ShapingBio

The bioeconomy of the future

Deliverable 2.2

Report on analysis of applied R&D and technology transfer

Submitted version

Report awaits European Commission approval

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Name	Organisation
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List of Abbreviations

Abbreviation	Full name
APRE	Agency for the Promotion of the European Research
ART	Agriculture Research Troubsko, Ltd
ATEX	ATmosphere Explosible
BBEPP	Bio Base Europe Pilot Plant
BIC	Bio-based Industries Consortium
CEO	Chief Executive Officer
CSO	Chief Scientific Officer
EU	European Union
FBCD	Food & Bio Cluster Denmark
Fraunhofer ISI	Fraunhofer Institute for Systems and Innovation Research ISI
IP	Intellectual Property
MAG	Multi-Actor Group
PDI	Pilot and Demo Infrastructure
R&D	Research and Development
SME	Small and Medium Entreprises
SUBNET	SUBMARINER Network
TTE	Tech Tour Europe
TTG	Tech Tour Global
TRL	Technology Readiness Level
VLAIO	Vlaanderen Agentschap Innoveren & Ondernemen
WP	Work Package

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Executive Summary

The global transition towards a sustainable bioeconomy necessitates a robust innovation ecosystem capable of translating cutting-edge research into tangible applications and marketable solutions. Recognizing this critical need, the European Union initiated the ShapingBio project, a collaborative endeavour aiming to bolster the bioeconomy innovation landscape within the EU. This project adopts a multi-stakeholder approach, engaging key actors from academia, industry, the public sector, and civil society to foster a synergistic environment conducive to knowledge exchange, technological advancement, and policy development.

Work Package 2 (WP2) of the ShapingBio project focuses on meticulously analysing the results generated in WP1 and subsequently developing best practices and comprehensive guidelines across four pivotal domains: Policy & Governance, Applied Research & Technology Transfer, Education & Skills, and Investment & Finance. This report delves into Task 2.2 specifically, which addresses the critical challenges of accelerating applied research and development (R&D) while facilitating effective technology transfer within the bioeconomy. Task 2.2 aims to identify existing barriers and opportunities hindering the successful translation of scientific discoveries into commercially viable products and services within the bioeconomy. Typically, TRLs are grouped into three broad categories: Low (TRL 1-3), Medium (TRL 4-6), and High (TRL 7-9). To adequately reflect the complexity and critical importance of these stages within the bioeconomy, a decision was made to deviate from the conventional TRL grouping and instead separate the levels into three blocks, resulting in three distinct sub-tasks within T2.2., namely Low TRL (Applied R&D: TRL 3-4), Medium TRL (Pilot 4-5 / Demo: TRL 6-7) and High TRL (Demo cases: TRL >7).

The methodology underpinning Task 2.2 is characterized by its multi-faceted approach, integrating both quantitative and qualitative data collection techniques. The process can be summarized as follows:

- Literature Review: Conducting a thorough review of existing academic literature, policy documents, and best practices reports related to technology transfer and commercialization strategies in the bioeconomy context.
- Conduct a Co-Creation Process with a Multi-Actor Group: Facilitate participatory workshops and discussions involving stakeholders from diverse backgrounds to co-create solutions and generate actionable recommendations.
- Stakeholder Engagement: Initiating a series of targeted interviews and focus groups with key stakeholders from academia, industry, and the public sector to gain in-depth understanding of their perspectives on the challenges and opportunities associated with applied R&D and technology transfer within the bioeconomy.

While each sub-task within Task 2.2 followed a core methodology focused on applied R&D and technology transfer, they were tailored with unique actionable points to address specific challenges and capitalize on emerging opportunities within the bioeconomy. This rigorous approach led to several key conclusions:

- Collaboration is Key: The report stresses the importance of strong collaborations between researchers, industry partners, and policymakers for successful innovation. Strategies are proposed to bridge gaps between these groups, including patents, industry collaborations, founding companies, better support of reaching IP agreements, and fostering trust through intermediary organizations.

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- Navigating Regulatory Hurdles: While regulations are crucial for safety and efficacy of products and processes, they can also act as barriers to innovation. The report advocates for streamlining approval processes, providing training for regulatory personnel, and ensuring consistency across sectors.
- The Power of Pilot and Demo Infrastructures (PDI)s: PDIs are identified as crucial drivers of innovation by providing access to expensive equipment and expertise. The report emphasizes the need for ongoing investment in these facilities to support a thriving and internally competitive bioeconomy ecosystem.

Task 2.2 plays a pivotal role in advancing the overall objectives of the ShapingBio project by providing valuable insights into the complexities of applied R&D and technology transfer within the bioeconomy. The findings and recommendations generated through this task will serve as a critical foundation for informing workshops (WP3) and ultimately contributing to policy recommendations (WP4). By fostering a collaborative environment and promoting best practices, Task 2.2 contributes significantly towards building a thriving and sustainable bioeconomy within the EU.

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1. Introduction

The ShapingBio project, funded by the European Union (EU), aims to enhance the bioeconomy innovation ecosystem within the European Union through a comprehensive analysis and co-creation process involving various stakeholders. By engaging key stakeholders from academia, industry, the public sector, and civil society, the project strives to foster a collaborative environment that drives innovation and supports the development of effective policies and practices within the bioeconomy. Specifically, Work Package (WP) 2 of the ShapingBio project focuses on analysing the results from WP1.

WP1 is about ‘Specification of methodological approach and mapping’ and it documented different gaps and inequalities ranging from, for instance, policy coordination and harmonization to the level of R&D activities, actor engagement and awareness and to having access to financing. Even though the urgency of the development of bioeconomy and its importance to the economy across all EU macro-regions has been recognized both on the EU and national level, it outlined that further efforts are necessary to harmonize the bioeconomy scene across Europe and improve the performance of all the member states. Insights on these aspects in the four macro-regions and comparative insights within them were further elaborated in the final public deliverable D1.4[1]. This report provides a mapping of an inventory of the bioeconomy activities, policy strategies and instruments and conditions for each macro-region, based on the prior identified information needs from within the ShapingBio project. Deliverable 1.4 complements the EU bioeconomy mapping (publicly available Deliverable 1.2). The work executed in WP2 accompanies the mapping results by a more detailed analysis of specific topics (i.e. policy coordination, R&D transfer, collaboration and financing) by developing best practices and guidelines across four key areas:

- **Policy & Governance:** Crafting effective policies and governance structures to boost the bioeconomy.
- **Applied Research & Technology Transfer:** Promoting the translation of research into practical applications and innovations.
- **Collaboration:** Enhancing cooperation among stakeholders from different sectors to stimulate progress and innovation.
- **Financing:** Ensuring adequate funding and financial support for bioeconomy initiatives.

Task 2.2 is dedicated to the topic of "Applied R&D and Technology Transfer." It aims to enhance the bioeconomy innovation ecosystem by focusing on applied research and technology transfer. This task involves setting up a Multi-Actor Group (MAG) to guide the co-creation process, ensuring the project's activities are relevant and impactful. The main objectives of T2.2 include mapping of stakeholder needs, defining the scope, identifying potential in-depth analyses, and conducting these analyses to provide actionable insights for further workshops and policy recommendations. This involves analysing current R&D and technology transfer activities to pinpoint successful case studies and best practices, which can be translated into actionable guidelines. This ensures diverse perspectives are integrated into bioeconomy innovations. Supporting technologies through various Technology Readiness Level (TRL) stages, from early-stage research (TRL 3-4) to market-ready solutions (TRL>7), aims to streamline the innovation pipeline. Developing evidence-based policy recommendations involves identifying gaps and suggesting improvements to existing frameworks, creating an environment conducive to sustainable growth in the EU's

[1] ShapingBio. (n.d.). D1.4 Report on macro-regions: Mapping of initiatives, structures, instruments, and key challenges for EU’s macro-regions.

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bioeconomy sector. Additionally, the task seeks to drive economic development, environmental sustainability, and social well-being by ensuring innovative technologies are effectively transferred to and adopted by industry.

The structure of this deliverable D2.2 is the following: The Introduction chapter offers an in-depth explanation of the project's aim, scope, and background, setting the stage for the detailed discussions that follow. The Concept chapter delves into the motivation behind Task 2.2, highlighting its significance within the ShapingBio project. It explains the TRL framework and its importance in applied R&D and technology transfer. Additionally, this chapter explores the differentiation of stakeholder needs according to different TRLs and outlines the approach, motivation, members, and activities of the MAG, emphasizing the co-creation process. Subsequent chapters are organized based on TRL stages. The chapter on Low TRL Applied R&D (TRL: 3-4) introduces the methodology used for studying low TRL Applied R&D and presents the findings and conclusions from this analysis. The chapter dedicated to Medium TRL Pilot & Demo (TRL: 4-5; TRL: 6-7) details the methodology for medium TRL pilot and demonstration projects, followed by a summary of the outcomes and implications of these activities. The chapter on High TRL Demo Cases (TRL >7) describes the approach for high TRL demonstration cases and provides insights and conclusions drawn from these activities. This is followed by the Overall Conclusions and Outlook chapter, which synthesizes the findings from all chapters and offers a forward-looking perspective on the bioeconomy innovation ecosystem.

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2. Concept

2.1.Motivation of the task

The ShapingBio project is divided into several work packages, each focusing on different aspects of the bioeconomy ecosystem. The current report is part of WP2 'Analysis of mapped information and involvement of stakeholders' to achieve the project objectives and ensure a systematic and inclusive approach to derive actionable insights for WP4 Policy recommendation. Figure 1 illustrates the methodology employed in Task 2.2 'Applied R&D and Tech Transfer,' which includes the steps mapping stakeholder needs, defining scope, identifying potential in-depth analyses, a co-creation process with a multi-actor group, and carrying out in-depth analyses. The results of these steps feed into workshops (WP3) and recommendations (WP4), ensuring effective achievement of project objectives.

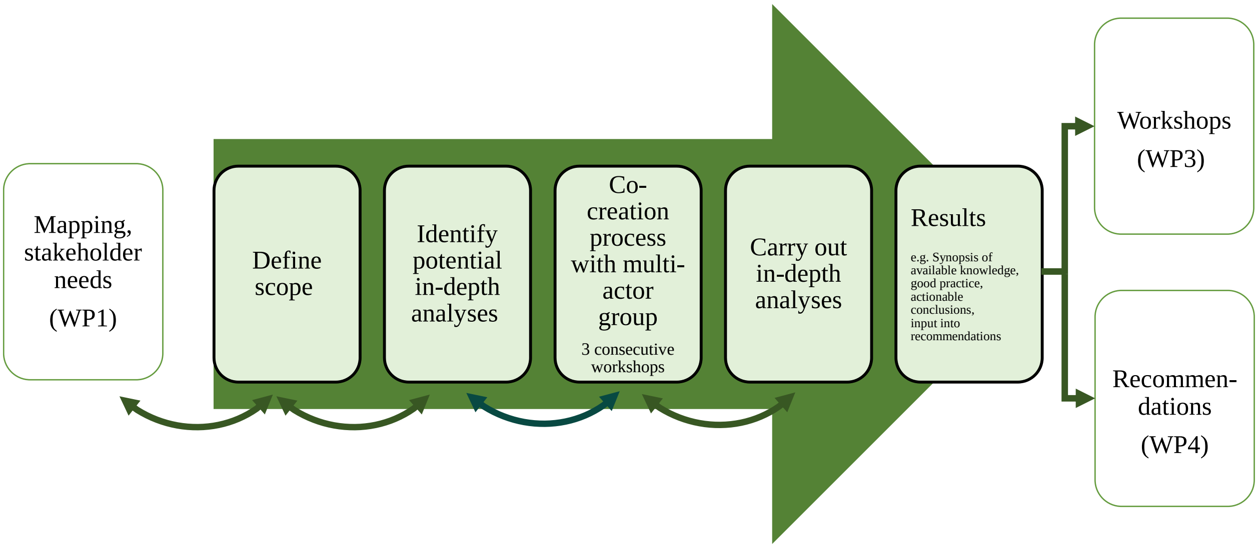

Figure 1: Methodological Framework of the ShapingBio Project for T2.2 'Applied R&D and Tech Transfer

To define the scope of the overall topic and the in-depth analyses, comprehensive desk research was undertaken. The sources of information included results from preceding work packages of ShapingBio, particularly the stakeholder needs assessment and bioeconomy mapping in the EU (D1.1[2] and D1.2[3]). Additionally, scientific publications, grey literature (e.g., reports), policy documents (e.g., bioeconomy strategies, action plans, decrees, and communications), and the home pages of pertinent organizations and institutions were consulted. This extensive data collection aimed to gather information about the involved actors, stakeholder groups, processes, and to characterize the respective regions. This foundational research ensured that the expert interviews were grounded in a comprehensive understanding of the bioeconomy landscape and stakeholder needs across Europe.

[2] ShapingBio. (n.d.). D1.1 Methodology and stakeholder needs report.

[3] ShapingBio. (n.d.). D1.2 Overall mapping of global and EU policies on bio-based sectors & food-systems.

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2.2. Technology Readiness Level and its significance in applied R&D and technology transfer

The journey of new technologies from concept to market involves various stages known as technological readiness levels (TRLs). This framework categorizes the maturity and readiness of a technology into distinct levels, each associated with specific goals, activities, and outcomes, ranging from TRL 1 to TRL 9 *Technology Readiness Assessment Guide*, n.d.).[45] By following the TRL framework, developers systematically advance technologies, reducing risks and increasing the likelihood of successful commercialization.[6] Each stage builds on the previous one, creating a clear path from concept to market-ready product. TRLs are usually grouped in these stages:

TRL Stages:

- TRL 1-3: Early-stage research and concept validation.
- TRL 4-7: Prototype development and laboratory testing.
- TRL >7: Pilot system demonstration and operational validation.

Applied R&D and technology transfer are critical components of the innovation process, particularly within the bioeconomy. Applied R&D focuses on the practical application of scientific discoveries to solve specific problems or create new products and processes. This phase is crucial for translating theoretical knowledge into tangible innovations that can be tested, refined, and eventually brought to market. Technology transfer involves disseminating these innovations from research institutions to industry, ensuring scientific advancements are effectively utilized. Effective technology transfer in bioeconomy can lead to significant advancements in e.g. sustainable agriculture, renewable energy, and bioproducts, contributing to economic growth and environmental sustainability. Task 2.2 aims to bridge the gap between research and practical application, ensuring that innovations are developed and implemented to address real-world challenges and support the growth of the bioeconomy.

2.3. Technology Transfer and Stakeholder Needs according to different TRLs

The stakeholder needs analysis, documented in D1.1[7] revealed several challenges that must be addressed in the T2.2 analysis:

- Diverse Stakeholder Needs: Different stakeholder groups have specific requirements for technology transfer, necessitating a tailored approach.
- Insufficient Development: Current R&D and tech transfer activities are not sufficiently developed across Europe, with significant regional disparities.

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[4] U.S. Department of Energy (2011): Technology Readiness Assessment Guide. DOE G 413.3-4A. Washington, D.C., available at https://www.directives.doe.gov/directives-documents/400-series/0413.3-EGuide-04a/@@images/file

[5] Mankins, J. C., & Mankins, K. (n.d.). Technology Readiness Assessment Guide.

[6] Santaniello, F.; Reyhani, N. M.; Pocaterra, C.; Wydra, S.; Hüsing, B.; Garthley, M.; Sabbah, Y.; Meyer, T. (2023): Methodology and stakeholder needs report. Deliverable D1.1 of the project "Shaping the future bioeconomy across sectoral, governmental and geographical levels (ShapingBio)". Karlsruhe: Fraunhofer Institute for Systems and Innovation Research ISI. Available at https://www.shapingbio.eu/media/t3dkk2qs/shapingbio_d-1-1_final_approval-remark.pdf

- Capacity Gaps: There is a need for keeping state-of the art open access pilot and demo plants to support technology validation and scaling.
- Collaboration Gaps: A lack of collaboration between academic research sectors and industry hinders effective technology transfer.
- Market Orientation Barriers: The main barriers relate to market orientation and lack of synergies between actors, impacting the overall innovation ecosystem.

Moreover, stakeholders' needs differ depending on the TRL stage. Typically, TRLs are grouped into three broad categories: Low (TRL 1-3), Medium (TRL 4-6), and High (TRL 7-9). However, during the process of task T2.2, it became evident that these broad categories were insufficient to capture the nuances and critical transitional phases in the development and demonstration stages of technologies in the bioeconomy sector. Specifically, certain stages, such as TRL 4 and TRL 7, represent pivotal points where the risks, challenges, and resource needs increase significantly. For instance, TRL 4 involves the transition from theoretical models to practical, lab-based testing, while TRL 7 marks the shift from pilot-scale testing to operational environments. These stages are not only technically demanding but also require considerable stakeholder engagement and validation, making them crucial for project success. To adequately reflect the complexity and critical importance of these stages, a decision was made to deviate from the conventional TRL grouping and instead separate the levels into three blocks, resulting in three distinct sub-tasks within T2.2. This approach allowed for a more focused analysis and strategy development tailored to the specific challenges and needs associated with these TRLs.

