the designation to provide the rationale behind the final conclusion. E.g., "*based on findings x, y and z, it is concluded that the indicator is PARTIALLY COVERED*".

Record any variations in conformance between types of certification standard, or certification models. Examples:

"An area of customary rights may be included within the PEFC FM standard, but does not form part of the definition of legality in the PEFC COC Controlled Sources section of the COC standard"

"FSC FM certification and FSC (FM) Controlled Wood standards may cover an indicator, whereas SLIMF certification does not."

Record the level of conformance of the Scheme with the indicator. Options[9] include: 1. Covered, 2. Partially Covered or 3. Not covered.

For A1, conclusions may be made at CRITERION level. In this case, an additional category, "Intent Covered" can be used where the scheme standard meets the intent at a criterion level, even if some indicators may not be fully covered.

An aspect is considered covered if the performance requirements are not simply stated but operationalised with corresponding criteria and indicators, e.g., specific indicators for legal compliance should exist. Each indicator in the SEF is analysed separately for indicator-level comparison. Sometimes there is a one-to-one match between indicators. However, one indicator in the SEF often links to several ones in the benchmarked standard. For example, suppose one indicator from the SEF corresponds to three indicators from the benchmarked scheme. If all of them together cover the SEF indicator, all are marked as "covered". When all three indicators collectively still do not fully address the one from the SEF, all are denoted as "partially covered". The following **issues are considered in the analysis process**:

When the scheme standard includes optional requirements, which are not mandatory (and will not become mandatory in the certification cycle), they are not considered part of the comparison. When there are stepwise requirements (e.g., indicators that become mandatory by a certain year in the programme), they are regarded as normative and will be included in the comparison.

If a scheme standard requires a procedure, we assume that it will be implemented and followed. On the other hand, if the Sustainability Framework requires a specific performance level or outcome, we assume that a relevant system/approach is implemented to achieve the result.

A single general indication in the scheme standard on a topic may not be considered sufficient to fully address the topic. An example would be a single generic statement about legal compliance. If there is such a general requirement, we consider if the scheme defines the scope of the legislation that is regarded as normative and applicable within scheme documentation (i.e., required to be followed). The scope should at least indicate general topics relevant to the criteria where we have legal compliance requirements.

When a SEF indicator does not have a corresponding one in the scheme standard, it is linked to the closest relevant criterion, and if it is not available either, it is linked to the applicable principle. If the criteria directly and explicitly address the indicator, then yes. Otherwise, it is marked "not covered".

When a Sustainability Framework indicator corresponds with an indicator and criterion from the scheme, only the indicator is linked.

In instances where the criterion is not applicable (e.g., animal welfare criterion for some commodities), the criterion is marked as non-applicable. However, when some critical aspects are missing and need

[9] As a result of having only three possible scores, the option of trying to divide partial coverage into a number of different levels is avoided, which carries a significant risk of becoming subjective.

to be addressed, the overall criteria are marked as such, indicating that they are a part of the checklist for field evaluation and need to be considered.

The definitions of the options are as follows:

Conclusion	Definition	Explanation
Covered	When available Scheme requirements and information - and any impacts evidence available - indicate the *coverage* of the SEF indicator.	Coverage is the ability of the Scheme to provide assurance that material traded via the Scheme has a low (negligible) risk of being illegally harvested, traded in line with the legality definition of the EU Timber Regulation.
Intent Covered	There may be differences or gaps in individual indicators within a criterion, however overall intent is addressed.	Intent is covered at a criterion level
Partially Covered	When available Scheme requirements and information - and any impacts evidence available - indicate only *partial coverage* of the SEF indicator. Alternatively, special concerns about Scheme standards, credibility, rigor or coverage may exist. NOTE: It is important to justify the partial coverage and indicate where the issues are which result in a Coverage conclusion not being given.	Partial Coverage means the Scheme is only partly able – or may be compromised in one or more ways – to provide assurance that material traded via the Scheme has a low (negligible) risk of being illegally harvested, traded in line with the legality definition of the EU Timber Regulation.
Not Covered	When available Scheme requirements and information - and any impacts evidence available - indicate that there is *no coverage* of the SEF indicator. NOTE: It is important to justify a no coverage conclusion.	The Scheme is not – or inadequately – able to provide assurance that material traded via the Scheme has a low (negligible) risk of being illegally harvested, traded in line with the legality definition of the EU Timber Regulation.
Not Applicable (N/A)	When, for whichever reason, the SEF indicator does not apply.	

Appendix D. Methodologies of WP5

The description of the final bioeconomy monitoring tool (BMT) has been developed as part of a collaborative effort between the three sister projects SUSTCERT4BIOBASED, STAR4BBS and HARMONITOR. The final outcome level methodology has been submitted as deliverable 5.3 as part of the overall BMT; in parallel to this report (D2.4). We therefore refer the reader to D5.3 for the comprehensive and final methodology. Below, we provide a summary describing the essential components of the outcome level.

The outcome level methodology is the third and final tier of the BIOBASEDCERT Monitoring Tool (BMT), developed collaboratively by the HARMONITOR, STAR4BBS, and SUSTCERT4BIOBASED projects. It focuses on evaluating the effectiveness of certification schemes and labels (CSLs) in terms of their measurable impacts and outcomes. The methodology was developed through an iterative process involving literature review, expert consultations, interviews with CSL representatives, stakeholder workshops, and validation rounds.

