EUROPEAN RESEARCH EXECUTIVE AGENCY (REA)

REA.B – Green Europe
B.3 – Biodiversity, Circular Economy and Environment

AMENDMENT No AMD-101182453-1

Project: 101182453 — bi0SpaCE

The parties agree to amend the Agreement as follows ('**Amendment**'):

1. Addition of an associated partner

The following new associated partner(s) are added as from:

– Noriware AG (NOR): 1 January 2025

This implies the **following changes** to the Agreement:

- The new associated partner(s) and the entry date are added to the list of participants in the **Data Sheet**.
- The new associated partner(s) are added to **Article 9.1**:
  – Noriware AG (NOR), PIC 875604063

2 . Removal of an associated partner

The participation of the following associated partner is ended as from:

- Isopine KLG (PISP):
  - end of work date ('exit date'): 18 October 2024
  - termination date: 18 October 2024 or the date of entry into force of this Amendment (whichever is the latest)

This implies the **following changes** to the Agreement:

- The associated partner is deleted from **Article 9.1**:
  - ~~10. Isopine KLG (PISP), PIC 878580702~~

  and the exit date is added to the list of participants in the **Data Sheet**.

3 . Change of Annex 1

Annex 1 is changed and replaced by the Annex 1 attached to this Amendment.

4. Change of Annex 2

The estimated budget in **Annex 2** is changed.

This implies the **following changes** to the Agreement:

- **Annex 2** is changed and replaced by the Annex 2 attached to this Amendment.
- The table on maximum grant amount and total estimated eligible costs and contributions in the **Data Sheet** is updated.

All other provisions of the Agreement and its Annexes remain unchanged.

This Amendment **enters into force** on the day of the last signature.

This Amendment **takes effect** on the date(s) mentioned in the amendment clause(s) (or — if no date was chosen — on the same date the Amendment enters into force).

Please inform the other members of your consortium (if any) of this Amendment.

SIGNATURES

For the coordinator

JESPER JUEL HOLST with ECAS id njueljes signed in the Participant Portal on 31/01/2025 at 12:42:16 (transaction id SigId-45597-JOIzO
mjUUzlevNcHAzMJosp079G4kyHFM8eCAO1CypyPtoHSZmZKTeVoSz
vJbws8zdXlcwGcUWCSgsQxJYam8Al-jpJZscgsw0KhhY806HcTDK-e7A
YGqNgiu9tDscbAHbRfDEQvBZyhamMcahPsSvrgwStfzyrLdt39vbTT6
dy9CzqUiTDdpQFnRUER1j8a7u6Wx). Timestamp by third party at 2025.01.31 12:42:59 CET

For the granting authority

Signed by Attila BERCZIK with ECAS id berczat as an authorised representative on 12-02-2025 13:53:33 (transaction id SigId-14699-z
zkbJnwqjWMsB8XZg2yf9JWw5a1ZRP2JCZU08W9035vAQtPBlzbSzRsS
5FmFgjk7HjZWNmQuL48dhoTR8akwlfG-
jpJZscgsw0KEWP44BeMPNO-3aUI2gl2zWcoNkr6PGbRt6lunKPruJgaJ
ORkrWk8LG2EgCd2QrvKDPvRj1UgkP4zXzJvthbb99q0kneJe5uXOxG)
2025.02.12 13:53:36 CET

Done in English

Enclosures: Grant Agreement Data Sheet
Grant Agreement Annex 1
Grant Agreement Annex 2

ANNEX 1

Horizon Europe (HORIZON)

Description of the action (DoA)

Part A

Part B

DESCRIPTION OF THE ACTION (PART A)

COVER PAGE

Part A of the Description of the Action (DoA) must be completed directly on the Portal Grant Preparation screens.

PROJECT *Grant Preparation (General Information screen) — Enter the info.*	
Project number:	101182453
Project name:	Industry 4.0 Enhanced Digital Product Passports and Circular Economy Dataspaces for Sustainable Bio-Based Industries
Project acronym:	bi0SpaCE
Call:	HORIZON-CL6-2024-CIRCBIO-01
Topic:	HORIZON-CL6-2024-CircBio-01-6
Type of action:	HORIZON-RIA
Service:	REA/B/03
Project starting date:	fixed date: 1 January 2025
Project duration:	36 months

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PROJECT SUMMARY

Project summary *Grant Preparation (General Information screen) — Provide an overall description of your project (including context and overall objectives, planned activities and main achievements, and expected results and impacts (on target groups, change procedures, capacities, innovation etc)). This summary should give readers a clear idea of what your project is about.* *Use the project summary from your proposal.*
The digital and circular economy (CE) transition of bio-based industries is a critical objective for Europe's climate ambitions and its economic competitiveness. Given the urgency of these demands, Europe's bio-based industries need to leapfrog over past digital technologies and implementations, pioneering innovative solutions for creating bio-based products and services that are circular, as well as environmentally and socially sustainable. To realise these ambitions, the bi0SpaCE project will deliver a suite of technologies, services, guidance frameworks, and standards, combined into the open-access bi0S platform, for rapid deployment and scaling of (CE) solutions and services across bio-based industries and their value chains. bi0SpaCE will advance the creation and implementation of Industry 4.0 enhanced Digital Product Passports (DPPs), linked to an International Dataspace (IDS) compliant CE dataspace, enabling the creation of dynamic and decentralised DPPs for secure and trustworthy sharing of CE and sustainability performance data of bio-based products across the value chain, as well as providing transparency of green and CE claims to consumers. bi0SpaCE brings together a consortium consisting of 1 HEI, 4 RTOs, 1 SMEs, 1 industrial assoc., 2 large industries, and 1 startup, across 5 EU and 2 associated countries, over a 36-month project period. The knowledge and technologies created in bi0SpaCE will be demonstrated and validated across 4 complementary bio-based sectors: (i) paperboard production, (ii) eco-industrial parks with bio-based energy and products producers and consumers, (iii) plant-based products and cosmetics, and (iv) bio-derived industrial chemicals.

LIST OF PARTICIPANTS

PARTICIPANTS

Grant Preparation (Beneficiaries screen) — Enter the info.

Number	Role	Short name	Legal name	Country	PIC
1	COO	AU	AARHUS UNIVERSITET	DK	999997736
2	BEN	FhG	FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV	DE	999984059
3	BEN	CAR	FUNDACION CARTIF	ES	999929836
4	BEN	NISSA	PRIVREDNO DRUSTVO ZA PRUZANJE USLUGA ISTRAZIVANJE I RAZVOJ NISSATECH INNOVATION CENTRE DOO	RS	965052225
5	BEN	UNI	UNI - ENTE ITALIANO DI NORMAZIONE	IT	944380458
6	BEN	FSK	FISKEBY BOARD AB	SE	882132745
7	BEN	GLB	GREENLAB SKIVE AS	DK	899122780
8	BEN	NAT	BIOFACTORIA NATURAE ET SALUS	ES	939400672
9	AP	SSF	SWITZERLAND INNOVATION PARK BIEL/ BIENNE AG	CH	909553093
10	AP	PISP	Isopine KLG	CH	878580702
11	AP	NOR	Noriware AG	CH	875604063

LIST OF WORK PACKAGES

Work packages

Grant Preparation (Work Packages screen) — Enter the info.

Work Package No	Work Package name	Lead Beneficiary	Effort (Person-Months)	Start Month	End Month	Deliverables
WP1	Project management	1 - AU	49.00	1	36	D1.1 – Data Management Plan (DMP) v1 D1.2 – Ethics & AI Use Report v1 D1.3 – Data Management Plan (DMP) v3 D1.4 – Ethics & AI Use Report v2 D1.5 – Data Management Plan (DMP) v2
WP2	Business Cases, Requirements and Architecture	2 - FhG	66.00	1	15	D2.1 – Use cases, KPIs and technical and societal requirements D2.2 – bi0SpaCE ontologies D2.3 – bi0SpaCE technical architecture and data collection framework
WP3	Data-Driven Sustainability and Circularity Assessment of Bio-Based Products	1 - AU	47.00	5	24	D3.1 – Technical documentation on sensor implementation and data pipe-lines D3.2 – Guidelines for environmental foot-printing of bio-based products D3.3 – Data-driven LCA & CE modelling framework D3.4 – Policy recommendations for environmental footprinting of bio-based products
WP4	Digital Technologies for Tracking & Tracing Bio-Based Resources	3 - CAR	46.00	12	24	D4.1 – ML models technology for bio-based process flows D4.2 – Enhanced resilience through improved materials tracing and flow modeling D4.3 – Digital tagging of bio-based products

Work packages *Grant Preparation (Work Packages screen) — Enter the info.*						
Work Package No	**Work Package name**	**Lead Beneficiary**	**Effort (Person-Months)**	**Start Month**	**End Month**	**Deliverables**
						D4.4 – Tracking and tracing technology validation
WP5	Circular Dataspace & Services Development for Bio-Based Products and Industries	2 - FhG	50.00	13	33	D5.1 – AAS-compliant digital twins for bio-processes and DPPs for bio-products D5.2 – bi0SpaCE data space
WP6	Technology Validation in Relevant Industrial Environments	3 - CAR	76.00	18	36	D6.1 – Methodology of validation D6.2 – Validation in relevant environment D6.3 – Lessons learnt and final results
WP7	Technical, Business, and Societal Impact Creation	5 - UNI	63.00	1	36	D7.1 – Dissemination and communication strategy D7.2 – Dissemination and communication report D7.3 – Exploitation plan D7.4 – Standardization Roadmap and CWA project plan D7.5 – Policy recommendations for standardization of DPPs for bio-based products D7.6 – Exploitation Plan Draft

Work package WP1 – Project management

Work Package Number	WP1	**Lead Beneficiary**	1 - AU
Work Package Name	Project management		
Start Month	1	**End Month**	36

Objectives
WP1 will ensure coordination, cooperation, cohesion and overall smooth operation of all aspects of the project in terms of day-to-day management and interfacing with the EC in all the foreseen activities. Project Coordination is led by AU, Technical Management and Scientific Management are led by FhG.

Description
T1.1: Project coordination (Leader: AU; Contributors: All) [M1-M36] This task will involve day-to-day management, the administrative coordination and financial management of the project, including the assessment of deliverables and milestones quality and timing, the establishment of procedures, methods, and tools (quality plan, decision making, risks management, conflict resolution, audits), the communications with the EC, the preparation of administrative reporting, and the organization of project meetings to guarantee the cooperation level needed. This task will also establish coordination activities with the Project Management Committee (consisting of coordinator + WP leaders) and an External Industrial Advisory Board to ensure the delivery of timely and relevant results. T1.2 Technical/scientific coordination (Leader: FhG; Contributors: All) [M1-M36] This task will coordinate technological aspects of the project, to guarantee the expected outcomes and to address potential deviations, and manage technical risks. T1.2 ensures all scientific and social aspects are properly addressed and implemented from both technical perspective and pilot preparation and operation point of view. Periodic virtual and physical meetings will be planned to monitor technical/scientific progress, evaluating the relevance of the proposed solutions and the progress beyond the state of the art. A Data Management Plan which presents the consortium's plan on handling data during and after the end of the project will be made and enforced. FhG leads the technical/scientific coordination of bi0SpaCE, given their specific expertise in DPP4.0 technologies, which play a unifying role in this project. AU and FhG will ensure the coordination of bi0SpaCE is efficient, and establish working agreements and protocols in the grant preparation phase. (Deliverables 1.1, 1.2, 1.3, 1.4, 1.5) T1.3 Risk assessment and management (Leader: AU; Contributors: All) [M1-M36] Risks will be constantly assessed and evaluated within the project duration and risk management will be implement-ed during the whole duration of bi0SpaCE. The project's risk management process will be based on the IRM Risk Management Standard also adopted by FERMA. Initial risks have been identified already (see section on risks below). In T1.3 an internal Risk Registry will be created and maintained reporting risks and their classification/importance determined by likelihood and impact, leading to the exposure level. If a new risk is detected, it is reported to the relevant management structure depending on the impact/ likelihood (Deliverable 1.2, 1.4). WP1 Roles: AU is responsible for administrative coordination and risk management implementation. FhG is responsible for technical/scientific coordination and DMP implementation. All WP leaders (AU, FhG, CAR, UNI) responsible for WP coordination. Participation in coordination procedures, deliverables, milestones, risks planning (All).

Work package WP2 – Business Cases, Requirements and Architecture

Work Package Number	WP2	**Lead Beneficiary**	2 - FhG
Work Package Name	Business Cases, Requirements and Architecture		
Start Month	1	**End Month**	15

Objectives
WP2 will define (i) project scope and stakeholder requirements that support the design of the bi0SpaCE ecosystem and associated scenario implementation, (ii) the technical foundation in terms of ontologies that support the description of

the bi0SpaCE environment and in the design of the technical architecture that supports its deployment, (iii) collection of historical data needed for data-driven models in WP3 and WP4 including data gathering of new information sources (new sensors, external databases, etc.).

Description
T2.1: Experiments scenarios & expectations (Leader: CAR; Contributors: All) [M1-M6] This task will provide an initial high-level analysis of the anticipated pilot scenarios in the industrial sectors. Activities involve the analysis of the as-is situation in the industrial cases, their requirements regarding the anticipated bi0SpaCE innovations and assessment of their capabilities (e.g., in terms of sustainability & CE assessment). A concrete set of goals and objectives will be made related to, but not restricted to, data sharing, sustainability, and traceability, and will be extracted from pilot partners, detailed interviews and then cross-checked with the scientific literature and best practices. In addition, these goals and objectives will be captured by pilot specific KPIs, whose baseline values will be reported together with their calculation methods and the necessary datasets. The overall performance will be continuously evaluated and monitored, enabling bi0SpaCE to assess decision making regarding the necessary strategies and actions along with their prioritization. The outcome of this task will be on one hand three distinct pilot-specific perspectives and on the other a unified conceptual view of bi0SpaCE that will guarantee transferability and impact for virtually any bio-based industry partner. (Deliverable 2.1) T2.2: Technical requirements specification (Leader: FhG; Contributors: CAR, NISSA, AU, SSF) [M4-M9] In T2.2, the user scenarios and business requirements from T2.1 as well as the scientific and technical innovations will be carefully analyzed in collaboration with the researchers and technology providers in order to determine the technical requirements for the solutions to be developed. The main requirements will concern DTs, data-driven models, DPPs, dataspaces and circularity aspects. At the functional level, the requirements will specify the design time (e.g., modelling of DTs and DPPs) and run-time capabilities of the bi0SpaCE ecosystem. At the non-functional level, the requirements will go beyond specifying usability, security, and reliability of the bi0SpaCE ecosystem. (Deliverable 2.1) T2.3: Societal requirements specification (Leader: AU; Contributors: UNI) [M4-M9] In T2.3 a comprehensive desk research study to understand the social requirements, considerations, and implications associated with the adoption and implementation of bio-based solutions across various sectors. Specifically, a literature review will be conducted focusing on academic literature, industry reports, policy documents, and case studies related to bio-based solutions, sustainability, and societal impacts. In addition, a stakeholder mapping exercise will be conducted that will aim to identify and map relevant stakeholders involved in the bio-based value chain, including producers, suppliers, consumers/citizens, policymakers, NGOs, and community representatives. The findings will be synthesized to develop a comprehensive report highlighting the social requirements, considerations, and implications of bio-based solutions. (Deliverable 2.1) T2.4: bi0SpaCE semantics and knowledge graphs (Leader: SSF; Contributors: FhG) [M4-M15] The task will provide for a semantics-based information modelling layer that will link existing or develop new ontologies for bio-based sectors including description of all lifecycle flows, i.e. material, energy, waste, products, and processes. For example, key material standards will be screened from Matportal ontologies (https://matportal.org/ontologies); Material Digital ontologies (https://www.materialdigital.de/); Industrial Ontologies Foundry (https://oagi.org/pages/industrial-ontologies) and the Knowledge Graph Alliance (https://www.kg-alliance.org/), among other sources. The bi0SpaCE top-level and domain-specific ontologies will be used to describe actors in the bio-product data space, their interactions, the DPPs they exchange, and DPP data usage restrictions. In addition, they will serve to semantify digital twins of bio-based processes and will support the development of data-driven models in WP3. Finally, the task will deal with management of datasets and associated data spaces, as the labelled datasets should be stored in a repository to foster reusability. The task involves annotating datasets with the bi0SpaCE ontology such that all necessary metadata (e.g. provenance-related) are available for adequate reuse in the form of appropriate Knowledge Graphs and made available respecting market standards. (Deliverable 2.2) T2.5: bi0SpaCE technical specification and system architecture (Leader: FhG; Contributors: NISSA, SSF, AU, CAR) [M7-M15] This task will define the system-level specification of bi0SpaCE, including high-level view of the layers and components, as well as tools and applications, and their interaction patterns. The basic system functionalities emerging from the requirements analysis will be mapped against the different system entities. Each module will be further decomposed into high-level functional blocks (to be used as basis for the subsequent detailed specification of each component) and supported primitives and interfaces. To enhance flexibility, a modular design will be pursued, while technology neutrality and/or standard interfaces will be considered as far as possible to maximize usability. To ensure a smooth deployment and monitoring of all project artefacts a project scope matrix with all specifications artefacts and the corresponding mappings will be maintained and will be the reference document for requirements and all specifications. (Deliverable 2.3)

T2.6: bi0SpaCE data collection framework (Leader: NISSA; Contributors: AU, CAR, FSK, GLB, NAT, NOR) [M7-M15] This task involves identifying and describing relevant data sources and collecting historical data to be used by data-driven bi0SpaCE services to train the corresponding models. The data infrastructure will be set early in the project with the aim to make the data available and construct early on test cases for accelerating the bi0SpaCE components development and testing. This will ensure that all consortium partners have access to the necessary data for experiments during the realization of the project. If necessary, the data is pre-processed. To ensure that the same data sources can be used in real time, they will be described with metadata for each type of data source (i.e. a machine, software system or sensor), its communication protocol or integration interface and all parameters. (Deliverable 2.3) WP2 Roles: FhG will lead all technical activities with the support of all research and technical partners. While the business requirements will be led by CAR with input from all partners, the societal requirements will be coordinated by AU with support from UNI. NISSA will work with the pilots to collect relevant historical data and prepare them for analysis. SSF will be responsible for the creation of bi0SpaCE ontologies and knowledge graphs and together with FhG will clarify their use for DPPs.

Work package WP3 – Data-Driven Sustainability and Circularity Assessment of Bio-Based Products

Work Package Number	WP3	**Lead Beneficiary**	1 - AU
Work Package Name	Data-Driven Sustainability and Circularity Assessment of Bio-Based Products		
Start Month	5	**End Month**	24

Objectives
WP3 will deliver technological building blocks enabling bio-based industries to assess, predict, and optimize sustainability and CE performance of their bio-based products. A specific emphasis will be placed on advancing simulation- and machine learning-based tools for the above, as well as advancing the assessment methods themselves. Results from WP3 will be implemented as DT enabled services in WP5.

Description
T3.1 Implementation of inventory and emissions data collection sensors (Lead: NISSA; Participants: All) [M5 – M15] This task will deliver the sensor infrastructure for the measurement of process inventory data (e.g., energy, water), operating conditions (e.g., pH, dissolved oxygen), and emissions (e.g., dissolved effluents in process water, biowaste) for the four bi0SpaCE pilots. This enables continuous tracking of process resource flows and exchanges for building online LCA and CE assessment models of bio-based processes, as well as developing causal, data-driven models for improving process performance. Data requirements for generating process life-cycle inventory models will be assessed, and a preliminary inventory for the LCA based on the data collection framework in T2.5. Cur-rent data aggregation, process information already captured, data collection infrastructure and communication protocols, data gaps, will be benchmarked for each pilot, including existing historical data. Each pilot partner will generate and deploy specific plans for implementing the required sensing systems. Sensor installation and testing will occur at the pilot facilities, and data quality for DT generation will be validated. (Deliverable 3.1) T3.2 Guidelines for environmental footprint and social value assessments of bio-based products (Lead: CAR; Participants: AU) [M5 – M15] In this task, the consortium will create the guidelines that will steer the environmental, social and circularity evaluation of the bio-based products used in the pilots, using as point of start our methodology proposed in Secc1.2 and finalizing in T6.6, with the lessons learnt to the future of DPP in bio-based products at the end of the project. These guidelines will include the definition of the KPIs of the project in line with the requirements under the Product Environmental Footprint (PEF) recommendations from the EU Commission, specific standards for bio-based products (EN 16760:2015, EN 16751:2016 and CEN/TR 16957:2016). Circularity indicators will also be defined in accordance with existing methodologies and standards under development to build a consistent set of indicators for the evaluation (ISO/FDIS 59020). Social aspects will be taken into consideration building upon existing methodologies such as UNEP SETAC's guidelines for social LCA or the Social Value Initiative. The task will also advance the definition of the goal and scope of the study, understanding the boundaries of the system under evaluation to support the identification of the right inventory data in T3.1. This task will also explore the links to the planetary boundaries framework to facilitate target setting for the pilots and to understand the extent of the impacts within the local (use case level) and global scale (bio-based products in general). The guidelines will consider interactions with the DT models to collect data from the

manufacturing stage and the bi0SpaCE data space for trusted information exchanges for DPP data collection related to Scope 3 environmental im-pacts. (Deliverables 3.2, 3.4) T3.3 Physics-based process simulation for prediction of LCA and CE indicators (Lead: CAR; Participants: AU, NISSA) [M6 – M18] The focus of this task is to advance the methodological frame-work enabling the use of physics-based process simulations for LCA and CE assessments of bio-based products. The task will extend existing tools for green process development (e.g., HSCSim, Aspen plus) in the following ways: (i) developing advanced a simulation environment enabling a more holistic and accurate assessment of product and process improvement potentials, and (ii) calibrating current physics-based simulation models with data from networked sensors (T3.1), for generating hybridized process inventory and emissions models enabling more accurate LCA and CE assessments. To this end, real-world sensor data will be exploited for calibrating simulation models as well as the simulation-based prediction of process LCA and CE performance, via progressive parameter and model refinement. The developed data-calibrated physics-based models will be used for green process optimization in T3.4 and generating process DTs in T5.1. (Deliverable 3.3) T3.4 Sustainability and circularity focused process optimization under uncertainties (Lead: AU; Participants: CAR) [M12 – M24] This task will develop an optimization framework to identify process parameters that maximize the sustainability and circularity performance under statistical uncertainties. More specifically, this task includes 3 main subtasks as follows: i) Uncertainty Quantification (UQ): herein, mathematical modelling of the dominant sources of uncertainties will be performed. This includes measurement errors from sensor data, sampling errors and inherent variability in process parameters. ii) Uncertainty Propagation (UP): The modelled uncertainties will be propagated to the LCA and CE indicators. To this end, computationally efficient adaptive sampling of the physics-based process simulation framework developed in Task 3.3 will be employed. ML models, i.e. multi-output deep-learning-based surrogate models for stochastic simulators, will there after being trained on the sampling data to directly model the uncertainty in both LCA and CE indicators. iii) Multi-objective Robust Optimization: Herein, the worst-case prediction of the combined LCA and CE indicators (de-fined with a certain probability measure) will be maximized with respect to the process parameters under the modelled statistical uncertainties. (Deliverable 3.3) WP3 Roles: AU will develop guidelines for CE assessment using micro-level indicators, develop hybridized inventory and emissions models, and ML models for LCA- and CE-focused process optimization, accounting for uncertainty. FhG will identify sensor requirements for process DT as well as for LCA modelling. CAR will develop PEF and social LCA guidelines, simulation models of bio-based processes, and generate simulation data generation for process optimization. NISSA will lead sensor implementation and support calibration of process simulation models based on sensor data. UNI will support partners in the identification of the latest relevant CE standards and gather inputs for WP7 pre-standardization activities; Pilot partners (FSK, GLB, NAT, NOR) will implement sensors for process data collection and provide process data from production IT systems. SSF will develop solutions for sensor data representation for integration with IMF semantic models.

Work package WP4 – Digital Technologies for Tracking & Tracing Bio-Based Resources

Work Package Number	WP4	**Lead Beneficiary**	3 - CAR
Work Package Name	Digital Technologies for Tracking & Tracing Bio-Based Resources		
Start Month	12	**End Month**	24

Objectives
WP4 will develop advanced models, techniques, and technologies that enhance the overall traceability of continuous process flows in bio-based manufacturing. Robust traceability and tracking tools will be established to contribute to help the seamless integration of bio-based industries into the CE through secure and efficient traceability of flows and generated products. WP4 is builds on scope and experimental scenarios from WP2 and WP3 technological building blocks defining sustainability and CE assessment of the bio-based products. Results from WP4 will be interoperable with the DT services implemented in WP5.

Description
T4.1 Machine learning models for tracing continuous process flows (Lead: AU; Contributions: CAR, FSK, GLB, NAT, NOR) [M12-M24] In this task, machine-learning (ML) models capable of tracing continuous process flows in bio-based manufacturing will be developed. More specifically, this task includes the following subtasks: i) Computational Fluid

Dynamics (CFD) simulations will be conducted to simulate complex thermo-fluidic systems. The simulation results will provide detailed information on important parameters of the process flow ii) A comprehensive dataset of experimental measurement will be assembled. This subtask also includes processing and cleansing of collected data from pilots to eliminate inconsistencies and noise. iii) The next phase includes leveraging numerical simulations and experiments to achieve ML models capable of tracing continuous process flows in bio-based manufacturing. The ML models will be trained based on both synthetic simulation data and real experimental data to capture the ongoing transport phenomena accurately. iv) To assess ML models' capabilities, a number of measurement data and CFD simulations will be used to validate the accuracy of the models, ensuring their ability to extrapolate to unseen conditions. (Deliverable 4.1)

T4.2 Improved resilience through enhanced materials tracing and flow modelling (Lead: SSF; Contributions: AU, CAR, FSK, GLB, NAT, NOR) [M12-M24] Enhance material tracing techniques for resilient and circular bio-based energy production, incorporating Material Flow Analysis (MFA) and stakeholder network-based evaluation of resilience and advanced digital technologies defined in WP2. This task aims to optimize material flows in bio-based manufacturing by developing comprehensive and efficient traceability systems. It involves the design of methodologies and data requirements de-fined in WP2 essential for creating a robust flow tracing system, emphasizing interoperability interfaces with the data space. Additionally, it includes strategies for increasing the resilience of biomass sourcing through the optimization of transportation from multiple distributed sources where these models will be validated finally in WP6. (Deliverable 4.2)

T4.3 Digital tagging for bio-based manufacturing (Lead: CAR; Contribution: AU, SFF, FSK, GLB, NAT, NOR) [M15-M24] the tagging system involves generating a solution that serves for operational excellence at the bio-based process scale and also integrates with the project's digital twin platform. The task begins by setting standard protocol (1), that ensures system's compatibility across IT/OT systems. The analysis of data from the 4 pilot projects will identify essential data points and commonalities (2), which will drive the design as a versatile and modular digital tagging system (3). It must allow event-based (e.g. new batch start) and real-time updates and being capable to function both as a standalone system—with dashboards for factory personnel—and as an integral component of a larger digital eco-system, contributing to digital product passports. A proof of concept (PoC) is then developed (4), in which the tagging system will capture an increased level of detail about each product's manufacturing journey, assigning unique digital identifiers (Digital Identification Codes) to each batch of raw materials, intermediate products, and final products. These codes are generated at different manufacturing unitary process steps and will be designed to carry relevant information about the product, including its origin, composition, processing parameters, and quality metrics. (Deliverable 4.3)

T4.4 Tracking and tracing technologies validation at lab-scale (Lead: CAR; Contribution: AU, SFF, FSK, GLB, NAT, NOR) [M15-M24] This task will validate the different proof of concepts technologies of tracking and tracing from previous tasks at laboratory scale (based in off-line data validation) to ensure functionality and reliability in controlled conditions. It serves as a crucial step in the development process, verifying the effectiveness of the tracking and tracing technologies before their application in the relevant environment of the pilots (real-time data or online connection). The validation testing will include evaluating scalability and adaptability to different production volumes and product types, ensuring the technologies can meet a broader bio-based industry's needs. It will also con-sider different functionalities: providing actionable insights through internal dashboards for immediate operational decision-making and enriching project's DT results with detailed, real-time product and process data including integration with AAS sub model templates defined in WP5. (Deliverable 4.4)

WP4 Roles: CAR will lead this WP, and the tagging and traceability technology, the pilots (FSK, GLB, NAT, NOR) will provide information about their facilities and validate the technologies proposed. The models, ML, will be leaded by AU and deployed by CAR. SFF will deploy network models to quantify existing dependencies, pathway circularity efficiencies, and overall system resilience under uncertain future scenarios.