The descriptions of the TRLs below are adapted from sources such as NASA (2012)[8] and the European Commission (2017)[9].

Low TRL (Applied R&D: TRL 3-4)

- TRL 3: Proof of concept established through foundational research, initial concepts, and models, and proof of concept studies.
- TRL 4: Laboratory testing of prototype components or processes, involving prototype creation and extensive lab tests.

Medium TRL (Pilot 4-5 / Demo: TRL 6-7)

- TRL 4: Laboratory testing of prototype components or processes, involving prototype creation and extensive lab tests.
- TRL 5: Laboratory testing of integrated systems, integrating components, and conducting lab tests to identify technical challenges.
- TRL 6: Prototype system verified in simulated environments, gathering performance data and making necessary modifications.

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[8] NASA. (2012). Technology Readiness Levels. Retrieved from https://ntrs.nasa.gov/citations/20120002572

[9] European Commission. (2017). Technology readiness level – Guidance principles for renewable energy technologies – Final report. Directorate-General for Research and Innovation. Retrieved from https://data.europa.eu/doi/10.2777/577767

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- TRL 7: Integrated pilot system demonstrated in operational environments, collecting feedback and validating performance.

High TRL (Demo cases: TRL >7)

- TRL 7: Integrated pilot system demonstrated in operational environments, collecting feedback and validating performance.
- TRL 8: System complete and qualified through comprehensive tests, qualifying for operational use, and documenting performance metrics.
- TRL 9: System proven in operational environments, implementing the system, monitoring performance, and making final adjustments.

In the ShapingBio project, T2.2 focuses on technologies at TRL 3 and above, which are categorized into three main stages. Technologies at TRL 1-TRL 2 are excluded from this study because they are in the early stages of development and remain in the validation phase, where technology transfer has not occurred yet.

The differentiation of T2.2 into distinct sub-categories within the expert interviews and stakeholder engagement process was driven by the need to address the specific perspectives, needs, and concerns of various stakeholder groups involved in the bioeconomy. The diverse nature of stakeholders, ranging from industry professionals and academic researchers to policymakers, necessitated a tailored approach to ensure that the unique requirements and viewpoints of each group were adequately considered and addressed.

2.4.Multi-Actor Group and the co-creation process

2.4.1. Approach

The ShapingBio project employs a comprehensive methodological approach, as shown in Figure 1, emphasizing qualitative multi-case studies. This approach includes defining the scope of the topic and conducting in-depth analyses, developing a selection scheme for cases, setting up the MAG, engaging in a co-creation process with the MAG, collecting information through desk research and interviews with key experts, and synthesizing and interpreting the findings. The conclusions drawn from these analyses inform recommendations and are refined and validated through ShapingBio workshops, contributing to the overall goals of the project.

A cornerstone of the ShapingBio project is the multi-actor group (MAG), an assembly of experts and stakeholders from various sectors, including academia, clusters and industry. This diverse group ensures that a wide range of perspectives and expertise are incorporated into the initiative, enriching it with comprehensive insights. The MAG's diversity is not limited to professional backgrounds; it also includes geographic diversity, with representatives from numerous countries across Europe. This ensures that regional challenges and opportunities are well-represented and addressed, contributing to a holistic approach to innovation and problem-solving.

Members of the MAG are selected through a meticulous process that considers their expertise, experience, and ability to contribute meaningfully to the goals of task 2.2 of ShapingBio. This process ensures that the group comprises individuals who are not only knowledgeable in their respective fields but also possess a passion for fostering innovation and addressing complex challenges. The selection criteria include a proven track record in their area of expertise, the ability to collaborate effectively with others, and a commitment to the goals of ShapingBio. Representing different stakeholder groups from various countries, the members

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bring broad knowledge across different sectors, supported by long-term experience in the bioeconomy, typically ranging from 5 to 10 years. Their diverse backgrounds are crucial for developing practical and impactful solutions, making the co-creation process robust and inclusive.

The MAG plays a critical role in the ShapingBio initiative by providing continuous insights, feedback, and expertise for the WP2.2 task duration. This collaborative engagement, known as the co-creation process, involves stakeholders jointly contributing to project activities' design, development, and implementation. The co-creation process ensures that the solutions developed are well-informed, broadly supported, and more likely to succeed due to the group’s collective intelligence and shared commitment. The process involved 3 workshops, where 2 were online and 1 was set-up as a hybrid workshop. With some MAG members bilateral telcos were held prior or after some of the workshops due to unavailability of these members to the time when the workshop was held. This iterative process allows for constant refinement and improvement of project activities, ensuring their relevance and effectiveness in addressing the challenges at hand.

2.4.3. MAG Members and their roles

The MAG includes representatives from various countries and organizations across Europe, each bringing unique expertise and perspectives. The following table lists the members of the MAG, showcasing their affiliations and countries of origin. These experts from diverse sectors and regions across Europe contribute unique perspectives and expertise to the ShapingBio initiative, ensuring a holistic and inclusive co-creation process for advancing biotechnology from research to market deployment.

Table 1: Comprehensive List of Members of the MAG, including their affiliations and countries of origin.

No.	Affiliation	Name	Surname	Country	Stakeholder type
1	ACATECH	Steffen	Steglich	Germany	Associations and regional networks and clusters
2	Agritec	Jana	Mikisková	Czech Republic	Business & innovation support centre
3	Algen	Maja Liza	Berden Zavrl	Slovenia	Bio-based and food industries
4	B4C	Anne	Kokel	France	Business & innovation support centre
5	BioEast	Katerina	Stonawska	Hungary	Associations and regional networks and clusters
6	CLIB	Peter	Stoffels	Germany	Associations and regional networks and clusters
7	Clusterfood + I	Olga	de Blas	Spain	Bio-based and food industries
8	F6s	Ana Sofia	Rodrigues	Ireland	Business & innovation support centre
9	FhG IGB	Christine	Rasche	Germany	Research institute
10	FranceAgriMer	Aurore	Payen	France	Business & innovation support centre

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No.	Affiliation	Name	Surname	Country	Stakeholder type
11	Galanakis Laboratories	Charis	Galanakis	Greece	Bio-based and food industries
12	SPRING	Giulia Leonardo	Lhongi Gaiani	Italy	Associations and regional networks and clusters
13	Teknologisk	Anne Christine Anna Maria	Steenkjær Hastrup Hansen	Denmark	Tech provider
14	VTT	Pauliina	Tukiainen	Finland	Research institute

2.4.4 Terms of Reference and Activities

The terms of reference for the MAG include co-creating the framework and key issues for the in-depth analyses with the ShapingBio team, providing further insights into the planned in-depth analyses, suggesting and commenting on the planned analyses, critically discussing interim results and outputs, contributing to overall conclusions and draft recommendations, and providing suggestions on how best to communicate the results, conclusions, and recommendations to those who should take action. The MAG's activities involve fine-tuning guiding questions, selecting cases, suggesting experts or literature, discussing the relevance and practicality of results for practitioners, identifying good practices, determining prerequisites for successful implementation, and formulating actionable conclusions and recommendations.

The MAG's engagement in the co-creation process is implemented through a series of three workshops where the expert group and the ShapingBio team collaborated. These workshops facilitated the exchange of ideas and the development of strategies, ensuring that the project's activities are continuously refined and improved. The following image illustrates the co-creation process with the MAG, detailing the three workshops that were conducted as part of this process. Figure 2 below illustrates that Workshop 1 focused on clarifying parameters and expectations, Workshop 2 emphasized interactive group work and stakeholder connections, and Workshop 3 involved discussing results, drawing conclusions, and preparing for dissemination and implementation.

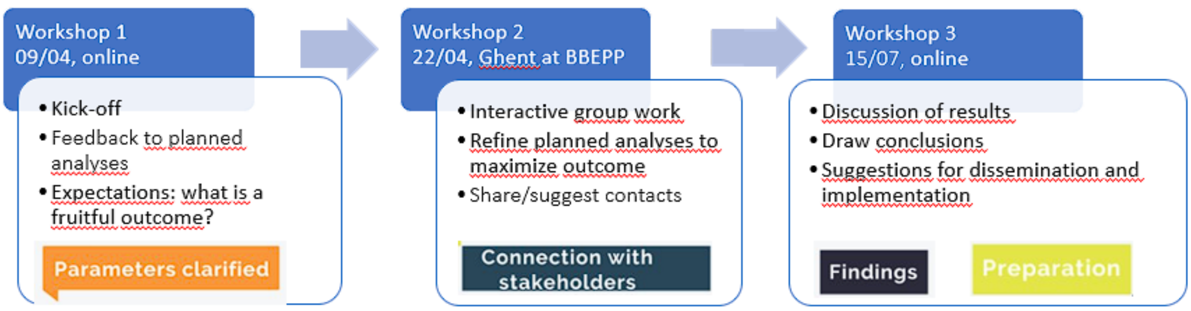

Figure 2: The co-creation process with the MAG, detailing the three workshops conducted.

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The MAG contributed to several stages of this research. In the first stage of the research, the MAG provided feedback on the study design, the choice of the countries and the themes to be tackled into the interviews conducted with interviewees. Once the methodology was set, the MAG provided feedback on the companies selected, with some experts recommending further interviewees or providing help to get in touch with interviewees. The MAG also provided more detailed feedback on the questions to be tackled to make the study results useful for a wide range of stakeholders. In the final workshop, the MAG provided feedback on how to best target our messages to different stakeholder groups and audiences who may benefit from this analysis.

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3. Low TRL Applied R&D (TRL: 3-4)

3.1.Introduction

As outlined in the chapter 2.2 TRL 3-4 represents applied R&D activities, sometimes also called industrial research, where the process of knowledge generation starts to be translated into technology with specific domains of application in mind. The particularity of this TRL range is, that it represents a junction, where different types of actors/stakeholders are involved, especially researchers/academics and industry. Indeed researchers/ academics are mostly involved in TRL 1-4, while industry is usually doing research about TRL 3-4. While these types of stakeholders can perform applied research individually and independently from other actors, it is within this scope, that we are expecting to witness technology transfer between research organisations and industry. Technology transfer activities aim at using the results of research activities (e.g. outputs, technology and product) into society, in many cases through companies which will develop the outputs further and make them commercially viable. These technology transfer activities can amongst others take the shape of spin-off formation to translate research results into commercial applications, collaboration between researchers and industry, or other forms of engagements. Thus, a successful innovation system would enable relevant knowledge and technologies supported by public research funding to find its way towards industrial applications through academic/industry interactions. Transformation of technologies in higher TRLs and issues relating to their upscaling, are usually undertaken by industry solely, and research organisations would only be involved marginally at this point. For instance, the main risks linked to the technology reaching maturity lies in successful scaling up from prototype to production which comes with its own range of technical issues, and access to financial resources to support this process, where its economic viability also becomes increasingly important. More information on the high TRL is summarised in chapter 5.

The result of this research will highlight the key facilitators and barriers for research and companies, who work on applied R&D, as well as discussing how the country context and policy can affect technology transfer in this setting. The conclusion will provide several suggestions relevant for different stakeholders and will serve within the ShapingBio project as an input for WP4 and the policy recommendations discussion.

3.2. Methodology

To study TRL3-4, and the important issues linked to it, we decided within scope of T2.2 to investigate the relationship between research and industry, and especially the factors that make this interaction attractive for both stakeholder groups. Understanding this relationship has advantages both at the macro level and micro level. Also how to support the building of successful relationships at meso level (e.g. clusters, intermediaries such as regional development agencies etc.) could be of an advantage to understand. At the macro level, understanding system conditions that may help or hinder this relationship can guide policy makers to work on reducing these frictions, and ensure that knowledge and technology generated in public institutions are leveraged for industrial use. At the micro level, it would help companies and researchers to build successful relationships. Thus, this task focuses on the following research questions:

How to make applied R&D (TRL 3-4) useful for companies and academics / researchers?

- What is the interest/benefit to engage in such a relationship for companies and for academics?
- What are the enablers and barriers?

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3.2.1 Country selection

We will follow the aim of the project to study innovation systems of different EU member states. This enables to understand also whether frame conditions in different countries affect this relationship. We use the mapping created in D1.4 to identify specificities of countries and choose a sample of countries which have major points of variation along two main lines: (i) Level of investment in R&D, (ii) Track record on technology transfer activities. These countries were also chosen considering the ease of access to gather this information, considering the potential links for contacts of the ShapingBio consortium partners and their network. The **sub-task therefore focuses on three countries**:

- Czech Republic: limited R&D funding and limited technology transfer activities
- Germany: good record on applied R&D and technology transfer
- Spain: good research investment but not much activity in technology transfer

To understand the interplay between frame conditions existing within each country, and enablers and barriers for both stakeholder groups, this sub-task relies on interview data with companies and researchers. These interview data enable to understand the innovation system and where researchers and companies stand within it. It also provides the opportunity to discuss different conditions within concrete examples, and to explore specificities of doing applied R&D within the bioeconomy.

3.2.2 Case studies through interviews

The study concept highlights the focus on the R&D carried out between companies and researchers in the public sector, and whether any frame condition linked to national innovation systems would facilitate this R&D engagement. To build an understanding around this issue, there is a need to discuss specifically how the interaction takes place. Important contextual factors such as the technology developed, the area of the bioeconomy that the technology is embedded in, as well as what makes the country context potentially different from one another points towards a need to greater details to perform an analysis informative to policy makers. The only way to achieve this is through interviews. Indeed, interviews enable the project partners and the interviewees to have a structured discussion, where the project partners design questions around selected themes of interest, and interviewees can provide a story about how R&D activities are conducted with collaborators giving important context information, and conditions under which these exchanges may or may not work.

Given the focus of the task, we aim at interviewing both researchers in the public sector and companies who are involved in applied R&D activities between public research and industry. We also aim to have good representation about the three countries selected above (Czech Republic, Spain and Germany). We also decided to focus on actors, who had experience in engaging across organisational boundaries (i.e. not only one engagement). Furthermore, we focussed on small and medium enterprises (SMEs). Although, large companies may also engage in those activities, we believe that these interactions would be different from smaller companies, given their structure, financing and presence on the market. The limited number of interviews in this sub-task would not allow to differentiate between enablers, barriers and context for those different types of industry players and it was therefore decided to focus on smaller companies, as their situation is usually more precarious than larger companies.

The below subsections further explain about the themes tackled in the interviews, as well as further background about the selection of the interviewees. This should help the reader to reflect on the results and recommendations based on how the data was collected.

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Themes tackled in the interviews

The questions of the interview are clustered into several themes:

- What does the applied R&D engagement entail?
- How were these engagements set up?
- What are the useful outcomes (benefits/motivations) of these engagements, what outcomes of these engagements are perceived as useful?
- How can public policies be improved to tackle the difficulties?

Within these themes, we also discussed whether external organisations facilitated any of the above aspects, whether the national policies or national institutional incentives / frame conditions had a role to play and finally whether any of the above was influenced by the sector of activity.

These themes were derived in the first instance from the discussion in the literature about important points made from academic-industry engagements. The themes and questions were developed in an iterative manner, by first discussions within the Fraunhofer ISI team, then by comments from experts in the MAG workshops. In the first workshop the experts gave feedback on the themes to be tackled in interviews as well as the overall study design. In the second workshop, experts in the MAG gave further feedback on the specific questions, as well as recommendations about whom to contact for interviews.

Participants' recruitment

In order to find companies and researchers in the bioeconomy aligned to the specification above, we relied on a combination of different approaches summarised in Figure 3.