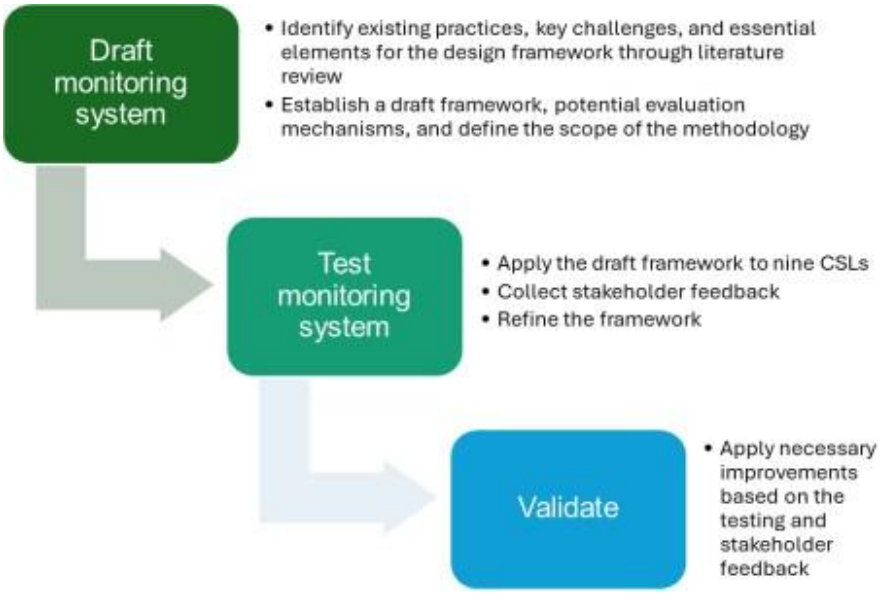

Figure D1 Development Process.

As shown in figure D1, the development of the outcome-level methodology began with a comprehensive literature review. This review highlighted that, compared to governance and sustainability criteria, outcome monitoring remains underdeveloped in CSLs. Drawing on literature such as the Delta Framework and ISEAL guidelines, the methodology established a conceptual foundation that emphasizes tracking measurable progress over time.

Two rounds of testing were conducted, each involving detailed interviews with CSL owners. These interviews explored how CSLs define impact, track progress, and measure sustainability outcomes.

Stakeholders provided feedback on the applicability and relevance of the proposed indicators, which informed successive refinements of the methodology.

The development process culminated in a structured framework, organized hierarchically into categories, principles, criteria, and indicators. Additionally, a set of "add-on" indicators was introduced to represent aspirational aspects of outcome monitoring.

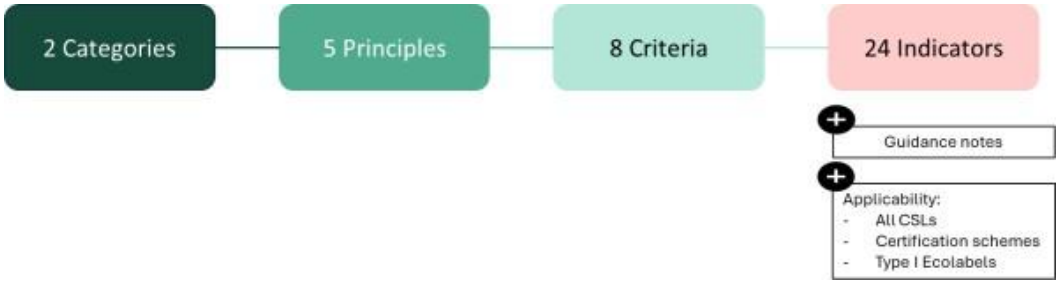

Figure D2 Structure of the BMT outcome level methodology.

As shown in figure D2, The outcome level comprises a structured set of components designed to assess effectiveness, including 2 Categories (Measurable Progress of Operators and Measurable Progress of the CSL), and 5 principles (see below), 8 Criteria (see below) and 24 Indicators. The indicators are applicable to two primary CSL types—certification schemes and Type I ecolabels. Guidance notes accompany each indicator to ensure consistent interpretation and application across different types of schemes.

The key principles and criteria of the methodology are:

1. **Measurable Progress of Operators**

This principle evaluates whether CSLs require certified operators to demonstrate progress over time through outcome-oriented performance management. It promotes the idea that compliance should go beyond static requirements, emphasizing ongoing improvement. The criterion belong to this principle is Criterion A.1: Monitoring and demonstration of the effectiveness of the systematic approach to achieve sustainability goals by economic operators and CSL; assessment of sustainability hotspots; baseline assessment.