Work package WP5 – Circular Dataspace & Services Development for Bio-Based Products and Industries

Work Package Number	WP5	**Lead Beneficiary**	2 - FhG
Work Package Name	Circular Dataspace & Services Development for Bio-Based Products and Industries		
Start Month	13	**End Month**	33

Objectives

The objectives are (i) to model and develop DTs for bio-based processes; (ii) to model and generate DPPs for bioproducts based on process DTs; (iii) to build a data space based on DPPs and extend it with relevant services; (iii) to integrate all project services/tools into a holistic solution.

Description
T5.1: AAS-compliant DTs enriched with sustainability and circularity assessment services (Leader: FhG; Contributors: AU, CAR) [M13-M21] This task addresses modelling and the creation of DTs for bio-processes. The DT model will be based on the AAS specification and relevant submodel templates (e.g. carbon footprint). If not available and required, some AAS submodel templates could be introduced. The DT software counterpart will be created based on the DT model and the configuration file, which will specify how to connect to a physical asset (e.g. PLC of a machine) and relevant sensors (selected and implemented in T3.4) and internal (e.g., MES) or external (e.g., EPCLA) software systems. This will allow to create a DT without writing any code. The DT will be kept in sync with the real world in a protocol-agnostic way. The DT will also provide standardized AAS-compliant interfaces for interaction of the DT with the outside world. Finally, this task will provide support for the enrichment of DTs with smart services to be developed in WP3. This requires modelling the metadata of a service as AAS submodel template and providing sup-port for the execution of this service in a model execution environment that can be deployed inside and/or outside a DT. (Deliverable 5.1) T5.2: DPP creation services for bio-products (Leader: NISSA; Contributors: FhG, AU) [M16-M24] This task includes the modelling of DPPs for bioproducts, their components and materials. As the DPPs will be AAS-compliant, the existing sub-model templates will be reused (e.g. environmental data) and the required sub-model templates will be developed with the aim of modelling the entire life cycle of a bio-product. To create a DPP for a particular bio-product, the static data (e.g. the manufacturer) will be provided manually by a user interface or extracted from the existing software systems (e.g. MES). For the dynamic real-time data (e.g. energy or CO2 consumption), the values will be pro-vided automatically via DT of a process that produces the product, also taking into account the CO2 footprint of the material and sub-components. Finally, the DPPs will be extended by the LCA service to be developed in WP3. (Deliverable 5.1) T5.3: bi0SpaCE dataspace creation and DPP onboarding (Leader: FhG; Contributors: SSF, NISSA) [M19-M27] This task will follow the IDS initiative and build a data space based on DPPs for bio-based sectors to facilitate DPP exchange in a secure, trusted and semantically interoperable way. The bi0SpaCE data space will not only provide the functionality for data sharing but will also form the basis for smart services (e.g. traceability) and cross-company business processes, while ensuring DPP owners' sovereignty over their content. To make DPPs findable and accessible to actors in value chains according to FAIR principles, a DPP registry (based on the AAS registry specification) and a DPP onboarding service will be developed. While the standard functionality of the AAS registry will be extended to support intelligent search based on the bi0SpaCE ontology (T2.3), the DPP onboarding will require an extension of the IDS connectors (e.g. EDC) and possibly the IDS protocol to handle AAS-compliant DPPs. (Deliverable 5.2) T5.4: bi0SpaCE dataspace extension with cross-DPP services (Leader: SSF; Contributors: FhG) [M25-M30] This task aims to extend the bi0SpaCE data space with traceability service to increase value across the different levels of the supply chain and incentivize a network-wide transition to sustain-ability. The traceability service will enable intelligent search in DPP value chains. It will ensure traceability as it will provide information about the route a material/product has taken from production through distribution to its destination. However, bio-products could consist of several (sub)products, different materials could be used for their production, after the end of the product life, secondary raw materials could be produced. Collecting and sharing data on the origin, composition, and sustainability aspects of raw materials and components is challenging, as it requires the modelling of dependencies between DPPs to represent the different phases of the product life cycle (from design to production to end-of-life) and take into account the DPPs of all components and materials used. Thus, the traceability service will also consider the dependent DPPs by propagating search requests to them and integrating their search results in an intelligent way. (Deliverable 5.2) Task 5.5: Integrated bi0SpaCE software framework with DPP services for consumers (Lead: FhG; Contributors: CAR, NISSA, AU, SSF) [M13-M33] his task delivers the integrated ICT solution combining all the services from WP3-WP5 and methodology as a final package with deployment and replication guidelines. The main activities include a) continuous monitoring of the Project Scope Matrix, where all project requirements artefacts (stakeholders, pilots, system, use cases, etc.) are consolidated and monitored; b) definition of a testing and validation plan for the bi0SpaCE offerings; c) integration activities and d) definition of the deployment and replication guidelines. This task also includes supporting consumers, which are either software systems or customers. In the case of software systems, this means providing standardized APIs for DPPs. For customers, an APP for DPPs will be pro-vided. (Deliverable 5.2) WP5 Roles: All involved partners will contribute to the realization of the bi0SpaCE data space and services for DTs and DPPs by focusing on specific areas. While FhG will be responsible for DTs, data spaces and integration, NISSA will

focus on the provision of DPPs as a service and SSF will lead the smart search for DPPs. AU and CAR will support the process DTs. AU will contribute to the DPPs from a CE perspective.

Work package WP6 – Technology Validation in Relevant Industrial Environments

Work Package Number	WP6	**Lead Beneficiary**	3 - CAR
Work Package Name	Technology Validation in Relevant Industrial Environments		
Start Month	18	**End Month**	36

Objectives
This WP has two main objectives, the validation in relevant environment of the technologies deployed in each use case including the validation of the bi0SpaCE software framework, and the collection of the lessons learnt and results for the effective dissemination and exploitation based on the pilot feedback.

Description
T6.1: Pilot management and evaluation (Lead: CAR; Contributors: AU, FhG, FSK, GLB, NAT, NOR, SSF) [M18-M30] In this task it will be defined the parameters of validation each of the solutions particularised for each use case. This task will take in account all the possible differences between each demo use case, and the similarities between all, the demonstration of the DPP created in the bi0SpaCE software framework and it will be created a check list with the KPIs associated to each one defined in T2.1, and updated if it was necessary. This validation must take in account the achievement of the KPIs, the availability of the data started to be collected in T2.5, the stability of the data, and the reliability of the information provided. The improvements in each demo use case, must be measured in terms of energy reductions and CO2 footprint reduction based on the specific application for each of the use cases of the framework for LCA and CE assessment defined in WP3. The methodology of evaluation will be reported in the deliverable D6.1. (Deliverable 6.1) T6.2: Circular water use in paperboard production (Lead: FSK Contributors: CAR, AU, FhG) [M28-M34] Fiskeby will validate the solutions created under bi0SpaCE software framework, with the help of the check list created, and the KPIs defined to be validated. It will be validated the amount the water recycled, and the platform to have available the DPP of each roll. The validation will cover too, the new sensors installed, and the availability of the data. Thanks to the improvements of the project, the accuracy of tracking material will be improved, and validated to. (Deliverable 6.2) T6.3: Enhanced tracking of mass and energy flows in bio-industrial clusters (Lead: GLB; Contributors: AU, FhG) [M28-M34] The objective of this task is to match the data from GreenLab's SymbiosisNet, a system for energy trading within a circular economy in an eco-industrial cluster, with the bi0SpaCE software framework. Focusing on the biomass streams and the energy used to convert them into fully processed products (e.g. bio-based protein for animal feed), the knowledge transfer will ensure that the bi0SpaCE software framework can manage integrated energy streams of different sources in the formulation of DPPs and help guide industrial compatibility with digital twin models. The validation of the pilot will also investigate the estimation of the CO2 EQ for drying fish waste and the improvement in estimating unit conversion efficiencies of biomass flows to energy flows. (Deliverable 6.2) T6.4: Validation of the digital transition of a bio-industry (Lead: NAT, Contributors: CAR, FhG) [M28-M34] In this task it will be validated the integration and the tracking the relevant parameters obtained thanks to the sensors of temperature and PH integrated into the new bi0SpaCE software framework developed, this new data integrated inside this software framework, will be validated by the consumers, they will be the final users of this information. The validation must take in account, the stability of the data, the process efficiency, and the decrease of wastes and user friendly of the platform for the end users. (Deliverable 6.2) T6.5 Substituting fossil fuel-based plastics with sustainable bio-derived alternatives (Lead: NOR, Contributors: SSF, FhG) [M28-M34]: This task will focus on the noriware use case, where relevant process parameters for producing seaweed-derived plastics will be tracked using the bi0SpaCE sensors, with the overall objective of quantifying process performance. Process CO2 emissions and energy intensity will be reduced, thanks to the DT layer and optimization, and this task will validate improvements to process efficiency. DPPs will be created for at least two different seaweed-based material grades. (Deliverable 6.2). T6.6: Lessons learnt and results exploitation (Lead: CAR, Contributors: All) [M29-M36] Results from all the pilots will

be analyzed collectively to evaluate the success and future opportunities for the bi0SpaCE technologies and software framework. The task will adopt a socio-technical line of inquiry to revisit the social/societal and business requirements identified in T2.3 and evaluate their implementation in the pilots, and the lessons learnt in this process. Results from this task will also enable the sharing of recommendations between the industrial pilots on best practices for deploying digital, LCA, and CE technologies, and how to further extend these results in the future. (Deliverable 6.3)

WP6 Roles: CAR, as WP leader will stablish the methodology of validation in the use cases and report the lessons learnt and the final results of the project. Then, in T6.2 to T6.5 the pilots (FSK, GLB, NAT, NOR) will lead the validation in their facilities of the biOSpaCE software platform, the new biOSpaCE sensors installed and the DPPs. UNI will support in the pilot management, informing about latest standardization developments and ensuring alignment with WP7 activities.

Work package WP7 – Technical, Business, and Societal Impact Creation

Work Package Number	WP7	**Lead Beneficiary**	5 - UNI
Work Package Name	Technical, Business, and Societal Impact Creation		
Start Month	1	**End Month**	36

Objectives
The objectives are: (i) to provide the maximum visibility and public awareness of bi0SpaCE by following a sound dissemination and communication strategy targeting the key actors in the broader European community,(ii) to publish results in international industrial and academic conferences, work-shops and journals to inform the relevant interested third parties (academic/research and private/public organizations) about bi0SpaCE, its goals and achievements and to gather valuable feedbacks, (iii) to support cluster collaboration and crosspollination, (iv) to develop individual and joint exploitation plans and manage IPR within bi0SpaCE and beyond (v) to create business models that enable its transferability to other sectors, and provide industrial strategies for applying project results (vi) to contribute to standards in an impactful manner.

Description

T7.1: Communication, industrial and scientific dissemination (Lead: NISSA, Contribution: All) [M1-M36] This task will devise the dissemination and communication strategy (D7.1) by M6 and implement the corresponding activities listed in Table 5. The dissemination activities will include
a) Publications: at least 6 peer-reviewed publications in esteemed venues;
b) Dissemination events: a final dissemination event organized by GLB in M33 for demonstrating the SymbiosisNET and bi0SpaCE results from bio-energy and bio-materials companies; c) Participation in external events: The communication activities will include ≥50 attendees involved in pilot demonstrations; pilot activities demonstrated for >6 months; ≥10 technological conferences, workshops, symposia, roundtable, trade fairs; a) Website: which will be the "one-stop-shop" to find the latest developments and achievements of the project; b) Social media: a new LinkedIn page will be created to engage with professionals and will be managed by NISSA with the support of all partners; c) Newsletter: at least 4. D7.2 will report all these activities. (Deliverables 7.1, 7.2)

T7.2: Clustering and liaison activities (Lead: UNI, Contribution: All) [M13-M36] bi0SpaCE will seek to network with other projects financed under the same topic and other relevant Horizon Europe once (e.g. Bioradar, CIRPASS) to establish a core cluster and discuss cross-fertilization and the implementation of joint activities listed in Table 5. bi0SpaCE will be linked with the European standardization community from the preliminary stages: a liaison with at least a relevant European or International technical committee will be promoted by UNI (e.g. ISO/TC 323; CEN/TC 411; CEN-CLC/JTC 24). By M30, possibly at CEN/CENELEC premises, UNI will organize an ad hoc workshop focused on bio-products DPP standardization needs. HsBooster and Euroconsumers will also be invited to such event. Clustering activities will also consider the European level in communities like SPIRE, EFFRA, IDTA, IDSA or CBEJU. (Deliverables 7.1, 7.2)

T7.3: Exploitation, transferable business models & industrial strategies, and IPR (Lead: NISSA, Contribution: ALL) [M9-M36] bi0SpaCE will systematically develop its business models to incentivize the commercialization of its innovations using them as tools to identify industrial strategies favoring bio-based manufacturing. Key fundamentals for the business plan will be fully substantiated, including a feasibility study, opportunity analyses, licensing potential, ROI projections, etc. PESTEL and SWOT analyses and Osterwalder Business Model canvasses will be used where appropriate. It will be done: with targeted surveys (N total=1,000 across the market regions for the bi0SpaCE EU pilots), an assessment of public acceptance of bio-based technologies; a confrontation with sectoral domain experts, to understand general beliefs, barriers to market and expedited ways to circumvent these. The business plan will look at the potential for broader opportunities for commercialization across the project's partners, through systematic interrogation of the various innovation streams. Starting from T6.6 results key exploitable results from pilot implementations will be explored through for e.g. stakeholder interviews and focus group discussions, also involving the Advisory Board. T7.3 will support business models enabling results transferability to other sectors and industrial strategies suitable for SMEs. The main bi0SpaCE IPR activities are included in this task: a cautious IPR monitoring will be provided so that CDA, NDA and IPR imperatives for all partners (foreground and background) are fully respected. (Deliverables 7.3, 7.6)

T7.4: Standardization activities (Lead: UNI, Contribution: All) [M9-M36] T7.4 will support the alignment of the bi0Space with standardization. 1) it will map the most relevant EN and ISO standards for CE, LCA, bio-products and DPP. This should avoid duplications (T6.1). TCs will be scanned as well to back T7.2. 2) from WP3-4 results, standardization needs will be gathered in a systematic way (e.g. through a survey and face2face calls) and a dedicated workshop is foreseen in T7.2 to extend the gap assessment to external stakeholders. 3) starting from T5.2 results, UNI and all partners will evaluate which results may be transformed into a CWA. The CWA is a European pre-standardization document that may be developed in 10-12 months. UNI, with the support of all partners, will guide the development of the CWA project plan (PP), D7.4. Should CEN approve the PP, a CEN/Workshop will be initiated and all the partners with the relevant expertise will participate to the development of the CWA, while UNI will manage the process and ensure the compliance with CEN/CENELEC rules. In this way, will pave the way for the wider adoption by the market of bi0space achievements and maximization of its impact. (Deliverables 7.4, 7.5)

WP7 Roles: All partners will contribute to the communication, dissemination, exploitation and standardization activities. UNI will lead the WP and the standardization activities; NISSA will lead the communication, dissemination and exploitation activities.

STAFF EFFORT

Staff effort per participant

Grant Preparation (Work packages - Effort screen) — Enter the info.

Participant	WP1	WP2	WP3	WP4	WP5	WP6	WP7	Total Person-Months
1 - AU	20.00	9.00	12.00	12.00	5.00	8.00	8.00	74.00
2 - FhG	10.00	15.00	1.00		24.00	4.00	5.00	59.00
3 - CAR	5.00	8.00	15.00	16.00	3.00	17.00	5.00	69.00
4 - NISSA	2.00	13.00	7.00		9.00	1.00	15.00	47.00
5 - UNI	2.00	3.00	1.00			1.00	20.00	27.00
6 - FSK	2.00	2.00	2.00	2.50		9.50	2.00	20.00
7 - GLB	2.00	2.00	2.00	2.50		9.50	2.00	20.00
8 - NAT	2.00	2.00	4.00	2.50		13.50	2.00	26.00
9 - SSF	2.00	10.00	1.00	8.00	9.00	3.00	2.00	35.00
11 - NOR	2.00	2.00	2.00	2.50		9.50	2.00	20.00
Total Person-Months	49.00	66.00	47.00	46.00	50.00	76.00	63.00	397.00

LIST OF DELIVERABLES

Deliverables

Grant Preparation (Deliverables screen) — Enter the info.

The labels used mean:

Public — fully open (⚠ automatically posted online)
Sensitive — limited under the conditions of the Grant Agreement
EU classified —RESTREINT-UE/EU-RESTRICTED, CONFIDENTIEL-UE/EU-CONFIDENTIAL, SECRET-UE/EU-SECRET under Decision [2015/444]

Deliverable No	Deliverable Name	Work Package No	Lead Beneficiary	Type	Dissemination Level	Due Date (month)
D1.1	Data Management Plan (DMP) v1	WP1	2 - FhG	DMP — Data Management Plan	PU - Public	6
D1.2	Ethics & AI Use Report v1	WP1	1 - AU	R — Document, report	PU - Public	18
D1.3	Data Management Plan (DMP) v3	WP1	2 - FhG	DMP — Data Management Plan	PU - Public	36
D1.4	Ethics & AI Use Report v2	WP1	1 - AU	R — Document, report	PU - Public	36
D1.5	Data Management Plan (DMP) v2	WP1	2 - FhG	DMP — Data Management Plan	PU - Public	18
D2.1	Use cases, KPIs and technical and societal requirements	WP2	2 - FhG	R — Document, report	PU - Public	9
D2.2	bi0SpaCE ontologies	WP2	9 - SSF	R — Document, report	PU - Public	15
D2.3	bi0SpaCE technical architecture and data collection framework	WP2	2 - FhG	R — Document, report	PU - Public	15
D3.1	Technical documentation on sensor implementation and data pipe-lines	WP3	4 - NISSA	R — Document, report	SEN - Sensitive	15
D3.2	Guidelines for environmental foot-printing of bio-based products	WP3	3 - CAR	R — Document, report	PU - Public	15

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Deliverable No	Deliverable Name	Work Package No	Lead Beneficiary	Type	Dissemination Level	Due Date (month)
D3.3	Data-driven LCA & CE modelling framework	WP3	1 - AU	OTHER	PU - Public	24
D3.4	Policy recommendations for environmental footprinting of bio-based products	WP3	1 - AU	R — Document, report	PU - Public	18
D4.1	ML models technology for bio-based process flows	WP4	1 - AU	OTHER	PU - Public	24
D4.2	Enhanced resilience through improved materials tracing and flow modeling	WP4	9 - SSF	R — Document, report	PU - Public	24
D4.3	Digital tagging of bio-based products	WP4	3 - CAR	OTHER	PU - Public	24
D4.4	Tracking and tracing technology validation	WP4	3 - CAR	R — Document, report	PU - Public	24
D5.1	AAS-compliant digital twins for bio-processes and DPPs for bio-products	WP5	2 - FhG	OTHER	PU - Public	24
D5.2	bi0SpaCE data space	WP5	2 - FhG	OTHER	PU - Public	33
D6.1	Methodology of validation	WP6	3 - CAR	R — Document, report	PU - Public	30
D6.2	Validation in relevant environment	WP6	1 - AU	DEM — Demonstrator, pilot, prototype	PU - Public	34
D6.3	Lessons learnt and final results	WP6	3 - CAR	R — Document, report	PU - Public	36
D7.1	Dissemination and communication strategy	WP7	4 - NISSA	R — Document, report	PU - Public	6

Deliverables

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Deliverable No	Deliverable Name	Work Package No	Lead Beneficiary	Type	Dissemination Level	Due Date (month)
D7.2	Dissemination and communication report	WP7	4 - NISSA	DEC —Websites, patent filings, videos, etc	PU - Public	36
D7.3	Exploitation plan	WP7	4 - NISSA	R — Document, report	SEN - Sensitive	36
D7.4	Standardization Roadmap and CWA project plan	WP7	5 - UNI	R — Document, report	PU - Public	36
D7.5	Policy recommendations for standardization of DPPs for bio-based products	WP7	5 - UNI	R — Document, report	PU - Public	36
D7.6	Exploitation Plan Draft	WP7	4 - NISSA	R — Document, report	SEN - Sensitive	6

Deliverable D1.1 – Data Management Plan (DMP) v1

Deliverable Number	D1.1	**Lead Beneficiary**	2 - FhG
Deliverable Name	Data Management Plan (DMP) v1		
Type	DMP — Data Management Plan	**Dissemination Level**	PU - Public
Due Date (month)	6	**Work Package No**	WP1

Description
Initial DMP describing data management lifecycle for data to be collected, processed and/or generated during/by the project, including the data types, reuse of existing data, operations to be performed, procedures to access data and prevent unauthorized use, sharing policies. The work for developing the DMP is conducted in Task 1.2.

Deliverable D1.2 – Ethics & AI Use Report v1

Deliverable Number	D1.2	**Lead Beneficiary**	1 - AU
Deliverable Name	Ethics & AI Use Report v1		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	18	**Work Package No**	WP1

Description
Report containing a plan describing the planned AI algorithms and tools used in the project, including results on the technical robustness and reproducibility, integrity and accuracy, safety, social robustness, and ethical concerns. Specific steps taken to mitigate these identified concerns are also described. The work for developing this report is conducted in Tasks 1.2 and 1.3.

Deliverable D1.3 – Data Management Plan (DMP) v3

Deliverable Number	D1.3	**Lead Beneficiary**	2 - FhG
Deliverable Name	Data Management Plan (DMP) v3		
Type	DMP — Data Management Plan	**Dissemination Level**	PU - Public
Due Date (month)	36	**Work Package No**	WP1

Description
Final DMP describing data management lifecycle for data to be collected, processed and/or generated during/by the project, including the data types, reuse of existing data, operations to be performed, procedures to access data and prevent unauthorized use, sharing policies. The work for developing the DMP is conducted in Task 1.2.

Deliverable D1.4 – Ethics & AI Use Report v2

Deliverable Number	D1.4	**Lead Beneficiary**	1 - AU
Deliverable Name	Ethics & AI Use Report v2		
Type	R — Document, report	**Dissemination Level**	PU - Public

Due Date (month)	36	**Work Package No**	WP1

Description
Final report describing the AI algorithms and tools used in the project, including results on the technical robustness and reproducibility, integrity and accuracy, safety, social robustness, and ethical concerns. Specific steps taken to mitigate these identified concerns are also described. The work for developing this report is conducted in Task 1.2 and Task 1.3.

Deliverable D1.5 – Data Management Plan (DMP) v2

Deliverable Number	D1.5	**Lead Beneficiary**	2 - FhG
Deliverable Name	Data Management Plan (DMP) v2		
Type	DMP — Data Management Plan	**Dissemination Level**	PU - Public
Due Date (month)	18	**Work Package No**	WP1

Description
Interim DMP describing data management lifecycle for data to be collected, processed and/or generated during/by the project, including the data types, reuse of existing data, operations to be performed, procedures to access data and prevent unauthorized use, sharing policies. The work for developing the DMP is conducted in Task 1.2.

Deliverable D2.1 – Use cases, KPIs and technical and societal requirements

Deliverable Number	D2.1	**Lead Beneficiary**	2 - FhG
Deliverable Name	Use cases, KPIs and technical and societal requirements		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	9	**Work Package No**	WP2

Description
Report describing the refined analysis and specification from the bi0SpaCE use cases, corresponding KPIs, and stakeholder requirements based on results from Task 2.1. The descriptions of the user scenarios will include technical requirements for the solutions and technologies developed in bi0SpaCE (based on Task 2.2) as well as societal requirements identified through desk research and results from stakeholder requirements mapping (based on Task 2.3).

Deliverable D2.2 – bi0SpaCE ontologies

Deliverable Number	D2.2	**Lead Beneficiary**	9 - SSF
Deliverable Name	bi0SpaCE ontologies		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	15	**Work Package No**	WP2

Description
Semantics-based information modelling layer with ontologies and knowledge graphs. Definition of semantics-based information modelling layer applicable to bio-based sectors. Description of results from T2.4 implemented in the form of an open-access ontology model.

Deliverable D2.3 – bi0SpaCE technical architecture and data collection framework

Deliverable Number	D2.3	**Lead Beneficiary**	2 - FhG
Deliverable Name	bi0SpaCE technical architecture and data collection framework		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	15	**Work Package No**	WP2

Description
Specification of the bi0SpaCE technical and system architecture. Results from mapping of pilot requirements to the technical functionality of the bi0SpaCE platform. The above results are based on work conducted in Task 2.5. Description of relevant data sources based on historical data from pilot partners, including metadata for each type of data source and data communication protocols. The above results are based on work conducted in Task 2.6.

Deliverable D3.1 – Technical documentation on sensor implementation and data pipe-lines

Deliverable Number	D3.1	**Lead Beneficiary**	4 - NISSA
Deliverable Name	Technical documentation on sensor implementation and data pipe-lines		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	15	**Work Package No**	WP3

Description
Data requirements for generating life-cycle inventories, data aggregation process, data collection infrastructure, communication protocols, and the identified data gaps for the four bi0SpaCE pilots. Report on sensor implementation, including technical specifications for the sensors and preliminary validation of data collection pipelines. The above results are based on work conducted in Task 3.1.

Deliverable D3.2 – Guidelines for environmental foot-printing of bio-based products

Deliverable Number	D3.2	**Lead Beneficiary**	3 - CAR
Deliverable Name	Guidelines for environmental foot-printing of bio-based products		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	15	**Work Package No**	WP3

Description
Report on guidelines including the definition of the KPIs in line with the requirements under the PEF and standards for bio-based products, as well as including definition of social and circularity indicators. Results from mapping bi0SpaCE pilot targets to the planetary boundaries framework to facilitate target setting for the pilots. The above results are based on work conducted in Task 3.2.

Deliverable D3.3 – Data-driven LCA & CE modelling framework

Deliverable Number	D3.3	**Lead Beneficiary**	1 - AU
Deliverable Name	Data-driven LCA & CE modelling framework		
Type	OTHER	**Dissemination Level**	PU - Public

Due Date (month)	24	**Work Package No**	WP3

Description
Methodology for data-driven modelling simulation for sustainability and circularity improvement of bio-based processes and products. Description of simulation methods and tools, model calibration and validation. The above results are based on work conducted in Task 3.3. Optimization framework for maximizing the sustainability and circularity performance assessed through simulation-based models under statistical uncertainties. Description of identified uncertainty sources and used sampling and ML-based optimization algorithms. The above results are based on work conducted in Task 3.4. Results for this deliverable are in the form of simulation models, software code, and technical documentation for implementing the simulation driven LCA & CE modelling and optimization.

Deliverable D3.4 – Policy recommendations for environmental footprinting of bio-based products

Deliverable Number	D3.4	**Lead Beneficiary**	1 - AU
Deliverable Name	Policy recommendations for environmental footprinting of bio-based products		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	18	**Work Package No**	WP3

Description
Policy brief describing the existing status, learnings, best practices, and guidance for conducting environmental footprinting studies of bio-based products with the goal of including these results in DPPs. The policy brief will be based on results from Task 3.2.

Deliverable D4.1 – ML models technology for bio-based process flows

Deliverable Number	D4.1	**Lead Beneficiary**	1 - AU
Deliverable Name	ML models technology for bio-based process flows		
Type	OTHER	**Dissemination Level**	PU - Public
Due Date (month)	24	**Work Package No**	WP4

Description
Lab scale prototype of ML models for tracing continuous process flows in bio-based manufacturing. Results describing the validation of ML models based on offline, historical, simulation and experimental data. The above results are based on work conducted in Task 4.1. Results for this deliverable are in the form of digital models, accompanying datasets and technical documentation for training and validating the ML models.

Deliverable D4.2 – Enhanced resilience through improved materials tracing and flow modeling

Deliverable Number	D4.2	**Lead Beneficiary**	9 - SSF
Deliverable Name	Enhanced resilience through improved materials tracing and flow modeling		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	24	**Work Package No**	WP4

Description
Material tracing methodologies and data requirements for flow tracing and increasing resilience of biomass sourcing based on material flow analysis and transportation optimization. The above results are based on work conducted in Task 4.2.