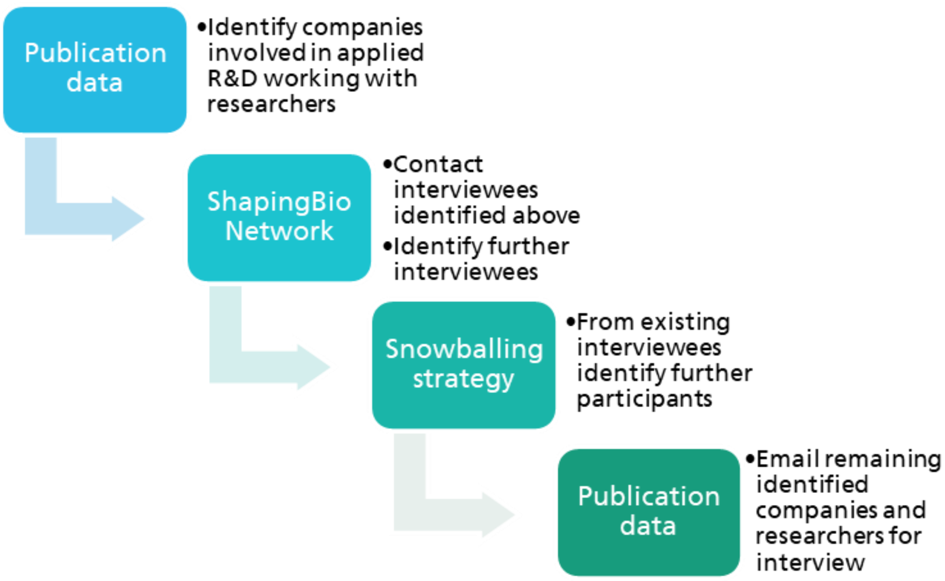

Figure 3: Process of identifying and contacting interviewees in subtask "low TRL"

Figure 3 shows that our starting point was publication data, to identify a number of research work co-produced between researchers and companies. Publication data was collected using the Web of Science, using their custom-made categorization, filtering by publications in the Biotech category, published in 2010

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or after and then only selecting publications with at least one co-author in each of the selected countries. Subsequently, organizations affiliations were analysed to identify publications including companies. This research gave thus a first list of target companies, which could be circulated through the ShapingBio network, who would help us getting in contact with companies and researchers in this list or who have a similar sectoral focus to the ones identified. This approach included ShapingBio partners, as well as MAG participants and people from their network. It was aimed to facilitate success rate of getting interviews, as the request would come from the interviewee's own network. Once the interview started, we also asked interviewees to suggest others who may be interested in participating in the study. Unfortunately, the above process did not generate enough interviews, and therefore we complemented the above with emailing researchers and companies directly from the list of publications identified.

Participants overview

Overall, we emailed 43 people directly and relied on the network of 4 partners and two experts from our network to contact potential interviewees in addition of the direct requests. The interview request was shared by email, stating the objective of the project and of this task, the type of questions tackled and what the interview would involve. Once the invitation was accepted, we shared a link to the video-meeting, and also the information sheet and consent form, detailing the data use and anonymisation procedure. The consent was collected either through signing of the form, email response, or recording or through the recording of the interview. At the beginning of the interview, the interviewer did summarise again the objective of the research and data use, to make sure these were well understood by the interviewees.

We interviewed a range of researchers and companies in the field of industrial biotech, food sector, water sector, novel biocontrol agents, pellet production, biomass extracted from algae, biomass used as innovative material, farming sector etc. Tables 2 and 3 show that overall, 14 interviews took place from May to July 2024. The interview lasted from 45 minutes to 1h30 minutes and were on average 1h15 minutes long.

Table 2: Interviewee count based on countries and organization types

	Czech Republic	***Germany***	***Spain***	***Total***
Universities / Public Research Organization	3	2	2	*7*
Private Research Organizations	1	0	0	*1*
Companies	2	1	3	*6*
Total	*6*	*3*	*5*	*14*

Analysis of the interviews

For each interview, notes were taken by the interviewer, and interviews were also recorded and transcribed using the Microsoft Teams dedicated feature. Both the notes and the transcriptions are used to extract key themes from these interviews. These themes were then searched and standardised across interviews, through a spreadsheet including information on whether the theme was discussed and written comments to explain how this theme was specifically discussed in the interview as illustrated in the figure below.

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	04 comme	05	05 comme	06	06 comme	07	07 comm
Motivations for academic/industry							
For industry							
certification / evidence for efficacy / com		Y	Provide services to certification .			Y	Example
access to expensive and specialised equip	Universities are well funded to g			Y	Example o	Y	we have
access to skills	From the r	Y	Some type of research is to reach out to skills that co				
access to new ideas							
Needing for funding							
For researchers							
help companies solve their problem - rese	This is something I think is impor			Y	I like to kn	Y	With the
companies have not enough time to share							
need of data for research purposes	ere is not m	Y	. the second benefti is the data that we are collecting				
Get extra salary at university to work with	It check re	Y	we need to get projects to cover all salaries, in univer				
Need to be selective for projects that are	Selection of projects that I know have higher chances of success						
Being able to get funded - part of public fi		Y	. We have not a another source of money to finance				
Unclear what can be used for business pu		Y					
Applied researcher need to understanding				Y	to go from TRL 5 to 6 and 7 - th		

Figure 4: Illustration of the interview coding

Once key themes had been identified, these were organised into broader clusters of topics. Seven of these were identified:

- General statements about the characteristics of the engagement or collaboration
- Aspects related to funding
- Aspects related to intellectual endeavour / skills
- Tension between types of organisations / institutional drive
- Points related to regulations
- Administrative / contractual and bureaucratic aspects
- National context characteristics

The following section discusses the insights gained through the interviews from the thematic analysis.

3.3.Analysis

The results will be presented as follows. Firstly, we characterize what was discussed in the interviews under the umbrella of Applied R&D engagements for companies and researchers, this will detail what these activities mean to the interviewees and what they entail (see 3.3.1). Secondly, we go deeper into the reasons and motivations for academics and companies to engage with each other in applied R&D (see 3.3.2). Thirdly, the section will describe in more depth the recurring topics discussed across interviews, highlighting specific barriers (see 3.3.3). Finally, we are going to discuss country specificities for the three countries identified (Germany, Spain and Czech Republic) (see 3.3.4).

3.3.1 Background on academic-industry engagement

At the beginning of our interviews, participants were invited to give examples of their experience of academic-industry engagement, and in most of the cases the examples involved formal collaborations around research projects. All interviewees had projects either funded through public grants, at the national or EU level, or through their own means - where research organizations and companies finance part of the research, or projects are directly financed by companies. Most of the interviewees, either companies or researchers, were relying on all these three types of collaborations. External funding is not the primary reason for engaging in these activities, these were rather to solve specific problems, generally formulated by companies.

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Beyond formal collaborations, companies and researchers engaged through other means, such as co-training of PhD students (half of the interviewees reported this), or university spin-off formation. Other less frequent engagements involved exchange of staff to learn new techniques and skills or internships of master students. When setting up the engagement, the topic was usually problem driven, where researchers or companies found collaborators in their own network, or extended network. Participants across both public research and industry reported, that their field of research was quite small especially within their country and therefore would find partners relatively easily. Alternatively, another way to find partners was through organized events around funding opportunities. This was either done through a collaborative approach where companies and researchers would have preliminary discussions about problems they would like to focus on and how to address them before setting up a formal collaboration, or through finding partners who would be willing to participate in a research proposal under development for a specific call. Finally, internet searches and cold contact also enabled the formation of new collaborations.
Facilitating organizations (cluster organizations, tech transfer offices, formal networks ...) were seen as helpful in this process but not key for the success. These organizations' main function is to help both researchers and companies to network, introduce new potential partners, and give advice on funding or on regulation.

3.3.2 Types of research and motivations for public research-industry engagement

The type of research carried out in these public research-industry engagements can be quite varied. This can be at the initiative of the researchers or the company. When it is at the initiative of the researchers, the involved companies were asked to contribute by providing some material, expertise or skills, or to use their ability to move technologies or products towards the market. For companies, there are a variety of reasons to engage. We can differentiate two types of companies, the ones that are research intensive, on the look-out for knowledge or technologies related to their business, or also getting new ideas of how to expand current technologies or products. This can be a primary motivation for them to engage in such activity (as shown in Table 3). The ranking in the table is based on how many interviewees mentioned this aspect. These knowledge-based companies later shape their own products and market offer based on what technologies may have the most attractive market opportunities or are easier to scale up and produce. A number of these companies are also interested in finding new ideas from experts in the field to further develop their business.

Other companies were only seeking engagement with researchers in a more targeted manner, for technologies directly related to their current business need. Most of the interviewees across both types of companies highlighted, that many companies need access to specialized, and expensive equipment for part of the technological development, that is necessary for the company to use but is used too rarely to justify investments. This equipment also relies on specialized and skilled associated labour and again is too specialized and expensive for companies. Therefore, equipment available in a research laboratory can be accessed by companies within such a public research-industry engagement. A second important aspect for both these types of companies was to conduct research providing some form of certification or to prove regulatory compliance. Indeed, companies in the bioeconomy need to show the quality or characteristics of their products or technologies to satisfy certification purposes - this can range about safety, quality (e.g. water quality), or sustainability related (e.g. CO_2 emissions etc.) -, or regulatory purposes (fertilizing products need to be approved, or livestock feeds), or to prove the efficacy of the product over other products. These two aspects were mentioned in the majority of interviews both by researchers and companies. Table 3 summarizes the motivations for both stakeholder groups.

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Table 3: Motivations for public research-industry engagements

Motivations for companies	Motivations for researchers
1. Access to expensive and specialized equipment	1. Applicability of research into industry
2. Research for certification, evidence of efficacy, compliance to regulation	2. Additional resources to improve own research
3. Access to specialized skills	3. Get external funding for research
4. Access to new ideas for business development	
5. Access to funding (public grants)	

On the one hand, the motivation of researchers to engage with industry is to ensure that their research finds an application, either by using their knowledge to help companies solve their problems or by helping the process of creating technologies or products that stems directly from their own research. Seeing their knowledge applied is an important motivation. Being closer to the market may also imply being closer to understanding societies' needs in terms of research and technologies. On the other hand, for researchers working with companies is a way to access additional resources to improve their research. This can take the form of data that is not publicly available or also learn new techniques from partners.

Finally, for both companies and researchers, the access to financial resources is deemed helpful but more secondary compared to the aspects above. As will be discussed in the next section, access to public funding comes with some barriers, but in many cases is also quite necessary. It is particularly helpful to engage in long-term, more exploratory research projects, where public researchers have time and space to explore and test a technology. These projects are the ones bringing new knowledge, capacities and skills to companies, as well as connecting them with researchers who can explore related ideas which may be useful for the longer-term product portfolio of the company. It enables a wider development and transfer of broader skills and knowledge but are not essential short-term work of the company.

3.3.3 Results of the thematic analysis

Following on from the discussion on motivations, this part focuses on the discussion along benefits and barriers through several recurrent themes that emerged across many interviews: these include aspects related to regulation, funding, tensions arising from different organizational pressures and culture between academia and industry, and finally bureaucracy which overlaps also the three earlier themes. The main features of the themes are summarized in Figure 5 and are discussed in more detail below.

Regulation and funding are aspects, that were already discussed in the previous section as they are both motivations for engaging in research activities (see section 3.3.2) but will be further discussed in this section.

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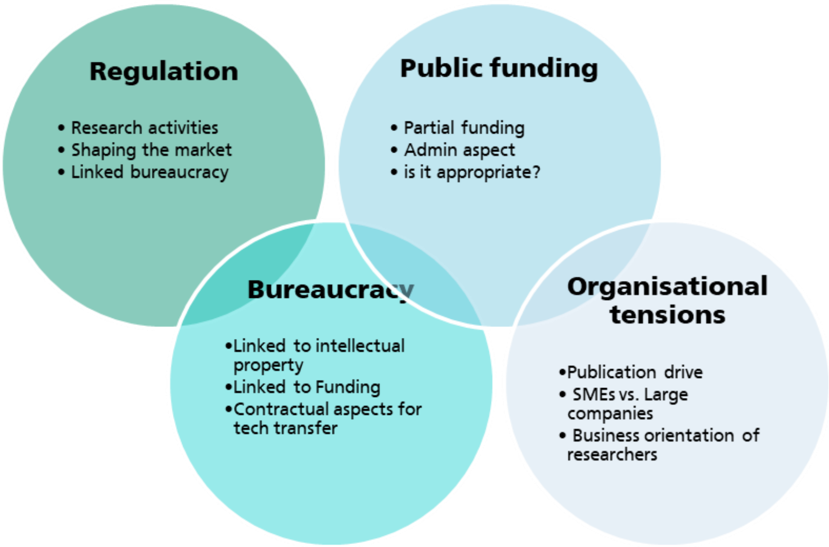

Figure 5: Major themes emerging from the interviews

Regulation

Starting with regulation, from the interviews it became clear that this aspect shapes both the research and the activities of companies. For firms in the bioeconomy, many need to comply with regulations both if they have laboratory facilities to work on genetically modified organisms and/or to place their innovative products on the market. This is one main reason why companies collaborate with researchers, as applied research activities are needed to show compliance with regulations. Related to this aspect, regulations also shape the market in which companies operate. A significant number of companies interviewed reported focusing on one specific sector at their creation and then would develop new products that would be less restrictive in other markets and therefore change the business offer of the company, following regulatory and thus market attractiveness. While regulation is needed, it is often a hurdle for companies, especially small companies, who need to spend significant time to meet regulation, and where regulatory approval can take a long time thus delaying the introduction to market of products which impact their financial sustainability. Regulation seems quite complex to deal with for companies, as some struggle to keep up with the number of rules, or the many changes to regulation. Some interviewees call for more consistency of regulations between human health, animal applications and environment, where the use of technologies are regulated differently and inconsistently across sectors, for example for food/feed regulations.
There are also inconsistencies between funding offered at the European level to develop products in particular areas, while regulations would not allow their commercialization, e.g., Novel Food Regulation, making the uptake of these technologies unattractive for industry. Finally, regulation can also seem more adapted for chemical products rather than biologically active products, which one interviewee was under the impression that it put their product at a disadvantage, and where regulatory evaluators overseeing the approval may have lacked the required specific knowledge to evaluate fairly the product. Overall, regulation is perceived as being very bureaucratic, an overly lengthy process, and often mentioned as a barrier to the application of the applied research undertaken by both researchers and companies.

Public funding

Public funding is seen as a major enabler to engage in the development of technologies and products, which can be valuable on a long-term basis. In contrast many companies decide to commission pieces of research directly to research organizations mainly if they are strategic for the company, should be completed on a

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shorter time frame, or are not too costly especially for SMEs (can be conducted with a few thousand euros). Any of these factors or a combination of them would define whether the company would self-fund the research.

Public funding access is seen as a relatively slow and bureaucratic process. While the speed was not seen as a barrier that could be avoided, many interviewees commented on the bureaucratic aspects, which makes these funding not always attractive. The bureaucratic aspect is also to be seen considering the likelihood of success (i.e. including the strength of the consortium or the topic being attractive to funders or reviewers) and the general rate of success of the grants. Indeed, the participation in these grants requires an ability to provide documentation that complies with the funder's requirements and being able to prepare budget and their related documentation to justify costs over several years to a great level of detail that are not straight forward and, in many cases, difficult to predict. A few of the "knowledge-based companies" interviewed had the capacity to undertake this kind of work in the form of trained personnel, who could identify the calls, potential partners and engage in the writing of the proposal and comply with the requirements, while other companies did not have in house expertise which makes it harder for them to participate. Some interviewees reported that they provide dedicated support for other companies who are not usually involved in research projects (e.g. farmers) to support them to be part of such initiatives.
Another barrier for companies to capture public grant income is that the grants usually support only part of the required research budget. The level of their own contribution is important for a firm to decide whether they want to participate, but smaller companies may just not have the budget in terms of co-funding to be able to participate in such grants or consortia.

Indeed, there are many opportunities to be funded regionally, nationally (depending on the countries i.e. see next section), or at the European level for this type of applied R&D research. However, there was disagreement between interviewees about whether this funding was sufficient. Several of the interviewees found the funding sufficient, while others did not. For those who did not, there was a range of reasons discussed. Some interviewees reported that the bioeconomy was not as well funded compared to other sectors. Indeed, they require significant investment in terms of costs of development, requiring laboratories, facing regulation and some expressed that too few projects are funded compared to the role it could play in terms of the sustainability transition or in terms of the circular economy. For instance, the biotech sector for health applications has much better funding comparatively. Some interviewees feel that the funding for small companies is too little and there could be more dedicated funding for them to ensure the development of technology and their survival.

Organizational tensions

Universities, research institutes, small and large companies have different ways to operate, different sizes, different organization and different culture. All these aspects influence the ability of researchers and companies to collaborate with one another and can create tensions or ease collaboration. We present below separately the view of companies about public research organizations, and then the view of public research organizations about companies. While overall some tensions are reported, it is important to note that most interviewees are satisfied with their engagement and want to renew the experience with some of the same collaborators as well as new ones. Hence, the tensions below should be seen as potential leverage points for further improvements rather than important barriers to overcome. It is important to note here those interviewed were relatively well experienced in public research –industry interactions and therefore may have already overcome some barriers which may be more noteworthy for first time collaborators or those who have not collaborated because facing such barriers. Thus, inexperienced individuals interacting in such types of collaboration may face additional barriers that cannot be reported here.