2. **Impact Monitoring of the Scheme**

This principle requires CSLs to have frameworks such as a Theory of Change or causal pathways to define and assess their intended sustainability impacts. It stresses the importance of tracking actual outcomes using qualitative and quantitative methods. The two criteria that apply to this principle are: Criterion B.1: Clear definition of intended impacts; Theory of Change, causal pathways or similar framework; and Criterion B.2: Regular performance monitoring, outcome evaluation, and impact evaluation; quantitative assessment of sustainability outcomes

3. **Procedures to Validate Impacts**

To ensure the credibility of claims, this principle calls for mechanisms that verify the accuracy and validity of monitoring data. It also applies to scenarios where CSLs recognize third-party schemes, ensuring that performance under such recognition remains accountable. The respective criterion is criterion C.1: Procedure for verification of impact monitoring data; verification of impact monitoring data by third-parties.

4. Reporting or Demonstration of Impacts

Transparency is essential to CSL effectiveness. This principle assesses whether CSLs report on their progress and achievements through detailed and public documentation. This principle goes with Criterion D.1: Regular reporting to track progress, allow comparisons, and explain improvements; quantitative results of monitoring.

5. Continuous Improvement of the Scheme

A CSL's ability to adapt and evolve based on monitoring results and stakeholder input is critical. This principle evaluates whether schemes regularly revise their standards and operations in response to feedback and performance data. Two criteria complement this principle: Criterion E.1: Revision of standards based on operator progress; and Criterion F.1: Continuous learning and improvement of the standard

The BMT outcome-level methodology is intended to support continuous improvement within individual certification schemes, rather than to enable direct comparisons across different schemes. Accordingly, the associated evaluation mechanism is designed to identify areas for internal development and enhancement. In line with this purpose, the methodology adopts a qualitative rather than quantitative scoring approach, allowing for nuanced, non-numeric assessments of CSL performance against the outcome-level framework.

The benchmarking process applies a four-tier qualitative assessment scale: Fully, Partly, Missing, and Not Applicable. Assessment results are presented at the indicator level, with indicators organised under their respective criteria (see Figure D3). This structure offers a detailed overview of each scheme's strengths and areas for improvement, thereby facilitating focused, scheme-specific enhancements.

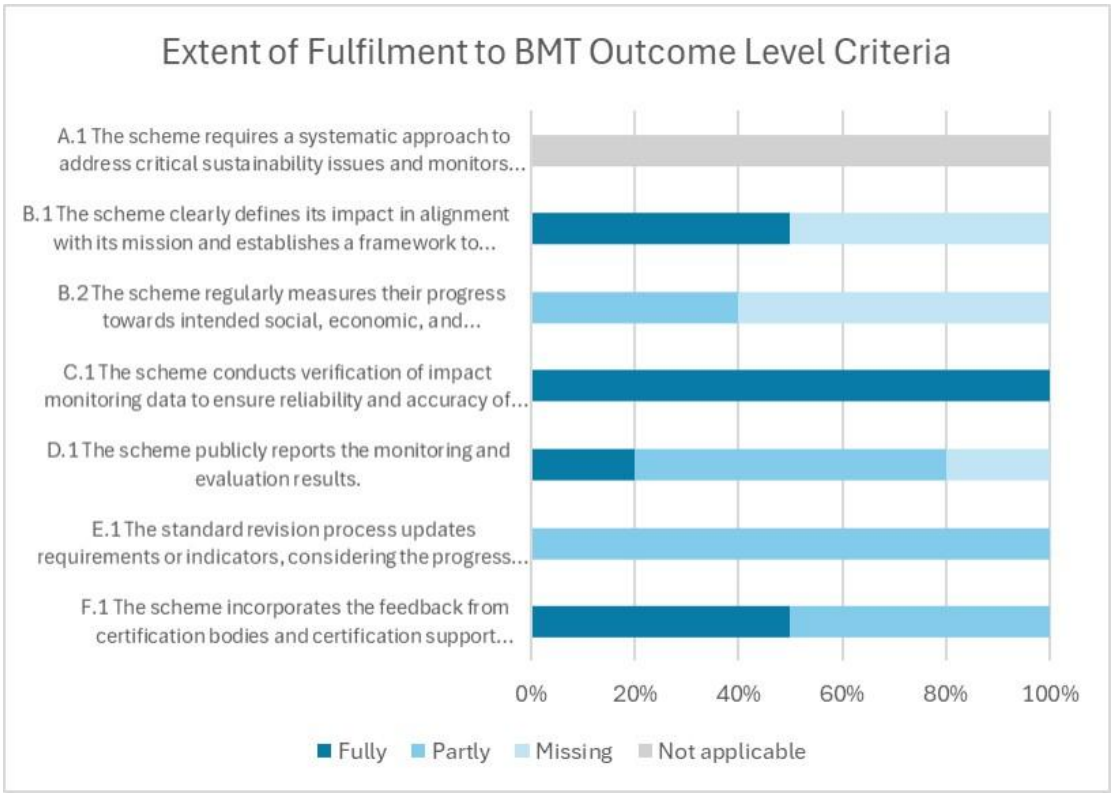

Figure D3. Example visualisation of benchmarking results. The percentage refers to the degree of fulfilment of the assessed CSL with respect to a criterion.

The evaluation mechanism is also supported by a structured approach to evidence collection, organised around three sequential gates:

1. Availability of evidence – confirming that relevant documentation or data exists.
2. Consistency of evidence – where multiple sources are available, assessing whether they lead to the same conclusion.
3. Demonstration of progress – evaluating whether the evidence shows measurable improvement over time.