Deliverable D4.3 – Digital tagging of bio-based products

Deliverable Number	D4.3	**Lead Beneficiary**	3 - CAR
Deliverable Name	Digital tagging of bio-based products		
Type	OTHER	**Dissemination Level**	PU - Public
Due Date (month)	24	**Work Package No**	WP4

Description
Definition of standard protocol for tagging bio-based products. Description of data points and commonalities for digital tagging system. Implementation of proof-of-concept system for digital tagging as a lab scale prototype and validated using offline data from pilots. The above results are based on work conducted in Task 4.3. Results for this deliverable are in the form of datasets, algorithms, software implementation, and corresponding technical documentation.

Deliverable D4.4 – Tracking and tracing technology validation

Deliverable Number	D4.4	**Lead Beneficiary**	3 - CAR
Deliverable Name	Tracking and tracing technology validation		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	24	**Work Package No**	WP4

Description
Tests results from validation of proof of concepts technologies of tracking and tracing from previous tasks at laboratory scale, based on offline data from pilots. Results evaluating preliminary DT platform integration interoperability with AAS representation for bi0SpaCE tracking and tracing technologies. The above results are based on work conducted in Task 4.4.

Deliverable D5.1 – AAS-compliant digital twins for bio-processes and DPPs for bio-products

Deliverable Number	D5.1	**Lead Beneficiary**	2 - FhG
Deliverable Name	AAS-compliant digital twins for bio-processes and DPPs for bio-products		
Type	OTHER	**Dissemination Level**	PU - Public
Due Date (month)	24	**Work Package No**	WP5

Description
AAS sub-model templates for bio-based processes and the life cycle of bio-products and services for DTs and DPPs. Configuration of connections between assets, sensors, external/internal software in the bi0SpaCE pilots for developing DTs. The above results are based on work conducted in Task 5.1. Software service for the creation of AAS-compliant DPPs for bio-based products based on results from Task 5.2. Results for this deliverable are in the form of software-based models and accompanying technical documentation.

Deliverable D5.2 – bi0SpaCE data space

Deliverable Number	D5.2	**Lead Beneficiary**	2 - FhG
Deliverable Name	bi0SpaCE data space		
Type	OTHER	**Dissemination Level**	PU - Public
Due Date (month)	33	**Work Package No**	WP5

Description
The result will be the bi0SpaCE dataspace for the exchange of DPPs of bio-based products. The bi0SpaCE dataspace will extend/customize the standard set of technical building blocks of a dataspace with a set of services specialized for the DPPs of bio-based products. These services include: - T5.3: a service for onboarding DPPs in a dataspace and a DPP registry to make the DPPs findable; - T5.4: a traceability service for DPPs that enables the track and trace functionality for DPPs of bio-based products in a value chain, including the primary and secondary materials used/generated; - T5.5: a service for consumers of DPPs in the form of an APP for customers and in the form of a client API for software systems that will use DPPs. T5.5. will also include integration, testing and deployment functionalities. We will deliver: - a report documenting all the research and technical challenges we need to address. - a set of software modules for all services to be developed (see above); - a running dataspace in which all these services are provided, and which can be used by external partners to share their DPPs.

Deliverable D6.1 – Methodology of validation

Deliverable Number	D6.1	**Lead Beneficiary**	3 - CAR
Deliverable Name	Methodology of validation		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	30	**Work Package No**	WP6

Description
Methodology to validate a new software framework in relevant use cases. Description of methodology for validating KPIs defined in bi0SpaCE pilots as well as achievable energy reductions and CO2 footprint reductions. These results are based on work conducted in Task 6.1.

Deliverable D6.2 – Validation in relevant environment

Deliverable Number	D6.2	**Lead Beneficiary**	1 - AU
Deliverable Name	Validation in relevant environment		
Type	DEM — Demonstrator, pilot, prototype	**Dissemination Level**	PU - Public
Due Date (month)	34	**Work Package No**	WP6

Description
Demonstration of the bi0SpaCE software framework across the four use cases. Results validating the application of the bi0SpaCE software framework across the four use cases. These results are based on work conducted in Task 6.2-6.5.

Deliverable D6.3 – Lessons learnt and final results

Deliverable Number	D6.3	**Lead Beneficiary**	3 - CAR
Deliverable Name	Lessons learnt and final results		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	36	**Work Package No**	WP6

Description
Results and lessons learnt for the future based on use cases. Results quantifying the level of achievement of the use case objectives and identified KPIs. Mapping the results from the use cases to socio-technical requirements and recommendations for deployment of the bi0SpaCE software framework. These results are based on work conducted in Task 6.6.

Deliverable D7.1 – Dissemination and communication strategy

Deliverable Number	D7.1	**Lead Beneficiary**	4 - NISSA
Deliverable Name	Dissemination and communication strategy		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	6	**Work Package No**	WP7

Description
Plan on communication and dissemination activities in the project and generation of project visual identity, website, social media, and newsletters. These results are based on work conducted in Task 7.1.

Deliverable D7.2 – Dissemination and communication report

Deliverable Number	D7.2	**Lead Beneficiary**	4 - NISSA
Deliverable Name	Dissemination and communication report		
Type	DEC —Websites, patent filings, videos, etc	**Dissemination Level**	PU - Public
Due Date (month)	36	**Work Package No**	WP7

Description
Report describing results from the communication, dissemination, clustering, and liaison activities. These results are based on work conducted in Task 7.1 and Task 7.2.

Deliverable D7.3 – Exploitation plan

Deliverable Number	D7.3	**Lead Beneficiary**	4 - NISSA
Deliverable Name	Exploitation plan		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	36	**Work Package No**	WP7

Description
Plan for results exploitation, detailing the consortium strategy for market entry, replication, transferability, and sustainability. These results are based on work conducted in Task 7.3.

Deliverable D7.4 – Standardization Roadmap and CWA project plan

Deliverable Number	D7.4	**Lead Beneficiary**	5 - UNI
Deliverable Name	Standardization Roadmap and CWA project plan		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	36	**Work Package No**	WP7

Description
Results of the standards mapping emerging standardization needs (addressed to CEN/ISO Technical Bodies) and the project plan of a new CWA. These results are based on work conducted in Task 7.4.

Deliverable D7.5 – Policy recommendations for standardization of DPPs for bio-based products

Deliverable Number	D7.5	**Lead Beneficiary**	5 - UNI
Deliverable Name	Policy recommendations for standardization of DPPs for bio-based products		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	36	**Work Package No**	WP7

Description
Policy brief describing the existing status, learnings, best practices, and guidance for standardization of DPPs for bio-based products. The policy brief will be based on results from Task 7.4.

Deliverable D7.6 – Exploitation Plan Draft

Deliverable Number	D7.6	**Lead Beneficiary**	4 - NISSA
Deliverable Name	Exploitation Plan Draft		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	6	**Work Package No**	WP7

Description
Draft version of results exploitation plan, outlining the consortium's initial strategy for market entry, replication, transferability, and sustainability. These results are based on work conducted in Task 7.3.

LIST OF MILESTONES

Milestones *Grant Preparation (Milestones screen) — Enter the info.*					
Milestone No	**Milestone Name**	**Work Package No**	**Lead Beneficiary**	**Means of Verification**	**Due Date (month)**
1	bi0SpaCE initialization: Scenarios and technical and social requirements	WP2	2 - FhG	Requirements mapping exercise completed with key stakeholders. Acceptance of the outlined conceptual model for the bi0SpaCE software framework by the consortium partners. Refined use case specifications and linked KPIs. Linked deliverables: D2.1.	9
2	bi0SpaCE design: technical architecture, ontologies, sensorisation, data collections and guidelines	WP3, WP2	2 - FhG	Completed the definition of bi0SpaCE technical and system architecture and data infrastructure. Completed sensor implementation and data pipeline for bi0SpaCE use cases. bioSpaCE ontologies and guidelines for environment footprinting are defined. Linked deliverables: D2.2, D2.3, D3.1, D3.2.	15
3	bi0SpaCE quality assurance and ethics	WP1	1 - AU	Project risks are evaluated, and risk mitigation plan is updated. Interim evaluation of ethics issues and responsible AI usage completed. Linked deliverables: D1.2, D1.3.	18
4	Initial bi0SpaCE development: ML models, methods for LCA and CE, ser-vices for tagging, tracking, DTs and DPPs	WP3, WP5, WP4	1 - AU	Methodology for bi0SpaCE tracking and tracking technologies as well as LCA and CE assessment have been defined and validated using historical/representative data. Linked deliverables: D3.3-3.4, D4.1-4.4, D5.1.	24
5	bi0SpaCE software and evaluation framework: bi0SpaCE dataspace and services and methodology	WP6, WP5	2 - FhG	bi0SpaCE dataspace is fully defined, tested and integrated with DPP onboarding, cross-DPP and consumer services. Methodology for validating bi0SpaCE dataspace and services in use cases	33

Milestones *Grant Preparation (Milestones screen) — Enter the info.*					
Milestone No	**Milestone Name**	**Work Package No**	**Lead Beneficiary**	**Means of Verification**	**Due Date (month)**
				have been defined. Linked deliverables: D5.2, D6.1.	
6	bi0SpaCE validation: Technical results validated in industrial environments	WP6	3 - CAR	Successful application and validation of bi0SpaCE software framework to the four use cases. Use case demonstrations are up and running. Linked deliverables: D6.2.	34
7	bi0SpaCE lessons learnt: Project results and objectives fully achieved	WP1, WP6, WP7	1 - AU	Delivery of final project results, including roadmap for exploiting project results. Outlined objectives and KPIs for each use case and the overall project have been met. Linked deliverables: D6.3, D7.2, D7.3.	36

LIST OF CRITICAL RISKS

Critical risks & risk management strategy *Grant Preparation (Critical Risks screen) — Enter the info.*			
Risk number	**Description**	**Work Package No(s)**	**Proposed Mitigation Measures**
1	General Risk - A partner leaves the bi0SpaCE consortium on their own, or by the decision of the project management team. L: Low, S: Medium	WP1	Project coordinator and management team will closely monitor all partners' progress within WP1. If a partner proves unwilling to cooperate, project boards and plenary discussions will address the issue promptly and identify suitable alternate partners. This allows us to either resolve the problem early or rapidly identify a suitable internal or external replacement to take over the tasks.
2	General Risk - Partners underperforming or low	WP1	Addressed through established methodologies for project planning and control, including regular quality reviews and assignment of peer reviews for each result.

Critical risks & risk management strategy *Grant Preparation (Critical Risks screen) — Enter the info.*			
Risk number	**Description**	**Work Package No(s)**	**Proposed Mitigation Measures**
	commitment from key personnel leading to low quality of results. L: Low, S: Medium		
3	General Risk - Significant delays in tasks due to insufficient resource allocation or inefficient project collaboration.	WP1, WP6, WP3, WP5, WP7, WP2, WP4	bi0SpaCE had developed a detailed work plan and the partners' proven experience in similar projects form a strong foundation for success. bi0SpaCE will employ a proactive project management approach, meticulously identifying critical paths and taking decisive action to ensure timely delivery of results.
4	Technological Risk - Conceptual failure of the architecture design and/or problems in the integration of technologies for data-driven sustainability, circularity assessment, tracing, DT, DPP and data spaces. L: Low, S: High	WP3, WP5, WP4	Incremental development of the integrated solution to minimize failure risks, leaving room for refinements and corrections in due course. Allocated efforts to validate technologies at lab-scale. The bi0SpaCE architecture design will be sufficiently flexible to react to such changes.
5	Technological Risk - Challenges in developing high-accuracy ML-based data-driven models and tracking technologies due to issues with input data quantity and quality. accuracy, etc. L: Medium, S: High	WP3, WP4	bi0SpaCE involves leading researchers in the field, and domains will be continuously monitored for state-of-the-art and research challenges to avoid potentially disruptive technologies.
6	Technological Risk - Low integration of quality, circularity, and sustainability with envisaged technologies for the DPP and data spaces. L: Medium, S: Medium	WP3, WP5, WP4	An experienced and multidisciplinary Consortium of experts in the fields of DTs, DPPs, AI, data spaces and ICT development and integration.
7	Technological Risk - Reluctance from pilot partners to provide data due to data confidentiality and security issues. L: Low; S: High	WP6, WP2	CA and potentially additional confidentiality agreements between pilot partners and the supporting technology partners will be adopted to regulate the terms regarding access to data and existing knowledge. Secure data exchange mechanisms in digital architecture.
8	Social Risk - bi0SpaCE technologies fail to address societal and business requirements leading to low user acceptance. L: Low, S: High	WP3, WP5, WP2, WP4	A user-driven technology development approach is embraced in bi0SpaCE, emphasizing continuous iterations of requirements, development, and validation, implemented with the actual and engaging presence of key business users in these fields. Specific tasks in WP2 for early understanding of social and business needs.
9	Societal Risk - Lack of sufficient participation	WP7	Continuous engagement of stakeholders from the beginning of the of the project.

Critical risks & risk management strategy *Grant Preparation (Critical Risks screen) — Enter the info.*			
Risk number	**Description**	**Work Package No(s)**	**Proposed Mitigation Measures**
	from stakeholder and consumer groups in surveys assessing acceptance of bi0SpaCE digital technologies and DPPs.		Collaborations with interest organizations, European consumer association, industrial networks, and EU digital innovation hubs.
10	Societal Risk - Inadequate outreach & exploitation out-comes. L: Low, S: High	WP7	Relevant activities will in WP7 be closely monitored, based on de-fined KPIs. Strategies will be redesigned if the envisioned results are not satisfactory

PROJECT REVIEWS

Project Reviews *Grant Preparation (Reviews screen) — Enter the info.*			
Review No	**Timing** (month)	**Location**	**Comments**
RV1	21	to be determined	
RV2	36	to be determined	

bi0SpaCE: Industry 4.0 Enhanced Digital Product Passports and Circular Economy Dataspaces for Sustainable Bio-Based Industries

HISTORY OF CHANGES			
VERSION	DATE	DoA Section	
Application	22/02/2024		Initial/submitted version
Part A			
GAP	19/06/2024		Added the following Deliverables: -D1.3 (DMP in M36) -D1.4 (Ethics & AI Use Report in M36)
			Introduced the newly added Deliverables to the following Milestones: -D6.3 to M7 -D1.2 to M3 -D1.4 to M3
			Added another set of deliverables: -D3.4 (Policy recommendations for environmental footprinting of bio-based products (M18)) -D7.5 (Policy recommendations for standardization of DPPs for bio-based products (M36)) -D7.6 (Exploitation Plan Draft (M6))
			Added detailed descriptions for each Deliverable.
			Added detailed descriptions of Means of Verification to each Milestone.
GAP	Second submission	Work Package Descriptions	Added relevant Deliverable number to each task description.
AMD-101182453-1	12/12/2024	Work Package Descriptions	WP 1, WP2, WP3, WP4, WP6, WP7: Updated to reflect the withdrawal of Isopine (ISP) and the introduction of a new associated partner noriware AG (NOR). Changes in the descriptions of tasks T2.6, T4.1, T4.2, T4.3, T4.4, T6.1, T6.5 as well as WP roles.
Part B			
GAP	19/06/2024		Deleted the list of participants from the first page.
			Deleted the Headers and information included, such as the project acronym etc.
			Edited Footers to include information specified in DoA: Project nr., acronym, “Part B”, page nr.
		Section 3: Quality and efficiency of the implementation	Deleted tables 3.1.2., 3.1.3., 3.1.4., 3.1.5., 3.1.6., 3.1.7, transferring the information to the System for Grant Management/Part A.
			Added “History of Changes table” on the first page.
			Added the section “Ethics” in Section 5
			Updated Table 3.1.2 “Resources to be committed” with additional information reg. purchase costs.

			Updated Gantt chart (Figure 12) to include new deliverables and revised length of tasks related to these. Task 3.2. is revised to end in M18, task 7.3 is revised to start in M6.
GAP	Second Submission	Use of Resources	Update table 3.2.1 for Partner NAT
		Changes of the numbering of some deliverables due to the request of new deliverables to be added	D1.3 is now D1.2 D1.5 is now M18 D1.6 and D1.7 have been deleted.
AMD-101182453-1	12/12/2024	Pilot 4 table	Changed to reflect the withdrawal of Isopine and inclusion of noriware AG.
		Section 4.2.	Capacity of participants and consortium as a whole: Deleted the short introduction of Isopine and added a short introduction of noriware.
		Impacts	Impact 13 – The text about the cooperation between bi0SpaCE and noriware substitutes the text outlining the cooperation between bi0SpaCE and Isopine.
		Table 8	Adjusted for the change of associated partners.
		Figure 12	Adjusted for the change of associated partners.

Table of Contents

1 Contents

Glossary

AAS: Asset Administration Shell
AI: Artificial Intelligence
API: Application Programming Interface
CE: Circular Economy
CEN: European Committee for Standardization
CFD: Computational Fluid Dynamics
CWA: CEN Workshop Agreement
DMP: Data Management Plan
DPP: Digital Product Passport
DPP4.0: Digital Product Passport for Industry 4.0
DT: Digital Twin
EU: European Union
FAIR: findable, accessible, interoperable and reusable.
I4.0: Industry 4.0
ISO: International Standards Organisation
IDS: International Data Spaces
IMF: Information Modelling Framework
LCA: Life Cycle Assessment
MFA: Material Flow Analysis
ML: Machine Learning
PEF: Product Environmental Footprint
TC: Technical Committee

2 EXCELLENCE #@REL-EVA-RE@#

The European Green Deal aims to transform Europe into a modern, resource-efficient, and competitive economy, overcoming existential threats from climate change and environmental degradation[1]. Key to this goal is the need for European industries to drive resource-decoupled economic growth and achieve climate-neutrality. This ambition is especially relevant for the European bio-based industry. On one hand they rely on natural ecosystems and their provisioning services for securing material resources, which makes them vulnerable to climate change impacts; on the other hand, they have a high potential for decarbonization[2] through applying nature-inspired processing and for regenerating local ecosystems by closing biological material loops. There is a growing recognition that the convergence of digital and bio-based economies is essential to meet the above goals[3]. However, the pace of this digital-green transformation, and participation of bio-based industries in Europe's digital infrastructure needs to be quickened requiring them to leapfrog over past digital implementations and pioneering new standards-based interfaces[4,5].

Vision: The bi0SpaCE project envisions a future European bio-based sector that is economically competitive, environmentally regenerative, resilient, and socially inclusive. Bio-based industries are highly digitalised, exploiting open access I4.0 solutions for, high-fidelity

Mission: The bi0SpaCE project will advance the creation of circular bio-based products and value chains by delivering the open access bi0SpaCE software framework for rapid deployment and scaling of CE solutions and services across bio-based industries and their value

1 https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
2 Carus (2017). https://doi.org/10.1089/ind.2017.29073.mca
3 Rennings et al. (2022). https://doi.org/10.1002/bsd2.223
4 Kitney et al. (2019). https://doi.org/10.1016/j.tibtech.2019.03.017
5 https://cefic.org/app/uploads/2023/04/ADL_CEFIC_Digital_technologies_for_sustainability_2023.pdf

tracking of resource flows and emissions, and delivering sustainable and circular bio-based products and services. The marketplace for circular bio-based products and services is enabled through dynamic, decentralised DPPs that perform the dual role of providing, i) accurate and updated product information to consumers and regulators, and ii) dynamic feedback enabling the value-chains to continuously optimize their production processes.

chains. The framework will, i) enable the creation of CE-focused process DT models for dynamic creation and management of I4.0 enhanced DPPs for bio-based products, ii) pioneer the development of a CE dataspace for standards-based exchange of sustainability and CE data across process industries, and iii) demonstrate the creation of DPP-based data sharing and optimization services linked to the CE dataspace.

The main benefits targeted by bi0SPaCE are shown in Table 1:

Table 1: The main benefits targeted by bi0SpaCE.

Boosting the economic and digital competitiveness of European bio-based industries and their value chains, by building the scientific and technical know-how for exploiting state-of-the-art technologies, including progressive ML models, process DTs, and semantic information modelling, towards enabling green transition.	**Advancing data-driven sustainable and circular solutions for the bio-based sector** through delivering guidelines for PEF-compliant LCAs for bio-based products. Online data collection and monitoring enabling continuous quality assessments and reuse of process resources and wastes, and DT-driven process optimisation informed by LCA and CE assessments.
Enhancing tracing of products and resource flows enabled by ML models for tracking continuous process flows and emissions, and digital tagging and watermarking of bio-based products based on existing digital information (MES, ERP etc.) on unitary process manufacturing steps from raw materials to final products.	**Increasing data sharing and transparency for circular bio-based products** through adapting the DPP4.0 framework[6] for dynamic authoring and decentralised management of product sustainability and CE data, and associated IDS-compliant CE dataspace services enabling data sharing and CE software services, and consumer transparency of green claims.
Pioneering a DPP market for circular bio-based products by harmonizing state-of-the-art standards across digital, LCA, and CE domains and delivering a CEN Workshop Agreement Project Plan and a standardization roadmap for DPPs in the bio-based sector.	**Enabling interoperability with EU's digital ecosystems** by adopting a standardized approach to manage and exchange information about assets within digital environments based on the AAS standard and extending it to the bio-based industry to help it improve efficiency, transparency, and sustainability.
Promoting economically and socially competitive bioeconomies by developing CE solutions for rural and agricultural settings, incl., eco-industrial parks, emphasising local ownership. Societal interests, end-user acceptance of DPPs, and social LCAs will be inform bi0SpaCE technologies and pilots.	

To magnify the impact of the above benefits and to ensure the widespread adoption of project results, the consortium will implement, contribute to, and/or liaise with existing proven standards, relevant CEN and ISO technical committees, and other initiatives. These include EU projects on developing DPPs in other relevant industrial sectors including projects coming from call DIGITAL-2023-CLOUD-DATA-04-DIGIPASS, EU project CIRPASS, CircularTwAIn, etc. and the most influential German projects such as CATENA-X and new projects from the Manufacturing-X initiative such as Factory-X.

The bi0SpaCE project ecosystem will adopt the **DPP4.0 initiative**, enabling the creation of dynamic and decentralised DPPs enabling secure and trustworthy sharing of CE and sustainability performance data of bio-based products across the value chain, as well as providing transparency of green and CE claims to consumers. Key to this objective is the mobilization of state-of-the-art I4.0 technologies for realizing circular bio-based industries. The deployment of the above technologies is envisioned in four layers: the *physical (hardware) layer, DT layer, DPP layer,* and *IDS-dataspace layer.* The interoperability between these layers will be ensured by using

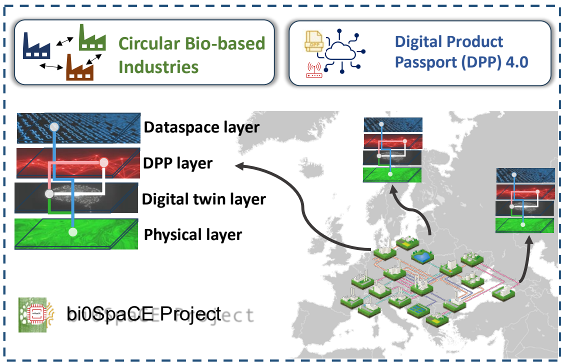


Figure 1: The bi0SpaCE Project Ecosystem

[6] https://dpp40.eu/

the standards (e.g. AAS) and through a semantic IMF. **The adoption of the DPP4.0 framework will align bio-based industries with the benefits envisioned from the emerging European data economy, aligning with the forthcoming DPP marketplace requirements and the common European data spaces framework.** Additionally, bi0SpaCE project, through the bi0SpaCE software framework, will co-define business and social frameworks, operational processes, including data governance frameworks, data quality assurance, standards creation, and onboarding processes to ensure uptake and scaling of project results across industries.

bi0SpaCE will **accelerate the bio-based industry's transition** to sustainability through digitalization, promoting transparency and efficiency. It will develop innovative solutions for material tracing and flow modelling, fostering resource independence and resilience. By collaborating with stakeholders, it will drive adoption of digital and circular economy practices, benefiting industries and the environment. Through DPPs, it will enhance accountability and transparency within the industry, contributing to unlocking the full potential and benefits of the circular economy and the bioeconomy. bi0SpaCE brings together a **diverse consortium of 10 partners**, including RTOs, SMEs, industry assoc., large industries, a standardization body and start-ups across 5 EU and 2 associated countries, over a 36-month project period. The knowledge and technologies created in bi0SpaCE will be demonstrated and validated across 4 complementary bio-based sectors: (i) paperboard production, (ii) eco-industrial parks with bio-based energy and products, (iii) plant-based products and cosmetics, and (iv) bio-derived industrial chemicals.

2.1 Objectives and ambition #@PRJ-OBJ-PO@#

2.1.1 Objectives

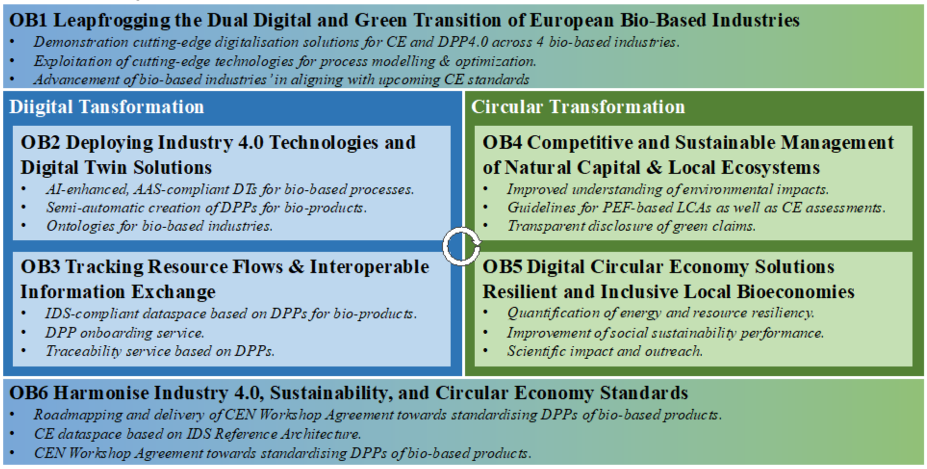


Figure 2: bi0SpaCE objectives and linked key results.

The **bi0SpaCE** project will advance creation of circular bio-based products through developing a software framework **for rapid creation, deployment and scaling of CE solutions and services** across process industry value chains. The bi0SpaCE software framework will enable the creation of CE-focused process DT models for dynamic creation and management of I4.0 enhanced DPPs for bio-based products. The bi0SpaCE project will also pioneer the development of a CE dataspace for standards-based exchange of sustainability and CE relevant data across process industries and demonstrate the creation of DPP-based data sharing and optimization services linked to the CE dataspace.

OB1 Leapfrogging the Dual Digital and Green Transition Processes of European Bio-Based Industries and their Value Chains: bi0SpaCE project will address the urgent need for modernizing digital systems and decarbonizing bio-based industrial value chains to meet European climate ambitions. It aims to advance the digital and green capabilities of the European bio-based sector by enabling them to bypass current static DPP implementations. Through the adoption of emerging technologies, best practices, and standards, the project facilitates rapid and proactive experimentation, allowing bio-based industries to pioneer the development of cutting-edge digital and green solutions.
Results: bi0SpaCE will deliver various advancements that will be integrated into the proposed bi0SpaCE software framework, and enabled through rapid experimentation, lab-scale validation of technologies and eventual demonstration in the bi0SpaCE pilots. ■ **R1.1** Exploitation of cutting-edge networked sensors, DT capabilities and ML technologies for process modelling & optimization, as well as sustainability and circularity performance prediction (D7.3). ■ **R1.2** Pioneering novel ML based approaches for materials and emissions tracking in continuous process flows and digital tagging/watermarking of bio-based products (D4.4). ■ **R1.3** Advancement of bio-based industries' in aligning with upcoming CE standards (ISO 59000 series, and eventual CEN/TC 473 new standards), and state-of-the-art LCA frameworks (PEF) (D7.4).
Measurable indicators: ■ **KPI 1.1** Demonstration cutting-edge digitalisation solutions in **4 bio-based industries**. ■ **KPI 1.2** Deployment of DPP4.0 solutions for at least **4 bio-based products**.