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For companies, one aspect that creates tensions is the academic push for publication or for researchers to expand their own research interests rather than being interested in working on problems that have been put forward by industrial collaborators. This creates tensions to fulfil the agreed project objectives or for some researchers to focus enough on aspects relating to applied research. Both researchers and companies agree that it is important for researchers to have an interest in helping the upscaling of the technology / products and have a sense of what is commercially viable or what makes sense business wise. While the academic specific incentives, such as the drive towards publication, were prominent, many interviewees admitted that they can see a shift in the academic culture where the newer generation of researchers have a higher interest for the application of research, and are happier to engage with companies, both at the individual level, but as well as the institutional level with a push for technology transfer activities.
The second aspect of this academia-industry tension is different time pressures that people are under; small companies need to develop products in the short term, while researchers work on a longer time scale in the medium term. This can be differentiated from research institutes which can be slightly faster or have more capacity in the shorter term than university. Besides academic staff, to establish a formal collaboration there is the need for contracting between research organizations and companies. Workers working at the organizational level, for example administrative staff in charge of/ required for contacting issues are not under the same pressure to start research projects, and this can delay the start of a collaboration. The push for contracting may have arisen from a general policy push for stronger intellectual property (IP) rights to capture value within research organizations. While these can generate revenues, they can also be costly to maintain and would render the research more expensive, by for example increasing the amount of overhead paid per euro invested in research. The push for IP means that contracting is more complex, and renders setting up the collaboration through either technology transfer departments or universities contractual services lengthy and bureaucratic, which can be prohibitive for companies. Researchers have also reported that this creates tensions in their collaboration and delays the development of technologies and products stemming from their research.

Researchers in public organizations reported that relationships and projects can be quite different depending on whether they are dealing with smaller or larger companies. Smaller companies are quite agile, and it is easier to set up contracting with them and start the research activities promptly. However, smaller companies have a limited budget for their own research. For larger companies, the budget is potentially larger, however the timescale to agree on what needs to be done within the projects require several levels of approval within the organization which can make the process slow and more complex. Large companies are also more focused on contractual agreements, which take longer to negotiate with public research organizations.

Overall, a pre-requisite for a good relationship is the establishment from the start of a relationship, where both researchers and companies have trust in one another, share information about the objective of the project, find a common and mutually interesting and beneficial problem to solve and ensure that the use of research results are well defined in order for companies to keep a competitive advantage on the knowledge and technology they finance and for researchers to have a clear understanding of the aspects of research that are publishable.

Bureaucracy
As discussed in the above paragraphs on regulation, funding and organizational tensions, bureaucracy is a pervasive issue that affects the academic-industry engagement at different levels. While this subsection does not bring many new elements it summarizes the points made above and aims to highlight the increasing bureaucratic pressures that both researchers and companies are facing.

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Comparatively the biggest source of bureaucracy for both the companies and the researchers are publicly funded research projects. For companies, the most reported hurdle for companies are the steps undertaken in the proposal, which requires financial planning over several years, and a good understanding about what is needed in the proposal. Some companies reported that sometimes details may make the company or proposal ineligible, thus potentially wasting time and resources. As discussed above, having internally dedicated staff to public grant funding can help this process. One interviewee noted that in regional and national tenders (in Germany), staff from the funding agency were available to answer questions and help with the compliance of the proposal which made this process much easier compared to European Commission projects. Post-funding bureaucracy is also increasing, including the completion of time sheets, increased number of supporting documents needed to justify expenses etc. On the university side, this increases the compliance processes. To sum up, bureaucracy requirements push researchers and companies to spend increasingly more time on administrative tasks per euro of research funded.

The second aspect is the administrative tasks and bureaucracy linked to regulation. As discussed above the process can be lengthy, lack of consistency between different regulations that may apply to the respective innovation, and regular changes to laws and regulation make this aspect very difficult to manage for companies.

The third level is the bureaucracy linked to collaboration between companies and research organizations and universities in line with technology transfer policies. These means that a lot of time and effort is put on building contracts and working out intellectual property, which delay the start of the work, especially as administrative staff within public organizations may not be affected by the same time pressures that companies or even public researchers may have. This is also the case with patenting, which makes access to the technologies more difficult for smaller companies. Companies have reported that this aspect can be quite prohibitive, and some companies would not seek many collaborations or formalize them unless it became necessary for the company to do so.

The conflation of the above aspects shows that technology transfer through collaborative applied R&D activities can be hampered by bureaucracy, as well as increase the time in which the technology is developed and can reach the market. Interviewees implied that the bureaucratic pressures have been increasing over time.

3.3.4 Country characteristics

While the themes outlined above are crosscutting across at least two if not for all three countries, there are important differences in terms of the innovation system and technology transfer system of the three countries under consideration (Czech Republic, Spain and Germany). The starkest difference to note is Czech Republic compared to the two other countries, which is the focus of the first part. The part thereafter tackles both Spain and Germany and discusses the similarity and differences between these two countries.

Czech Republic

Interviews have revealed that the activities of engagement between public researchers and industry are strongly affected by how the innovation system is organized and by the internal policies in Czech Republic itself. In Czech Republic, collaborations between industry and researchers in the public sector are not only encouraged by policy makers, researchers and companies, but is essential for all the actors especially for researchers in universities and public institutes. A first aspect to be considered is the acquiring of public funding. In Czech Republic, universities and public research institutes are only partially funded, even for projects only involving public researchers. All public researchers in Czech Republic reported, that the

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requirement for co-funding is an issue for them. These require research organizations to allocate internal funds to these projects for them to be fully financed. Our interviewees pointed out that these internal funds are not readily available and need to be acquired to make such publicly financed projects feasible. Funds raised by doing research for companies can contribute to finance these public research organizations to carry out these publicly funded research projects. Interviewees have also reported that university researchers' salaries are not very attractive, and securing funding from industry will contribute to help top-up researchers' salaries. These reasons are a strong push for researchers to carry out research with or for industry. A second aspect lies in policy incentives for universities to collaborate with industry. Indeed, interviewees have reported that there is a strong push from universities to have events for better networking and setting up such kind of engagement. One interviewee received dedicated funding for setting up and maintaining a network of interested researchers and companies in the bioeconomy to facilitate such collaborations.

The types of firms interviewed in Czech Republic were also quite different in terms of activities compared to those of Spain and Germany. These firms had under 10 employees and were developing products through their network. These firms were designing the products and technologies, commissioning public research organizations and other companies, with the research and production, and would market the final products. They decided on the strategy of the firms and product depending on the market opportunities. But these firms did not develop research capabilities internally. While these companies may not be representative of other companies in Czech Republic working with researchers in the bioeconomy, it is important to note this difference as companies interviewed in other countries did not share this organization.
Finally, many interviewees in Czech Republic highlighted that one of the biggest barriers to their research in the bioeconomy was linked to the political instability, and that policy would change regularly with changes of government. Sectors of the bioeconomy which were once incentivized would not be supported anymore (e.g. change of incentivizing energy using biomass changed towards solar panels). Interviewees also reported a lack of national strategy towards the bioeconomy, where decisions are fragmented across different ministries, which makes the support towards bioeconomy harder to access for all stakeholders.

Germany and Spain

In Germany and Spain, the types of companies encountered were knowledge-based companies, where companies interacted with universities, to expand their own technologies, knowledge and ideas of products and services, both on the shorter term and for the medium term. They engage regularly in research projects and are likely to do so in the future.

In terms of public funding, both Spain and Germany have access to a range of national funding on top of EU funding. The national funding in Spain for companies means that they are funded to a partial level which may not make national funding particularly attractive. Secondly, many national and regional funds for companies are in the form of loans which need to be reimbursed. This makes European funds more attractive for Spanish firms compared to national funds. In Germany, when companies apply for public funding, the national funding is on partial level. However, funding is mainly by grants which do not need to be reimbursed, but a certain share of company-own financial contribution (depending on the size of the company) is mandatory. On top of that, there is a variety of funds accessible at the regional and national level, which terms are as equally attractive as European funds. Regional and national contacts were more reachable compared to the EU funding, which helped the application processes for companies.

In terms of the innovation system, the results confirmed the assessment made by ShapingBio within D1.1, namely that Spain still needs to improve its technology transfer capabilities, while Germany features a good technology transfer system.

In *Spain*, in research organizations the drive towards publications is still quite strong and this was reported to be a barrier for technology transfer engagement. In the last 10 years a shift has been observed both in terms of culture, with more researchers being willing to engage in collaborative research with industry, and at the organizational level with technology transfer offices becoming more common. However, these are seen as bureaucratic and rigid and unable to adapt to a wide range of situations. While there is a shift in mentality in terms of collaboration, there is still a limited number of companies in the bioeconomy, and therefore not that many collaboration opportunities. This can be due to the financing issues discussed above, the lack of capital risk funding in the sector and the limited incentives for researchers to be involved in new companies, for example as being the founder of a start-up company.
In *Germany*, the ability of the country to transfer technology from research to industry is perceived as good. There is a rich public research sector, with universities, technical universities, and several applied public research institutes making it possible to access research results and find good partners to work with for transferring this technology. Applied research institutes are better able to work in the short term and their administration is reported to be able to handle contractual agreements on a shorter-term basis. Universities are more focused on co-development of technology in the medium-term, leaving time in the process for exploring potential new avenues for research and technologies. The newer generation of university researchers are reported to be also keener to work with industry. The only aspect mentioned, that may hamper this ability is the contractual side, involving also working out intellectual property issues. This is seen by both industry and researchers as an administrative process slowing down prospected research and technology transfer. In Spain, the contractual side of technology transfer is also a problem as dedicated infrastructures are more focused on these aspects rather than easing collaboration. In both countries it has been noted that venture capital may be lacking (in Spain) or financially unattractive (in Germany), which makes it more difficult for these companies to find funding and grow to develop their technologies and product portfolio.

3.4. Conclusions for the low TRL

Engagement between public researchers and small and medium-sized companies for applied R&D activities (TRL 3 and 4) is important for both parties. These relationships are seen as usually beneficial and once initiated there aren't any problems finding partners to collaborate with. The technologies developed by companies within these public research-industry collaborations are those technologies providing either the best market opportunities, technologies which have present better opportunities for scaling up or new knowledge critical for the company development. Companies can benefit from good relationships with researchers, to have access to a broader range of technologies which are then more likely to reach applications.

The countries selected featured salient differences. The first difference lies in the organization of public research in the three countries. In Czech Republic the partial funding of public grants even to research organizations means that research organizations need to find matching funds, which comes from industry projects. The incentive to collaborate with industry for public research organization is therefore vital. Germany has a diverse public research ecosystem, with universities, technical universities, Fraunhofer institutes, Leibniz institutes etc. which means that companies can find partners from the more basic to the more applied spectrum, with on the applied side, researchers and organizations who have experience dealing with companies and technology transfer, which makes the collaboration easier for companies. Spain and Germany feature companies that do research to build capabilities, to develop a variety of technologies and related knowledge in turn helping the products that they put on the market. Czech Republic firms were smaller in terms of employees, and research projects were smaller in size, and their results were needed on a shorter time scale. Overall while in all countries there were a range of types of collaborations from aimed

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at providing services providing certifications or analysis to justify compliance with regulations to those that aimed at building new technologies or know-how beneficial to both parties, the structure and incentives in place in the three countries meant that different types are prominent in different countries. In Czech Republic services were much more commonly reported, while in Spain and Germany the building of new technologies and know-how were more predominant.

Four major themes structured these relationships. Regulation and funding shaped the type of research conducted but was also seen as a potential barrier. The differences between culture and incentives within universities, public research organizations and companies also shaped their engagement. Underlying these three themes, bureaucracy is a cross-cutting aspect, which is increasing for all actors in the eco-system.

Based on the barriers identified (in the thematic analysis in section 3.3.3) across the four themes (funding, regulation, bureaucracy, organisational tensions) several suggestions for points of attention can be made. They are shown in the table 4 below. The suggestions are organised by stakeholder groups that are either involved in the technology transfer activities (researchers or companies), or stakeholders who have an influence in the process (universities, technology transfer intermediaries and policy makers).

Table 4: Points of attention to facilitate technology transfer in low TRL for different stakeholder groups

Stakeholder groups	***Points of Attention***
Industry (Bio-based and food industries, Tech providers)	• Be aware of (i) regulation early, this renders some markets less accessible and (ii) the time it takes to get approval of your product. • If public funding is key, dedicate personnel to develop know-how on how to apply for national and European grants/ loans/research funds
Researchers	• Be aware of the business aspect of the research, understand that proof of concept does not mean easy scaling, and understand economical aspects. • Ensure clear rules with companies from the outset about strategic knowledge, secrecy and publishing strategy to avoid tensions and create a trusting environment. • Be aware of the timescale companies work with
Universities	• Administrator: be aware of the speed of the process, both in drawing contracts, negotiating IP etc. • Apply a broader set of indicators beyond publications and citation rates for academic careers (e.g. patents, industry collaborations, ….) to help them collaborate more with industry.
Tech transfer intermediaries	• Help to understand each other's need, publication vs IP needs, understand the business side of the research, facilitate the building of trust between parties. • Ease existing bureaucracy rather than creating additional requirements. • Provide key information on funding opportunities and conditions of access to this funding, networking opportunities, and regulatory changes.

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Tech Transfer Offices (TTOs) and Universities	• Strengthen collaboration between academic research and industry to facilitate smoother transitions from lab-scale research to high-TRL industrial applications. • Offer licensing and intellectual property support that aligns with industry needs for scalability and market entry. • Develop innovation hubs or incubators within universities that provide access to shared pilot facilities, mentorship, and commercialisation expertise. • Encourage faculty and student entrepreneurs by offering dedicated resources and funding to support technology commercialisation efforts. • Standardize and streamline the intellectual property (IP) management process to reduce delays and uncertainties that may discourage industrial partnerships. • Work closely with companies to align licensing agreements with the needs of scaling technologies.

Policy makers, funding agencies	• Funding:
	  ◦ The percentage of required co-funding for companies can be prohibitive for smaller companies.
	  ◦ Make funding conditions clear and easy to understand.
	  ◦ Have dedicated personnel to support companies' submission.
	  ◦ Reflect on the pre- and post-submission bureaucracy and whether they are necessary or proportionate.
	• Regulation:
	  ◦ Be aware of the reviewing time.
	  ◦ Ensure that regulation and personnel are well equipped to deal with biotech products, not only chemistry-based products.
	  ◦ Strive for higher consistency between regulations which cover different applications of an innovation, e.g. human health, animal and environmental applications.
	• Gather evidence whether patenting and IP protection is prohibitive for small companies to access technologies from universities.

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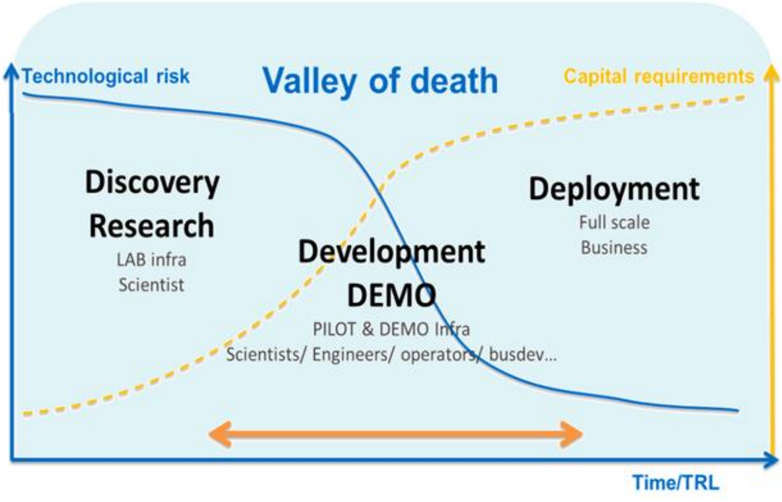
4. Medium TRL Pilot (TRL: 4-5) & Demo (TRL: 6-7)

4.1.Introduction

The recent unprecedented COVID-19 crisis has brought to the surface a much wider role that the bioeconomy can have in diversifying supplies for food, feed, and raw materials, contributing to circularity and climate neutrality, while at the same time creating employment and fostering rural development. In these challenging times with increasing geopolitical tensions, the sustainable and circular bioeconomy is a central element in supporting the transition to an economy that is climate-neutral, while preserving the biosphere. It will also increase EU global competitiveness with US and Asia.

Compared to the stable and long-developed fossil economy, the bioeconomy is still industrially in its infancy. Europe is strongly committed to research[10] in bioeconomy, with many innovative technologies being developed in the lab. To have sufficient impact, rapid development of innovations on a large scale is necessary. It comes down to getting bioeconomy innovations towards the industrial scale as much and as fast as possible[11]. To get from the lab scale (TRL 1-3) to the industrial scale (TRL 8-9), the pilot (TRL 4-5) and demo stages (6-7) are a crucial phase for companies developing innovative technologies. This transition phase is particularly important for small companies, such as start-ups. It determines their survival. After all, the technological risks are still very high and the capital requirements to conduct trials on pilot and demo scale in industrial biotech are high either. There is no proof yet that the start-up's innovative technology is scalable, which makes finance actors very reluctant to provide means needed for the innovation's pilot and demo phase. This is why people often refer to this phase as the 'valley of death' as shown in Figure 6.