An illustrative example of this assessment and visualization process is provided in Table D1.

Table D1 Illustrative example of assessment results for a fictitious scheme, visualising results from the literature review

BMT Sustainability Principle	Impact monitoring indicators	Data from CSL owners			Data from independent parties	
		Regularly monitored?	Regularly reported?	Trend identified?	Evidence from third party available?	Consensus reached?
ENVIRONMENTAL						
Climate change	Greenhouse Gas emissions per tonne of certified materials produced					
Chemical use	Volume of pesticide active ingredient applied					
SOCIAL						
Portection of labour rights	Numbers of workers protected under CSL standard					
ECONOMIC						
Productivity	Yield					

Indicators under the Measurable Progress of Operators principle apply specifically to certification schemes, while those under the remaining four principles generally apply to both certification schemes and ecolabels, with exceptions clearly stated in the guidance notes.

This methodological clarity ensures fair and context-sensitive assessments. For example, Type I ecolabels—designed to recognize best-in-class products—are not expected to show operator-level improvement in the same way as certification schemes, which often require ongoing performance tracking.

Finalization and Reassessment

Following validation and stakeholder feedback, the methodology was finalized, and participating CSLs were reassessed. This reassessment confirmed the improved usability and relevance of the indicators and helped generate updated benchmarking results. These results are shared with CSL owners to identify strengths and opportunities for improvement.

In summary, the outcome level of the BMT provides an essential lens for understanding whether certification schemes are truly effective in achieving sustainability goals. By emphasizing both measurable progress and procedural robustness, it lays the groundwork for credible and transparent sustainability certifications within industrial biobased systems.

Appendix E. Methodologies of WP6

WP6 methods

Certification of biological resources and bio-based value chains entails costs and benefits that depend on the type of CSL, the level of stringency in terms of sustainability criteria and assurance system, the quantification and monetization of externalities, and case-specific characteristics such as e.g., biological resource, agricultural or forestry management practices, value chain, and location. Questions on better understanding the economic feasibility of CSLs can come from diverse backgrounds. For example, a policy maker may want to know the costs of certification at an ambition level of sustainability requirements as a co-regulation instrument in the policy framework of the EU bio-based economy. A market actor may want to know the direct and indirect costs for getting certified and getting access to the EU market, or whether increased costs from getting certified can be recovered by increased benefits from the certification. A certification scheme operator may ask what the costs are from transitioning a scheme with minimum sustainability requirements towards more stringent requirements for specific aspects or for the entire scheme. So far, there is a lack of detailed understanding of the economic feasibility of certification, including the variability of results depending on the biological resources, value chains and uncertainties in method and data, and the net effect of certification, i.e., internalizing and monetizing positive and negative externalities for giving a comprehensive overview of costs and economic feasibility of CSLs. Besides economic aspects, the overall feasibility of certification is also affected by non-economic aspects, for example the administrative and operational steps required for the certification process, the technical capacity within the company, whether external support is available, how the company is organised, and more.

To determine the feasibility and economic performance of CSLs, it is important to distinguish and understand the different associated costs and benefits. For costs, there are: (a) the **direct costs of getting certified** by a CSL (Task 6.1); and (b) the **cost of achieving the sustainability criteria** set by the CSL (Task 6.2). The direct costs consist of, for instance, certification and audit fees, whilst the indirect costs are associated with upgrading the management and production system to meet the sustainability criteria. At the same time, certification promises numerous benefits such as (increased) access to certain end user markets, higher prices for certified products or co-benefits from increased ecosystem services. The latter are called externalities and are not normally valued in monetary terms. They will be quantified to estimate the **co-benefits of CSLs** (Task 6.3). Taking the different direct and indirect costs and benefits from the previous steps, the **overall feasibility** of CSLs were evaluated (Task 6.4).