OB2 Mobilize the Deployment of I4.0 Technologies and DT Solutions for Realizing Circular Bio-Based Products and Industries: bi0SpaCE will address the pressing need of bio-based industries to enhance sustainability and circularity by providing methods and tools for creating and managing I4.0-compliant DTs for processes. These digital solutions, including AI-enhanced DTs and DPPs, offer promising avenues for achieving sustainability objectives.
Results: ■ **R2.1** Methods for the creation and management of AI-enhanced, AAS-compliant DTs tailored for bio-based processes, ensuring interoperability and real-time data integration (D5.1). ■ **R2.2** AAS models and accompanying tools for the semi-automatic creation of DPPs for bio-based products, utilizing AAS of the process that produces the product and domain-specific ontology, ensuring traceability and sustainability across the product lifecycle. ■ **R2.3** Ontologies tailored for bio-based industries, capturing domain-specific knowledge and characteristics to support standardized modelling and representation within DTs and DPPs, facilitating interoperability and data exchange.
Measurable indicators: ■ **KPI 2.1** **≥3 AAS submodel templates** created to model DTs and DPPs. ■ **KPI 2.2** **≥3 services** implemented to realize DTs. ■ **KPI 2.3** **≥2 services** implemented to generate DPPs. ■ **KPI 2.4** **≥1 ontologies** created to model circularity- and sustainability related aspects in bio-based industries ■ **KPI 2.5** **≥10 bi0SpaCE DPPs generated** and **≥3 publicly disseminated**.

OB3 Advance Digital Technologies for Tracking Resource Flows and Interoperable Exchange of Sustainability & Circularity Information in Bio-Based Value Chains: The digitisation of bio-products and their life cycles is still isolated, and traceability is still in its infancy. For that reason, bi0SpaCE will provide methods and tools for the exchange of digital information of bioproducts, components and materials via a data space specialised in the bio-based industries (IDS and FAIR compliant), and provide data space services for easily findable and accessible tracking and tracing of products, components, and materials (e.g. through DPPs)
Key Results: An IDS compliant data space specialized for bio-based industries, with onboarding and value-added services such as for DPPs, guaranteeing secured, trustworthy sharing and FAIR for matchmaking services**,** increase transparency, traceability, consistency, and supply-demand matching in bio-product value chains (e.g. exchanging DPP data or other flow traceability information). ■ **R3.1** Project architecture definition and realization of IDS-compliant dataspace for bio-products (D5.2). ■ **R3.2** DPP onboarding service generated for the products involved in the project (T5.4). ■ **R3.3** Traceability service for bio-based products in scope, based on DPPs (T5.3). ■ **R3.4** ML models for tracing quantity and quality of continuous process flows in bio-based industries (D4.1). ■ **R3.5** Identification of the product specifications end to end in the DPP (D6.2).
Measurable indicators: ■ **KPI 3.1** **≥1 reference implementations** on IDS-compliant data space for bio-based products. ■ **KPI 3.2** **≥ 3 data space services** implemented to specialize the data space for DPPs and bio-based industry. ■ **KPI 3.3** Improving efficacy of tracking and tracing by **50%** in terms of both amount and consistency of tracked information. ■ **KPI 3.4** **≥4 value chain actors** onboarded in the bi0SpaCE data space. ■ **KPI 3.5** ML models for continuous tracing developed and validated for **≥1 industrial bio-based process flows.** ■ **KPI 3.6 Traceability of production process ≥2 production specifications in bio-based industries.**

OB4 Promote Competitive and Sustainable Management of Natural Capital & Local Ecosystems in Bio-Based Industries: Assessing process industry sustainability requires extensive data sets to evaluate impacts across a product system's lifecycle, enabling identification, quantification, and benchmarking. bi0SpaCE will leverage advanced digital technologies to apply environmental and circularity assessment tools like LCA and MFA, supporting methodological advances by contributing to initiatives such as the EU's PEF and evolving circularity standards like ISO/FDIS 59020.
Results: ■ **R4.1** Improved understanding of environmental impacts for bio-based industries, focusing on critical areas like carbon accounting and biodiversity, by enhanced data collection and substance tracing techniques (D3.2). ■ **R4.2** Guidelines for PEF based LCAs as well as CE assessments standardizing methodologies to ensure bio-based industry-wide comparability and consistency (D3.2). ■ **R4.3** Transparent disclosure of green claims based on DPPs.
Measurable indicators: ■ **KPI 4.1** Demonstration of PEF method and circularity assessment in **4 bio-based value chains**. ■ **KPI 4.2** Development of **4 updated datasets** for the LCA of bio-based products.

OB5: Innovate Digital Circular Economy Solutions for Creating Resilient and Inclusive Local Bioeconomies: bi0SpaCE project aims to enhance circularity for feedstock and energy, assessing value chain resilience to disruptions via ecological network analysis. It will develop tracking tools for comprehensive material and energy

management, focusing on societal impacts in pilots, especially in rural settings, to boost social benefits and profit redistribution.
Results: To accelerate stakeholders' adoption of project results, bi0SpaCE will produce the following. ■ **R5.1** Demonstration of sound business value propositions (e.g. improved circularity resilience, positive impact on local communities) by involving diverse stakeholders across biobased value chains (e.g., primary suppliers, process industries, consumers, regulators, etc.). ■ **R5.2** Guidelines and governance standards for building high societal readiness solutions. (T2.3) ■ **R5.3** Dissemination and evaluation of results in scientific, consumer, and citizen forums for increasing societal acceptance of the developed digital and CE technologies. bi0SpaCE consortium benefits from strong networks involvement across relevant stakeholder categories (D7.2).
Measurable indicators: ■ **KPI 5.1 Resilience assessment:** Feedstock resilience analysis for at least **4 bio-based industrial value networks**. **KPI 5.2 Societal impacts:** Measured by the improvement of at least **5 social sustainability indicator categories** based on UNEP social LCA framework for each pilot. ■ **KPI 5.3 Ecosystem adoption:** **≥10 actors** interested in evaluating the bi0SpaCE software framework. ■ **KPI 5.4 Demonstration and Outreach:** See Section 2, Table 5. ■ **KPI 5.5 Scientific impact:** See Section 2, Table 5.

OB6: Harmonise I4.0, Sustainability, and CE Standards for Accelerating DPP Deployment for Bio-Based Products and Value Chains: The bi0SpaCE project will create the knowledge for building I4.0 enhanced DPPs for bio-based products, by systematically characterizing data requirements for creating DPPs from diverse bio-based products and associated material and energy flows, from the pilots (incl., paperboard, biogas, bio-based energy flows, industrial process water, bioplastics), and from interfacing with ongoing projects CIRPASS, ECO-FACT, DPP4.0, DigInTrace, ELLIPSE funded by the Circular Bio-based Europe JU, and 1 sister project in this call. This knowledge will be implemented in delivering first-of-its-kind results.
Results: ■ **R6.1** Standards-based DPP authoring and management service, extending the DPP4.0 framework, towards linking DPP creation and AAS compliant process DT models (T5.2). ■ **R6.2** CE dataspace based on IDS Reference Architecture, enabling exchange of sustainability and CE information (incl. PEF compliant LCA results, social impact assessment, CE assessments) and APIs for third-party services, ensuring product performance tracking, tracking, and reporting is standardized in line with EU Green Deal ambitions and standards (D5.2). ■ **R6.3** Development of a Project plan for a DPP-related pre-standard for bio-based products (CEN Workshop Agreement) (D7.4).
Measurable indicators: ■ **KPI 6.1** **≥3 linked standardized data collection protocols** and **≥3 linked standardized assessment frameworks** for CE and sustainability information linked to bi0SpaCE DPPs. ■ **KPI 6.2** **≥3 linked I4.0 standards/reference architectures** for creating bi0SpaCE DPPs. ■**KPI 6.3** Organization of a workshop, possibly at CEN/CENELEC premises, focused on bio-products DPP standardization needs. ■ **KPI 6.4** Realization of the Project Plan of a new CEN Workshop Agreement (CWA) in compliance with CEN rules.

2.1.2 Ambitions Beyond the State-Of-The-Art

ML Models for Tracking Continuous Process Flows and Emissions	
Linked Objectives: OB3, OB4	**Linked WPs: WP4**
State of the Art: Tracing material and energy flows in bio-based industries for CE requires continuous monitoring of key parameters (flow rate, concentration, temperature, and pH), within piping/production systems. Apart from real-time measurements and experiments, detailed and local information of key parameters need to be ascertained using fluid-mechanics models. CFD modelling can provide local quantities of interest at grid points on the computational domain acting as sensors (e.g., thermo-fluidic properties in a ferrochromium refining reactor[7], emissions in industries[8], recycling[9]). High-fidelity CFD [10] provides precise solutions but with high computational costs[11] and are therefore challenging to deploy in real-world tracking applications. To strike a balance between accuracy and computational cost, there is a need for developing lightweight ML-based fluid dynamics models that can capture complex physics and in bio-based industrial processes[12].	
Progress beyond state of the art: bi0SpaCE will develop ML models for continuous tracking and prediction of process flows (e.g., process water) and emissions (e.g., dissolved salts and particles). These models will enable bio-	

[7] Eric (2018). https://www.pyrometallurgy.co.za/InfaconXV/0027-Eric.pdf
[8] Mikulcic et al. (2012). https://doi.org/10.1016/j.energy.2012.04.030
[9] Dimas et al. (2022). https://doi.org/10.1016/j.procir.2022.02.020
[10] Balachandran et al. (2021). http://hdl.handle.net/20.500.12708/40381
[11] Siebler et al., 2020
[12] Jablonka et al. (2023). https://doi.org/10.1126/sciadv.adc9576

based industries to develop and deploy custom "virtual sensors" for estimation flow quantities and qualities in their cesses. In turn, this enables creating verified DPPs (e.g., using mass balances and other physical conversation principles) for bio-based products at a high level of granularity, advancing current state of the art in this domain, which is largely limited to DPP creation for easily discretisable quantities (e.g., individual products).

Digital Tagging of Bio-Based Products	
Linked Objectives: OB3, OB4	**Linked WPs: WP4**
State of the Art: current landscape of tagging and watermarking mechanisms in the bio-based industry primarily focuses on physical identification codes such as RFID tags, QR codes, and barcodes. These methods are effective for basic tracking and identification but exhibit significant limitations to managing complex and variable nature of bio-based products[13]. The variability in raw material quality, the diversity of manufacturing processes, and the complexities of supply chain logistics demand a more accurate approach to traceability and quality assurance[14]. Existing systems are inadequate to capture the dynamic and multi-variable data required for comprehensive lifecycle analysis, sustainability assessments, and real-time quality control[15]. Relying on physical tags introduces vulnerabilities in durability, tamper-resistance, and data capacity, which lead to gaps in traceability and challenges in ensuring product authenticity and environmental compliance.	
Progress beyond state of the art: Digital Tagging of Bio-Based Products introducing a novel integration of physical and digital identification codes. The hybrid approach will be designed to capture an increased level of detail about each product's manufacturing journey: raw material sourcing, manufacturing processes, final product delivery, ... based on available data. Using existing digital IT/OT infrastructure (SCADA, MES, and ERP systems) and enhancing it with novel digital marks (data analytics of multivariable flow information), the innovation promises a comprehensive, and tamper-proof method of tracking and analysis. Digital marks will serve as repositories of rich, multi-dimensional data with material origins, process parameters, and quality metrics in different timescales (real-time, batch, lot, series ...). The approach will address limitations of traceability and quality assurance offering precise data for sustainability assessments, CE practices, and consumer transparency.	

Modelling and Deployment of Process DTs in Bio-Based Industries	
Linked Objectives: OB1, OB2	**Linked WPs: WP3, WP4, WP5**
State of the Art: To scale and optimize processes in bio-based industries, advanced digital tools and services can play a crucial role. DTs have already been used to simulate and optimize the process by e.g. testing different scenarios to identify the most efficient processes and optimize their operations[16].They require large amounts of data from various sources that are difficult to access or not yet available. New sensors[17] are needed to provide data that can be combined with other sources so that predictive analytics can help optimize processes. Additionally, bio-based industries are often characterized by a lack of standardization (e.g., in waste materials) and data silos inside of a company. Technology interoperability[18] is even more challenging in value chains because different companies use different technologies and software systems, making it difficult to seamlessly share the data and information needed to track and monitor the progress of materials as they move through the supply chain.	
Progress beyond state of the art: The bi0SpaCE project will pioneer the development of standards-compliant and interoperable DTs for bio-based processes, leveraging the AAS standard to ensure protocol-agnostic control and real-time data capture. This advancement will facilitate the optimization of resource usage, environmental monitoring, and circular economy practices within bio-based industries.	

DPP Creation, Management, and Exploitation	
Linked Objectives: OB1, OB3, OB6	**Linked WPs: WP5, WP7**
State of the Art: Digital Product Passports (DPPs) aim to enhance CE by compiling data along products' value chains, offering insights for consumers, and ensuring regulatory compliance. However, it is imperative to agree on	

[13] Franz D. Bähner; https://doi.org/10.1021/acs.iecr.1c01792
[14] Bezama, A.; Ingrao, C.; O'Keeffe, S.; Thrän, D. (2019). https://doi.org/10.3390/su11247235
[15] ProBioTracker. https://assets.ey.com/content/dam/ey-sites/ey-com/nl_nl/topics/ccass/cas-case-study/ey-case-study-cas-probiotracker.pdf
[16] Perno et al. (2022). https://doi.org/10.1016/j.compind.2021.103558
[17] Friedrich et al. (2022). https://doi.org/10.19080/AJOP.2022.05.555668
[18] Pan et al. (2021). https://doi.org/10.1016/j.compind.2021.103435

the content, representation, and access to the relevant information, which leads to the standards for DPPs[19]. The DPP4.0 initiative proposes to use the AAS standard of representation and exchange of data in Part I and Part II and CE information (carbon footprint) in the AAS sub-model template. However, there is no support yet for DPP modelling for the product life cycle (from design to end of life), such as documentation of product use and maintenance or the representation of waste valid for secondary raw materials. The lack of a unified framework results in not interoperable DPPs, creating challenges in data comparison inside and across sectors. Although there are sector-specific DPPs (e.g. for batteries), the use of DPPs for bio-based products is still in its infancy.
Progress beyond state of the art: bi0SpaCE will follow the DPP 4.0 initiative, enhancing AAS standard, creating AAS submodel templates to model all aspects relevant to CE of bioproducts and providing clear guidelines and stimulating innovation and competition among bio-based product providers. bi0SpaCE will enable creation and maintenance of DPPs that provide comprehensive information about bio-based products, including their composition, origin, production processes, etc.

Semantic Models and Optimisers for Bio-Based Materials and Resource Flows	
Linked Objectives: OB2, OB3	**Linked WPs: WP2, WP4, WP5**
State of the Art: Several methods and frameworks have been proposed for implementing CE principles in manufacturing[20]. There is a strong focus on closing-the-loop by reengineering supply chains to minimise waste and lessen negative effects on the environment. For this, re-distributed manufacturing is key CE strategy and aims to re-engineer old supply chains into more flexible and localised ones, leading to faster response times, better customer product lifecycle monitoring, and lower costs[21]. A crucial step in implementing CE is monitoring the status of materials and products throughout their life cycles using sensors, ID devices, and other systems that record, gather, organise, and share important and meaningful data for the computation and assessment of characteristics and KPIs in various contexts along the lifecycle. As of today, methodologies and techniques to model data so that are FAIR and sharable are still under development.	
Progress beyond state of the art: By implementing an IMF based on semantic foundations, data sharing in bi0SpaCE expands upon the concepts of enterprise modelling and integration. IMF will build on the so far achievements on industrial ontologies and knowledge graph developments of Industrial Ontologies Foundry, EU Onto-Commons project and the recently created Knowledge Graph Alliance so that data in bi0SpaCE are FAIR and trustfully sharable. Furthermore, bi0SpaCE will extend state-of-the-art tools for industrial logistics management by developing interlogistics optimisers that increase the efficiency of distributed supply and transportation systems for extracting raw materials for bio-based industries from geographically dispersed natural sources.	

CE Dataspaces and Marketplace Services based on DPPs	
Linked Objectives: OB1, OB3, OB6	**Linked WPs: WP5, WP7**
State of the Art: DPPs should be sharable, aiding information exchange between manufacturers, suppliers, customers, and regulators. Data spaces help this sharing, but they should be extended for the needs of DPPs. Current data spaces provide generic building blocks[22] (connectors, identity management, etc.), but lack domain-specific requirements[23]. CE domain requires product traceability along the value chain to help consumers make informed choices and allow economic operators, repairers, recyclers, and authorities to access necessary information. Current DPPs challenge users accessing and understanding data. More intuitive interfaces and analysis tools are required (e.g. protection of owners' sensitive information and comply with EU standards).	
Progress beyond state of the art: bi0SpaCE aims to enhance data spaces for circular manufacturing by focusing on DPPs with FAIR principles for material, component, and product data sharing. This will be done by (1) connectors to support effortless onboarding on DPPs, (2) data space building blocks with DPP relevant services and (3) building blocks with circularity services such as locating a DPP in a value chain, sourcing of materials, production, and end-of-life management.	

[19] https://circthread.com/download/deliverable-9-3-standardisation-and-regulatory-needs-assessment/
[20] https://ellenmacarthurfoundation.org/circular-economy-diagram
[21] https://www2.deloitte.com/content/dam/Deloitte/fi/Documents/risk/Circular%20economy%20FINAL%20web.pdf
[22] https://dssc.eu/space/BBE/178421761/Building+Blocks+%7C+Version+0.5+%7C+September+2023
[23] Usländer et al. (2022). https://doi.org/10.3390/automation3030020

Simulation and Data-Driven Sustainability and CE Assessment of Bio-Based Products	
Linked Objectives: OB2, OB3, OB5	**Linked WPs: WP3, WP5**
State of the Art: Generic process models from commercial databases (e.g., Ecoinvent, Agribalyse) used for sustainability assessments of bio-based products can have significant uncertainties due to limited geographical and technological representativeness[24]; they also offer limited insights for process optimization. To address challenges in data collection, process simulation tools (e.g., HSCSim, ASPEN) are useful for sustainability-oriented process planning but they do not enable assessment and monitoring of process flows. Application of AI and ML models have been explored for predictive LCA and CE assessment[25,26] and for online inventory data collection in process industries[27] . However, such approaches need high-levels of sensorisation and are not suitable for proactive process optimization, e.g., by exploiting simulation-based (physical) process models[28].	
Progress beyond state of the art: Enhance the ease of conducting PEF-based LCA and CE assessment of bio-based products by introducing a novel hybrid approach integrating accurate primary process data from AAS-compliant DTs (i.e., based on process sensors) with physics-based simulation tools. This enables developing physics-informed ML models that overcome limitations, such as inadequate data coverage, and inaccuracies in purely data-driven models, and ML-driven, sustainability- and CE-focused process optimisation. Additionally, bi0SpaCE will investigate new ecology-based methods to measure the resilience of bio-based value chains, ensuring the industry's adaptability to disruptions and fluctuating supply and demand, thereby supporting the green and CE transition.	

2.1.3 Research and Innovation Maturity

Table 2: bi0SpaCE technologies and TRLs

Tech.	Description	Partner	TRL bef-aft
FA³ST	Fraunhofer Advanced AAS Tools for DTs is Java-based software ecosystem for creating and managing I4.0-compliant, hybrid and data-sovereign DTs. In bi0SpaCE, it will be extended to realise AI-enhanced DTs for bio-based processes as well as for DPPs.	FHG	4 - 6
Lifecycle Co-Simulation	AU has developed a research framework for co-simulation-based estimation of CE & LCA indicators. In bi0SpaCE this framework will be extended to enable LCA & CE focused process optimisation under uncertainty using surrogate modelling methods. .	AU	3 - 5
ML models for flow tracing	AU has developed CFD driven Reinforcement learning (RL) algorithms for wall modelling in large-eddy simulations (LES). In bi0SpaCE, these models will be adapted and validated for modelling and tracing continuous material flows (e.g., water, dissolved materials) for bio-based processes.	AU	3 - 5
Digital Tagging of bio-based	Digital Tagging of Bio-Based Products introducing a novel integration of physical and digital identification codes. The hybrid approach will be designed to capture an increased level of detail about each product's manufacturing journey.	CAR	3 - 5
Intralogistics Optimiser	SSF has developed a suite of tool & intralogistics optimizers for industrial production. In bi0SpaCE this suite will be extended with optimizers that makes distributed systems for extracting raw materials from geographically dispersed natural sources and the associated transport more efficient.	SSF	3 - 5
Semantic modelling	SSF is developing a semantics-based information modeling framework including system-modelling, ontology development based on the system model, and knowledge-graph creation based on the developed ontology. The so created knowledge graph is to be used as reference to the data to be used by selected bi0SpaCE apps	SSF	3 - 5

bi0SpaCE uses the **Technology Readiness Levels (TRL)** approach to provide a quantitative assessment of the maturity of the proposed system. Work performed in previous research initiatives has provided the consortium partners with a solid background of performing basic technology research. Hence, within bi0SpaCE implementation, existing tools will be used and integrated to create innovative results and **reach a TRL 5/6**. Table 2 above presents both the research prototypes and commercial technologies to be utilized for different purposes of the project. #§PRJ-OBJ-PO§#

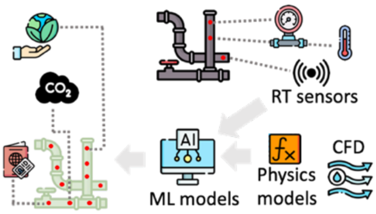
[24] Khoo et al. (2018). https://doi.org/10.1016/j.spc.2018.06.002
[25] Jamwal et al. (2021). https://doi.org/10.1108/JEIM-09-2020-0361
[26] https://ecofact-project.eu/
[27] https://s-x-aipi-project.eu/
[28] Mowbray et al. (2022). https://doi.org/10.1039/D1RE00541C

2.2 Methodology #@CON-MET-CM@# #@COM-PLE-CP@#

2.2.1 Overall methodology and concepts

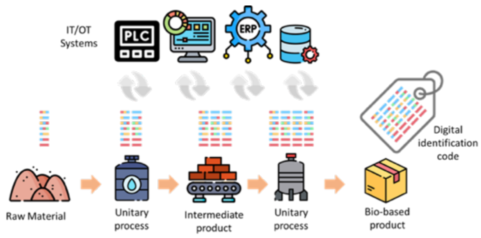
The bi0SpaCE software framework for CE solutions and services across bio-based industries and their value chains will be comprised of the following nine modules.

1-Tracking Continuous Process Flows and Emissions in bi0SpaCE



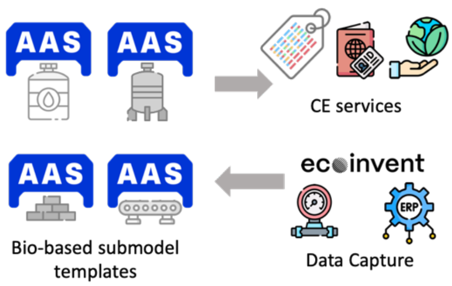
Integration of ML models with CFD can offer unprecedented accuracy and efficiency in monitoring bio-based industrial processes. This approach is designed to surmount existing cost-related challenges in real-time industrial tracking by creating virtual sensors providing detailed insights on parameters like flow rates and concentrations. By enhancing ML-based CFD models through the inclusion of physical laws, the models' predictive capabilities and explainability, will be improved, addressing critical trust issues among end-users. The resultant ML-driven system can dynamically capture and predict the nuances of process flows and emissions, facilitating more sustainable operations.. The developed methods can significantly contribute to the creation of dynamic LCA and CE tools, offering real-time tools with low computational overheads. Furthermore, the detailed and accurate tracking of flow quantities from this system can support the generation of DPPs, documenting the environmental and circularity credentials of bio-based products. This methodology, therefore, enhances operational efficiency, environmental accountability and sustainability within the bio-based industries.

2-Digital Tagging of Bio-Based Products in bi0SpaCE



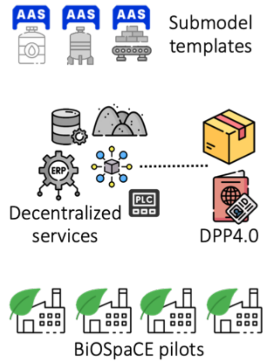
The core of digital tagging is the establishment of a digital set of information that mirrors the physical process and product manufacturing unitary processes and lifecycle affecting stages. This information intends to create a robust and dynamic system for tracking, verifying, and optimizing the production and supply chain of bio-based products. Digital Tagging involves the assigning unique digital identifiers (Digital Identification Codes) to each batch of raw materials, intermediate products, and final products. These codes are generated at different manufacturing unitary process steps and will be designed to carry relevant information about the product, including its origin, composition, processing parameters, and quality metrics. The digital tags will be updated in real time through each stage of the manufacturing process, incorporating data from systems such as SCADA, MES, and ERP IT/OT systems, as well as online and offline laboratory analyses along the production steps.

3-Process DTs for Bio-Based Industries in bi0SpaCE



The development and deployment of process DTs in bio-based industries under the bi0SpaCE project comprises three key steps. (1) Initiation by designing standardized AAS sub-model templates explicitly tailored for modelling bio-based processes, prioritizing the integration of CE principles. These templates will serve as foundational structures for the subsequent construction of DTs, ensuring compatibility and coherence with industry standards and will consider the entire life cycle of a bio-product and its subcomponents, ensuring comprehensive representation of key parameters such as energy consumption, carbon footprint, and quality. (2) Implementation of robust data capture mechanisms capable of acquiring real-time information from diverse sources, involving deployment of specialized sensors, supplemented by historical data and secondary LCA databases, e.g., EcoInvent. (3) bi0SpaCE will configure the DTs to provide advanced CE-related services, including but not limited to simulation and data-driven optimisation of manufacturing resource-optimisation and establishing comprehensive tracking systems for components and materials. By leveraging these process DTs, the project will ensure the availability of accurate environmental and social impact information crucial to produce bio-based products. This comprehensive data framework will enable stakeholders to identify and exploit opportunities for reusing, repairing, refilling, removing, and recycling components and materials, thereby promoting a more sustainable and circular bioeconomy.

4-DPP4.0 in bi0SpaCE



The advancement of DPP4.0 within bi0SpaCE entails three main steps aimed at enhancing the creation, management, and utilization of DPPs in bio-based industries. (1) Firstly, the adaptation of the DPP4.0 framework will focus on enabling decentralized and dynamic authoring and sharing of accurate product information through the development of novel DPP-based software services. These services will advance existing DPP solutions by implementing semi-automatic creation mechanisms, enabling real-time data collection, digitization, and integration from various data sources via process DTs. (2) Secondly, to meet the specific needs of bio-based industries, bi0SpaCE will take advantage of AAS submodel templates tailored for modelling aspects relevant to CE of bio-products. (3) All these advancements will be integrated into the proposed bi0SpaCE software framework, enabling rapid experimentation and validation of technologies in industrially relevant environments through bi0SpaCE pilots. By integrating different data sources (e.g., material selection, production, logistical processes, supplier information, etc.), bi0SpaCE aims to create a flexible framework for DPP data continuity and transparency. This comprehensive approach enables stakeholders and consumers to access accurate and up-to-date information on bio-based products, fostering transparency, traceability, and sustainability across the bioeconomy.

5-bi0SpaCE Semantic Models and Optimisers

bi0Space ensures the interoperability of the physical, DT, DPP, and dataspace layers by implementing an IMF based on semantic foundations. With the goal of enabling scalable implementation, the IMF will be designed as a standards-compliant collection of libraries, structuring principles, and modelling techniques for creating models and optimisers of engineering assets in bio-based industry domain. This is accomplished by employing ontologies for classification and verification, application-independent formats via semantic technologies, straightforward method implementation, and user-friendly software for end users. Enforcing model consistency, or making sure all models have the same design, is one of the framework's objectives. The IMF, standards, and common ontologies will provide cross-domain technological harmonisation. This allows for the enhancement of the digitalisation of manufacturing assets, optimisation of data management, and data-driven process efficiency optimisation, for I4.0 based automation across the entire material/product/process life cycle.

6-bi0SpaCE CE DataSpace Architecture Overview and

bi0SpaCE delivers a data space based on DPPs with the bio-domain at the centre. Creating an IDS-compliant dataspace for bio-based industries, with services like DPPs, ensures adherence to DPP-secured, trustworthy sharing, and FAIR principles. This improves DPP matchmaking services. This will increase transparency, traceability, consistency, and supply-demand matching in bio-product value chains (e.g. exchanging DPP data or other flow traceability information). This will be done by extending data space connectors to support effortless onboarding on DPPs and extending standard data space building blocks with DPP relevant services. The architecture is designed for ease of implementation and maintenance, relying on a decentralized infrastructure controlled by stakeholders. While the use of AAS standards for modelling processes, digital tools and DPPs ensures interoperability, enabling data sovereignty ensures trustworthiness between partners in a value chain. Additionally, CE requires extending a data space marketplace building block with circularity related services such as the traceability service to locate a DPP in a value chain, including sourcing of materials, production, and end-of-life management.