[10] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=R%26D_expenditure&oldid=551418#:~:text=Highlights&text=In%202022%2C%20EU%20research%20and,compared%20with%202.08%20%25%20in%202012

[11] https://www.europabio.org/biomanufacturing-global-series/

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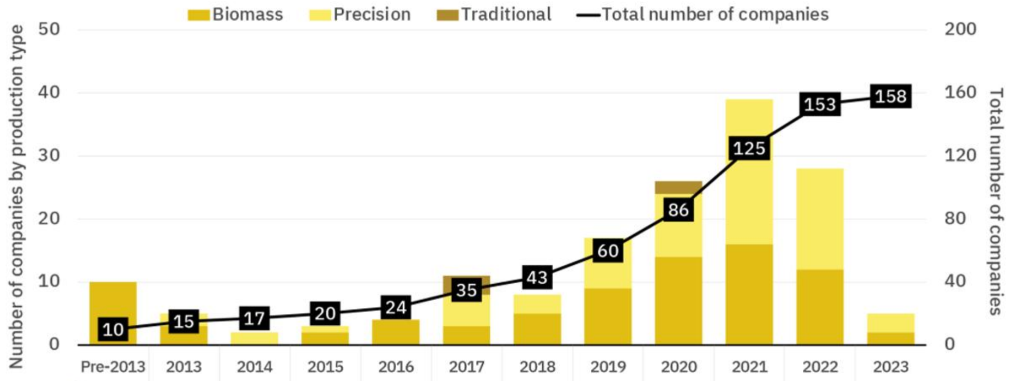
Figure 6: Illustration of the “Valley of death” in bioeconomy innovation
The primary reason for technology/innovations not to reach the market, is that the scale-up phase in the biotechnology sector is particularly expensive, as well as the manufacturing phase (e.g. large(r) infrastructure is needed for demo trials), and financial support is limited.
Open Access pilot and demo-infrastructures could provide a solution to this challenge. These facilities are offering a broad spectrum of state-of-the-art equipment and required expertise of staff with the aim to help innovative companies scale-up their successful research to an industrial scale.
Collaboration, in an early stage of technology development, with experienced personnel in such a flexible facility, can substantially reduce costs, risks and development time/time-to-market and reinforces the chance to successful market entry. Companies can get a proof-of-concept and first product samples which will help them convince clients (application testing, market development) and investors.

In the following subtask, we will pursue the question of sufficient capacity of open access pilot and demo facilities for the bioeconomy in Europe. This question results from the following factor. As a result of the post-covid enthusiasm of investors, more innovators, on average in the period 2020-2022, hit financial resources quite easily to get scale-up work done. A sharp increase in the number of new companies in the bioeconomy during that period was clearly detected[12] (see Figure 7, showing the example of the field of fermentation).



	Pre-2013	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Traditional						3	3		2			
Precision		2	2	1		5	3	8	10	23	16	3
Biomass	10	3		2	4	3	5	9	14	16	12	2

Source: GFI company database.

Figure 7: New and total publicly announced companies by year founded in fermentation.

Fermentation is yet an important technology within the bioeconomy. There is no "activity barometer" for the whole bioeconomy, only for specific parts/sectors. A recent report shows a similar trend in investments in the agri-food sector.[13] Part of the bioeconomy also takes place in this sector.

[12] https://gfi.org/resource/fermentation-state-of-the-industry-report

[13] AgFunder Global AgriFoodTech Investment Report 2024

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As a result, start-ups and SMEs were queuing in 2021 and 2022 at the front door of pilot and demo facilities and waiting times to start scale-up work became longer than average during that period. Many European pilot and demo infrastructures also started expanding capacities during that period to meet the soaring demand. In March 2023, we saw the Biden administration in the US writing down bold ambitions on biotechnology and biomanufacturing[14] with a high commitment to expanding biomanufacturing capacity through the organization BioMADE (equivalent of Biobased Industries Consortium BIC in Europe)[15].
As a result of the above developments, the idea seems to have emerged within European policy circles that, as a top priority, we also need to focus heavily on the expansion of scale-up infrastructure to fulfil European ambitions regarding the growth of the bioeconomy. However, is this truly the case? Is there adequate capacity and availability of scale-up facilities in Europe to meet the current and future demands of bioeconomy innovators? To address this critical question, the project consortium sought definitive answers directly from the shared pilot and demonstration infrastructures already present Europe.

4.2.Methodology

Europe already has a performing network of open access pilot and demo facilities for the bioeconomy[16]. Pilots4U is known worldwide as the European reference for this ecosystem. The platform contains an open and freely accessible database listing all multipurpose equipment located within the walls of European open access Pilot and Demo Infrastructures (PDIs) as well as a direct contact of such. The database was finalised within the implementation of a Bio Based Industries Joint Undertaking project (BBI JU) in late 2019 and efficiently shortlists the names, technology areas, locations and direct contact details of existing European PDIs.

4.2.1 Updating the PDIs contacts

During the research it became evident, that not all contacts in the Pilots4U database were up to date, due to the staff turnover rate in the 2019 to 2024 timeframe. This immediately triggered the first labour-intensive action, namely updating the contact details of the 108 PDIs in the database. They were contacted one by one to sound out whether the contact is still the same as five years ago. If not, the coordinates of a new contact were polled. The result is a usable mailing list with more than 100 current contacts.

4.2.2 Set-up questionnaire

A questionnaire was then compiled which, in addition to the main questions on PDI capacity and availability, also included other aspects on the operation of a PDI:

- Degree of incorporation of the infrastructure within the broad bioeconomy technology scope
- Types of services offered
- Possible expansion plans in the short term
- Questions related to the business model of PDIs (profit versus non-for-profit, dependant versus independent, financially self-sustainable or not)

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[14] https://www.whitehouse.gov/wp-content/uploads/2023/03/Bold-Goals-for-U.S.-Biotechnology-and-Biomanufacturing-Harnessing-Research-and-Development-To-Further-Societal-Goals-FINAL.pdf

[15] https://www.biomade.org/infrastructure

[16] https://biopilots4u.eu/

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- Questions related to the existence of regional public funding schemes that financially support SMEs when using scale-up facilities

These questions should allow for an understanding of the capacity and availability of PDIs as well as the elements that may influence them, such as the business model chosen and the existence of regional public funding schemes for PDI users.

Finally, shortlisted PDIs were contacted by e-mail during May – September 2024 asking them to schedule an online interview from 30-60 min. The interviews were conducted in a semi-structured way using an online survey immediately completed during the phone interview with the approval of the PDI contact concerned.

4.3. Analysis

4.3.1 Participating shared pilot & demo infrastructures and their business models

Interest in participating in this survey proved remarkably high. Of the initial shortlist of 62 PDIs invited by e-mail to participate, more than two-thirds responded positively without further follow-up (using reminders). A total of 35 interviews were conducted. The group of respondents consisted of 21 men and 14 women.

This group is representative of the ecosystem of PDIs, as it represents about half of the European shared pilot and demo infrastructures PDIs and includes both the large generic players, covering a wide range of technologies[17] as well as the smaller specific ones, covering only 1 or 2 technologies (see Table 5).

Table 5: PDIs participating in survey

Pilot and Demo Infrastructure name	**Location**
AINIA	Valencia (ES)
Air Liquide Innovation Campus Frankfurt	Frankfurt (DE)
Ajinomoto Foods Europe - Industrial Fermentation Services	Nesle (FR)
ARD	Pomacle (FR)
Bio Base Europe Pilot Plant (BBEPP)	Gent (BE)
BIO2C - CENER	Aoiz (ES)
Biomass and Bioenergy Research Infrastructure (BBRI)	Lisbon (PT)
Biosphere	Forli (IT)
BOKU University - Core Facility - BioIndustrial Pilot Plant	Vienna (AT)
Brightlands Multipurpose Pilot Plant	Geleen (NL)
Biomass Technology Group (BTG)	Enschede (NL)
Celabor	Liège (BE)
CERTH/CPERI	Thessaloniki (GR)
Centre for Process Innovation (CPI)	Wilton (UK)
Danish Technological Institute - Biosolutions Technology Center	Taastrup (DK)

[17] https://biopilots4u.eu/sites/default/files/2020-11/pilots4u_technology_areas.pdf

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Envipark	Torino (IT)
Extractis	Dury (FR)
Fraunhofer Center for Chemical-Biotechnological Processes CBP	Leuna (DE)
Fraunhofer UMSICHT	Sulzbach-Rosenberg (DE)
Green Tech Innovation Center Luxembourg Institute of Science and Technology (LIST)	Luxembourg (LU)
Improve	Dury (FR)
Moorepark Technology Ltd	Fermoy (IE)
Mycelia	Deinze (BE)
National Algae Pilot Mongstad	Mongstad (NO)
Natural Resources Institute Finland (LUKE)	Helsinki (FI)
NGP2 Biorefinery	Aachen (DE)
Phytowelt GreenTechnologies GmbH	Köln (DE)
Pivert	Compiegne (FR)
Politecnico di Torino	Torino (IT)
Research Institute of Sweden (RISE)	Örnsköldsvik (SE)
Senbis	Emmen (NL)
Tectero	Destelbergen (BE)
University of Almeria, Sabana platform	Almeria (ES)
VTT Technical Research Center of Finland	Espoo (FI)
YDLabs	Nof HaGalil (IL)

The distribution of the 35 sites from 17 different countries according to the four European macro-regions, as specifically defined in the ShapingBio project (Figure 8), corresponds quite well to the known distribution of shared pilot & demo infrastructures included in the Pilots4U database.

The largest share (60%) comes from Western Europe (Belgium, France, Germany, Luxemburg, the Netherlands, Ireland, United Kingdom, Austria). Then a quarter (26%) from Southern Europe (Cyprus, Greece, Italy, Malta, Portugal, Spain). Finally, a very limited group (14%) from the Baltic Sea Region (Estonia, Latvia, Lithuania, Denmark, Finland, Sweden, Norway, Poland) and no representation at all from Central and Eastern Europe (Bulgaria, Croatia, Czech Republic, Hungary, Romania, Slovakia, Slovenia).

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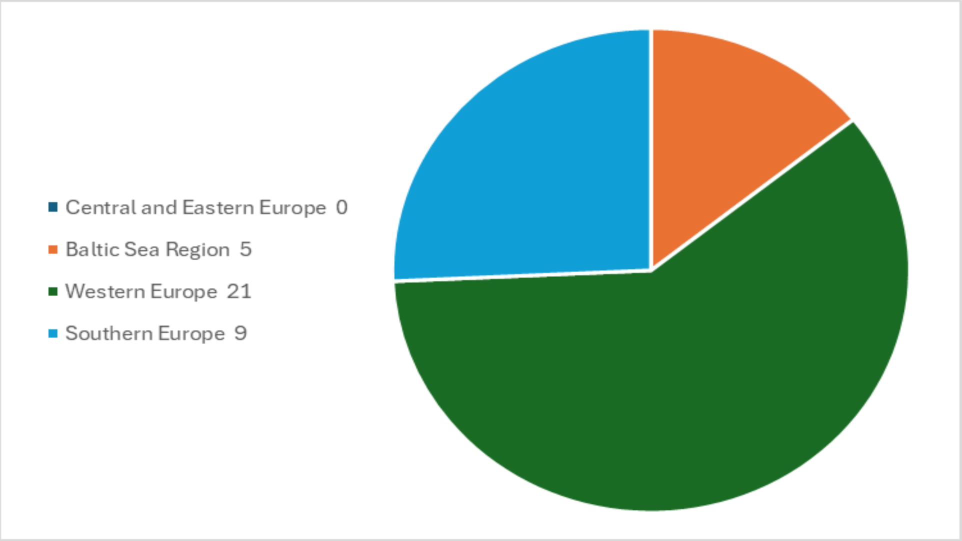

Figure 8: European Macro-Region distribution of participating PDIs

The largest share (60%) comes from Western Europe (Belgium, France, Germany, Luxemburg, the Netherlands, Ireland, United Kingdom, Austria). Then a quarter (26%) from Southern Europe (Cyprus, Greece, Italy, Malta, Portugal, Spain). Finally, a very limited group (14%) from the Baltic Sea Region (Estonia, Latvia, Lithuania, Denmark, Finland, Sweden, Norway, Poland) and no representation at all from Central and Eastern Europe (Bulgaria, Croatia, Czech Republic, Hungary, Romania, Slovakia, Slovenia). For full distribution of (all listed) PDIs within the Pilots4U database, please see published report D1.4.

There is broad coverage of the 10 technology areas within the bioeconomy (Figure 9). Among these, industrial biotechnology is the outlier, which includes fermentation technology (standard liquid fermentation, solid state fermentation and gas fermentation as technologies in strong emergence).

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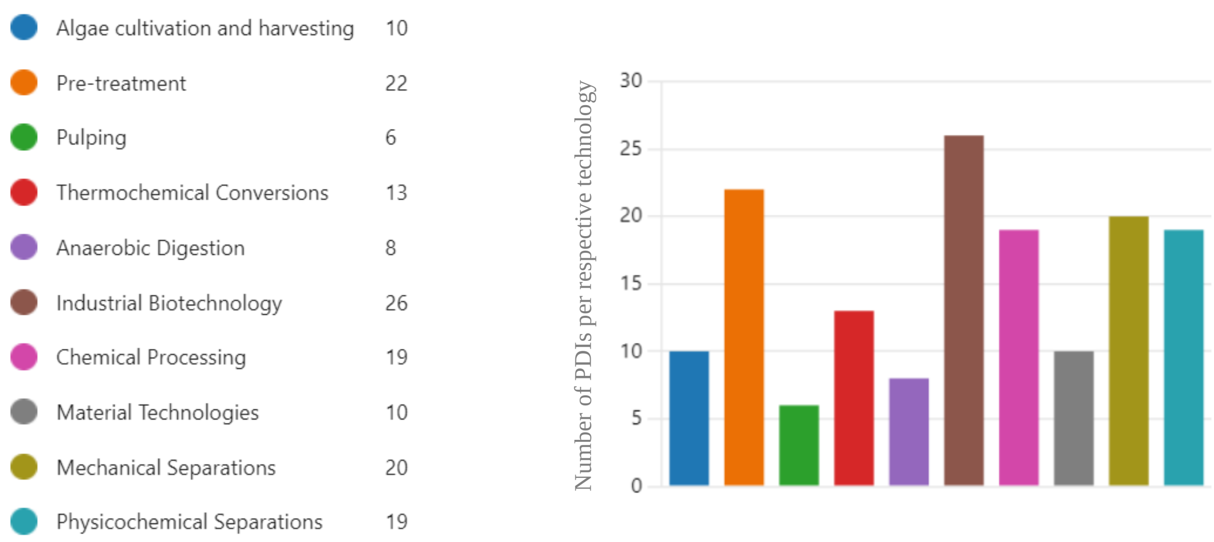

Figure 9: Technology coverage of participating PDIs

The distribution of service types offered, is very much in line with that of the Pilots4U ecosystem (Figure 10). The facilities provide broad support for both process development and for scale-up. In addition, some PDIs offer the possibility of carrying out an initial pre-industrial production (custom manufacturing) to convince the first potential customers and, from there, make the leap to industrial scale.

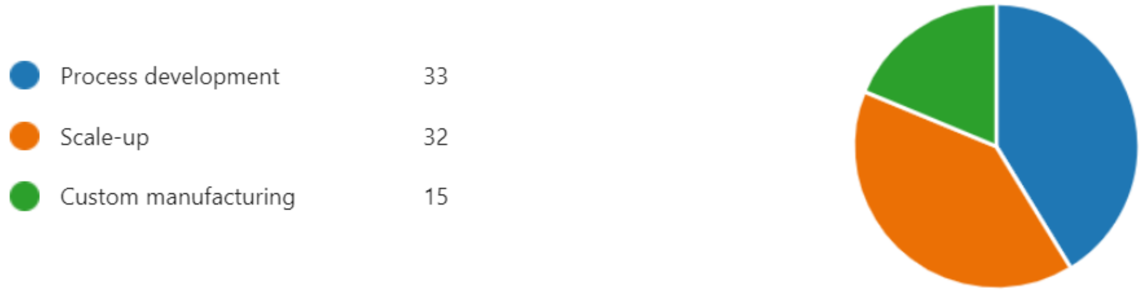

Figure 10: Service distribution of participating PDIs

The momentum of direct contact with the PDIs was used to also get a view on the business model of open access pilot and demo infrastructures in the questionnaire. That can vary strongly from one infrastructure to another. For example, 60% of the PDIs involved in the survey are nonprofit organisations (Figure 11). This does not mean that these entities do not make any profit, but that any profit made is immediately invested in personnel (skills) and equipment (capacity). Among those that do not make an annual profit, it is often regional governments that provide financial support.