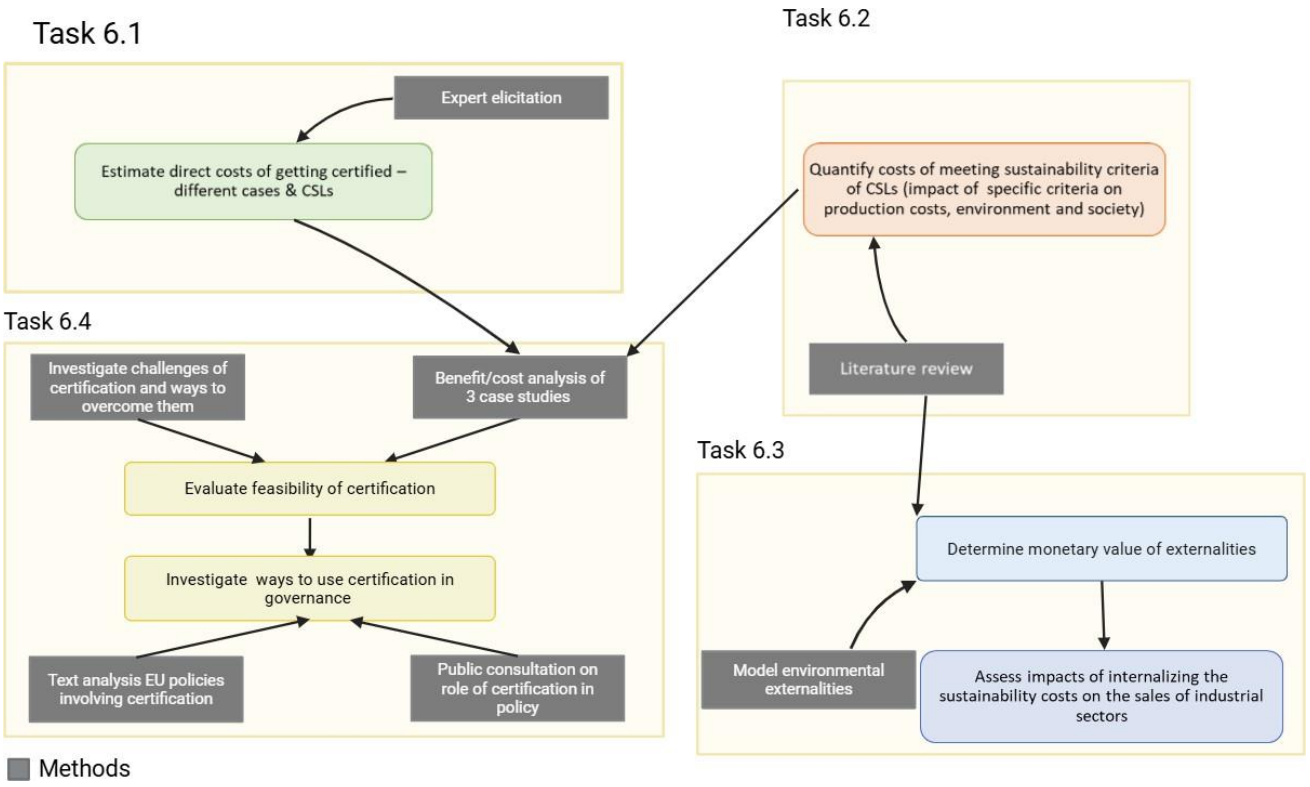

Figure 2. Main tasks of WP6 along with objectives and methods used (methods shown in grey boxes). The arrows show how the tasks/methods are connected with each other.

Task 6.1 Quantifying direct costs of certification

To quantify the direct cost of certification, the following direct cost items of certification are identified:

- the fees charged by the certification body (CB) to conduct the audit;
- fees charged by the certification scheme owners; and
- any fees for trademark usage incurred for participating in the CSL.

The direct costs data were collected for, and then sorted by, the type of certification, supply chain element and region, as these factors influence the costs of auditing or certificate fees. This general information as well as the cost item categories that were collected are provided in Table 4.

Table 4: Overview of data collection for direct costs

General information		Direct cost items
CSL		Certificate fees
Group/individual certification		Annual membership fees (if applicable)
Region		Administration
Supply chain element		Auditing, reporting
Feedstock category		Technical review
Feedstock specific		Expenses
Size of farm (if supplier)		Fees for trademark usage (if applicable)
Annual biomass input (if processor, trader)		

Based on the comprehensive review of CSLs in WP2, the selection of CSLs for the direct cost estimation in Task 6.1 was narrowed down to nine CSLs. This selection was driven by the aim to represent the diversity of CSLs (including coverage of different feedstocks relevant for next analysis steps in WP6) and by consideration of the knowledge and first-hand information on auditing costs available through the HARMONITOR partners, including those not assigned to WP6. The collective expertise is predominantly guided by the partners' role as certification body for various schemes.

By leveraging the combined knowledge and expertise of the project partners, the selection process aimed to capture a well-rounded representation of aspects relating to the direct costs in line with the scope of Task 6.1 and the further use in WP6. The nine CSLs are:

- Forest Stewardship Council (FSC)
- Programme for the Endorsement of Forest Certification (PEFC)
- Sustainable Biomass Program (SBP)
- Rainforest Alliance (RA)
- Global G.A.P
- Roundtable on Sustainable Palm oil (RSPO)
- International Sustainability & Carbon Certification (ISCC)
- Sustainable Agriculture Initiative Platform (SAI)
- Sustainable Forestry Initiative (SFI)

By comprehensively covering direct costs aspects, the current selection allows catering to a very wide selection of schemes and their comparison. The approach allows additional CSLs to be added in the future. WP6 partners have been in contact with certification bodies and other experts in the sister projects to contribute to this.

This method as well as the results were presented in deliverable D6.1.

Task 6.2 Indirect costs and benefits of getting certified

In task 6.2 the indirect costs and benefits of achieving the sustainability criteria set by CSLs are quantified. First, a review of the existing literature on costs and benefits of certification will be conducted. Then, additional information will be collected through a structured analysis of the experience of certification bodies involved in the project and interviews with certification companies. The information gathered will then be used to select and examine 5 case studies to determine the impact of meeting specific sustainability criteria on the production costs, environment, and society. The studies will be chosen trying to represent the diversity of the bio-based economy as much as possible.

Methods literature review

The aim of the literature review is to determine the direct and indirect costs and benefits of getting certified. The focus of the review will be on the agricultural and forestry products, and within these sectors specifically address currently underrepresented and relevant feedstocks, such as palm oil, natural rubber, soybean, sugar cane, wood, and raw cotton. The study will follow a systematic approach based on the PRISMA guidelines for systematic reviews (Page et al., 2021)[10]. Different databases will be scanned to find relevant studies. The eligibility of the studies will be determined in two phases

[10] Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., et al. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ, n71.