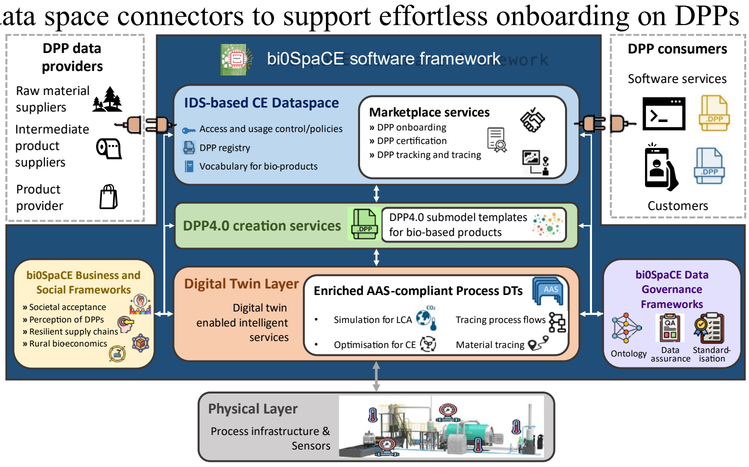


Figure 3: bi0SpaCE conceptual architecture

The decentralized nature of the bi0SpaCE data space will be also leveraged to provide traceability functionalities.

7-bi0SpaCE's Data-Driven Environmental, Social LCA and CE Assessment

bi0SpaCE will streamline sustainability assessments for bio-based industries using cutting-edge digital tools, focusing on lifecycle environmental impacts as well as on circularity and social aspects. The environmental dimension will be addressed by integrating LCA and MFA methodologies, building upon existing standards (ISO 14040, ISO 14044, PEF). CE metrics will be advanced (currently under development in ISO/TC 323) to enhance benchmarking and drive methodological innovation. Social impacts will be assessed considering existing methods such as UNEP SETAC's guidelines. This will be achieved through improved data collection and impact assessment, material and energy flow monitoring and emission and effluent characterisation to build new and updated datasets. The models will be fed by accurate primary data from AAS-compliant process DTs. bi0SpaCE will also couple hybridization of data and models for bio-based products, i.e., fusing data from online process sensors with physics-based models to address existing challenges such as costly process data collection and limited fidelity of estimations. The developed models will be based on leading digital standards in DT modelling (AAS) and data communication (e.g., OPC-UA, MTCONNECT). Finally, bi0SpaCE will explore novel ecology-based approaches and the link with the planetary boundaries' framework for quantifying resilience in bio-based value chains.

8-Digital CE Solutions for Creating Resilient and Inclusive Local Bioeconomies

The bi0SpaCE project aims to advance CE methodologies in bio-based industries, focusing on assessing feedstock and energy flows' circularity. The resilience of the value chains to potential disruptions e.g., due to climate change and future scenarios will be estimated using metrics derived from material flow network analysis. The project will develop tracking tools for material and energy at various scales (intra-organizational, inter-organizational, and regional) and will quantify societal impacts of the developed digital and CE solutions in the pilots across diverse stakeholder (e.g., local job creation; social acceptance, usage of local feedstocks), including in bio-based eco-industrial parks situated in rural areas. Specific focus is set on identifying models for ensuring a more positive social impact and redistributing profits, through developing innovative bio-based products and solutions that can be deployed in rural and agricultural communities. Finally, to promote inclusive technology development, bi0SpaCE emphasized the role of social sciences in understanding consumer and end-user awareness and acceptance of digital tools (e.g., ML, DT, DPP, etc.) and will conduct bench studies and surveys with these user groups to include them in technology and policy development.

9-Contributing to Standardization development and Harmonisation in bi0SpaCE

Best-practices and standards developed for defining DPPs of technical materials-oriented products (e.g., batteries) may not be directly extendable to bio-based products and their value chains. To this end, bi0SpaCE will create the knowledge for building I4.0 enhanced DPPs for bio-based products by systematically characterizing data requirements from diverse bio-based products, associated material and energy flows (such as paperboard, biogas, bio-based energy flows, bio-based food products and industrial process water), while interfacing with ongoing projects like CIRPASS, ECOFACT, DPP4.0, DigInTrace, ELLIPSE project from the Circular Bio-based Europe JU (WP7,T7.2), and 1 sister projects in this call. This initiative addresses the limited understanding of product lifecycle data types, including environmental, social, economic sustainability and circularity data, essential for ensuring the simultaneous digital and circular transition of bio-based products and industries. Within WP7, these findings will be the starting point for the possible development of a new pre-standardization document (CWA).

biOSpaCE S&T methodology

For the ambitious objectives set, biOSpaCE intends to align own S&T developments with established and proven frameworks (CRISP-DM, MLOPS, LCA, DT) through six key steps to ensure a systematic approach to data analysis, model development, and technology deployment, ultimately enabling the successful transition of innovative technologies from concept to industrial application in the bio-based environments of the pilots. Finally, the proposed methodology will enable a reliable evolution towards the final validation of the biOSpaCE technologies (TRL5) taking advantage of the industrially relevant environments offered by the bio-based industrial partners pilots:

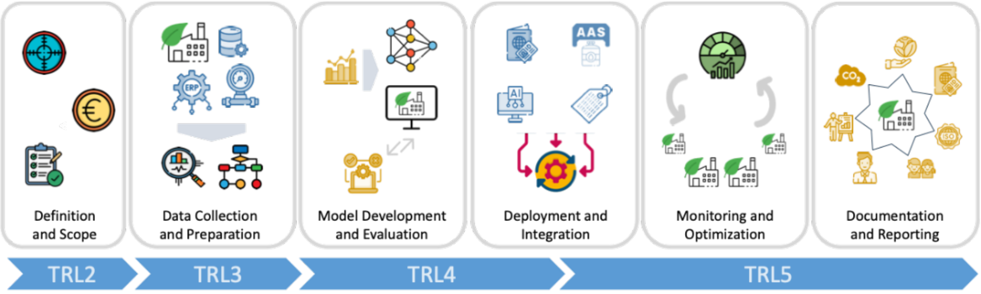


Figure 4: bi0SpaCE methodology to achieve project objectives

1-Definition and Scope (TRL2): the focus is on formulating the technology concept and refining targets and scope. This step involves understanding the potential applications of ML and DT technologies in bio-based industries, identifying key business questions, and establishing initial project scope and stakeholders' requirements. In this step the relevant ontologies for data interoperability will be defined for an optimal design of bi0SpaCE software framework including dataspace that ensures scalability, security, and functionality across various technological modules.

2-Data Collection and Preparation (TRL3): This step involves collecting and preparing data from various sources for modelling and analysis. The data collected may include historical data from bio-based manufacturing processes and other relevant sources (e.g. ECOINVENT, new advanced sensors) for an accurate initial process inventory and emissions in the bi0SpaCE pilots. Pre-processing and data ECOINVENT). Pre-processing and cleaning will be crucial for building initial models and conducting reliable proof-of-concept experiments.

3-Model Development and Evaluation (TRL4): Here, the focus is on developing models (ML, simulation, physics-based, hybrid, etc.) and DT modules based on the collected data. For the DT this step includes the generation of AAS submodel templates, that are crucial for ensuring adherence to interoperability and data exchange standards. In this step the models are evaluated to assess their performance and accuracy initially against the relevant environments of pilots. This step also includes refining and optimizing the models based on feedback and insights gained from initial testing and pilot's stakeholders. The aim of the models will be focused on the tracing of flows, tracking, sustainability and circularity performance of their bio-based products.

4-Deployment and Integration (TRL4-5): partners pilots. This step focuses on deploying the developed DT models and modules in pilot industrially relevant environments within bio-based manufacturing processes. It also involves integrating them into existing systems and processes, ensuring interoperability and compatibility with DT infrastructure thanks to the developed AAS sub model templates that guarantees effective data transit.

5-Monitoring and Optimization (TRL5): This step involves real-time evaluation of DT models and the bi0SpaCE software framework within the pilot environments. This stage is critical for assessing stability and reliability, ensuring the accurate tracking of material flows and energy usage. Continuous refinement and optimization will be guided by pilots' feedback: enhancing process efficiency, reducing CO2 emissions, and ensuring the technology's effectiveness and adaptability in bio-based industries.

6-Documentation and Reporting (TRL5): This final step involves documenting methodologies, findings, and results throughout the project evolution. Results will be generated and disseminated to relevant stakeholders and target groups, including bio-based industrial associations, standardization community (CWA), consumers, researchers, and policymakers, to ensure expected outcome and impacts (section 2.1).

2.2.2 DNSH 'do no significant harm' principles

bi0SpaCE is fully compliant with the Do No Significant Harm (DNSH) Principle since its activities (during the course of the project and in the expected life cycle of the innovations), not only do not significantly harm any of the 6 environmental objectives set out in Art. 9 and 17 of EU Regulation No 2020/852 (see Table 3). Given the strong sustainability & circularity focus in bi0SpaCE the aim of project is to have a net positive impact on the specified environmental indicators. To ensure that bi0SpaCE maintains these ambitions, the project will adopt the precautionary principle, as a core tenet in technology development. Additionally, bi0SpaCE will apply a life-cycle oriented approach (T3.2) to avoid burden shifting and rigorously quantify the environmental burdens of the proposed solutions. The data and methodology for conducting such assessments will be made transparent, within the limits of industrial confidentiality, and results will be critically reviewed by an external evaluator when possible.

Table 3: bi0SpaCE project response to Do Not Significant Harm (DNSH) Principle

Environmental objectives	bi0SpaCE response
Climate change mitigation	Activities DO NOT lead to significant greenhouse gas emissions.
Climate change adaptation	Activities DO NOT lead to an increased adverse impact of the current climate and the expected future climate, on the activity itself or on people, nature or assets.
Protection of water and marine resources	Activities ARE NOT detrimental to the good environmental status or ecological potential of (i) bodies of surface water and groundwater; or (ii) marine waters.
Transition to a circular economy	Activities DO NOT lead to i) significant inefficiencies in the use of materials or natural resources; ii) significant increase in the generation, incineration or disposal of waste; iii) significant harm to the environment from long-term waste disposal
Pollution prevention and control	Activities DO NOT lead to a significant increase in pollutants emissions into air, water or land, compared with the baseline situation.
Protection and restoration of biodiversity and ecosystems	Activities ARE NOT: i) significantly detrimental to the good condition and resilience of ecosystems; or ii) detrimental to the conservation status of habitats and species, including those of Union interest.

2.2.3 Use cases

Pilot 1: Circular & sustainable paper production via decreasing energy use and reusing water streams

Partner: Fiskeby AB	**Impact:** Increase system temperature by reusing heated water streams will increase production capacity and lower energy consumption per produced tonne.
Industry: Paper Production	

Technologies/Solutions Deployed: Sensors for energy, water quality and flow measurement (WP3); Process DTs of LCA and CE (WP3,5); ML models for process flow tracing (WP4); Watermarking of paperboards (WP4); DPP4.0 for paperboards (WP5);

Background: Fiskeby AB produces 170,000 Tonnes of multi-layered boards annually using recycled paperboard, handling the entire production in-house. The focus of this case study will be on improving CE and sustainability performance of the paperboard production process, with a focus on circular use of water and heat. The current production process for paperboard, as shown in *Figure 5*, is as follows: i) collection and sorting of recycled materials, ii) pulping and separating plastic from paper fibre using a 40-meter-long drum, iii) screening for separation of fibres from impurities, iv) fractionation where the paper fiber is separated into different fractions based on their size, shape, and density using pressure screens, v) refining the fractions to enhance final product performance, vi) forming the blended pulp mixture into a continuous wet sheet using a paper machine, and vii) drying, finishing, and customization. The board is cut into sheets or smaller rolls.

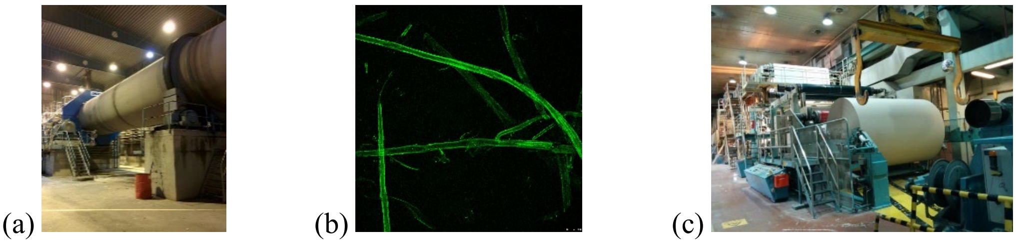


Figure 5: (a) 40-meter-long drum at Fiskeby AB for pulping & separation, (b) Paper fiber fractionation, (c) Paperboard roll at Fiskeby

Current status & need for improvement: Warm water (25°C) after water treatment plant is today released back to the river instead of reused inside the mill. Cold river water (4°C during wintertime) is instead pumped in and heated up. During production stop, cold water is also leaking in as sealing water, which will cool down the factory and it takes days to regain the system temperature. Currently, the mill uses a distributed control systems (DCS) to monitor critical process parameters, and they can be linked to the quality parameters of a specific bath of the produced paperboard. However, there is no digital data collection setup for monitoring inventory data and MFA for LCA and CE assessments or water quality monitoring. Increasing demands on the paperboard industry to achieve more circular production and become more transparent about the impacts of its production processes (e.g., through creating environmental product declarations and eventually DPPs), requires Fiskeby to improve the energy and water circularity. Reusing water and waste heat will also contribute to the business competitiveness of Fiskeby.

Pilot description: The pilot will focus on enabling circular reuse of process water after water treatment plant, requiring that water quality parameters are continuously monitored and regulated. Historically water was reintroduced without pH control, and a solution for dissolved calcium carbonate which created major problems in nozzles and wires. Parameters like hardness, pH, Legionella, PFAS/PFOS, chemical oxygen demand (COD) and retention chemicals needs to be monitored together with an innovative technique to handle already dissolved calcium carbonate and Legionella bacteria. Fiskeby also has regulatory requirements to monitor water quality parameters as they produce paperboards safe for contact with food (BfR). They include, e.g., requirements on COD, suspended solids, phosphorus, and nitrogen content, pH, heavy metals, etc. Given that Fiskeby's process also uses water/steam with significant heat energy, the pilot will also explore the potential for reuse of waste heat. Apart from these material benefits enabled through circular material use, the pilot will also demonstrate tracking of material and resource flows for quantifying the environmental and CE impacts of paper production, demonstrating the potential gains derived from circular material use, as well as measuring the transfer of waterborne effluents into environmental streams. These tracking and assessment data will be linked to process parameter and production data in Fiskeby's DCS, enabling the creation of process DTs and linked DPPs for paperboard production.

Innovation potentials: Reusing warm water streams will improve the water cycle and less river water would be used for the production. Furthermore, effective tracking of material flows and effluents will contribute to improved management or material resources and protect local biodiversity.

Pilot KPIs & validation: Large-scale deployment of water and energy reuse have a potential to unlock around 7600 MWh and 1500 tonnes of CO_2 annual savings in Fiskeby's plant. bi0SpaCE will demonstrate the knowledge and technologies for Fiskeby to achieve this potential, incentivizing them to further invest and scale the solutions after the project. Within this project, KPIs include:

■ *Digitalization:* Tracking of at least 4 water product quality properties (pH, hardness, flow rate, temperature), at least 2 types of effluents ($CaCO_3$; Legionella) for paperboard production.

■ *Tracking & tracing:* Accuracy of tracking material flow balances (e.g., for paperboard, solid wastes) ≥95%; Accuracy of tracking and predicting continuous process flows (e.g., water, dissolved substances) ≥90%.

■ *CE & sustainability:* Lower energy consumption per produced tonne by at least 3%.

■ *DPP4.0:* DPPs created for at least 3 paperboard varieties.

Pilot 2: Circular & resilient eco-industrial parks tracking bio-based material and energy flows

Partner: GreenLab Skive A/S	**Impact:** Demonstrating blueprints for circular and resilient operation of industrial parks containing bio-based industries and online tracking of bio-material and associated energy flows.
Industry: Eco- Industrial Park with bio-based products and energy companies.	

Technologies/Solutions Deployed: Sensors for material and energy flow data collection (WP3); Resilience-based optimization of bio-feedstock sourcing (WP4); Energy and bio-mass flows tracing (WP4); Symbiosis Net™ energy tracking and DPP4.0 solutions for eco-industrial parks (WP5,6);

Background: GreenLab is an industrial park organised as an eco-industrial cluster, with companies leasing the land in the park and gaining access to the infrastructure. Greenlab is located in a rural agricultural region in Denmark with many companies having biomass as a primary feedstock. GreenLab aims to enable a circular economy for its industrial partners, currently hosting 9 separate companies and having partnerships with 10 innovation and technology providers.

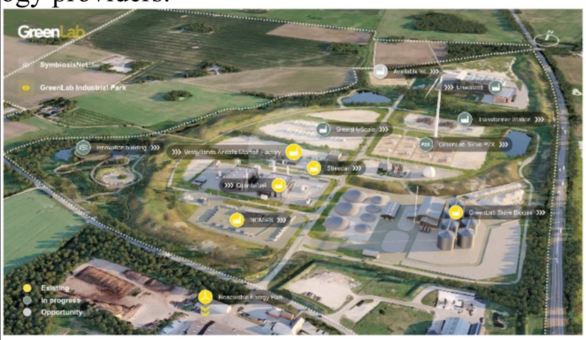


Figure 6: Overview of Greenlab industrial park

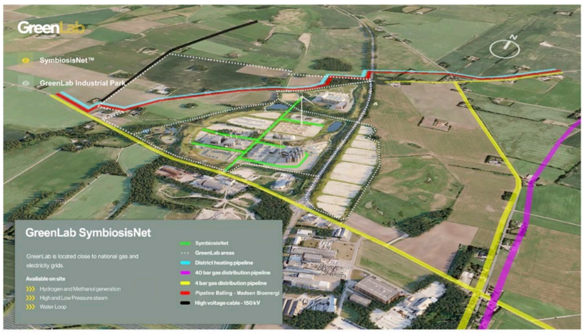


Figure 7: Deployment of SymbiosisNet™ in GreenLab

Current status & need for improvement: As GreenLab builds the needed infrastructure, both physical and digital, a key focus is also the sustainability of the means of production for energy and bio-based products. GreenLab has been working on deploying the SymbiosisNet™ a new concept for an intelligent grid of energy and data. SymbiosisNet™ and the associated energy infrastructure is built to suit the needs of the companies in the industrial park, as they increasingly share their surplus energy and resources. The SymbiosisNet™ is a replicable system enabling export of the GreenLab platform to other local communities. To operate on a more circular basis, there is a need for bio-based industries in GreenLab to track material flows, in addition to the energy flows that are tracked today. Furthermore, there is a need to ensure resiliency of the park in the face of future changes (e.g., loss or addition of industrial partners, feedstock availabilities) as well as the ambition to increase social benefits to the local community.

Pilot description: The ambition of this pilot is to demonstrate the provision of data for deploying accurate DPPs for bio-based products by linking energy data from the SymbiosisNet™ platform with material flow data tracking services enabled by bi0SpaCE DPPs and CE Dataspace. GreenLab will provide access to data from the park, offer a real-life circular economy to test ideas and benchmark how the project could be implemented in a setting with multi stakeholder involvement. Energy and material flow tracing will be demonstrated for two clusters as shown in Figure 8: Clusters analysed in Greenlab pilot

. In Cluster 1 material flows: biomass pellet for producing pyrolysis gas, water/steam, and the biomethanol fuel flow from existing data streams and material flow tracking sensors, will be linked to energy supplied to this cluster from Greenlab's renewable energy plant and from the grid. These flows will be used to define the data required for accurately estimating the environmental footprints (e.g., kg. eq. CO_2 emissions) of producing biomethanol (end-product). Such data will be needed for DPP generation by bio-based industries who are consumers of biomethanol. In Cluster 2, material flows: H_2 gas flows, and sustainable bio-protein (e.g., produced from agricultural biomass and marine sources), will be linked to energy for green H_2 production (e.g, from solar, wind, grid sources). These data will be used to demonstrate the construction of DPPs for the product (bio-protein), based on varied CO_2 intensity of the H_2 gas. Furthermore, these flow demands, and potentials for local sourcing of biomass will be used for resilience assessment of these clusters, and to evaluate the potential social benefits due to feedstock localisation.

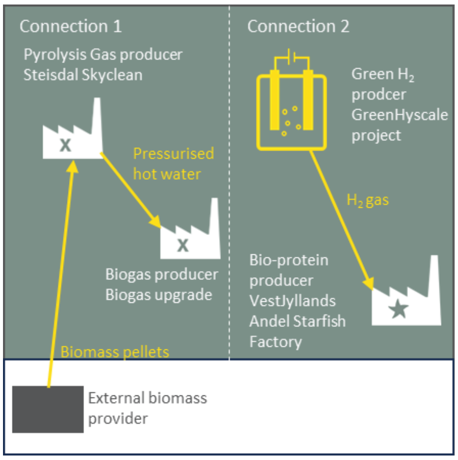


Figure 8: Clusters analysed in Green-

Expected benefits: The material and energy flow information will help steer the way GreenLab helps the companies in their park ensure regulatory compliance. Through data handling on their behalf GreenLab can help provide bi0SpaCE DPPs, already embedded in their SymbiosisNet™ platform, accounting for complex multi-stakeholder material and energy flows. Furthermore, the project results will provide a digital solution that can be used as blueprint for more circular and resilient operation of eco-industrial parks.

Innovation potentials: Results from the project will improve the digital infrastructure GreenLab is building and will help ensure CE transition has a measured impact on rural agricultural communities through the development of eco-industrial parks with circular bioeconomies. As more companies enter the park, and more synergies emerge more utilisation of the biomass at every stage may be possible, and therefore traceable.

Pilot KPIs & validation:

■ *Digitalization:* Data and sensor systems for biomass and bio-derived energy flows operate with ≥95% accuracy.
■ *Tracking & tracing:* Tracking systems established for up to 4 different energy streams; Tracking systems for energy use in separating of 0.5 mio. tonnes of biomass into wet and dry streams.
■ *CE & sustainability:* Estimating the $CO_{2\,EQ}$ for drying fish waste with ≥90% accuracy. Estimating $CO_{2\,EQ}$ impact for a unit of biomass with ≥90% accuracy and validating $CO_{2\,EQ}$ neutrality of biomass to biofuel conversion process.
■ *DPP4.0:* SymbiosisNet™ platform can be exploited for producing DPPs of ≥2 bio-based products.

Pilot 3: Integration and digitalization of quality data during the manufacturing of aloe Vera juice and cosmetics. This data can be utilized for internal metrics and also for providing information to consumers through a digital passport	
Partners: Naturae Et Salus	**Impact:** Integration of manufacturing data to improve our quality system and reduce the use of materials or to share information with the consumer (digital passport)
Industry: Food and cosmetic industry	
Technologies/Solutions Deployed: Sensors for material and energy flow data collection (WP3); Process DTs of LCA and CE (WP3,5); Digital tagging for aloe vera products (WP4);	
Background: Naturae, a manufacturer of aloe vera juice and cosmetics, aims at integrating data such as temperature, water, aloverosa and ph quality, to make its manufacturing processes more environmentally friendly by adjusting energy and raw material usage.	
Current status & need for improvement: Manufacturing data such as temperature, water, pH and aloverosa are not digitised and integrated into a programme. Therefore, no information about manufacturing data that affects the sustainable management of resources or affects product quality are available. The integration of data improves the	

competitiveness of the company through the sustainable use of resources or by providing updated information to the consumer about the product (digital passport).

Pilot description: The pilot tests will involve installing and integrating various sensors, including temperature, bottle counting, aloverosa levels, pH measurements, and harvest dates. Data obtained from laboratory analysis of parameters such as aloverose and aloin will also be integrated into the data framework collection. This integration aims to enhance resource management, improve product quality, and facilitate information sharing with consumers through a transparent reporting for consumers of the processing.

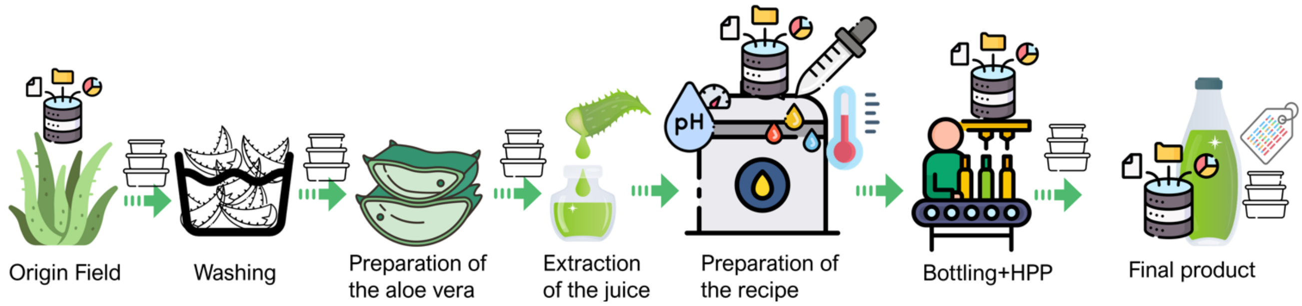


Figure 9: Description of the Aloe Vera Juice production process

The production process, see Figure 9, consists in: The reception of the fresh aloe vera leaf, cleaning the leaves with water and brushes, preparation of the aloe vera by cutting the edges and surfaces of the leaves to obtain the pulp of the aloe, extracting the juice after storing for one day, preparation of the recipe with control of the temperature and pH, and bottling and High Pressure Processing.

Expected benefits: The project offers various benefits, through the collection of two types of parameters. The first set of parameters includes those that are specific to aloe vera, such as aloverose and aloin. These parameters are directly related to the quality of the seasonal harvests and the bottles produced. The second set of parameters includes indicators for juice production, which are the processing temperatures, pH levels, and bottle counter. These indicators are used to calculate the ecological, carbon or water footprints. This information can be accessed by the consumer through a QR code**.**

Innovation potentials: The integration of data during manufacturing, including information on the raw material of origin, would result in a competitive advantage over other manufacturers. This strategy also gives the opportunity to pioneer the implementation of transparent reporting for consumers. This provides valuable information to the consumer, reinforcing the commitment to transparency and innovation.

Pilot KPIs & validation: KPIs for this project will be: pH<4, Tª [2-10ºC], aloverosa/harvest date, aloin/ harvest date, footprints (ecological, carbon and water).

■ *Digitalization:* Tracking of two relevant parameters, Temperature and pH, using bi0SpaCE sensors and data collection frameworks. Add relevant information to the database of the fields of the production, other quality analysis (aloverose>5%, aloin, solid contents > 0,45%), and intermediate storages.

■ *Tracking & tracing:* Process efficiency can be improved by tracking and optimizing key parameters; Automated control & parameter optimization will decrease the wastes of production.

■ *CE & sustainability:* the decrease of wastes, can be extrapolated to the reduction of CO_2, the CO_2 of replace the product not valid to be consumed.

■ *DPP4.0:* a transparent reporting for consumers will be created, including relevant information to consumers.

Pilot 4: Production of Sustainable Packaging Materials based on ocean grown seaweed	
Partners: noriware AG **Industry:** Bio-based Packaging	**Impact:** A new seaweed-based material production method for packaging and a new value chain for companies interested in the reduction of CO_2 emissions and cleaning up the atmosphere and the oceans.
Technologies Deployed: Sensors for energy, material flow, material temperature and material pressure measurement (WP3), Process DTs (WP3); ML models for process flow tracing (WP4); Resilience-based optimization of bio-feedstock sourcing (WP4); DPP4.0 for seaweed-based packaging material production (WP5);	
Background: Packaging is one of the largest contributors to plastic pollution, and noriware tackles this issue directly. Our solution lowers the barrier to transitioning from plastic by introducing the first	

water-resistant, fully biodegradable packaging material made from fast-growing seaweed. This innovation mimics the functionality of plastic without leaving harmful residues and is produced without toxic chemicals. Moreover, because it is compatible with existing plastic production infrastructure, our solution is scalable globally from day one. Additionally, scaling this material fosters the growth of seaweed—a resource essential for restoring natural ecosystems. This dual approach not only addresses plastic pollution but also contributes to global environmental regeneration.