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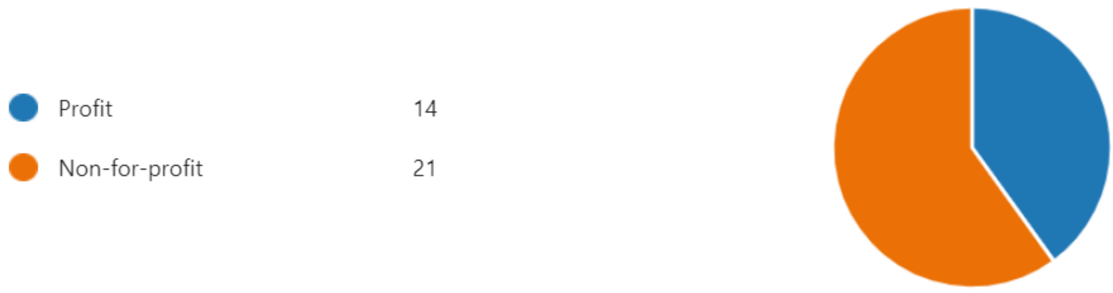

Figure 11: Distinct types of organisations of PDIs

Half of the PDIs claim to be legally independent (Figure 12): There is no shareholding from public bodies such as universities or research institutes. In these cases, there is no pressure or influence present for the PDI to give priority to scaling up the technology developed in-house by the knowledge institution. This also means that there is no corporate (large company) as shareholder determining which technology owners (start-ups, scale-ups, SMEs) will be helped mainly and less in scaling up. Nor determine which part of the IP developed at scale-up remains the property of the innovators who use these facilities.

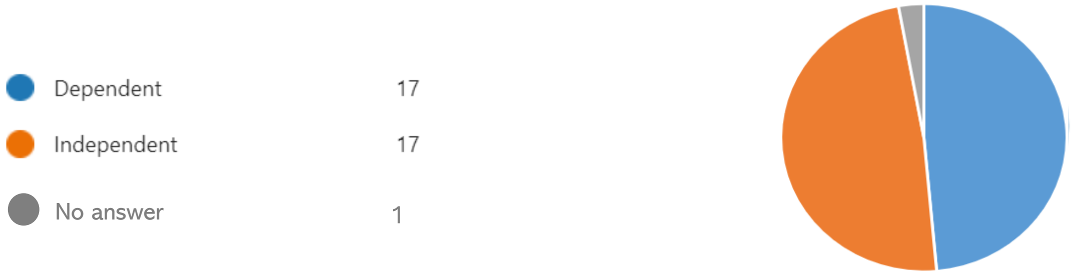

Figure 12: Degree of legal dependence of PDIs

From the questionnaire, 76% end up being financially self-sustainable (Figure 13). The revenues generated from the execution of their services, often the bilateral work delivered for small and large companies, exceed the cost of amortization of investments for infrastructure, staff and operational costs. When the PDI is not financially self-sustaining, the local government sometimes contributes financially for a certain percentage, or the corporate shareholder provides topping up the annual loss. Only one PDI was not willing to answer this question.

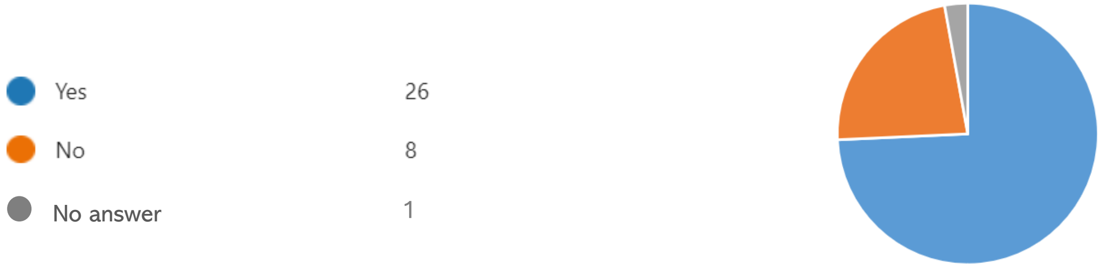

Figure 13: Degree of financial self-sustainability of PDIs

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4.3.2 Capacity and availability of participating shared pilot & demo infrastructures

The second part of the survey looked more closely at the capacity and availability of PDIs to meet the current demand for scaling up of bioeconomy innovators. The strong growth in demand in the post-covid period, as described in chapter 4.1 Introduction, showed that by 2021 demand continued to grow exponentially, putting pressure on the availability of existing shared pilot/demo facilities in Europe. Under this pressure, many PDIs invested in additional capacity. Rolling these capacities out takes 2-3 years, as it often involves complex and customised infrastructure that needs extensive testing before deployment. Several PDIs are still rolling out new equipment in 2024. Meanwhile, from 2022 onwards, a slowdown is happening in the biotech sector because of inflation that caused much higher interest rates, leading to investors to become a lot more cautious. This made it harder for innovators to get the money needed for scale-up work. We see this for instance in the Agrifoodtech world[18] to which a part of the bioeconomy belongs (Figure 14). We see the same of biotech venture capital funding globally, showing a downward trend in 2022 and 2023 (Figure 15).

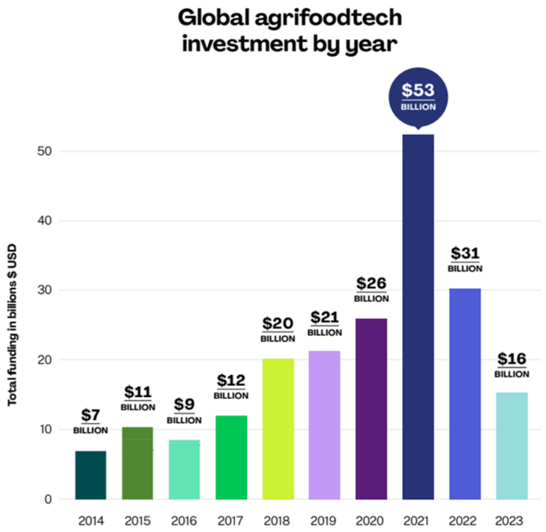

Figure 14: Global Agrifoodtech investments- AgFunder Global AgriFoodTech Investment Report 2024

[18] https://research.agfunder.com/agfunder-global-agrifoodtech-investment-report-2024-1.pdf

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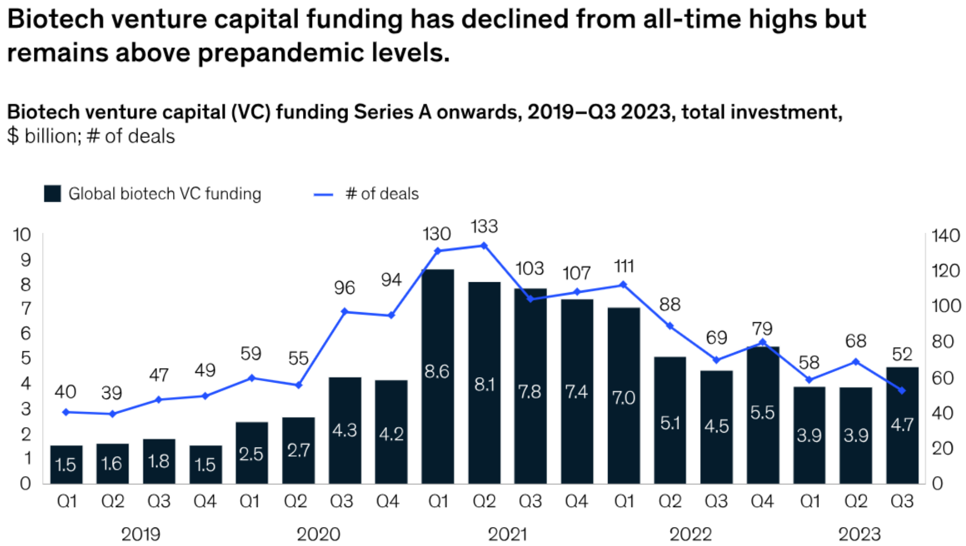
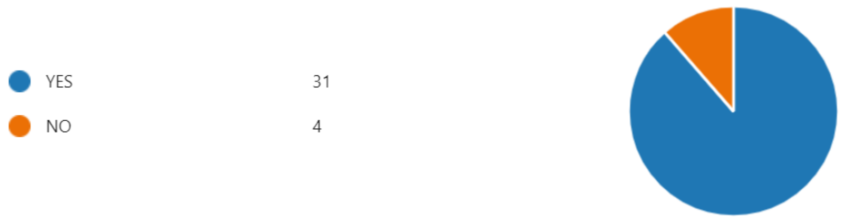


Figure 15: Evolution Global Biotech Venture Capital Funding – McKinsey & Company article December 12, 2023[19]

The above evolutions over the past 2 years should thus result in a greater scale-up supply (capacity) at PDIs combined with a lower demand for scale-up from innovators. To know how the European scale-up ecosystem is really doing economically, PDIs were asked whether they experience this trend the same way.

A first remarkable result of the survey was the fact that 91% of PDIs surveyed felt that their infrastructure was state-of-the-art. They are confident of working with the latest technological bioeconomy developments present and having or using the latest techniques or equipment. So, the shared infrastructure available for scaling up innovative processes is in their opinion, of a solid quality, capable of meeting industry's needs. But what about the quantity?

When asked whether PDIs have sufficient capacity of scale-up infrastructure to meet the current demand for process development, for upscaling processes and for custom manufacturing, 89% replied that they in fact do (Figure 16). A limited number of interviewees said they would have to invest in additional capacity. This was then mainly equipment additional to the existing infrastructure (e.g. pre-treatment or downstream processing equipment or a larger version of existing equipment).



[19] McKinsey & Company. (2023, December 12): VC funding trends in biotechnology | McKinsey

Figure 16: Degree of sufficient scale-up capacity present at existing PDIs

PDIs may have significant capacity with a wide range of equipment for scaling up various technologies, but that does not mean it is immediately available for use. If demand is high, part of the infrastructure may be in use, which can increase waiting times for innovators before they can embark on a scale-up exercise. Therefore, PDIs were also polled on the availability of their infrastructure (Figure 17).

The result of this survey is also very special, with 94% of those surveyed saying they had ample availability. Of course, some popular equipment (e.g. fermentation) is not always available quickly and demand for one specific device may temporarily spike, but in general there is no shortage of availability.

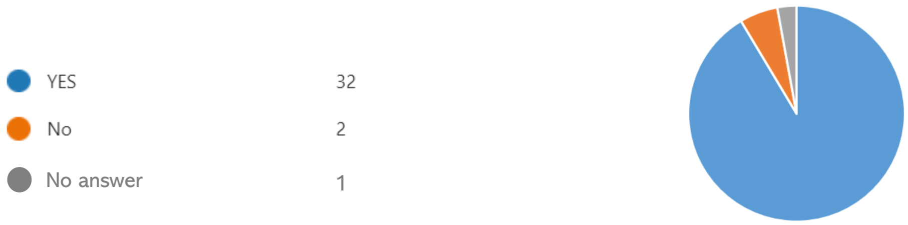


Figure 17: Degree of sufficient scale-up availability present at existing PDIs

Related to the availability aspect, several PDIs indicated that in some cases there is also a need to work on the "expectation management" of start-ups and scale-ups. These innovators sometimes do not have a realistic view on the usual lead time of a scale-up journey. They sometimes think that if they order today, they can start working tomorrow and that the day after tomorrow the results will be known. However, a pilot or demo trial always needs solid and thorough preparation to maximize the chances of success. Few respondents highlighted that the lack of availability can sometimes relate to the staff needed to run scale-up work, rather than the availability of the infrastructure itself. Availability can also be flexibly adjusted by PDIs by working multiple shifts (e.g. 2 or 3) per day. Some PDIs work directly for companies on the one hand and work at the same time within public projects on the other hand. In this case the availability of specific infrastructure can, according to them, be improved flexibly by shifting/ optimising the various project schedules.

Despite the large existing scale-up capacity for the bioeconomy that apparently currently amply meets demand and despite the even greater availability of this infrastructure, a large proportion of existing European PDIs still have short-term expansion plans. This goes hand in hand with PDIs' inherent drive to keep infrastructure state-of-the-art. These expansion plans cover both broadening of technologies and services offered as well as very targeted investments at specific stages answering the needs of the innovators. For examples, in some cases, this involves the addition, expansion or upgrading of existing equipment (e.g. downstream processing filtration units, ATmosphere Explosible (ATEX) proofing, food grade modifications). Sometimes it involves the acquisition of very specific equipment (e.g. gas fermentation, hydrothermal liquefaction or circular economy related equipment related to bioplastics or bio textiles production). Such expansions are often strongly demand-driven and serve to capitalise on specific trends in the bioeconomy.

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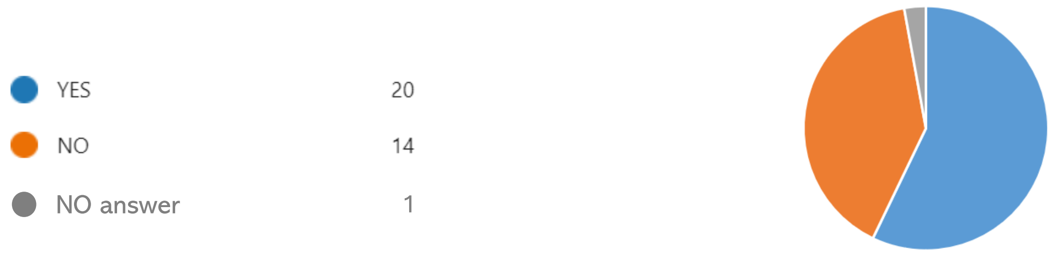

Figure 18: Degree of presence of expansion plans at existing PDIs

Overall, 59% of respondents said they had short-term expansion plans (Figure 18). However, it was frequently added that the final purchase of the wish list will depend on the available budget, which is linked to the revenue achieved from current activities.

4.3.3 Existence of regional public financial scale-up support for SMEs

Although it is a rather difficult topic to talk about freely, it was clear during the interviews with the various PDIs that for many the demand for scale-up work in 2023 and 2024 is significantly reduced. As described in the previous chapter, the cause unambiguously lies in the much-changed investment climate, making it more difficult for innovators to find the necessary private funding to implement their scale-up trajectory towards industrial scale.

The expenditure on R&D as a share of GDP in the EU-27 countries increased between 2000 and 2022. In 2022, approximately 2.11 percent of GDP was spent on research and development[20]. National and regional governments spend considerable amounts of financial support mechanisms earmarked for innovative SMEs, with the aim of achieving the transition to a sustainable bioeconomy and strengthening the development of the national and regional economy. These support programmes vary greatly from country to country. Key actors in the bioeconomy are trying to make an overview of the regional support that exists in Europe in different countries. For example, Bio-based Industries Consortium (BIC) has a Regional Funding Platform[21]. However, this is only accessible to members of BIC.

Today, it is not always clear whether this financial innovation support can also be used by SMEs to carry out scale-up work. At the end of the Q&A survey towards PDIs, a few questions were therefore raised that are not so much related to the pilot and demo facilities themselves, but rather to their potential customers. These are the innovators, spin-offs, start-ups, scale-ups and SMEs busy scaling up their innovative technology in the bioeconomy and could use all possible financial public support in the process.

In the survey, firstly, respondents were asked if they are aware of the existence of regional financial support mechanisms, that SMEs can use to carry out scale-up work at PDIs. About three quarters reported knowing about one or more regional support programmes. Most of the respondents could also confirm which national or regional body develops these support programmes.

[20] https://www.statista.com/statistics/461748/share-of-gdp-expenditure-on-research-and-development-european-union-eu/
[21] https://biconsortium.eu/regional-funding-platform

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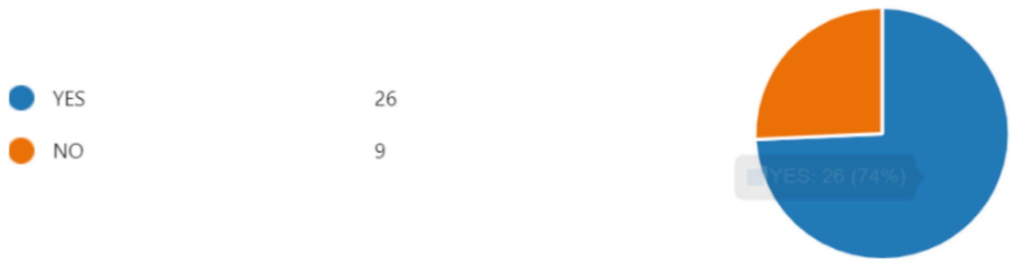

Figure 19: Degree of knowledge about existing national or regional financial public scale-up support

For most, however, it was unclear what the framework conditions of the mechanisms are, i.e. for what technology area and scale-up work, with what support rate, with what maximum amount of aid, valid for what period, etc. No clear European overview is currently available, leaving SMEs to make their own regional search and getting an understanding of the individual call requirements, each time to find the possible public financial support that can help them for de-risking their scale-up work.

The development of new technologies in the bioeconomy is very broad and varied. For example, Pilots4U's technology scope[22] includes 9 technology areas with 34 different technologies. For an innovator in the scale-up phase, it is important to find the open access pilot and demo infrastructure that best suits their process. Chances are that this infrastructure is in another country. This is certainly the case for innovators located in the Eastern part of Europe where a limited number of PDIs are present. This immediately raises the question of whether the largely existing national or regional public scale-up funding can also be used abroad. To this question, 97% of respondents gave a negative answer (Figure 20).