(scanning titles and abstracts, and full-text reading) based on a set of inclusion and exclusion criteria. A preliminary list of exclusion criteria is:

- Full-text not available
- Not in English
- Only focused on environmental impacts of certification (no socio-economic impacts mentioned)
- Not on feedstocks of interest for the review (i.e., coffee, tea)

Both qualitative and quantitative papers will be included and synthesized; for quantitative studies, data on costs and benefits of certification will be extracted, as well as information on data collection and analysis.

Methods for analysis of case studies

Data on three case studies (palm oil, wood, cotton) were collected from literature. The data were later used in T6.4 to calculate the benefit/cost ration of certification, and the methodology and results are available in D6.3 – Overall feasibility of certification schemes. To complement the data collected from literature, interviews were also conducted (see D6.3).

A detailed description of the methods applied in this task and results can be found in deliverable D6.1, D6.3, as well as the resulting peer-reviewed journal article (Rossi et al. 2024).

Task 6.3 Modelling environmental and social externalities

Description

While the growth of EU's bio-based economy in recent years[1] might be viewed a positive development towards sustainable production and consumption, there are environmental challenges (such as climate change due to GHG emissions, and the use of water and land) associated with producing bio-based commodities and services.[2] These production side impacts refer to the direct impacts of production activities, for instance, the use of water for cultivating wheat in France or Germany, independent of where the biomass is used. To manage and reduce the environmental damage, it is, however, not sufficient to estimate the environmental impacts solely from the production side. Accounting for the environmental impacts caused upstream of supply chains due to the consumption of bio-based commodities in the EU region is also necessary if the environmental footprint of the EU bioeconomy is to be minimised.

Relevant terminology

We use the term "domestic" to refer to any impact caused within the geographical region of focus, and the term "external" to refer to any impact caused outside the region. The consumption of a bio-based commodity by end users in a region can have two kinds of associated impacts- "direct" and "indirect". Direct impacts are those that occur domestically due to the production of a bio-based commodity for consumption by end users within a region. Indirect impacts are the impacts associated with the production of intermediate commodities that are required as inputs to the production of a commodity for end use (or "final demand"). These can be domestic, i.e., when the upstream inputs are produced domestically, as well as external, i.e., when the upstream inputs are imported from other regions. For instance, soy grown in Brazil has some amount of water use associated with it. The soy may be

exported to the Netherlands as feed for livestock. The livestock is consumed by people, i.e., the final demand is for livestock. The water used for growing the soy in Brazil that is an input to the Dutch livestock sector is an indirect external upstream impact of the Dutch livestock sector. Further, the impacts associated with commodities that are imported directly for final consumption (and not as inputs to domestic production processes) also fall under this category. For instance, vegetables and fruits may be imported into a country to be sold directly to consumers.

Approach

We use environmentally extended multi-regional input-output (EE MRIO)[11] analysis to estimate the direct and indirect impacts associated with the consumption of bio-based commodities in all member states of the EU-27. The impacts are estimated at the individual member state level as well as at the total EU region level .

Research steps

1. **Defining relevant sectors (bio-based sectors)**

The first step is to define all sectors that are relevant to the bioeconomy. From the chosen MRIO database, first, the sectors that comprise of biological resources and bio-based products are identified. All sectors are categorized into 1) fully bio-based 2) partially bio-based, and 3) non-bio-based sectors.[1] Seven partially bio-based sectors were identified, namely “Textiles”, “Wearing apparels; furs”, “Plastics basic”, “Chemicals nec”, “Rubber and plastic products”, “Furniture; other manufactured goods nec.”, and “Electricity by biomass and waste”. These were disaggregated into their bio-based and non-bio-based components. Depending on data availability, the sector’s disaggregation was based either on the market share of its bio- versus non-bio components or on its average bio-based trade share (imports or exports) with all other regions combined.

Three data sources were used to disaggregate the sectors: the UN Comtrade database[12], IEA’s World Energy Statistics[13], and a technical report from the European Commission’s Joint Research Centre (JRC)[14]. However, these sources were not specifically focused on the EU, and may not provide data for all EU member states, particularly those with lower GDPs. For these states, EU-level average values for bio-based and non-bio-based shares were applied. A detailed discussion of regions and partially bio-based sectors with missing data can be found in deliverable D6.2.**Quantifying the environmental impacts**

This study uses an Environmentally Extended Multi-Regional Input-Output (EE-MRIO) model to evaluate the global environmental impacts of bio-based commodity consumption by EU-27 member states. The EE-MRIO approach combines economic data from multi-regional input-output (MRIO) tables with environmental impact data, enabling a comprehensive view of supply chain emissions.