Figure 10: *A selection of raw materials and processed seaweed-based materials (top-left), viewing window made out of seaweed-based materials for cardboard packaging (top-right), transparent packaging film for cutlery packaging (bottom-left), noriware's seaweed-based packaging film (bottom-right).*

Current status & need for improvement: noriware has established its norilabs with state-of-the-art laboratory equipment, including essential chemistry lab synthesis tools, lab-scale twin-screw extruders for continuous manufacturing processes, and analytical instruments for material characterization. noriware aims at addressing existing barriers for commercial scaling and adoption of our seaweed-based packaging materials, including (i) significant variabilities in input feedstock materials, (ii) optimal sourcing of feedstock material's based on competing priorities such as location, CO2 emissions, biodiversity preservation, costs, (iii) ensuring transparency for output mechanical and chemical material properties to achieve the relevant certifications, and (iv) minimising environmental impacts of production, to retain competitive advantages from a sustainability perspective. While basic sensory equipment—such as environmental, processing, and biodegradation sensors—is already in place, these sensors currently lack cloud connectivity and often require manual operation. Consequently, noriware cannot yet leverage its sensory equipment for addressing the above challenges, as modeling our process accurately requires creating advanced process DTs and e.g., training new ML models to trace and

link process flows to product and production performance. These limitations affect both the optimization of bio-feedstock sourcing and the establishment of a DPP4.0 system for its seaweed-based packaging material.
Pilot description: This pilot project aims to establish a new digitized production infrastructure for production of noriware's seaweed-based packaging film in applications related to weaving windows in combination with cardboard for watch packaging, and polybags for e-commerce packaging. The aim is to integrate all relevant process flow and process parameter measurements for the extrusion process into an AAS-compliant process DT for optimized operations and thorough documentation. While material and energy flows are currently measurable on a lab scale, bi0SpaCE's tracing technologies are essential for conducting cost-effective measurements at a production scale. The developed technological infrastructure will enable accurate estimation and documentation of the resource requirements, environmental impacts, and circularity of seaweed-based packaging production that can be shared through a DPP. Additionally, transportation from multiple seaweed production sites to seaweed-based packaging manufacturing locations will be optimized and incorporated into the DPP using bi0SpaCE's interlogistics optimizers. The generated DPPs will be validated to ensure they deliver comprehensive sustainability and CE data to downstream value chain partners, such as film producers utilizing seaweed-based pellets as input materials, highlighting noriware's commitment to sustainable and naturally sourced packaging solutions.
Expected benefits: The material and energy flow data will guide noriware in assisting its customers and brand partners to increase transparency of data required for relevant regulations such as the European Single Use Plastics Directive (SUPD), and European Packaging and Packaging Waste Regulation (PPWR) and identify a truly sustainable packaging solution for their needs. Additionally, the project outcomes will deliver a digital solution that serves as a blueprint for developing more circular and resilient material solutions for bio-based packaging production across the industry.
Innovation potentials: Integrating data into seaweed-based material production offers an opportunity to enhance sustainability transparency in the bio-based packaging and materials industry. The development of Industry 4.0-linked DPPs is central to noriware's mission, as it provides a verifiable and transparent comparison that highlights the superior sustainability of noriware's seaweed-based packaging materials over competitors, who typically blend natural materials with fossil-derived components to achieve water resistance or thermoplastic properties. This transparency not only underscores noriware's environmental advantages but also supports the justification of premium pricing for seaweed-based packaging solutions. Additionally, it allows us to understand how we can adjust our existing production and sourcing practices to increase sustainability and circularity performance of our materials.
Pilot KPIs & validation: • <u>Digitalization:</u> Tracking of at least 4 relevant flow parameters (e.g. used electricity, material flow, air temperature, air humidity) using bi0SpaCE sensors and data collection frameworks. • <u>Tracking & tracing:</u> Production energy intensity decreased by ≥15% by tracking and optimizing key life cycle and process parameters, including e.g., reduction of transportation impacts, and increasing the extruder nozzle and screw elements durability. • <u>CE & sustainability</u>: The DT layer & optimization will reduce the CO_2 emissions in the overall production of seaweed-based materials by ≥10%. • <u>DPP4.0</u>: DPPs will be created for at least two different seaweed-based material grades.

2.2.4 Relevant national and international research and innovation activities

Project (partners)	Short Description and relation with bi0SpaCE
CIRCTHREAD (CAR, AU, UNI)	CIRCTHREAD provides a Circular Digital Thread Platform to capture, link to, combine, and share both data and information as part of a collaborative information infrastructure using a cloud data catalogue-based software infrastructure. The bi0SpaCE project will exploit and extend the integrated sustainability and circularity indicators from CIRCTHREAD toward developing the LCA & CE assessment models in WP3.

CircularTwAIn (FhG, NISSA)	CircularTwAIn project is about research, development, validation, and exploitation of a novel AI platform for circular manufacturing value chains. The bi0SpaCE project will exploit and extend the building blocks for circular data space and results on the DPPs for products.
COGNITWIN (FhG, NISSA)	COGNITWIN was focused on improving performance in cognitive production plants in the process industry sectors using hybrid and cognitive DTs. The bi0SpaCE project will exploit and extend the AAS-compliant DTs towards business logic relevant for DPPs like LSA.
CAPRI (CAR, NISSA)	Digital transformation of relevant process industries and reduction of CO2 footprint thanks to a reference architecture for a cognitive automation platform.
Factory-X (FhG)	Factory-X is a Manufacturing-X project with the aim of accelerating the digitalisation of the manufacturing industry. The bi0SpaCE project will use and extend the results of the "Circular Manufacturing" use case, which deals with AAS-compliant DPPs for machines, as well as the results of AAS integration with data spaces to adapt them to the needs of the bioindustry.
RE4DY (SSF)	demonstrate how European industry can jointly build unique data-driven manufacturing and supply network active resilience strategies and yet sustain competitive advantages through digital continuity and sovereign data spaces across all phases of product and process lifecycle, building upon and extending the DFA Zero-X manufacturing.

2.2.5 AI technologies assessment

Within the bi0SpaCE project, the use of AI will be limited to, (i) surrogate models, and regression-based prediction models for predicting LCA and CE performance of bio-based processes and products, (ii) reinforcement learning algorithms for tracking process flows and transport of materials, and (iii) data quality assurance of sensor data collected from instrumenting bio-based processes in the various pilots. Our project will not use AI algorithms for any social- or human-related aspects, and we will not collect any personally identifiable or sensitive information. **(i) Technical robustness, and reproducibility:** We will select state-of-the-art models with proven robustness and reproducibility. The ML models will be trained and validated on high-quality datasets. Transparent documentation and version control will maintain reproducibility. The ML models will be systematically verified for edge-cases by technology providers before deployment. Additionally, the models, methods, datasets, results are made available on request; **(ii) Integrity and Accuracy:** bi0spaCE will establish strict protocols governing data collection, cleaning, and pre-processing to safeguard model input. Uncertainty quantification will be used to identify potential sources of error and guiding decisions. bi0spaCE will also ensure open disclosure of model prediction accuracies along with results to all relevant stakeholders, ensuring transparent communication highlighting the level of risks they represent; **(iii) Minimizing unintended and unacceptable harm:** bi0spaCE will not use AI/ML in use cases where their use can cause a significant risk of harm/injury to humans. Our project will ensure the co-development of models with stakeholders to define risks of harm to property (i.e., machines, IT systems) and create a risk management analysis for any deployed technologies; **(iv) Social robustness:** bi0spaCE will ensure that all ML models will be trained with data on relevant environments (e.g., using historical and real-time data from industries) with feedback from key stakeholders. bi0spaCE will ensure that human decision-makers can freely choose to select/ignore any predictions that are made **(v) Discrimination and ethics:** Training datasets used for ML models will be carefully selected in collaboration with a diverse set of stakeholders to minimize bias. Strict adherence to ethical and gender policies adopted in bi0SpaCE.

2.2.6 Our interdisciplinary approach

The methodology for interdisciplinary research (MIR) framework[29] is used a guiding principle for framing and executing the bi0SpaCE project. The work packages and tasks in bi0SpaCE address complex problems emphasising the role of working beyond disciplinary boundaries. Researchers and technical experts from different specializations (engineering, industrial ecology, chemistry, biology, social sciences) are collaboratively involved, with a keen emphasis that researchers consider interdisciplinary research areas. The data collection and interpretation activities in bi0spaCE integrate techniques from different fields and cross-disciplinarity, enabling them to synthesize multiple viewpoints to uncover unique insights and reach conclusions. Furthermore, the results and findings will be communicated to a diverse audience. **Role of social sciences and humanities (SSH):** bi0SpaCE also emphasises the role of SSH in the development of the technological solutions for supporting the circular transition of bio-based industries. A comprehensive study will be conducted to understand the social requirements, considerations, and implications associated with the adoption and implementation of bio-based solutions. An emphasis is also place on evaluating and addressing the social acceptance of bio-based technologies with targeted surveys. The bi0spaCE technologies and pilots will also focus on providing benefits to rural agricultural communities by the acceleration of bioeconomy solutions enabling local sourcing of bio-feedstocks, co-operative ownership of infrastructure, and creating a blueprint for establishing circular and resilient eco-industrial parks.

[29] Tobi, H., & Kampen, J. K. (2018). https://doi.org/10.1007/s11135-017-0513-8

2.2.7 Gender dimension

The sectors and activities involved in the bioeconomy are sectors which have stronger male participation[30]. To positively contribute to addressing the gender gap in this sector bi0SpaCE adopts a multi-tier approach as follows. Gender and inclusivity aspects will be considered in the development of the in the development of the bioSpaCE technologies and solutions through ensuring representation of underrepresented groups in research activities, as well as the co-development and deployment of technical solutions. Any data collection and activities involving consumers/citizens (e.g., surveying acceptance of technologies, consumer perceptions) will ensure a balanced representation of genders. From a consortium management perspective, the focus is on ensuring a balanced representation of genders and ensuring any gender issues can be raised to the top management. The management team will also ensure no gender discrimination is implied in the team members when participating in the project execution and relevant events. The project will follow the principles for guaranteeing responsible research and adopt a "Science with and for the Society" philosophy, considering ethics, public engagement, and science education and holding dissemination events.

2.2.8 Approach to open science practices

bi0SpaCE will produce various scientific research findings, including publications, datasets, software for DTs/DPPs, management and use related DT and DPP standards. bi0SpaCE will strive to make all these results available, subject to partners' agreement, to the EU research community, the industries, as well as SPIRE, IDTA, IDSA, BDVA-DAIRO through, (i) Open access publications made available as Gold Open Access, project website, and other open repositories; (ii) Early access to bi0SpaCE results as informal publications; (iii) Development of open-source software (OSS), including publishing open-source, -access or -use software, in select public repositories. The bi0SpaCE partners have a track record of managing open codebases, tools, models, and communities and delivering business-friendly license models (e.g., Apache 2.0); (vi) Publishing open Data and FAIR Data in various FAIR repositories (e.g., EOSC, OpenAIRE, EUDAT) and ML models and data shared in open repositories like OpenML, AI4EU; (vii) Open industrial demonstration for the transfer of knowledge from the industrial pilots to the research teams and vice versa; (viii) Promoting open innovation in national and international networks31 32and EU BBIC33 for utilising the potential of collaboration with partners' academic and business networks as well as other HEU clusters across diverse domains (e.g., ICT technologies, bio-based industry); (ix) Promoting open education by sharing the developed knowledge, results, and guidance materials openly on the project website, enabling creation of open training material targeting bio-based industries and university students. Furthermore, bi0SpaCE has planned scientific, industrial, and standards workshops and webinars, to identify and disseminate best practices and lessons learned, as well as explore opportunities for collaboration with existing initiatives.

Table 4: Targeted open projects (open-source (OS), open-access (OA), and open-use (OU)) and intended.

Name	Description	Partner	Type
FA³ST [link]	The **FA³ST** Service implements the AAS standard [link] and builds an easy-to-use web service based on a custom AAS model instance.	FhG	OS
Eclipse AAS4J [link]	An implementation of the AAS metamodel in Java. It contains all classes and properties as defined by the document 'Details of the AAS' [link].	FhG	OS
CircThread [link]	CircThread project, CAR & AU are participants, will deliver an open-source Circular value chain Data Space code base based on IDSA standards in 2024. Technical collaborations with the CircThread association (recently being founded) will be mobilised.	ECO, CAR, AU, UNI	OS
IOF suite [link]	The IOF Ontologies 202301 has been released in early February 2023. They support digital manufacturing by standardizing industrial terminology and improving consistency and interoperability across many operational areas of manufacturing and the product life cycle.	SSF	OS
OTTR [link]	Reasonable Ontology Templates (OTTR) is a framework and language for representing ontology modelling patterns and is designed to support interaction with OWL or RDF knowledge bases at a higher level of abstraction, using modelling patterns rather than OWL axioms or RDF triples.	SSF	OS

[30] https://cordis.europa.eu/project/id/101000519
[31] https://www.materialdigital.de/
[32] https://www.made.dk
[33] https://biconsortium.eu

2.2.9 Strategy on data management and management of other research outputs

bi0SpaCEwill produce several algorithms and models that do not raise any confidentiality issues and can be promoted to the public and researchers in the respective fields. To comply with the EC's requirements for open science and access research practices, the project intends to publish non-confidential datasets produced during the design and execution of the DPPs, data for simulation and optimization, experiments from industrial use cases, and lectures and training materials. The project will conform to FAIR data guidelines to make the data findable, issuing and tracking a unique DOI for each dataset released using well-known data repositories, e.g., Zenodo, supported by the EU-funded OpenAIRE initiative. The provided datasets will respect and support interoperability considering the most used and widely adopted data representation and transformation standards. A "readme" file will be created per dataset to explain its structure, universal resource identifier (URI), and potential instructions for use through open source or project-specific tools. This will be documented in the bi0SpaCE's DMP (initial D1.2 in M6, final version D2.2 in M36) will be a living document that presents the consortium's plan on handling data during and after the end of the project.

#@CON-MET-CM@# #@COM-PLE-CP@#

3 Impact #@IMP-ACT-IA@#

3.1 Project's pathways towards impact

3.1.1 Contribution to the outcomes of the topic

OUTCOME: Mobilising the potential of digitalisation of bio-based sectors enabling efficient, sustainable and climate neutral production processes and transparent information.

bi0SpaCE will facilitate the **digital transition** of the bio-based industries in adopting emerging technologies, best practices and standards focused in unlocking the potential of digital and green capabilities inside the bio-based sector. bi0SpaCE will improve the **production processes efficiency** leveraging DT and ML approaches (R1.1, R1.2), tailored for real-time tracking of materials and emissions in continuous processes. It aims to enhance **sustainability and climate neutrality** by the adoption of Circular Economy standards and state-of-the-art LCA frameworks (R1.3), paving the way for developing DPP4.0-related pre-standardization document (CWA) (R6.4), innovative for the bio-based product sector. bi0SpaCE also tackles the urgent demand within bio-based sectors to raise **sustainability and circularity** through the provision of cutting-edge methodologies and resources. By focusing on Industry 4.0-compatible Digital Twins and Digital Product Passports powered by AI, the project pioneers' innovative pathways toward achieving **sustainability goals**. Essential to this effort is the development of models and tools enabling the semi-automated generation of DPPs for bioproducts (R2.2), ensuring the seamless integration of real-time data, **sustainability metrics**, and interoperability. This transformative approach transcends traditional limitations, driving impactful sustainability measures throughout bio-based industries. The establishment of methods for AI-enhanced DTs tailored to bio-based processes (R2.1) and the development of **ontologies customized for bio-based sectors** (R2.3), will foster standardized modelling and interoperability within digital frameworks. An improved understanding of the **environmental impacts** (R4.1) coming from bio-based industries activities will pave the way to the development of new guidelines for PEF based LCAs as well as CE assessments (R4.2), along with a **transparent** disclosure of **green claims** (R4.3). bi0SpaCE will deploy advanced methods and tools for facilitating the exchange of **digital information** among bio-based industries through a specialized data space, compliant with International Data Spaces (IDS) and FAIR principles. This initiative will offer accessible tracking and tracing services for bioproducts, components, and materials, leveraging DPPs. Key outcomes will include the establishment of an IDS-compliant data space (R3.1) tailored for bio-based industries, alongside value-added services such as DPP onboarding (R3.2), traceability services based on DPPs (R3.3), and machine learning models for tracking the quantity and quality of continuous process flows within bio-based sectors (R3.4). Additionally, the implementation of digital tagging mechanisms (R3.5) will further enhance product identification and traceability throughout bio-product value chains. bi0SpaCE is also focused in advancing circularity in feedstock and **energy management** while evaluating the resilience of value chains against disruptions, through ecological network analysis. With a special focus on **societal impacts**, especially in **rural areas**, the project will enhance social benefits and facilitate profit redistribution. Demonstrating credible business value propositions (R5.1) by involving diverse stakeholders across biobased value chains, and developing guidelines and **governance standards** for high societal readiness solutions (R5.2) will be part of the project advancement. The dissemination and evaluation of results will be held in various forums to increase **knowledge**, understanding of **science** and societal acceptance of digital and circular economy technologies (R5.3) that will allow the bio-based sector **transition**. These advancements will be integrated into the **bi0SpaCE software framework** and validated through rapid experimentation and lab-scale testing, ultimately demonstrating their

effectiveness in bi0SpaCE pilots. Harmonisation will be managed through the development of a CEN workshop agreement (**CWA**) to facilitate broader deployment of I4.0 enhanced DPPs across three bio-based product categories (R6.4), with a standardized roadmap envisioned to ensure widespread adoption within bio-based industries (D7.4).
See below an analysis of bi0SpaCE contributions to the outcome focused on each considered target group (TG):

Target groups	**TG1**: Bio-based industries: provide cutting-edge digital solutions tailored to their specific needs, enabling them to digitize their operations, optimize production processes for efficiency and sustainability and ensure transparency in information sharing. **TG2**: Bio-based industries associations: access to knowledge and tools necessary to advocate for digitalization initiatives within their respective sectors. **TG3**: Researcher and universities: scientific knowledge and technological capabilities, providing researchers and universities with valuable insights and tools for further exploration and development. **TG4**: Customers and consumers: enhance transparency and trust in bio-based products by providing access to accurate and reliable information about their production processes and environmental impact. **TG5**: Policymakers and **TG6**: Environmental NGOs and Advocacy groups: provide evidence-based recommendations and policy frameworks for promoting digitalization and sustainability in the bio-based sector. **TG7**: Tech providers: access to new market opportunities, to the latest trends, collaboration and networking with new entities and enhancement of visibility and recognition among bio-based sector.
OB to O1	OB1, 2, 3, 4, 5 & 6
Scale & Significance	**SCALE**: The target groups identified are going to be affected by the project results at different scales. The bio-based industries and associations can be easily reached in a big share due to the existing links with the main bio-based associations, like CBE JU, Food4Life, A.SPIRE, SUSCHEM and BIOENERGY EUROPE. The influence of the project in this target group will be high as bi0SpaCE focuses on the bio-based sector, which is running in a very early stage in terms of DPP. Researchers and universities are also strongly relevant for our project and will be contacted through the dissemination activities of bi0SpaCE, as well as Policymakers and Society (customers and consumers), who will be influenced thanks to project communication strategy. Finally, environmental NGOs and advocacy groups will be reached through D&C actions, like workshops and symposia. **SIGNIFICANCE**: • Bio-based industries and associations: 4 bio-based industries and 1 association (CBE JU) already involved. KPI6.3 > 4 liaison activities with EU ongoing projects (1 from CBE JU). **CBE KPIs** (Annex IV from CBE JU SRIA): 2 bio-based industries with innovative processes that contribute to GHG emissions reduction and energy efficiency (NOR and GLB) / 1 bio-based industry with an innovative process to improve on resource efficiency and water consumption reduction (FSK). / 1 bio-based industry developing industrial symbiosis (GLB). /2 innovative bio-based value chains created based on sustainably sourced biomass (NAT and NOR). / 1 project using feedstock generated with practices contributing to climate change mitigation (NOR). / 1 innovative product that is biodegradable and compostable (NAT) • Society (customers and consumers): at least 5 social sustainability indicator categories per pilot (based on UNEP sLCA framework). Researchers and Universities: ≥10 academic and industrial researchers involved and ≥4 junior researchers trained, ≥6 peer-reviewed publications in esteemed venues. 200 researchers will be reached through D&C actions. Policy makers: >25 policy makers will be reached through D&C actions.

3.1.2 Contribution to wider impacts

bi0SpaCE will set out a credible pathway towards advancing the circular economy and bioeconomy sectors through the implementation of innovative digital solutions. By leveraging AI-enhanced Digital Twins (DTs) and Digital Product Passports (DPPs), we aim to boost resource management, ensuring sustainability and circularity. Through our efforts, we seek to unlock the potential and benefits of the circular economy for the bio-based sectors addressed by our industrial partners. Through a near future wide deployment and market uptake of our innovative technologies, particularly in bio-based systems, we aspire to make a tangible difference.

IMPACT I1: "Regional, rural, local/urban and consumer-based transitions are accelerated towards a sustainable, regenerative, inclusive, just and clean circular economy and bioeconomy across ..."

bi0SpaCE will address the challenges in balancing **circularity**, **resilience**, business and **social impacts** in the bio-based sector through the metrics derived from ecological network analysis, to estimate the resilience of value chains to potential disruptions. It will also develop tracking tools for material and energy at various scales and will quantify societal impacts of the developed digital and circular economy solutions, to be applied accross different entities inside the bio-based sector in the short term. To promote **inclusive technology development**, the project emphasizes the role of social sciences in understanding consumer and **end-user awareness** and acceptance of digital tools, to integrate them into a medium-term **policy** development. The advancements will be measured by the improvement of at least **5 social sustainability indicator categories** based on UNEP social life cycle assessment framework (KPI5.2) and more than 100 **people engaged** annually (KPI5.4).

IMPACT I2: "European industrial sustainability, competitiveness and resource independence are strengthened by ..."

bi0SpaCE will collaborate with GLB eco-industrial park, where it will serve as testing ground, offering real-life circular economy scenarios to evaluate the project's implementation with multiple stakeholders involved. bi0SpaCE will directly collaborate with 9 existing companies and this demonstration will focus on two clusters, one for tracing material flows like biomass pellets, and other to track energy flows like H2 gas, linking them to energy sources for production processes. The expected benefits include regulatory compliance assistance and the development of a digital blueprint for more circular and resilient eco-industrial parks across bio-based industries. The project's outcomes will enhance GLB's digital infrastructure and contribute to the transition to a circular economy by fostering synergies among companies within the park, leveraging the deployment of **SymbiosisNet™**, intelligent grid of energy and data. This underscores GLB's commitment to resource sharing among the eco-industrial park. This system, designed to match the needs of park occupants, can be **replicated** in other communities. With the entry of additional companies into the park and the **emergence of more synergies**, there is a high potential for increased utilization of biomass and energy flows at different stages.

To demonstrate the benefits of **higher resource efficiency** in bio-based sector, bi0SpaCE, through the collaboration with FSK manufacturing, will pilot an initiative that will focus on circular reuse of process water post-treatment through continuous monitoring and regulation of water quality parameters. It will explore **waste heat reuse** potential to align with sustainability goals and enhance business competitiveness. Through innovative water quality management and **waste heat recovery** techniques, coupled with material flow tracking, the pilot aims to quantify environmental impacts and showcase the benefits of circular material use, to be widespread along the bio-based value chain in the medium term. bi0SpaCE will contribute to the DPP creation for at least 3 paperboard varieties that could be extended to other paperboard manufacturers or among industries with exhausted thermal flows coming out from their processes, such as biomass/biogas/biofuels industries, sugar mills or ethanol distilleries, etc.

IMPACT I3: "Innovative and sustainable value-chains are developed in the bio-based sectors ..."

An additional collaboration among bi0SpaCE and noriware (NOR), a company which aims to produce sustainable bioplastics as an alternative to fossil fuel-derived plastics, will help to optimize energy and material flows in production settings, leveraging bi0SpaCE's tracing technologies for accurate measurements and documentation. noriware's seaweed-based bioplastics will offer sustainable alternatives to fossil fuel-derived plastics, aligning with European Green Deal and other sustainability related policies, such as Circular Economy Action plan and Ecodesign for Sustainable Products Regulation. The project will develop digital production infrastructure to minimize environmental impacts and circularity, and to provide transparent and verifiable sustainability information across the value chain. The integration of data in bioplastics production will improve process efficiency and enable the implementation of DPPs for sustainable and circular sourcing of feedstock materials. bi0SpaCE will contribute to the creation of DPP for at least two different seaweed-based material grades. Such DPPs can be adapted to other companies in the bioplastics manufacturing sector, and in other bioplastics consuming sectors, e.g., e-commerce packaging.

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IMPACT I4: "The benefit for consumers and citizens, including those in rural areas, are improved ..."

The implementation of detailed and precise flow and materials tracking within bio-based industries will offer multiple benefits. Beyond enhancing operational efficiency and sustainability, this tracking capability facilitates the generation of Digital Product Passports (DPPs), which serve as comprehensive documentation of the environmental and **circularity credentials** of bio-based products. Moreover, extensive details concerning bio-based products such as their composition, source, production methods will be available for **consumers and citizens**, and other actors in the bio-based value chain. Consequently, this methodology not only strengthens accountability and **transparency** within the industry but also contributes to the broader ecosystem of environmental stewardship and product visibility. The project will contribute to the deployment of DPP4.0 solutions for at least **4 bio-based products from 4 different bio-based industries.** The mandatory implementation for the DPP begins in 2026, with batteries as pioneers in adopting this new tool. bi0SpaCE will lay the groundwork for DPP adoption within the bio-based sector, ensuring readiness for future implementation.