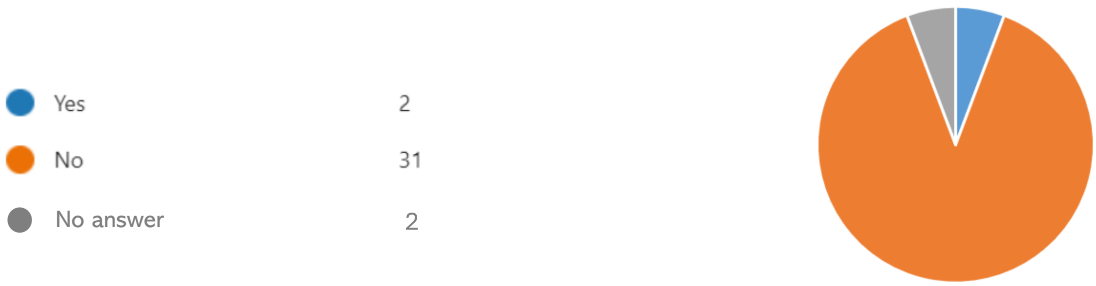

Figure 20: Degree of possibility to use financial national or regional public scale-up support abroad

No straightforward explanation could be given by respondents for this fact. Some gave as an argument that local governments are afraid that their SMEs will leave the country if they conduct their scale-up exercise in another country. According to others, local governments are not aware of the difference (technology focus area) between the available PDIs and the importance for innovators to be able to use the most suitable one, even if it is located abroad. According to some, it is rather a matter of principle not to spend public money abroad to maximise support to the local economy. So here, some further awareness creation and policy recommendation seems useful.

[22] https://biopilots4u.eu/sites/default/files/2020-11/pilots4u_technology_areas.pdf

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4.4. Conclusions for the medium TRL

Does Europe have enough open access pilot and demo facilities for the bioeconomy? Scale-up infrastructures are important to get the bioeconomy innovation ecosystem towards the market (industrial scale) faster, cheaper and better. This research led to a clear understanding of the existing situation in Europe. The gap analysis executed first in 2019 within the framework of the Pilots4U project[23] did not reveal a shortage in facilities as such, in terms of capability to meet industry needs, but rather a strong need to further strengthen and invest in existing open access infrastructures to keep them state-of-the art and increase flexibility. That appears to have been followed up just fine by the infrastructures (PDIs) themselves in the last couple of years, as could be detected from the direct interviews. Western Europe boasts the most mature bioeconomy ecosystem, fostering a higher concentration of PDIs. These European wide operational PDIs cover a broad scope of various technology areas in the bioeconomy and provide process development and custom manufacturing in addition to scale-up support. PDIs business models are of different natures, such as independent bodies, or public organisations or are entities as part of specific corporates. Equally different are their financial flows, which could be both profit and non-for-profit but almost all PDIs are financially self-sustainable.

Knowing these circumstances, it should also be mentioned that these situations could raise two key concerns regarding the structure and operation of PDIs. Firstly, the fact that only half of PDIs are legally independent entities suggests potential limitations on their impartiality. These PDIs might be linked to parent organizations like universities or research institutes, which could exert pressure to prioritize in-house technologies or projects aligned with their interests. This lack of complete independence could hinder a PDI's ability to serve a diverse range of innovators fairly and equally. Secondly, while most PDIs strive for financial self-sustainability, it implies that achieving this goal can be challenging for some. Reliance on external funding sources could introduce variability in their operational capacity and potentially influence decision-making regarding project selection. These concerns highlight potential vulnerabilities within the PDI system, potential downsides derived from critically analysing the provided information. The focuses of the analysis lays on the positive contributions of PDIs to bioeconomy innovation. It is crucial to remember that these concerns are not explicitly stated drawbacks by the interviewee but rather arise from a deeper analysis of the presented context. In the post-covid period, financial players were very eager to support the ecosystem of start-ups and SMEs, causing demand for scale-up infrastructure to peak in 2021 and many of the existing pilot and demo infrastructures to significantly expand their capacity in the 2022-2024 period. As an example, the Bio Base Europe Pilot Plant in Belgium tripled its fermentation capacity during this period. In addition, in other member states existing pilot- and demonstration facilities expanded (e.g. ARD in Reims, France; Biosphere in Italy) and new pilot facilities were set up (e.g. 21st Bio in Denmark, ASEBIO in Spain, and many more). However, since 2022 and certainly 2023, resulting from inflation and higher interest rates, private investors have become much more reluctant and cautious in making money available to innovators, resulting in a significant drop in demand for scale-up in 2023-2024. Hence, in the following years, with an increased supply and decreased demand for scale-up services, there will be challenges for some players to survive (example: 2022 bankruptcy of Bioprocess Pilot Facility (BPF), Delft, Netherlands).

Unlike the US, Europe already has a performant network of open access pilot and demo facilities for the bioeconomy. The equipment and the people of these infrastructures are at the service of start-ups, SMEs and innovators to help them scale up their innovative bio-based technologies. They have ample capacity and availability to scale up innovative processes and cope with the actual and future demand. The survey also found that quite a few regional and national governments provide financial support to SME in carrying

[23] https://www.cbe.europa.eu/projects/pilots4u

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out their scale-up activities. However, in almost all cases, these financial resources can only be spent in the home country or region. This may make it difficult for SMEs to choose the technologically most suitable PDI. Especially for SMEs in Eastern Europe, where few open access pilots and demo facilities exist. The European bioeconomy stands to benefit significantly from its strong network of open access pilot and demo facilities. By addressing the challenges outlined above and seizing opportunities for growth and collaboration, Europe can solidify its position as a global leader in bio-based innovation. Specific attention should be paid to the aspects listed in table 6.

Table 6: Points of attention to facilitate technology transfer in Medium TRL for different stakeholder groups

Stakeholder groups	***Points of Attention***
Industry (Bio-based and food industries, Tech providers)	• Consider leveraging the most suitable open-access pilot and demonstration facilities in Europe, rather than managing the scale-up process and associated capital-intensive investments independently. This approach can accelerate the transition to industrial scale, offering faster, more cost-effective, and efficient results. All available facilities can be accessed through the Pilots4U network and its comprehensive database • BIC database, available for BIC members only
PDIs	• Keep investing in modern equipment to keep your infrastructure state-of-the-art. Better inform yourself about the existing regional and national support mechanisms that exist for implementing scale-up work for SMEs. Make sure the information available on the Pilots4U database about your equipment and service is up to date. • PDIs should reach out to SMEs to make their services better known and to facilitate/support the access for SMEs to regional or national support mechanisms. • Promote Knowledge Sharing: Encourage best practices sharing among PDIs, fostering innovation and efficiency within the network.
Regional and national policy makers	• Cross-Border Collaboration: Facilitate collaboration between PDIs across European regions, enabling SMEs to access the most suitable infrastructure regardless of location. • Provide mobility for your funding schemes so that regional SMEs can tap into the performing and widely available scale-up facilities in Europe that best fit their scale-up needs. • Eastern Europe has high potential for collaborations from regionally based SMEs with European wide working PDIs. Develop targeted programs and initiatives to support regional SMEs.
European Policy Makers	• Europe boasts a well-established network of open access pilot/demo facilities, capable of supporting diverse bioeconomy technologies. • PDIs have undergone significant expansion in recent years (2021-2024), driven by increased demand from startups and SMEs. This expansion ensures ample capacity to handle current and future scale-up needs.

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5. High TRL Demo Cases (TRL >7)

5.1.Introduction

The transition of technologies through high TRL (>7) towards market deployment is a crucial phase in the innovation pipeline. This stage involves rigorous real-world testing, system demonstration, and final validation to ensure technologies are successfully commercialized. A strong innovation ecosystem is essential for this transition, fostering robust industry-academia partnerships, supportive regulatory frameworks, and access to financing.

Among the various TRL stages, the transition through high TRLs (above TRL 7) is particularly significant, as industry involvement becomes paramount, while research and academia continue to provide essential support. At TRL 7, technology prototypes are tested in conditions that closely simulate actual operational settings. This stage involves rigorous evaluations to ensure the technology's reliability, stability, and performance, validating its readiness for integration into existing systems or its standalone functionality. Moving to TRL 8, the technology (such as processes, products, or equipment) is fully integrated into a complete system and tested in its final form under operational conditions. This phase includes large-scale demonstrations, pilot projects, and extensive trials to confirm the technology's functionality, scalability, and interoperability. It also focuses on addressing any remaining technical issues and optimizing performance for full-scale deployment.

TRL 9 represents the final stage, where the technology is proven through successful real-world operations. At this point, the emphasis is on final validation and certification processes to ensure compliance with regulatory, safety, and quality standards. This stage also involves ramping up production capabilities, developing market entry strategies, and driving customer adoption. The transition from TRL 7 to TRL 9 is heavily industry-driven, requiring significant investments in manufacturing, marketing, and distribution. Collaboration among industry stakeholders, including suppliers, customers, and regulatory bodies, is essential to navigate the complexities of bringing a product to market. The main risks at these stages include ensuring production scalability, managing supply chain logistics, securing necessary certifications, and achieving economic viability.

In our study, we contacted and interviewed representatives from various countries and application areas, providing crucial context for interpreting our results. For example, participants were drawn from sectors such as Food and Feed (France, Germany, Netherlands), Agriculture (Hungary), Biochemicals (Italy), Cosmetics, BioPolymers, and Health (Finland), Energy & Fuel (Belgium), Fertilisers (Spain), and BioPlastics (Israel). This broad distribution allowed us to identify whether common challenges exist across these diverse sectors. While it was challenging to find universal challenges given the diversity within the bioeconomy, focusing on high TRL demonstration cases enabled us to address cross-cutting issues at a strategic level. This approach balances the need to consider sector-specific nuances with the identification of broader, shared challenges that can be effectively addressed through coordinated, high-level interventions.

5.2.Methodology

The methodology for conducting expert interviews was meticulously crafted to capture valuable insights from companies with technologies developed at TRL 8 and 9, which operate at or near the industrial or production scale. These companies were selected to include both those at their first industrial scale and those with more established operations, providing a comprehensive perspective on the challenges and

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opportunities at different stages of scaling. This distinction is important as companies at their first industrial scale may face unique challenges compared to those with more experience. The decision to conduct interviews, rather than alternative methods such as surveys or document analysis, was driven by the need for in-depth, first-hand experience and nuanced insights that only direct conversations with key decision-makers, such as CEOs, can provide.

Interviews allow for a level of detail and deeper knowledge that is often unattainable through other methods. By targeting primarily CEOs and key decision-makers from demonstration cases and showcases, we ensured that the insights gathered were both comprehensive and directly relevant to the challenges and opportunities faced by these companies. Moreover, with interviews, a smaller number of responses is needed to achieve meaningful results, as each interview offers rich, contextual information that can be critical for understanding complex issues. The following sections detail the structured process undertaken to find appropriate companies, define interview questions, and perform the interviews.

5.2.1. Finding Appropriate Companies

To identify and select companies with relevant technologies at TRL 8 and 9 for expert interviews, a systematic and thorough approach was followed. The initial stage focused on comprehensive desktop research by reviewing corporate websites, industry news, leveraging existing professional networks such as LinkedIn, and seeking recommendations from the MAG., as explained in chapter 2.4.

In support of understanding these high TRL stages, this task focuses on engaging directly with startups and SMEs. The process began by identifying a list of 20 companies with different technologies, application areas, and regional distributions within the high TRL range. These companies were contacted for interviews, and we successfully conducted in-depth interviews with 11 of them.

Identifying companies with diverse technologies, application areas, and regional distributions is essential due to the inherently multidisciplinary nature of the bioeconomy. Literature underscores the necessity of examining a broad spectrum of sectors to achieve meaningful impact, as the bioeconomy encompasses a wide array of industries, each with distinct challenges and opportunities. By analysing companies across various application areas, we aim to develop a comprehensive understanding of the factors that drive success at these critical stages of technological development, particularly as they pertain to market entry and manufacturing scale-up

5.2.2. Defining the Interview Questions

The interview questions were developed through a collaborative process with the MAG, collecting their input during workshops held with MAG members. This co-creation process ensured the questions addressed the diverse needs and perspectives of various stakeholders, were comprehensive and relevant, focusing on key areas of the company's journey to TRL 8 and 9, the challenges faced, and the strategies employed to overcome these challenges. The interviews, designed to last approximately 45-60 minutes, were documented by entering the answers in an online Microsoft form and structured around key topics to explore the background of the startups/SMEs, their applied R&D focus, organizational milestones, financial support utilized, and the technical and non-technical hurdles they have encountered.

Key areas of focus included the company's background, history, mission, operational years, and R&D efforts. These elements were crucial to understanding its innovation path, long-term goals, and the broader context in which it operates. The interviews offered insights into how companies position themselves in the innovation ecosystem and their growth potential. Questions also addressed applied R&D activities, TRL

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levels, and use of shared pilot/demo facilities, revealing how companies transition from research to commercialisation. The reasons for using or not using shared facilities provided insight into decision-making processes impacting scaling and validation. Additionally, interviews explored organisational milestones, achievements, and upcoming goals. These factors helped map the company's progress and identify key moments, successes, or obstacles. Financial support, including grants, investor attraction, and funding impact, was also examined to understand how companies leverage resources for growth. The interviews shed light on components of a successful innovation ecosystem, including access to funding, infrastructure, and collaboration, as well as barriers to market success.

Technical and non-technical hurdles were also discussed, with questions probing the main challenges encountered and the strategies for overcoming them. The interviews further explored internal and external factors influencing company growth, external challenges, and competitive impacts. Market entry strategies, including timeframes for commercialization, new production lines, investment needs, and market entry strategies, were examined. A significant focus of these discussions was on both market introduction strategies and the challenges of scaling up manufacturing across different technologies and regions. This allowed us to capture the nuanced experiences of companies as they transitioned from R&D to commercial operations. Lastly, the anticipated growth, job creation, and future plans for expansion, as well as next steps in the innovation track, long-term goals, and international expansion plans, were covered.

5.2.3. Performing the Interviews

The process of conducting interviews was designed to maximize the depth and quality of insights gathered from the selected companies. Initial contact was made via email or LinkedIn, primarily targeting CEOs or commercial managers to arrange meetings for semi-structured interviews. Despite anticipating a lower response rate, concerted efforts were made to schedule interviews with all the companies.

Interviews were conducted in a semi-structured format, allowing for flexibility and in-depth exploration of key topics. The 11 interviews were conducted from May to July 2024 with key experts across different countries and sectors, primarily from Western Europe (e.g., France, Germany, Belgium, Netherlands), Southern Europe (e.g., Italy, Spain), and Eastern Europe (e.g., Hungary), as well as Israel and Finland. Detailed notes and recordings were made during each interview to ensure accuracy and facilitate detailed analysis. The collected data was systematically analysed to identify common themes, challenges, and successful strategies across companies and sectors. The specifics for each in-depth analysis are detailed below. Table 7 provides a summary of the number of interviews conducted by country and sector, offering a clear view of the distribution of our data collection efforts and highlighting the concentration within specific parts of Europe.

Table 7: Number of companies interviewed per country per application area

Number of companies interviewed	Country	Application Area
1	France	Food, Feed
1	Hungary	Agriculture
1	Italy	Biochemicals
1	Finland	Cosmetics, Biopolymers, Health

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1	Belgium	Energy, Fuel
2	Spain	Fertilizer
2	Germany	Feed, Food, Pet Food
		Food
1	The Netherlands	Food
1	Israel	Bioplastics

Conducted with a diverse range of stakeholders from various countries and industries, these interviews illuminated the practicalities and challenges of advancing technologies through high TRL stages. By encompassing a wide range of industries and technological applications, these interviews ensured a thorough understanding of the current innovation ecosystem, and the challenges faced at high TRL stages with companies that served the purpose of getting a glimpse into a demo case.

5.3.Analysis

This section presents an interpretation of data obtained through interviews with various companies, providing insights into how these organizations are leveraging advanced technologies to drive growth and meet their sustainability goals. We will explore how innovations are influencing operational strategies, job creation, and future development. The following sections will analyse these trends, considering the motivations behind technological advancements, the role of research and development, key achievements, ongoing challenges, and the financial resources that support these efforts.

Company Motivations and Overview of High TRL Technologies

The analysis of start-ups and companies in our study reveals a significant and widespread commitment to sustainability across various sectors, including energy/fuel manufacturing, food production, biobased chemicals, biofertilizers, bioplastics, and waste management. The majority of the companies, regardless of their operational fields, share a unified mission to minimize environmental impact and advance sustainable practices. This collective dedication underscores a broad trend toward integrating sustainability into core business strategies.