[11] Miller, R. E.; Blair, P. D. Input-Output Analysis: Foundations and Extensions, 2nd ed.; Cambridge University Press: Cambridge, 2009. https://doi.org/10.1017/CBO9780511626982.
[12] Statistics Division, Department of Economic and Social Affairs, United Nations. UN Comtrade Database, 2024. https://comtradeplus.un.org/TradeFlow.
[13] International Energy Agency. *World Energy Statistics, 2022 Edition.* https://www.iea.org/data-and-statistics/data-product/world-energy-statistics
[14] Spekreijse, J.; Vikla, K.; Vis, M.; Boysen-Urban, K.; Philippidis, G.; M`barek, R. Bio-Based Value Chains for Chemicals, Plastics and Pharmaceuticals. **2021**, No. KJ-NA-30653-EN-N (online). https://doi.org/10.2760/712499

Data are sourced from the Exiobase database[15], which provides sector-specific environmental impact intensities (e.g., GHG emission intensities) across global regions. The analysis is based on the Leontief input-output model, which assumes a demand-driven economy—final consumption in the EU drives production and associated emissions worldwide.

First, a row vector of environmental impact intensities (say GHG emission intensities) is calculated using equation 1:

$$q = h\,(\hat{x})^{-1} \qquad (1)$$

The column vector *x* denotes the total output of nation-sectors. The row vector *h* is the satellite account row vector of total GHG emissions of nation sectors. The hat (∧) indicates diagonalizing the vector. GHG emissions driven globally by the final demand of each EU-27 member state (*c*) are calculated by equation 2:

$$c = q * L * \hat{y} \qquad (2)$$

The notation *L* denotes the Leontief inverse matrix and is computed as $(I\text{-}A)^{-1}$; *A* is the direct input coefficient matrix, and *I* is an identity matrix. An element a_{ij} of matrix *A* indicates the direct input from nation sector *i* required to produce unitary output of nation sector *j*. The element l_{ij} of matrix $(I\text{-}A)^{-1}$ indicates the direct and indirect inputs from nation sector *i* required to satisfy unitary final demand on nation sector *j*. The column vector *y* denotes the final demand of any EU-27 member state on all nation sectors. Therefore, an element c_{ij} of row vector *c* is the amount of GHG emissions occurring due to the final demand for nation sector *j*.

In this Leontief model, the production activities in an economy are considered to occur in order to meet final demands of regions. These final demands are considered to drive upstream production activities and the environmental impacts associated with them. Therefore, emissions are attributed to regions who finally consume goods and services. In addition to GHG emissions occurring due to consumption from domestic sectors, emissions embodied in imports to satisfy a region's consumption are included. The emissions embodied in exports are deducted. This net emissions value is the region's emission footprint. In this study, the focus is on the final demand of EU countries for bio-based materials.

The MRIO tables are in monetary units (million euros), whereas the environmental satellite accounts are in mixed units (e.g., tonnes of GHG emissions per million euros output of a sector). The results are in physical units (e.g., tonnes of GHG emissions to meet the final demands of bio-based sectors of EU countries).

For the GHG emissions, carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) emission accounts from Exiobase were collectively considered. The CH_4 and N_2O emissions were converted to their CO_2-equivalents based on IPCC 100-year global warming potential values. As per the Fifth Assessment Report[16], on a 100-year timescale, CH_4 has 28 times greater global warming potential than CO_2, and N_2O has 265 times greater potential than CO_2. Agricultural emissions are included, however, emissions from land use change are not considered. For land use, the Exiobase accounts contain data

[15]Stadler, K.; Wood, R.; Bulavskaya, T.; Södersten, C.-J.; Simas, M.; Schmidt, S.; Usubiaga, A.; Acosta-Fernández, J.; Kuenen, J.; Bruckner, M.; Giljum, S.; Lutter, S.; Merciai, S.; Schmidt, J. H.; Theurl, M. C.; Plutzar, C.; Kastner, T.; Eisenmenger, N.; Erb, K.-H.; de Koning, A.; Tukker, A. EXIOBASE 3: Developing a Time Series of Detailed Environmentally Extended Multi-Regional Input-Output Tables. Journal of Industrial Ecology 2018, 22 (3), 502–515. https://doi.org/10.1111/jiec.12715.

[16] IPCC. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; Geneva, Switzerland, 2014

on cropland, pastures and forests, which were collectively considered. For water use, blue water consumption data was used. Water use impacts vary significantly by region, as equivalent consumption in water-scarce areas poses far greater environmental risks than in water-abundant regions. To reflect this, we adjusted Exiobase water use data using AWARE[17] scarcity factors—differentiated for agricultural and non-agricultural sectors—to create a scarcity-weighted water use account that better aligns with the goals of sustainable water management under the UN Sustainable Development Goals.

Estimating the monetary value of impacts

To bring into a financial context the extent of the impact of EU's bioeconomy on the environment, we estimate the monetary equivalent of GHG emissions driven by the sectors of the EU countries. Such a financial assessment can facilitate more effective communication to decision-makers who are likely to be influenced to a greater degree by economic values as opposed to physical units of environmental damage.

The monetary equivalents are estimated by multiplying the GHG emissions calculated in earlier steps with a monetization factor—representing the cost per unit of CO_2-equivalent emissions. The monetization factor is derived from the True Price Foundation[18], which defines it as the marginal abatement cost—i.e., the carbon price needed to reduce atmospheric GHG concentrations to a level consistent with the 2°C target set by the Paris Agreement. This estimate is based on a meta-analysis of marginal abatement cost models conducted by Kuik et al.[19], and adjusted to 2022 price levels.