3.1.3 Analysis of target stakeholders and expected benefits

Target group	*Bio-based industries*		
Expected benefits: (1) Reduced waste outputs. (2) Promote a CE approach towards a better sustainability. (3) Increase in awareness of digital tools, in particular material DPPs.			
KPIs: KPI1.1, KPI 1.2, KPI3.3, KPI 4.1, KPI6.1, KPI 6.2 & KPI6.3.			
Tools to reach TG1: (1) Development of homologation (REACH) that allows utilization of waste bioproducts in industrial acceptable manner. (2) Consortium-level validation of the digital tools under development.			
Related objectives	OB 1,3, 4, 6	**Related impacts**	I2,3
Target group	*Bio-based Industry associations (BIC and others)*		
Benefits: Increase awareness in bio-based industry to ensure engagement with the DPP initiative, promote sustainability practices across bio-based industries.			
KPIs: KPI2.4, KPI2.5, KPI3.1, KPI5.2, KPI5.3, KPI5.4, KPI6.1, KPI6.2, KPI6.3, KPI6.4			
Tools to reach TG2: bi0SpaCE partners will actively involve relevant EU industrial groups through conferences, workshops and publications.			
Related objectives	OB 2, 3, 5, 6	**Related impacts**	I1,2,3
Target group	*Researchers and universities*		
Benefits: Increase awareness in research & industry to align research needs and vice-versa.			
KPIs: KPI5.3, KPI5.4, KPI5.5, KPI6.3, KPI6.4			
Tools to reach TG3: bi0SpaCE partners will actively involve research centres and try to extend the application involving other companies taking advantage of regional research-industry synergies.			
Related objectives	OB5, 6	**Related impacts**	I3
Target group	*Customers and consumers*		
Benefits: promote circularity and sustainable industry models, to support in making responsible and informed choices; and to relevant standardization organizations.			
KPIs: KPI1.1, KPI3.1, KPI 4.2, KPI5.2, KPI5.3, KPI5.4			
Tools to reach TG4: (1) Demonstrate the techno-economic feasibility of the three**f** pilots (2) Publicize achievements (conferences, workshops, publications…)			
Related objectives	OB 1, 3, 4, 5	**Related impacts**	I1,4,
Target group	*Policymakers*		
Benefits: development of innovative and sustainable value-chains in the bio-based sectors, aimed at replacing fossil-based systems and increasing circularity from sustainably sourced resources.			
KPIs: KPI5.4, KPI5.5, KPI6.1, KPI6.4			
Tools to reach TG5: (1) Policy briefs, (2) workshops with roundtable discussions, (3) CWA.			
Related objectives	OB5, 6	**Related impacts**	I2,4
Target group	Environmental NGOs and advocacy groups		
Benefits: could influence policy, consumer behaviour regarding bio-based products and CE practices.			
KPIs: KPI5.2, KPI5.4, KPI6.4			
Tools to reach TG5: (1) Policy briefs, (2) workshops with roundtable discussions.			
Related objectives	OB5, 6	**Related impacts**	I1,2,4,5,
Target group	Technology providers		
Benefits: accessing to networks of bio-based industries seeking digital solutions, to address industry challenges			
KPIs: KP1.1, KP2.4, KPI2.5, KPI3.4, KPI5.4			
Tools to reach TG6: (1) Industry events and conferences, (2) Newsletters, (3) Social media platforms			
Related objectives	OB 1, 2, 3, 5	**Related impacts**	I2, 3, 4

3.1.4 Potential barriers

Barriers	bi0SpaCE mitigating measures
Lack of standardized data: DTs have shown promise in simulating and optimizing processes, but accessing to large volumes of data remains challenging. This hampers effectiveness in process optimization, and the absence of standardized data and data silos within companies further exacerbate this challenge.	Addressing these barriers is crucial for scaling and optimizing processes in bio-based industries. Bi0SpaCE will pioneer the development of standards-compliant and interoperable DTs for bio-based processes, utilizing the AAS standard to ensure protocol-agnostic control and real-time data capture.
Lack of standards for DPP development: the absence of a unified framework results in non-interoperable DPPs, posing challenges for data comparison within and across sectors.	bi0SpaCE will align with the DPP 4.0 initiative, improving the AAS standard and developing submodel templates for CE-relevant aspects of bioproducts, and offering guidelines to foster innovation and competition among bio-based product providers.
Lack of CE domain-specific requirements: CE demands traceability throughout the value chain to enable stakeholders to access to pertinent information. Current DPPs pose challenges in data accessibility and comprehension for users. so there is a pressing need for more user-friendly interfaces and analytical tools to ensure efficient data usage.	bi0SpaCE will improve data spaces for circular manufacturing by focusing on DPPs. This involves three strategies: developing connectors for easy integration with DPPs, enhancing data space building blocks with DPP-specific services and incorporating circularity services to address aspects like DPP placement in value chains and end-of-life management.
Cost increase for bio-based industrial stakeholders: tech innovation can trigger changes in the way production is managed by industrial actors, so these could be reluctant to adopt bi0SpaCE innovations. There is also a risk that the services, processes and technologies adopted in bi0SpaCE cannot be scaled up at acceptable costs.	Using open software architecture and leveraging on company available digital technologies, bi0SpaCE solutions are meant to be low cost and fit for current industrial ecosystem. Additionally, the DPP for circular economy modelling will improve the ability to exchange information, speeding the ability to scale up and make available digital tools at low costs.
Lack of acceptance by key actors: to connect to bio-based dataspace by manufacturing suppliers, producer responsibility organisations, or recyclers, given required adjustment and enhancement of IT systems to ensure interoperability of data flows and product feedback.	bi0SpaCE capability of providing specifications and ontologies on what CE information needs to be integrated within the CE dataspaces, tied to product passports and EU legislations, to enhance uptake. Exploitation will consider a network of stakeholders, to ensure key actors and decision-makers are engaged.
Lack of flexibility of bi0SpaCE innovations: solutions developed can result effectively for the industrial stakeholders involved in the activities and in pilot development; however, it could be difficult to replicate these in other industrial environments.	The solutions developed in bi0SpaCE start from a general approach, that is then instantiated within project-specific industrial domains; so, it maintains either generality for extension or specificity for a vertical application.

3.2 Measures to maximise impact - Dissemination, exploitation and communication #@COM-DIS-VIS-CDV@#

bi0SpaCE aims to deliver a well-planned, and digitally supported communication and dissemination plan which will addresses the full range of potential stakeholders and target groups. The project will proactively mobilise the related agreements and actions for the dissemination, exploitation, and management of intellectual property rights (IPR). The next sections describe the programmed steps and available tools of dissemination and exploitation strategy.

3.2.1 Dissemination and communication plan (D&C plan)

The **Communication objectives** are (i) reach to the public and raise awareness about the project, expected results, outcomes, and impacts within defined target groups (TG); (ii) make the project a valid source of information; and (iii) create synergies and exchange experiences with projects and groups active in the field, to join efforts and maximize common potential. The **Dissemination objectives** are: (1) to create public awareness and generate scientific interest; (2) To directly involve stakeholders that could help bridging the gap between bi0SpaCE and its future market application; (3) to maximize the impacts of the project achievements; (4) to diffuse acquired knowledge, methodologies and technologies developed and tested during the project, and (5) to facilitate cooperation with other projects. The first D&C presented below concerns the first months of the project (M1-M9) where it will be consolidated. The overall timeline for the D&C activities is structured in four main phases according to the (Awareness, Interest, Desire, Action). It is a model used by a wide spectrum of organization's and is suitable for attracting and building relation with stakeholders. The stages that D&C strategy will follow are:

Awareness / Initial Phase / M1-M9: To build awareness for bi0SpaCE, to make project visible and recognizable, sharing its objectives, values, and technological innovation(s). Visual identity & logotype, templates website and social media accounts are set. The main stakeholder groups are identified, with focus on synergies, replication, transferability, and early adoption potential. The specific actions for activities such as capacity building will be established. ***Channels & Tools:*** *Website and social media, "bi0SpaCE Clustering" initiated.*

Interest / 1st Intermediate Phase / M10-M18: The early results will be disseminated via publications and scientific papers to journals, to increase the interest to researchers and scientific communities, presenting in conferences and events. Communication actions will continue leveraging the potentials of social media, website, and newsletters. Partnering with other projects is another important pursue during this phase. ***Channels & Tools:*** *Website, newsletters, social media, Networks, Publications, bi0SpaCE Clustering.*

Desire /2nd Intermediate Phase / M19-M27: This phase will focus on further engagement of the targeted audiences with the project. Dissemination of evolving results through events and publications will create additional interest in bi0SpaCE. Informing target markets about the technological breakthroughs and business benefits of bi0SpaCE is also an important part of this phase that works as a preparatory stage for the final mature phase. At this stage, the project will have made the headway needed to discuss shared activities with the CBE JU and other partnerships, as well as follow-up activities. ***Channels & Tools:*** *Website, newsletters, social media, Publications, bi0SpaCE Clustering*

Action / Mature - Final Phase / M28-M36: This phase will focus on maximizing future target markets and industry awareness about bi0SpaCE's exploitable results. All the results will be disseminated through the aforementioned channels. The innovation exchange and marketplace capabilities of the *bi0SpaCE Clustering Platform* will be utilised for enhancing the exploitation of the outcomes. Communication and dissemination efforts will support the project sustainability and its effective exploitation and future market evolution. All the efforts made in the previous phases will be leveraged in this final stage. ***Channels & Tools:*** *Website, Newsletters, Social media, Events/conferences, Videos, Publications, Articles, Data*

Table 5: D&C plan for the identified target groups

KPIs: 1×Website / 4×Newsletter / 10×Conferences/Events / 500×followers: LinkedIn / 6×Publications / 4×Videos / 10×Web articles / 4×Datasets /

Target Groups	Message and Goal	Channel
Scientific community: Universities and research institutes (fields on Sustainable production, Circular processes, bio-based value chains etc.)	Emphasize bio-based value chains and sustainability with technologies for research & access to Open data	/ / / /
Bio-based EU sectors linked to bi0SpaCE pilots	Show bi0SpaCE objectives and key results, technologies developed and validated, with respective benefits.	/ / / / / /
Related R&I initiatives: focusing on the CBE-JU, process industry and agrifood sectors.	Common ground, establishment of CE value chains interests & in fields of AAS, AI, Intelligent Production, DPP.	/ / /
EU Organizations, Standardization Actors and Policy Makers: Representatives of national bodies/ministries, EC and Standardization bodies	Value for them of the Results and knowledge for benefits of being applicable to many sectors.	/ / /
General Public and Media: EU citizens, online & offline Media, NGOs and others that have general interest in technology, innovation and engineering	Create awareness for the project's benefits for the society on sustainably designed products	/ / / / /
Associations, alliances and Hubs as CBE-JU, SPIRE, EFFRA, DAIRO, IDSA, DIHs, Euroconsumers	Diffuse knowledge and how results can be used & exploited by more entities, share benefits and improvements for end-users.	/ / / / /
Sustainable manufacturing platforms, DIHs, and Research Organizations working on circular economy, bio-based manufacturing and to relevant standardization organizations	Diffusion of knowledge and benefits of usage of the CE Action plan and adaptation of DPP and Data Spaces principles.	/ / / / / / /

3.2.2 Exploitation strategy and key exploitable results

bi0SpaCE overall exploitation strategy is built around the bi0S software framework and its modules for rapid deployment and scaling of CE solutions and services across bio-based industries and their value chains. bi0SpaCE recognises **three main exploitation pathways** for the project results**: 1) the research exploitation model**, which implies the use of the research know-how acquired in future research activities. **2) the technological exploitation model**, which implies the use of the technological know-how gained for the development of innovative products and the provision of advanced services built on top of them and **3)** the later **commercial exploitation model**, which implies the paid provision of services to end users and that will come once the maturity of results is enhanced at the end of the project or after the previous exploitation pathways happen. biOSpaCE initial key exploitable results are seen below:

KER #1 Holistic view on the LCA and CE assessment in bio-based product manufacturing (AU)
Description: Combined physics-based and data-driven framework to link the manufacturing process to sustainability and circularity indicators. Herein, we will advance solutions for ML based tracking of process flows, **Exploitation strategy:** engage with local industries in Denmark including SMEs through the TechCircle EDIH and MADE Denmark to extend the currently used industrial methods for sustainability and circularity assessment and process optimization. Exploitation in future research projects aiming at scaling-up and commercialization Any IP produced from this project, will be exploited with the help of the AU Technology Transfer Office & AU Kitchen.
KER #2: Extension of FA³ST to support bi0Space (ISB)
Description: suite for the creation, management, and enhancement of AAS compliant digital twins and DPPs, to the needs of mobility and production sectors. Specialised AAS sub-model templates that represent capacities of both digital and physical assets, ensuring standardization across the board. **Exploitation strategy:** develop and extend emerging technologies to create innovative solutions for industry and government and to achieve impact through standardization and technology transfer. Results from the project (e.g. extensions to be done for FA³ST) will be used in new projects towards the manufacturing industry.
KER #3: Digital tagging of bio-based products (CAR)
Description: Digital tagging creates a digital summary of relevant physical processes and products across their lifecycle, utilizing unique identifiers to track raw materials, intermediates, and final products through each manufacturing step. This system enables real-time updates and integrates data from various sources, enhancing traceability, quality and optimization in the bio-based product supply chain. **Exploitation strategy:** CARTIF as a research institution aims to increase the technological maturity of the result after the end of the project looking for a technological demonstration done in additional bio-based sectors.
KER #4: Data Quality Management for bio-based product manufacturing (NISSA)
Description: New data collection framework D2Port (TRL5) to provide a holistic view on the data collection process in the bio-based product manufacturing. The main goal is to determine the stability of the data collection process, which will ensure the collection of high quality data. **Exploitation strategy:** awareness creation among relevant manufacturing community for the new type of QM tools. Offer of so called free trials, as a risk-free mechanism for experimenting with new and immature technologies so potential customers can build proof-of-concepts for new technology and even provide additional requirements.
KER #5: Data as Asset (NAT)
Description: digitization of critical manufacturing data—such as temperature, pH levels, and aloverose and aloin content offering the entire journey of aloe vera, from cultivation to the table, ensuring sustainability. Naturae, an eco-innovative company headquartered in Spain, specializes in cultivating, processing, and bottling its own nationally sourced aloe vera. Our unwavering mission is to enhance people's health by delivering high-quality products accessible to all. With a comprehensive approach, we oversee the entire journey of our aloe vera, from cultivation to your table, ensuring sustainability and freshness at every step. **Exploitation strategy:** data integration (enhanced competitiveness), quality optimization (aloe vera-specific parameters), and consumer empowerment (transparent reporting). Naturae remains committed to sustainable practices, ensuring that our aloe vera products continue to nourish both people and the plane.
KER #6: DPPs compatibility with SymbiosisNet (GreenLab Skive A/S)
Description: Incorporation of DPPs into the SymbiosisNet enabling matching of renewable energies to bio-based projects that will create a unique selling point for GreenLab customers and improve the quality of industrial system, while ensuring early adaption to future regulatory requirements. **Exploitation strategy**: acting as a case study and pilot to help develop metrics for tracking energy usages in production of bio-based products (from traditional, renewable and alternative sources). GreenLab will build on the learnings from the project, and help disseminate the work, engaging in researchers both within the project and our wider network to create knowledge sharing.

3.2.3 Strategy for the management of intellectual property

bi0SpaCE will follow the principles described in DESCA 2020 model. Approach will be to deliver open access results as possible while conforming to necessary closed requirements to disseminate (yet safeguard) key results via IPRs. bi0SpaCE will consider three main elements of an effective system to protect and exploit Intellectual Property (IP). *Firstly,* a system that enables the **protection of IP** (*e.g.,* patents, copyrights, brand, industrial design) that includes clarity about the ownership and use of IP rights (IPR), the rights and freedom of parties to transfer (assign) IP, and the freedom to publish. *Secondly,* a **technology transfer framework**, preferably with the support of specialised knowledge transfer offices with professional staff, such as the European IPR Helpdesk. *Thirdly,* a **fair law enforcement system** in each partner's country caters to dispute settlement and can award penalties and sanctions where appropriate. **Specific IPR issues** will be identified and addressed in the Consortium Agreement. The basic principle is that foreground knowledge, *i.e.*, created within (or resulting from) the project, belongs to the project partner who generated it. If knowledge is developed jointly and separate parts cannot be distinguished, it will be jointly owned unless the contractor concerned agrees on a different solution. Regarding background, granting Access Rights will be royalty-free for the execution of work during the project unless otherwise agreed upon before the Grant Agreement signature. Since bi0SpaCE will produce open access artifacts, there will be regularly organized IP-related consultation with the IP specialists from AU Technology Transfer Office & AU Kitchen.

3.2.4 Contribution to policy making and standardisation

One of key barriers of applying digital twins is lack of common standards, which are needed for diverse devices, machines, production processes, supply chains, etc. to inter-operate seamlessly, sharing data and information. There are various activities (e.g., IEC 62832, ISO/IEC JTC1, ISO SC41 IoT and Digital Twin, etc.) regarding standardization of DTs. During the preparation of the proposal, a first assessment of the current standardization activities and committees was made. bi0SpaCE results will be based on the PI4.0 Asset Administration Shell specification (IEC 63278). Additionally, bi0SpaCE will not only follow this standard but more importantly contribute to it by Fraunhofer actively participating in the Industrial Digital Twin Association" (IDTA), which aims to drive the international standardization of the Industrial DT. The focus will be on topics such as modelling circularity aspect and business model representation and execution that are relevant to bi0SpaCE .

bi0SpaCE will consider the developments on the DPP guide, promoted by the Digital Europe program, in view of upcoming related regulations. The aim is to take advantage of the dynamically evolving product-related data, to suggest the most proper manufacturing strategies, at every life cycle stage. The intention is to make available the set of information in an open manner through the setup of standardisation efforts, such as in ISO/TC 184/SC4, the committee for ISO 10303 series, CEN-CLC /JTC 24 DPP and in other relevant European or International technical committees. Fraunhofer's participation in SCI 4.0, the working group 1941.0.2 "Digital Product Passport (DPP)", will ensure that bi0SpaCE will not only follow the standards for the DPPs, but also help to shape them.

IDSA Reference Architecture Model (IDS-RAM) is a de facto international standard for virtual data spaces that secure and standardized data exchange and data linked in a business ecosystem. bi0SpaCE will implement the IDS RAM and contribute to the extension of the architecture for DPPs and value chai services. bi0SpaCE will also benefit from Fraunhofer leading the IDS-I community, which is all about bridging the gap between I4.0 and IDS. biOSpaCE will use this channel to ensure that the results of IDS-I are reflected in bi0SpaCE data space and DPP onboarding services, and to provide feedback on ongoing and future developments to achieve greater impact. As far as the evaluation of material composition, the framework taken into account will be based on the IEC 62474 standard for materials declarations, to assess REACH & RoHS compliance and to assess critical raw materials information, to utilize geography location from the supplier's network to enable calculation of environmental and social-LCA information, using the PSILCA database.

#§COM-DIS-VIS-CDV§#

3.3 Summary

SPECIFIC NEEDS	EXPECTED RESULTS	D & E & C MEASURES
* Design a comprehensive technological framework for digitalisation of the information in bio-based value chains to optimize processes, track materials and emissions, predict sustainability and ensure compliance with CE and LCA standards. * Improve understanding of environmental impacts for bio-based industries and enhancement of data collection for ensuring specialized information about products and processes based on impacts such as carbon emissions, biodiversity, and soil, water, and air quality. * Stakeholders engagement across bio-based value chains to demonstrate credible business value propositions, showcasing the positive impact on local communities offered by bio-based products and processes, supporting actors in the value chain in making responsible and informed choices. * Development of DPP4.0 standards-based while supporting the harmonization and interoperability of digital information formats and design of interfaces between the digital information from bio-based products and other applications. * Definition and implementation of an IDS-compliant dataspace tailored specifically for bio-products to establish a secure and standardized platform that fosters seamless data exchange and collaboration among stakeholders within the bio-based industries.	R1.2 Pioneering novel machine ML based approaches for materials and emissions tracking in continuous process flows and digital tagging/watermarking of bio-based products R2.1 AI-enhanced, AAS-compliant DTs for bio-based processes. R2.2 Semi-automatic creation of DPPs for bio-products. R2.3 Ontologies for bio-based industries. R3.1IDS-compliant dataspace based on DPPs for bio-products R3.2 DPP onboarding service R3.3 Traceability service based on DPPs R3.4 Models for tracing of continuous process flows in bio-based industries. R4.1 Improved understanding of environmental impacts R4.2 Guidelines for PEF-based LCAs as well as CE assessments R4.3 Transparent disclosure of green claims R5.1 Quantification of energy and resource resiliency R5.2 Improvement of social sustainability performance R6.1 Standards-based DPP authoring and management service R3.5 Identification of the product specifications end to end in the DPP. R6.2 CE dataspace based on IDS Reference Architecture	**Exploitable results** **KER #1** Holistic view on the LCA and CE assessment in bio-based product manufacturing (AU) **KER #2:** Extension of FA³ST to support bi0Space (ISB) **KER #3**: Digital tagging of bio-based products (CAR) **KER #4**: Data Quality Management for bio-based product manufacturing (NISSA) **KER #5:** Data as Asset (NAT) **KER #6:** DPPs compatibility with SymbiosisNet (GLB) **Communication & Dissemination KPIs** 1×Web / 4×Newsletter / 10×Conf./Events / 500×follow.: LinkedIn 6×Pubs. / 4×Videos / 10×Web articles / /4×Datasets / 3

TARGET GROUPS		OUTCOMES		IMPACTS
TG1: Bio-based industries TG2: Bio-based industries associations TG3: Researcher and universities TG4: Customers and consumers TG5: Policymakers TG6: Environmental NGOs and Advocacy groups. TG7: Tech providers:		**OUT1: Mobilising the potential of digitalisation of bio-based sectors enabling efficient, sustainable and climate neutral production processes and transparent information.** bi0SpaCE aims to lead the digital transformation of the bio-based industries by adopting emerging technologies, standards, and best practices to enhance efficiency, sustainability, and circularity. Leveraging Digital Twins and Machine Learning, it tracks materials and emissions in real-time, while embracing Circular Economy standards and Life Cycle Assessment frameworks for climate neutrality. Through innovative approaches like Digital Product Passports, the project fosters interoperability and transparency, driving impactful sustainability measures. By advancing AI-enhanced Digital Twins and developing specialized data spaces compliant with International Data Spaces principles, bi0SpaCE facilitates seamless information exchange and traceability within bio-based industries. With a focus on societal impacts and stakeholder involvement, it demonstrates credible business propositions and promotes high societal readiness solutions, ensuring a smooth transition toward a digital and circular bio-based sector.		**IMPACT I1: "Regional, rural, local/urban and consumer-based transitions are accelerated towards a sustainable, regenerative, inclusive, just and clean circular economy and bioeconomy across ..."** bi0SpaCE will tackle circularity and resilience challenges in the bio-based sector through ecological network analysis and tracking tools, quantifying societal impacts of digital and circular solutions and integrating social sciences. **IMPACT I2: "European industrial sustainability, competitiveness and resource independence are strengthened by ..."** bi0SpaCE's collaboration with GLB eco-industrial park serves as a real-life testing ground for evaluating circular economy scenarios and industrial symbiosis advantages. Additionally, bi0SpaCE's initiative with FSK manufacturing plant will quantify environmental impacts related to exhausted thermal flows and will promote circular material use across the bio-based value chain. **IMPACT I3: "Innovative and sustainable value-chains are developed in the bio-based sectors ..."** Leveraging bi0SpaCE's tracing technologies, the project will develop a digital production infrastructure for sustainable bioplasticsproduction, aligning with EU sustainability initiatives. It seeks to enhance efficiency, implement DPPs and contribute to sustainability in various sectors, including packaging, polymer production, and others. **IMPACT I4: "The benefit for consumers and citizens, including those in rural areas, are improved ..."** DPPs will enhance transparency across the bio-based value chain. This initiative, led by bi0SpaCE, will pave the way for wider DPP adoption in the sector, bolstering environmental stewardship and product visibility.

#§IMP-ACT-IA§

4 Quality and efficiency of the implementation #@QUA-LIT-QL@# #@WRK-PLA-WP@#

4.1 Work plan and resources

4.1.1 Overall structure of the work plan

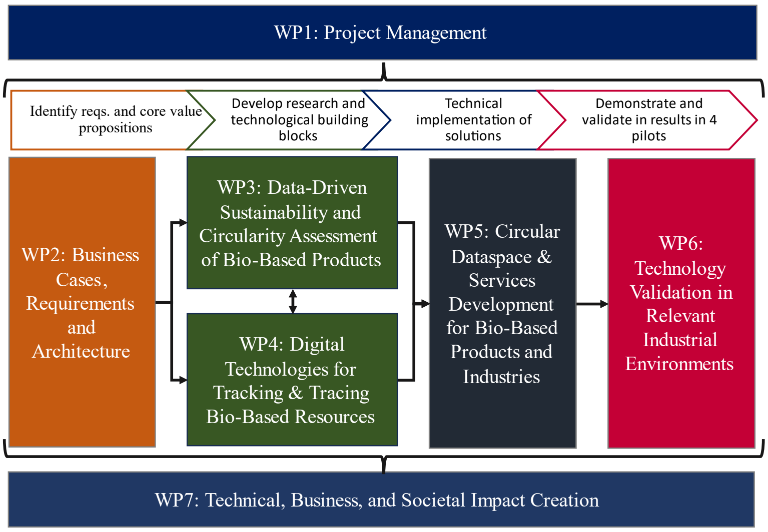

Figure 11: bi0SpaCE PERT chart.

The bi0SpaCE project implementation plan is scheduled over 36 months and broken down into 7 work packages. As shown in Figure 10, WP1 is the umbrella for project management and coordination activities and overall governance tasks. WP2 sets the scope of the project by defining requirements and designing the experimental scenarios that will validate the bi0SpaCE software framework. It also establishes the technical foundation of the project in the form of ontologies that will support the description of the bi0SpaCE environment and the technical architecture of the bi0SpaCE software framework. WP3 and WP4 deal with the critical conceptual and technical aspects of bio-based industries. While WP3 focuses on enabling bio-based industries to assess, predict, and consequently optimize sustainability and circularity performance of their bio-based products, WP4 focuses on advanced models, techniques, and technologies that enhance the overall traceability of continuous process flows in bio-based manufacturing. The bi0SpaCE software framework will be developed in WP5. This includes providing the means to model and develop digital twins for bio-based processes, to generate DPPs on bio-products and share them through the DPP data space specialized for the bio domain. The bi0SpaCE software framework will be deployed, customized and evaluated in WP6 using pilots' relevant environments. As horizontal actions, this work plan consists of WP7, which ensures industrial uptake of project activities and the maximization of impact, through outreach, exploitation, and standardization efforts. It also includes activities to raise awareness among academia and industry and collaborate with other R&I initiatives and clusters. The timing of the work packages in the project is shown in Figure 11.

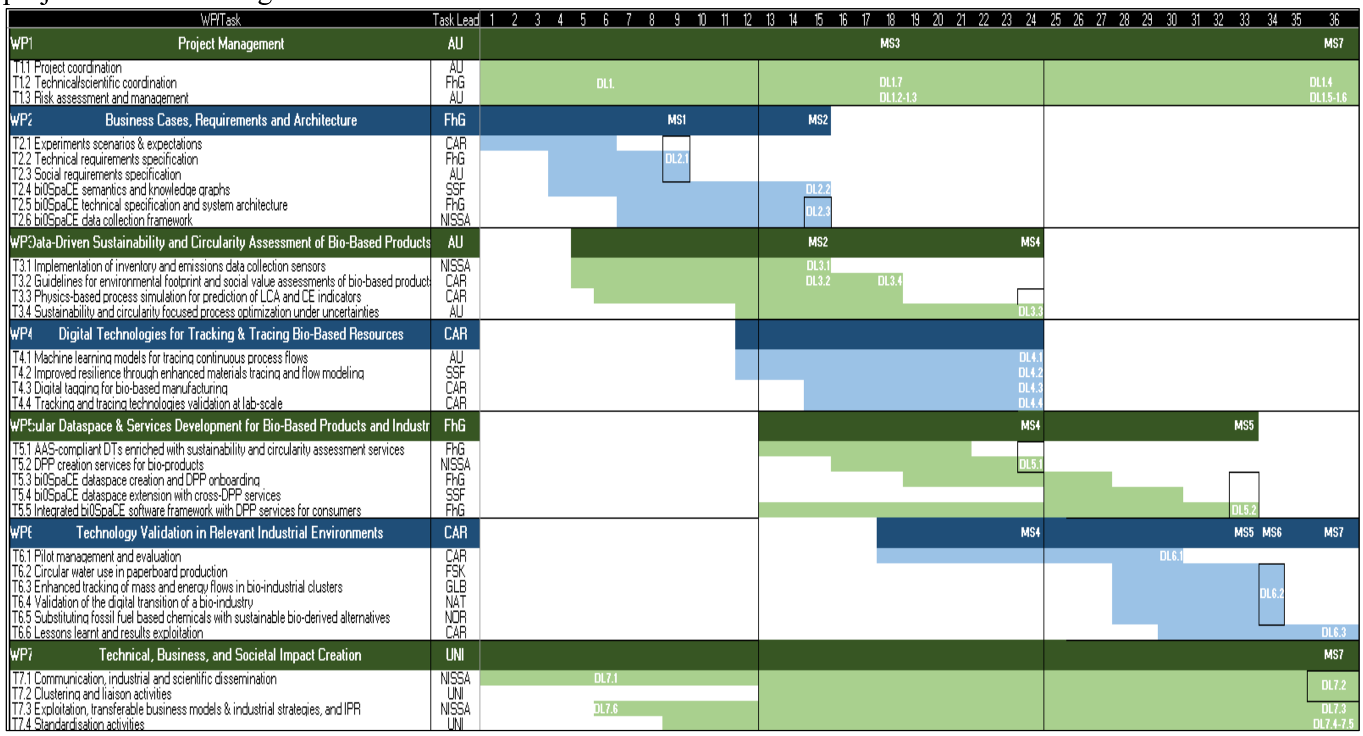

Figure 12: bi0SpaCE Gantt chart. (DL = deliverables; MS = milestones)

4.1.2 Resources to be committed

5/ UNI		
	Cost (€)	**Justification**
Other goods, works and services	13.000,00	CWA fee: 2.500,00 euros fee for CEN/CENELEC for the publication of the document. The amount is an estimation based on the latest CWA quotations UNI has submitted in 2024 (including VAT). This fee is an obligation due by CEN/CENELEC rules, in order to have the CWA publicly available on CEN/CENELEC dedicated webpage. Participation to a trade fair for the development of the CWA: 6.000,00 euros. The best option in the proposal phase has been considered to participate to Ecomondo with a bi0SpaCE booth. 6,000 euros is the average cost UNI has paid for basic booths in similar trade fairs. The participation to an important international trade fair is instrumental to the dissemination of the standardization activities, in particular for the development of the CEN Workshop Agreement (CWA) and reaching the consensus of key stakeholders on the market. CWA meeting: 1.000,00 euros. Estimation of the catering for the organization of a CWA meeting in UNI (30 participants). Standardization workshop organization: 2.500,00 euros. This is the direct cost amount estimated for the organization of the standardization workshop probably at CEN/CENELEC in Brussels. This will cover services for the organization of the event (for example to involve key panellists). Dissemination material: 1.000,00 euros. Estimation based on the costs incurred by UNI in 2024 to buy 50 recycled shoppers, 50 pens and 50 agendas branded with project logo and using its visual identity.
Remaining purchase costs (<15% of pers. Costs)	9.900,00	Travel costs: Based on the last data available in 2024, on average travels cost to UNI 1,100 euros per person per travel. For bi0SpaCE it has been estimated to have 2 people participating in 3 project meetings (one per year) as well as 3 travels for dissemination events or standardization meetings (CWA kick-off meeting + organization of a workshop at CEN + participation to a trade fair).
Total	22.900,00	

8/ NAT		
	Cost (€)	**Justification**
Equipment	3.000,00	pH sensors (2.500,00 €) - I/O MODULS (2*500,00 €).Technical WP, WP2, WP3, WP4, WP5.
Other goods, works and services	7.804,60	Quality tests to validate the bi0SpaCE software framework modules (digital tagging, sLCA, bi0SpaCE sensors, and the information for transparent reporting for consumers). Technical WP, WP2, WP3, WP4, WP5, WP6.
Remaining purchase costs (<15% of pers. Costs)	17.700,00	Travels WP1, 7 G.A. Meeting (x2 people) = 9000€ Other Costs: Consumables and installation supplies, humidity and temperature sensors, bottle count sensor. Technical WP, WP2, WP3, WP4, WP5.
Total	28.500,00	

4.2 Capacity of participants and consortium as a whole #@CON-SOR-CS@# #@PRJ-MGT-PM@#

Figure 13: Geography of bi0SpaCE partners.

Scientific/Technological Domains	AU	FhG	CAR	UNI
Life Cycle Assessment / Circular Economy	S		K	
Industrial process modelling	S		K	
Machine learning / Optimization	K	S		
Digital Twins modelling	S	K		
Dataspaces		K	S	
Digital Product Passports		K	S	S
Societal needs assessment	K		S	S
Standards development				K

Table 6: Competencies for RTOs in bi0SpaCE (Expertise Level S=Specialized, K= Knowledgeable).

The bioSpaCE consortium consists of 10 partners across 4 EU countries and in 2 associated countries.

Four leading edge RTOs from 4 EU countries drive the project to meet the S&T challenges towards a circular, carbon-neutral European bio-based industry by creating virtuous symbiotic business ecosystems.

DK**AU (Administrative Coordinator) – Aarhus University** is a major Danish university with expertise in reliability modelling and optimization, uncertainty quantification, LCA & CE assessment, fluids engineering, machine learning, digital twin modelling, as well as societal and consumer perception studies. AU is coordinating and participating in multiple ongoing Horizon Europe projects spanning a broad range of areas. AU is actively involved in multiple EU Partnerships, Made in Europe, Innovative SMEs, AI, Data, and Robotics, Processes4Planet, Clean Energy Transition, and hosts interdisciplinary research centers, including the Centre for Digitalization, Big Data and Data Analytics, Interdisciplinary Centre for Climate Change, and the Pioneer Center for Landscape Research in Sustainable Agricultural Futures. AU will act as administrative coordinator for the bi0SpaCE project, leading WP1 and WP3. AU will disseminate results through DK & EU associations and scientific publications.

DE**FhG (Technical/Scientific Coordinator) – Fraunhofer Institute of Optronics, System Technologies and Image Exploitation**, which is the largest ICT institute within the Fraunhofer. FhG will be represented by the "Smart Factory Systems" research group, which is working on AAS standard-compliant digital twins and DPPs and is actively involved in the IDTA (Industrial Digital Twin Association) to ensure that the AAS standard is not only followed, but also contributed to. IOSB leads the IDS-Industrial community, which aims to bridge the gap between IDS (International Data Spaces Association) and the I4.0 digital twins. FhG will act as technical/scientific coordinator and will lead WP2 and WP5.

ES**CAR – Fundacion CARTIF** is a leading Spanish Applied Research Centre in R&D and technology transfer activities created in 1994. CARTIF's mission is to offer innovative solutions to companies to improve their processes, systems and products, improving their competitiveness and creating new business opportunities. CARTIF is an active member of CBE JU through BIC (Bio-based industries consortium). CAR will act as pilot study coordinator and lead WP4, WP6.

IT**UNI – UNI** is a non-profit organization involved in the development, publication, and promotion of voluntary technical standards for over a century. By prioritizing the importance of standardization, UNI ensures the enhancement and uniformity of product and service attributes, while consistently upholding ethical standards and engaging all relevant stakeholders across several sectors. UNI will lead WP7 and will guide the consortium towards the proposal for development of a new pre-standardization document.

Two private industrial partners from two EU associated countries (RS, CH) addressing digital technological challenges to foster pervasive digitization of bio-based industrial systems and value chains.

RS**NISSA – NISSATECH Innovation Center**, is a Serbian innovation-driven SME developing advanced IT solutions for real-time processing used in various industries and companies. Within this project, NISSA will lead tasks related to sensors, data acquisition and DPP creation as well as to dissemination and exploitation.

CHSSF – **Swiss Smart Factory**, is Switzerland's leading DIH focusing on Industry 4.0 and sustainable, circular manufacturing. SSF addresses interdisciplinary research topics with a high degree of industrial relevance. The research ranges from industrial connectors (e.g. AAS) and their cross-company networking with the help of semantic modelling of manufacturing domain knowledge. SSF operates also a full-fledged real-world manufacturing environment that serves as TEF (e.g. in RE4DY, CircularTwAIn, Modul4r, DIMOFAC) to validate the project's developments. SSF will lead the semantics and knowledge graphs (T2.4), the advanced materials tracing and flow modelling (T4.2) and the dataspace extension with cross-DPP services (T5.4). Furthermore, SSF will actively promote the technology transfer within and beyond its established innovation ecosystems of more than 70 partner companies.

Table 7: Strengths of private industry partners (* very strong; ** strong; * medium).**

Digital Technologies	NISSA	SSF
Data collection and sharing	***	**
Data quality assurance	***	**
Data standards and ontologies	**	***
AI / ML	***	***
Data-driven modelling and optimization	***	***
DT Modelling	***	**
Dataspaces development	**	***
DPPs	***	**
Software services development	***	***

Three partners from EU countries and 1 partner from EU associated country (CH) implementing industrial pilots experimentations in 4 complementary bio-based sectors: (i) paperboard production, (ii) eco-industrial parks with bio-based energy and products, (iii) plant-based products and cosmetics, and (iv) bio-derived industrial plastics.

SE**FSK – Fiskeby AB** is one of Europe's leading packaging board manufacturers, specializing in producing packaging board made of 100% recovered fiber. Fiskeby Board AB is an independent company with all manufacturing based in Fiskeby, Norrköping, Sweden. Fiskeby AB is owned by Fiskeby Holding LLC, USA, under the leadership of the Coors family. To reduce the environmental impact of their production, Fiskeby uses renewable energy. Fiskeby is self-sufficient in steam and at normal production they produce up to 30% of their electricity needs. Since 2015 Fiskeby also has their own biogas plant to clean the process wastewater. In bi0SpaCE, Fiskeby will lead the pilot study (T6.2) aiming at circular reuse of process water and energy in paperboard production.

DK**GLB** – is an industrial park located in Skive, Denmark. It is organised as an eco-industrial cluster, with companies leasing the land in the park and gaining access to the infrastructure. Greenlab operates on a public/private partnership model and is co-owned by the local municipality, as well as private investment and energy companies. Currently Greenlab hosts 9 separate companies and has partnerships with 10 innovation and technology providers. Greenlab hosts the Greenlab Academy that collaborates with institutions of higher education as well as commercial partners. Here, professionals come to upgrade their skillset in some of the most complex areas of expertise within the green transition of industry. The Greenlab model demonstrates how different energy sectors can be integrated in a unique interplay between green hydrogen, industry, and energy infrastructure. Greenlab leads the pilot study (T6.3) aiming to develop a blueprint for building sustainable and resilient eco-industrials parks containing bio-based energy and product producers.

ES**NAT** – Founded in 2013, Biofactoría Naturae was born with a very clear mission: "Improve people's health thanks to the production of 100% natural, quality products available to everyone." They are the first bio-factory in Europe aimed at obtaining healthy and natural products, based on biotechnology and ecology. Naturae will lead the T6.4, aiming to optimize the production process, less wastes and can give transparent information about the origin of the products and main process characteristic to the consumers.

CH**NOR** – Founded in 2022 with the vision of revolutionizing the packaging industry by offering a truly sustainable, home-compostable alternative to traditional plastic. noriware has produced a packaging material based on which is fully home compostable, leaves no microplastic particles and can be manufactured on machines used in the traditional plastics industry. In Q1 2023, noriware raised pre-seed financing of 1 million CHF to further commercialize their product. noriware leads the pilot study (T6.5) aiming to establish a new digitized production infrastructure for optimizing the circularity and sustainability performance of their production process and for transparent sharing of these data via DPPs.

Table 8: Strengths of industrial pilots (* very strong; ** strong; * medium).**

Domain	FISKEBY	GREENLAB	NATURAE	noriware
Circular materials use potential	***	***	*	*
Energy recovery / reduction potential	***	***	*	*
Waste reduction potential	**	**	**	**
Industrial symbiosis applicability	*	***	*	*
Substitution of existing materials/energy streams with bio-based materials/energy	*	***	**	***
Environmental impact mitigation	***	***	***	***
Social value creation potential	**	***	**	***
Support for rural and agricultural bio-economies	**	***	**	***
Benefits from process digitalization	***	***	***	***
Application of digital product passports	***	***	**	***

Industrial Advisory Board

bi0SpaCE has already engaged with a preliminary Industrial Advisory Board (IAB), consisting of leading experts from, (i) Vitartis (ES): Food Industry of Castilla y León, (ii) VTU Engineering (AT), (iii) EU CircThread Association (BE), and (iv) Food & Bio Cluster Denmark (DK). The IAB will be confirmed before the start of the project period.

Other countries and international organisations.

bi0SpaCE includes two partners from Switzerland (SSF, noriware) and used the opportunity to seek funding for these partners from the Swiss State Secretariat of Education (SEFRI). SSF (PIC 909553093) requests 546.250 € (420.000 € personnel costs, 12.000 € travel costs, 5.000 € auditing costs, 109.250 € indirect costs) where the personnel costs will be allocated to WP1 (2 PM), WP2 (10 PM), WP3 (1 PM), WP4 (8 PM), WP5 (9 PM), WP6 (3 PM), and WP7 (2 PM). Noriware (PIC 875604063) requests 336.250 € (240.000 € personnel costs, 9.000 € travel costs, 20.000 € equipment costs, 67.250 € indirect costs) where the personnel costs will be allocated to WP1 (2 PM), WP2 (2 PM), WP3 (2 PM), WP4 (2.5 PM), WP6 (9.5 PM), and WP7 (2 PM).

The bi0SpaCE consortium will collaborate with the Bioindustrial Manufacturing Innovation Institute, USA (BioMADE) for enhancing the broader impact and dissemination of the project results. We are in contact with the BioMADE management team and ready to go ahead with the envisaged cooperation.#§CON-SOR-CS§# #§PRJ-MGT-PM§# #§QUA-LIT-QL§# #§WRK-PLA-WP§#

5 Ethics

5.1 Ethical dimension of the objectives, methodology and likely impact

The bi0SpaCE Consortium acknowledges the ethical and legal implications inherent in its proposed research. To guarantee compliance and ethical integrity, we've established the following rigorous safeguards:

HUMAN PARTICIPATION IN STUDIES: All studies in bi0SpaCE that involve human participants (incl., surveys, and stakeholder interviews in WP2,7) will be voluntary and always comply with informed consent protocols. This includes detailed information disclosure about the study, potential risks and benefits of participation, and signed consent forms. Neither children nor individuals lacking the capacity to provide informed consent will participate in the studies. Participants may withdraw from the studies without penalty at any time. The study designs will be approved by relevant institutional review boards and ethics committees, ensuring the surveys provide a net-positive benefit to society. A detailed record of content forms and approval records will be maintained. No personally identifiable information will be recorded in the studies, and all collected data will be treated as confidential and securely stored. All data involving human participants will be anonymized before publication and all data will be deleted after their use, or by the end of the project.

DATA PROTECTION: In bi0SpaCE the collection and processing of personal data (WP2,7) will be strictly minimized. No personally identifiable data will be collected; our surveys focus on eliciting consumers' technology acceptance and perceptions based on broad demographic data (e.g., country, occupation, income levels). Compliance with GDPR and any other applicable EU laws and national laws will be enforced throughout data handling, storage, protection, retention, and destruction. Informed consent for data processing will be a prerequisite for participant involvement.

NON-EU COUNTRIES: The bi0SpaCE consortium includes 2 partners from Switzerland and 1 partner from Serbia. All activities undertaken in bi0SpaCE will not import/export data or materials into or out of the EU, thereby mitigating potential ethical issues. The Consortium confirms that all the activities performed in such countries are allowed in the EU Member States.

ARTIFICIAL INTELLIGENCE (AI): bi0SpaCE will develop machine learning (ML) based solutions for predicting the technical performance of bio-based processes, flow tracking, and data quality assurance of sensor and DPP data. Our project will not use AI or ML algorithms for any social- or human-related aspects, and we will not collect any personally identifiable or sensitive information. The use of ML solutions will align with GDPR and emergent EU AI regulations. The consortium does not anticipate the use of the developed algorithms in high-risk applications or in situations where humans can be harmed. To prevent unforeseen harm, comprehensive audits evaluating technical and social performance will be conducted, focusing on transparency, trustworthiness, and explainability. Further details on our use of AI is presented in Section 1.2.4.

5.2 Compliance with ethical principles and relevant legislations

The bi0SpaCE consortium is committed to ensuring that project activities align with the GDPR, European Charter of Fundamental Rights, and all relevant EU data protection regulations, soft law, standardization, and policy initiatives. Data protection principles for securing and controlling personal information, as mandated by the EU's General Data Protection Regulation (GDPR) (EU) 2016/679, form the foundation of the handling practices in bi0SpaCE. The consortium will further respect broader privacy safeguards within the European Convention on Human Rights (Article 8), the EU Charter of Fundamental Rights (Articles 7 & 8), and related case law.

Finally, the bi0SpaCE project will uphold HORIZON's legal and ethical standards and the European Code of Conduct for Research Integrity, setting the benchmark for social research best practices. National legislation governing corresponding project activities—especially technology deployments in pilots—will be strictly observed, addressing any variances from EU legislation. The bi0SpaCE project design intrinsically adheres to the 'do no significant harm' principle (Article 17 of Regulation (EU) No 2020/852). Activities in bi0SpaCE will not jeopardize any of the 6 environmental objectives outlined within the EU Taxonomy Regulation. Further details are presented in Section 1.2.1.

The Consortium confirms that compliance with ethical principles and applicable international, EU and national law in the implementation of research activities not originally envisaged (or not described in detail) in the DoA will be ensured. The Consortium also confirms that any ethical concerns raised by those activities will be handled following rigorously the recommendations provided in the European Commission Ethics Self-Assessment Guidelines.

ANNEX 2

ESTIMATED BUDGET FOR THE ACTION

	Estimated eligible[1] costs (per budget category)											Estimated EU contribution[2]			
	Direct costs									Indirect costs	Total costs	EU contribution to eligible costs			Maximum grant amount[6]
	A. Personnel costs				B. Subcontracting costs	C. Purchase costs			D. Other cost categories	E. Indirect costs[3]		Funding rate %[4]	Maximum EU contribution[5]	Requested EU contribution	
	A.1 Employees (or equivalent) A.2 Natural persons under direct contract A.3 Seconded persons		A.4 SME owners and natural person beneficiaries	A.6 Personnel unit cost	B. Subcontracting	C.1 Travel and subsistence	C.2 Equipment	C.3 Other goods, works and services	D.2 Internally invoiced goods and services	E. Indirect costs					
Forms of funding	Actual costs	Unit costs (usual accounting practices)	Unit costs[7]	Unit costs[7]	Actual costs	Actual costs	Actual costs	Actual costs	Unit costs (usual accounting practices)	Flat-rate costs[8]					
	a1	a2	a3	a5	b	c1	c2	c3	d2	e = 0,25 * (a1 + a2 + a3 + a5 + c1 + c2 + c3)	f = a+b+c+d+e	U	g = f * U%	h	m
1 - AU	508 528.00	0.00	0.00	0.00	0.00	23 500.00	4 500.00	30 000.00	0.00	141 632.00	708 160.00	100	708 160.00	708 160.00	708 160.00
2 - FhG	0.00	529 112.00	0.00	0.00	0.00	18 000.00	0.00	8 000.00	0.00	138 778.00	693 890.00	100	693 890.00	693 890.00	693 890.00
3 - CAR	310 500.00	0.00	0.00	0.00	0.00	12 000.00	6 000.00	0.00	0.00	82 125.00	410 625.00	100	410 625.00	410 625.00	410 625.00
4 - NISSA	235 000.00	0.00	0.00	0.00	0.00	10 000.00	0.00	20 000.00	0.00	66 250.00	331 250.00	100	331 250.00	331 250.00	331 250.00
5 - UNI	135 000.00	0.00	0.00	0.00	0.00	9 900.00	0.00	13 000.00	0.00	39 475.00	197 375.00	100	197 375.00	197 375.00	197 375.00
6 - FSK	200 000.00	0.00	0.00	0.00	0.00	8 000.00	11 500.00	10 000.00	0.00	57 375.00	286 875.00	100	286 875.00	286 875.00	286 875.00
7 - GLB	134 000.00	0.00	0.00	0.00	0.00	9 000.00	5 000.00	4 000.00	0.00	38 000.00	190 000.00	100	190 000.00	190 000.00	190 000.00
8 - NAT	116 636.00	0.00	0.00	0.00	0.00	9 000.00	7 500.00	12 000.00	0.00	36 284.00	181 420.00	100	181 420.00	181 420.00	181 420.00
9 - SSF															
10 - PISP															
11 - NOR															
Total consortium	1 639 664.00	529 112.00	0.00	0.00	0.00	99 400.00	34 500.00	97 000.00	0.00	599 919.00	2 999 595.00		2 999 595.00	2 999 595.00	2 999 595.00

[1] See Article 6 for the eligibility conditions. All amounts must be expressed in EUR (see Article 21 for the conversion rules).
[2] The consortium remains free to decide on a different internal distribution of the EU funding (via the consortium agreement; see Article 7).
[3] Indirect costs already covered by an operating grant (received under any EU funding programme) are ineligible (see Article 6.3). Therefore, a beneficiary/affiliated entity that receives an operating grant during the action duration cannot declare indirect costs for the year(s)/reporting period(s) covered by the operating grant, unless they can demonstrate that the operating grant does not cover any costs of the action. This requires specific accounting tools. Please immediately contact us via the EU Funding & Tenders Portal for details.
[4] See Data Sheet for the funding rate(s).
[5] This is the theoretical amount of the EU contribution to costs, if the reimbursement rate is applied to all the budgeted costs. This theoretical amount is then capped by the 'maximum grant amount'.
[6] The 'maximum grant amount' is the maximum grant amount decided by the EU. It normally corresponds to the requested grant, but may be lower.
[7] See Annex 2a 'Additional information on the estimated budget' for the details (units, cost per unit).
[8] See Data Sheet for the flat-rate.

DATA SHEET

1. General data

Project summary:

Project summary
The digital and circular economy (CE) transition of bio-based industries is a critical objective for Europe's climate ambitions and its economic competitiveness. Given the urgency of these demands, Europe's bio-based industries need to leapfrog over past digital technologies and implementations, pioneering innovative solutions for creating bio-based products and services that are circular, as well as environmentally and socially sustainable. To realise these ambitions, the bi0SpaCE project will deliver a suite of technologies, services, guidance frameworks, and standards, combined into the open-access bi0S platform, for rapid deployment and scaling of (CE) solutions and services across bio-based industries and their value chains. bi0SpaCE will advance the creation and implementation of Industry 4.0 enhanced Digital Product Passports (DPPs), linked to an International Dataspace (IDS) compliant CE dataspace, enabling the creation of dynamic and decentralised DPPs for secure and trustworthy sharing of CE and sustainability performance data of bio-based products across the value chain, as well as providing transparency of green and CE claims to consumers. bi0SpaCE brings together a consortium consisting of 1 HEI, 4 RTOs, 1 SMEs, 1 industrial assoc., 2 large industries, and 1 startup, across 5 EU and 2 associated countries, over a 36-month project period. The knowledge and technologies created in bi0SpaCE will be demonstrated and validated across 4 complementary bio-based sectors: (i) paperboard production, (ii) eco-industrial parks with bio-based energy and products producers and consumers, (iii) plant-based products and cosmetics, and (iv) bio-derived industrial chemicals.

Keywords:

- Computer and information sciences
- Environmental engineering
- Other engineering and technologies
- Digital Product Passports, Digital Twins, Data Spaces.

Project number: 101182453

Project name: Industry 4.0 Enhanced Digital Product Passports and Circular Economy Dataspaces for Sustainable Bio-Based Industries

Project acronym: bi0SpaCE

Call: HORIZON-CL6-2024-CIRCBIO-01

Topic: HORIZON-CL6-2024-CircBio-01-6

Type of action: HORIZON Research and Innovation Actions

Granting authority: European Research Executive Agency

Grant managed through EU Funding & Tenders Portal: Yes (eGrants)

Project starting date: fixed date: 1 January 2025

Project end date: 31 December 2027

Project duration: 36 months

Consortium agreement: Yes

2. Participants

List of participants:

N°	Role	Short name	Legal name	Ctry	PIC	Total eligible costs (BEN and AE)	Max grant amount	Entry date	Exit date
1	COO	AU	AARHUS UNIVERSITET	DK	999997736	708 160.00	708 160.00		
2	BEN	FhG	FRAUNHOFER GESELLSCHAFT ZUR	DE	999984059	693 890.00	693 890.00		

N°	Role	Short name	Legal name	Ctry	PIC	Total eligible costs (BEN and AE)	Max grant amount	Entry date	Exit date
			FORDERUNG DER ANGEWANDTEN FORSCHUNG EV						
3	BEN	CAR	FUNDACION CARTIF	ES	999929836	410 625.00	410 625.00		
4	BEN	NISSA	PRIVREDNO DRUSTVO ZA PRUZANJE USLUGA ISTRAZIVANJE I RAZVOJ NISSATECH INNOVATION CENTRE DOO	RS	965052225	331 250.00	331 250.00		
5	BEN	UNI	UNI - ENTE ITALIANO DI NORMAZIONE	IT	944380458	197 375.00	197 375.00		
6	BEN	FSK	FISKEBY BOARD AB	SE	882132745	286 875.00	286 875.00		
7	BEN	GLB	GREENLAB SKIVE AS	DK	899122780	190 000.00	190 000.00		
8	BEN	NAT	BIOFACTORIA NATURAE ET SALUS	ES	939400672	181 420.00	181 420.00		
9	AP	SSF	SWITZERLAND INNOVATION PARK BIEL/ BIENNE AG	CH	909553093	0.00	0.00		
10	AP	PISP	Isopine KLG	CH	878580702	0.00	0.00		18/10/2024
11	AP	NOR	Noriware AG	CH	875604063	0.00	0.00	1/1/2025	
Total						2 999 595.00	2 999 595.00		

Coordinator:

– AARHUS UNIVERSITET (AU): from 9 October 2024 to present

3. Grant

Maximum grant amount, total estimated eligible costs and contributions and funding rate:

Total eligible costs (BEN and AE)	Funding rate (%)	Maximum grant amount (Annex 2)	Maximum grant amount (award decision)
2 999 595.00	100	2 999 595.00	2 999 595.00

Grant form: Budget-based

Grant mode: Action grant

Budget categories/activity types:

- A. Personnel costs
  - A.1 Employees, A.2 Natural persons under direct contract, A.3 Seconded persons
  - A.4 SME owners and natural person beneficiaries
  - A.6 Personnel unit cost

- B. Subcontracting costs

- C. Purchase costs
  - C.1 Travel and subsistence
  - C.2 Equipment
  - C.3 Other goods, works and services

- D. Other cost categories
  - D.2 Internally invoiced goods and services

- E. Indirect costs

Cost eligibility options:

- In-kind contributions eligible costs

- Parental leave

- Project-based supplementary payments

- Average personnel costs (unit cost according to usual cost accounting practices)

- Limitation for subcontracting

- Travel and subsistence:
    - Travel: Actual costs
    - Accommodation: Actual costs
    - Subsistence: Actual costs

- Equipment: depreciation only

- Indirect cost flat-rate: 25% of the eligible direct costs (categories A-D, except volunteers costs, subcontracting costs, financial support to third parties and exempted specific cost categories, if any)

- VAT: Yes

- Other ineligible costs

Budget flexibility: Yes (no flexibility cap)

4. Reporting, payments and recoveries

4.1 Continuous reporting (art 21)

Deliverables: see Funding & Tenders Portal Continuous Reporting tool

4.2 Periodic reporting and payments

Reporting and payment schedule (art 21, 22):

Reporting					Payments	
Reporting periods			Type	Deadline	Type	Deadline (time to pay)
RP No	Month from	Month to				
					Initial prefinancing	30 days from entry into force/10 days before starting date – whichever is the latest
1	1	18	Periodic report	60 days after end of reporting period	Interim payment	90 days from receiving periodic report
2	19	36	Periodic report	60 days after end of reporting period	Final payment	90 days from receiving periodic report

Prefinancing payments and guarantees:

Prefinancing payment	
Type	Amount
Prefinancing 1 (initial)	2 399 676.00

Reporting and payment modalities (art 21, 22):

Mutual Insurance Mechanism (MIM): Yes

MIM contribution: 5% of the maximum grant amount (149 979.75), retained from the initial prefinancing

Restrictions on distribution of initial prefinancing: The prefinancing may be distributed only if the minimum number of beneficiaries set out in the call conditions (if any) have acceded to the Agreement and only to beneficiaries that have acceded.

Interim payment ceiling (if any): 90% of the maximum grant amount

Exception for revenues: Yes

No-profit rule: Yes

Late payment interest: ECB + 3.5%

Bank account for payments:

DK8502164069053238 DABADKKK

Conversion into euros: Double conversion

Reporting language: Language of the Agreement

4.3 Certificates (art 24):

Certificates on the financial statements (CFS):

Conditions:

Schedule: only at final payment, if threshold is reached

Standard threshold (beneficiary-level):

- financial statement: requested EU contribution to costs ≥ EUR 430 000.00

Special threshold for beneficiaries with a systems and process audit(see Article 24): financial statement: requested EU contribution to costs ≥ EUR 725 000.00

4.4 Recoveries (art 22)

First-line liability for recoveries:

Beneficiary termination: Beneficiary concerned

Final payment: Each beneficiary for their own debt

After final payment: Beneficiary concerned

Joint and several liability for enforced recoveries (in case of non-payment):

Individual financial responsibility: Each beneficiary is liable only for its own debts (and those of its affiliated entities, if any)

Joint and several liability of affiliated entities — n/a

5. Consequences of non-compliance, applicable law & dispute settlement forum

Suspension and termination:

Additional suspension grounds (art 31)

Additional termination grounds (art 32)

Applicable law (art 43):

Standard applicable law regime: EU law + law of Belgium

Dispute settlement forum (art 43):

Standard dispute settlement forum:

EU beneficiaries: EU General Court + EU Court of Justice (on appeal)

Non-EU beneficiaries: Courts of Brussels, Belgium (unless an international agreement provides for the enforceability of EU court judgements)

6. Other

Specific rules (Annex 5): Yes

Standard time-limits after project end:

Confidentiality (for X years after final payment): 5

Record-keeping (for X years after final payment): 5 (or 3 for grants of not more than EUR 60 000)

Reviews (up to X years after final payment): 2

Audits (up to X years after final payment): 2

Extension of findings from other grants to this grant (no later than X years after final payment): 2

Impact evaluation (up to X years after final payment): 5 (or 3 for grants of not more than EUR 60 000)

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