The broader "true price" methodology accounts for four cost elements: restoration, compensation, prevention of reoccurrence, and retribution. For climate change, only restoration costs are applicable. While ideally monetization factors should reflect regional conditions, due to the lack of region-specific data, this study uses the global average value of €0.163 per kg CO_2eq as recommended in the True Price report. This value also aligns with the upper-bound estimate used in a CE Delft report[20], serving as a reasonable proxy for maximum abatement costs. The study monetizes only GHG emissions. Land use and water use impacts—while environmentally significant—are not monetized due to the high spatial and biome-specific variability that the EE-MRIO model does not resolve at the required level of granularity.

To further contextualize the costs of emissions with respect to an economy, we take the case of the Netherlands and show how a sector's profits are affected if it were to internalize the production-based GHG emission costs attributed to it. This example demonstrates how internalizing the production-based GHG emissions affects sectoral profits. Production-based GHG emissions associated with the Dutch bioeconomy (covering both domestic consumption and exports) are monetized and compared to sectoral profit estimates, using the "Operating surplus / mixed income (net) by industry" from the 2022 Dutch national accounts. Due to differences in sector classification between Exiobase and the national accounts, bio-based sectors were mapped to three main national account categories, namely, "Agriculture, forestry and fishing", "Manufacturing" (further divided into sub-sectors), and "Electricity and

[17] Boulay, A.-M., Bare, J., Benini, L., Berger, M., Lathuillière, M. J., Manzardo, A., Margni, M., Motoshita, M., Núñez, M., Pastor, A. V., Ridoutt, B., Oki, T., Worbe, S., & Pfister, S. (2018). The WULCA consensus characterization model for water scarcity footprints: Assessing impacts of water consumption based on available water remaining (AWARE). The International Journal of Life Cycle Assessment, 23(2), 368–378. https://doi.org/10.1007/s11367-017-1333-8

[18] Galgani, P.; Kanidou, D.; van Veen, B.; Westrik, H. Monetisation Factors for True Pricing Version 3.0.0; True Price Foundation: Amsterdam, The Netherlands, 2023.

[19] Kuik, O.; Brander, L.; Tol, R. S. J. Marginal Abatement Costs of Greenhouse Gas Emissions: A Meta-Analysis. Energy Policy 2009, 37 (4), 1395–1403. https://doi.org/10.1016/j.enpol.2008.11.040.

[20] de Bruyn, S.; Bijleveld, M.; de Graaff, L.; Schep, E.; Schroten, A.; Vergeer, R.; Ahdour, S. Environmental Prices Handbook EU28 Version; CE Delft: Delft, The Netherlands, 2018.

gas supply". Within "Manufacturing", six sub-sectors were identified as relevant for the bioeconomy, namely, Manufacture of food, beverages and tobacco, Manufacture of textiles and leather products, Manufacture of paper, wood products, and printing, Manufacture of chemicals, Manufacture of plastic and building materials, and Other manufacturing and repair.

While the Netherlands is not fully representative of the broader EU bioeconomy, this case study serves as a proof of concept. Future applications could extend this analysis to other EU countries to assess national-level economic vulnerabilities to internalized environmental costs.

A detailed description of the methods applied in this task can be found in deliverable D6.2. A scientific article is currently being prepared based on this research and will be submitted to a journal before the end of the project.

Task 6.4 Evaluating overall economic feasibility and governance options

The goal of this task was to evaluate feasibility and overall performance of certified supply chains. Costs and benefits of certification were assessed for three case studies (palm oil, wood, and cotton), using data collected in 6.1 and 6.2, as well as interviews to certified producers or certification experts. Besides economic aspects, overall feasibility of certification is also determined by non-economic aspects, which were assessed based on literature and extensive interviews with stakeholders. During these interviews, the main barriers and challenges of certification were discussed, along with possible mitigation measures. After assessing the overall feasibility of certification, governance options to improve feasibility and effectiveness of CSLs were defined.

In a second analysis, it was assessed how certification and other verification instruments are currently used in EU policies related to the bioeconomy and how assurance requirements by the policy translate to assurance requirements by CSLs. This analysis also included assessing stakeholder perspectives on opportunities and limitations of using CSLs as co-regulation instruments for the EU bioeconomy has improved as well as stakeholders' familiarity with certification as a support instrument.

This task was fundamental to broaden the discussion on how to improve the feasibility and effectiveness of sustainability certification for the bio-based economy. The methods for this task include a literature review (see also 6.2), interviews with experts, and two public consultations (one conducted in 2023, one in 2025).

Two public consultations were conducted for assessing the potential and limitations of CSLs as co-regulation instruments and stakeholders' familiarity with CSLs as a co-regulation instrument. The first public consultation was conducted in collaboration with T2.2 (open public consultation). The second public consultation focused these same questions, but also included questions about barriers and strategies to overcome them (for the feasibility analysis part of this task).

A detailed description of the methods applied in this task can be found in deliverable D6.3. Two articles will be prepared based on this work to be published as peer reviewed journal articles: i) barriers and strategies to overcome barriers, and ii) role of certification and other verification instruments in EU bioeconomy policies.