Exploring high TRL technologies highlights a vibrant landscape of innovation and environmental stewardships, with contributions from both start-ups and established companies. In our survey, we included 4 start-ups (founded within the last 10 years) and 6 established companies with longer histories, ranging from decades-old firms to those over a century old. This mix underscores the diverse maturity levels of organisations driving sustainability goals in the industry. Despite their differences in age and experience, all these companies are driven by common motivations. Additionally, there is a strong drive to address market gaps and emerging needs, such as the increasing demand for sustainable products and processes. These motivations reflect a deep alignment with urgent global issues and a shared commitment to impactful, positive change.

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R&D is the bedrock of innovation for these high TRL companies, driving forward advancements tailored to their respective fields. For instance, steel manufacturing firms are focusing on decarbonizing production processes and advancing gas treatment technologies to address high carbon emissions. Their R&D efforts include developing methods for capturing and treating emissions and recycling waste gases into useful byproducts, significantly reducing the industry's carbon footprint. Food production companies are developing sustainable protein sources and advanced fermentation techniques to reduce reliance on traditional animal agriculture. They are exploring new protein sources through fermentation of microorganisms and plant-based proteins, aiming to create more environmentally friendly and resource-efficient food systems. In the bioplastics sector, companies are developing biodegradable alternatives to conventional plastics using renewable resources, reducing environmental harm. R&D in the biobased chemicals sector focuses on pyrolysis and fermentation processes to convert organic materials into valuable chemical products. Advancements in bioplastics production aim to create materials from renewable resources like sugars, replacing petroleum-based plastics. Waste management innovators are transforming waste into valuable resources through advanced recycling and composting technologies, supporting a circular economy and reducing landfill waste. They are also focusing on valorising biowastes and optimizing anaerobic digestion processes, which enhance waste management and contribute to the production of sustainable biochemicals from organic materials.

Market strategies also vary. Some companies target broad sectors such as food production and biochemicals, while others focus on niche areas like steel manufacturing and waste valorisation. Strategic partnerships and collaborations are frequently emphasized as essential for enhancing market penetration and innovation capabilities. By leveraging external expertise and resources, companies can achieve their sustainability goals more effectively.

R&D and Technological Innovations

Despite significant advancements, companies face numerous challenges in their R&D efforts, particularly when scaling innovative technologies from the lab to industrial production. Key technical hurdles include achieving process efficiency and ensuring product consistency. Additionally, companies must navigate complex and varying regulatory landscapes, which can differ significantly by region and industry. Market acceptance and customer acquisition present further challenges, as new technologies often require extensive education and outreach to effectively prove their benefits and build customer and/or consumer trust.

A substantial number of companies—eight in total—have used shared pilot/demo facilities as part of their R&D processes. These facilities play a crucial role in scaling technologies from the lab to industrial scale, offering several strategic advantages. One of the primary benefits is cost efficiency, as these facilities eliminate the need for capital expenditure on proprietary pilot plants, enabling companies to redirect resources toward other critical R&D activities. Furthermore, shared facilities provide access to experienced staff and specialized technologies, which allows companies to conduct advanced testing and refine processes without the delays associated with setting up their own equipment, please see chapter 4.

The flexibility offered by shared facilities is another key advantage, as it allows companies to rapidly test processes, adjust project timelines, and address new challenges with minimal delay. Moreover, these controlled process environments help mitigate risks by enabling companies to experiment with different process parameter set-up and gather valuable process data, thereby reducing the risks and costs associated with scaling up to full-scale operations. Importantly, shared facilities also foster a culture of experimentation, which is essential for refining processes and developing new products.

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However, while shared facilities offer considerable benefits in terms of cost savings and operational flexibility, some companies chose to develop proprietary pilot plants. This approach provides greater control over R&D processes, ensuring that specific technological needs are met and that long-term strategic goals are fully aligned. The decision to use shared versus proprietary facilities is influenced by factors such as the speed of development, the availability of specialized equipment, and the company's long-term goals. For companies with unique technologies or ambitious expansion plans, investing in their own infrastructure may offer better alignment with future goals, allowing them to fully control and optimize their R&D processes to meet specific technological and strategic needs.

Key Achievements and Strategic Insights

The companies interviewed highlighted several significant milestones achieved in product development, market expansion, and strategic transformations. Over the past year, six companies successfully transitioned from pilot-scale to industrial-scale production. For example, one company successfully transitioned from pilot-scale to industrial-scale production, scaling up to 200m³ and progressing from seed funding to a Series C round while securing key customers and it provided capital for expansion and new technologies. Another one reached 1000 litres scale, and it enabled the company for the start of commercial production as well. Some of the interviewed companies experienced major strategic transformations, including acquisitions that enhanced their market positions and enabled the expansion of multiproduct value chains within the circular bioeconomy. Additionally, these companies proved adaptability by changing business models in response to external pressures, such as fluctuating gas prices.

Over the past year, all the interviewed companies achieved critical milestones, including successful technology transfers and scaling operations. For instance, one company transitioned end-product production to a contract manufacturing organisation. The launch of new products was a significant milestone for three companies, marking important progress in their commercialisation efforts, while others expanded their market presence by establishing new facilities and offices. Securing significant investments was crucial, with several companies completing major funding rounds.

The milestones achieved underscore diverse growth strategies, including technological advancements, market expansion, and strategic partnerships. However, challenges persist, particularly in specialized sectors. Many companies face difficulties advancing technologies from pilot to industrial scale, a challenge pronounced in biotechnology, advanced materials, and sustainable production sectors due to their complexity and the need for continuous innovation and substantial R&D investment. Regulatory compliance and business setup are significant hurdles, particularly in industries such as food, chemicals, and healthcare, where stringent regulations can delay product launches. Organizational challenges, such as securing talent (e.g. finding the appropriate educated staff) and structuring for growth (teams set-up, people management), are also prominent, especially in younger companies or highly regulated markets.

The alignment of recent milestones with future goals emphasizes the importance of strategic planning and operational execution. Companies that successfully navigate technological and regulatory challenges not only secure their market positions but also lay a strong foundation for future growth and innovation. Adaptability to changing market conditions, such as shifts in regulatory requirements or technological advancements, is crucial for sustained growth. Established companies in sectors like steel and chemicals generally have more robust systems for managing change, while newer companies in emerging fields such as biotechnology and sustainable production may face difficulties in these adjustments. Emerging sector companies face greater technological challenges but also have higher growth potential if these issues are addressed effectively, while companies in more established industries may encounter fewer technological obstacles but could struggle more with regulatory compliance and scaling operations. The maturity of a

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company plays a significant role, with older companies typically having more experience and resources to navigate these challenges effectively.

Financial support

Financial support has been instrumental in the development and growth of these companies, with all reporting grants from public R&D-focused funding programs such as Horizon2020, Vlaanderen Agentschap Innoveren & Ondernemen (VLAIO), Horizon Europe, and the European Regional Development Fund (ERDF). These grants, aimed at fostering innovation during early and high-risk phases, have played a crucial role in enabling the establishment of pilot plants, scaling processes, and conducting significant engineering work, often in collaboration with specialised firms.

The companies received varying levels of public funding, ranging from 2 million to over 50 million euros, depending on the size and complexity of their projects. This public funding has been essential in mitigating financial risk and accelerating technological advancements. Additionally, success in publicly funded projects has often attracted further private investment, with seven companies raising significant additional funds—one securing as much as 200 million euros—demonstrating the catalytic effect of these grants.

On average, companies that disclosed their fundraising achievements reported raising approximately €25.23 million. Beyond public grants, 9 companies used other forms of financial support, including equity investments and loans, to drive their innovation. 5 companies emphasised the importance of private funding, particularly from business angels and venture capital. However, the sufficiency of private funding varied across regions and sectors.

4 companies supplemented grants with loans and awards to secure the necessary capital for scaling operations and implementing advanced technologies. Despite these efforts, many companies noted that private funding alone was often insufficient, particularly during the critical "valley of death" phase, where transitioning from prototype to commercial-scale production remains financially challenging. This phase is especially risky, and private investors tend to be more cautious due to the uncertainty surrounding early-stage technologies.

In addition to funding challenges, companies expressed frustration with the complex and lengthy public grant application processes, which can take up to 9 months for evaluation. These bureaucratic delays hinder timely progress, highlighting the need for more efficient and flexible funding mechanisms to support the transition from prototype to large-scale production and to help companies overcome the "valley of death".

Growth and Future Prospects

The innovations developed by the companies interviewed are set to drive substantial growth across various areas, including staff expansion, equipment investments, market introductions, and the establishment of new industrial sites. Larger companies are poised for significant operational scale-ups, illustrating the strong connection between innovation and growth. Companies are not only planning to enter new markets but also to enhance their presence in existing ones. For instance, one company intends to replicate its TRL9 model across multiple countries by 2030, while others are focused on launching new products and branching into new industries such as food or cosmetics.

Job creation has been a notable outcome of these innovations, with the scale of job growth varying widely. In the past, these innovations have already led to the creation of numerous jobs, both direct and indirect. For instance, one company reported creating 54 direct jobs overall, with an additional 16 jobs specifically related to a new product. Another company noted the creation of 40 direct jobs and an impressive 160 indirect jobs linked to a new business model. Some companies expect modest increases of 2-6 jobs, while

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larger firms expect to create over 1,000 new jobs. This job creation is linked to new plant developments, product launches, and expansions in business models. Companies are prioritizing strategic investments in staff and equipment to support their growth strategies. These investments are essential for scaling innovations and meeting anticipated demand.

Future job creation is also expected to be substantial. For example, companies plan for both national and international growth, with one expecting to create 10 jobs locally and up to 15 jobs through global expansion. Another company, which had already created 200 jobs during a construction phase and expects to add 30 more jobs in the near term, illustrates the wide-ranging impact of these innovations.

The data reveals a strong positive correlation between innovation and growth, with every company confident that their innovations will lead to significant expansion. This impact extends beyond the companies themselves, influencing related industries and contributing to broader economic growth. Job creation forecasts suggest ripple effects across associated sectors, highlighting the extensive economic benefits of these innovations. For instance, one company projects that their developments could create up to 200+ jobs in associated industries, depending on the rollout and development. Planned international expansions further amplify these impacts, underscoring the global relevance of these innovations and their contributions to regional economies.

Looking ahead, companies have outlined their next steps in their innovation journeys. Four companies are focused on improving their technology by increasing efficiency, scaling processes to industrial levels, and developing new products. Five companies are working on launching new products, such as new flavours, chemicals, or sustainable materials, often alongside enhancements to production processes or exploration of new market applications. Additionally, three companies plan to extend their market reach and increase collaboration with other industries or international partners.

The long-term goals of the companies are ambitious, with many aiming to become leaders in their respective fields. This includes expanding market share, achieving high revenue targets, or establishing themselves as global players. Three companies focus on sustainability, aiming to enhance environmental benefits through green chemistry, waste valorisation, or the development of biodegradable products. Five companies are prioritizing innovation and diversification of their product portfolios, with a strong emphasis on sustainability and novel applications. All companies plan for international expansion, aligning with their goals of global leadership or increased market share. Six companies are targeting expansions into the USA and Asian markets, which are seen as critical for their global ambitions, while others plan to explore opportunities within Europe or in markets such as South America and the Middle East. The focus on technological advancements and new product development highlights these companies' strategies to remain competitive and innovative. By constantly improving technology and expanding product lines, they are positioning themselves to meet evolving market demands while maintaining a competitive edge. The integration of sustainability into product development reflects a shift towards responsible innovation, which is increasingly important in global markets. The companies’ long-term goals show a desire to lead in their fields, whether through global market leadership, enhanced environmental impact, or expanded product offerings. The intent to expand internationally underscores a strategic approach to accessing large, dynamic markets that can significantly boost revenue and market presence for the companies’ sustainability goals.

5.4.Conclusions for high-TRL

The transition of technologies through high TRLs towards market deployment represents a critical phase in the innovation pipeline, where the focus shifts from research-driven efforts to industry-led commercialisation. As technologies advance through high TRL stages, particularly TRL 8 and 9, companies

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increasingly concentrate on scalability, market readiness and regulatory compliance. The transition from TRL 7 to TRL 9 is not only technically demanding but also requires significant investment in manufacturing, marketing, and distribution.

A key observation is that companies at these high TRL stages, spanning industries such as energy/fuel manufacturing, bioplastics, or food production, are often committed to sustainability, driven by the urgent need to address environmental challenges. These companies use advanced technologies to minimize their environmental impact and meet sustainability goals.

One of the significant findings is the role of shared pilot and demonstration facilities in helping companies scaling up their technologies from the lab to industrial production. Companies that reported large technical development issues frequently benefited from using open-access shared pilot facilities, which offer cost efficiency, flexibility, and access to specialised expertise. These facilities have proven invaluable for companies aiming to commercialize new technologies, helping them overcome challenges related to process scaling and technology validation. However, the decision to use shared versus proprietary facilities depends on factors such as development speed, technological needs, and long-term strategic goals.

The companies interviewed have achieved notable milestones, including successful transitions from pilot to industrial-scale production, securing substantial investments, and entering new markets. Several companies reported regulatory issues as a significant challenge, highlighting the complex interplay between market expansion and compliance; most of them therefore expanded into the U.S.A. and Asia.

In this survey, identifying a fair number of companies at these high TRLs was challenging. While a few companies manage to succeed despite unfavourable conditions, many did not mention issues such as the lack of a level playing field with fossil-based products, inadequate waste collection infrastructure, public procurement challenges, or quotas. To extend their best practices and achievements to a larger number of companies, it is essential to address these market conditions. This consideration is also crucial for the WP4 policy recommendation section.

The availability of regional scale-up support programs has played a crucial role in enabling companies to advance through high TRL stages. Companies based in regions with strong scale-up support, such as Belgium, the Netherlands, and France, have benefited significantly from these programs, which include financial incentives, access to pilot facilities, and industry partnerships. These programs are particularly effective in regions where the innovation ecosystem is well-aligned with the needs of high-growth companies, accelerating their path to the market. In contrast, regions with less developed infrastructure (East European countries) and fewer financial resources face added barriers, often making it difficult for companies to scale up, secure private funding and navigate technical and regulatory hurdles.

While the diversity of companies and technologies analysed in this task reflects the broad impact of innovation across various sectors, it is important to recognise that the findings are primarily drawn from companies operating in regions with robust support systems. These regions, often characterised by strong government-backed initiatives, mature financial ecosystems, and established industry partnerships, provide an environment where companies can more easily transition through high TRL stages. The access to pilot and demonstration facilities, alongside targeted funding programs, allows firms to de-risk their projects and attract significant private investment. However, these conclusions may not fully apply to regions where the innovation ecosystem is less mature or where facilities and financing are more limited. In such areas, the

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lack of firms advancing through high TRLs may not reflect a lack of innovation but rather significant structural barriers that prevent companies from scaling and reaching market readiness.

In summary, the successful transition of technologies through high TRL stages relies on coordinated efforts between research institutions, industry players, and policymakers. In regions with robust support systems, companies are better positioned to overcome the "valley of death" between research and commercialisation. By fostering an environment that supports innovation, reduces barriers to commercialisation, and encourages sustainable practices, the innovation ecosystem can bridge the gap between research and market. However, these findings are most applicable to regions with established innovation ecosystems and may not fully reflect the realities in areas where resources are more limited. Strengthening collaboration across different regions and addressing the gaps in funding and infrastructure will be essential to ensuring that technological advancements can be scaled effectively and contribute to global sustainability and economic growth.

Table 8: Points of Attention to facilitate demonstrating in High TRL for different stakeholder groups

Stakeholder groups	***Points of Attention***
Industry (Bio-based and food industries, Tech providers)	• Be aware of regulation early. This renders some markets less accessible. Be mindful of the time it takes to get approval or certification for your product or technology, or production facility. • If public funding is key, dedicate personnel to develop know-how on how to apply for national and European grants. • Balanced team/ proper organisational set-up of company • Ensure your company is prepared for the possibility of needing co-funding, as it can be prohibitive for smaller firms.
Policy makers	• Reflect proportionate co-funding requirements for SMEs. • Streamline and simplify the submission and reporting processes, reducing unnecessary bureaucracy on regional/European level. • Make sure regulatory bodies are equipped to deal with emerging sectors, including biotech. / Allocate resources for more efficient reviewing processes to reduce delays e.g. New Food • Encourage regulatory consistency between industries and sectors, especially across applications in health, animal, and environmental contexts, for example for food/feed regulations. • Incentives to build a factory at a certain industrial site • Public investment funds/Public-Private Partnerships
Administrative and regulatory bodies	• Ensure that administrative processes for permits, product approvals, and certifications are streamlined to avoid delays in scaling up technologies. • Train regulatory personnel in dealing with biotech products, focusing not only on chemical-based products but also on biotech and bio-based products in sectors like food, pharmaceuticals, and environmental technologies.

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	• Establish collaboration between regulators and industry experts to ensure that regulations reflect current technological developments. • Align regulations across different regions (national and European) to avoid market entry barriers for companies scaling up across borders. • Ensure regulations are consistently applied across sectors, such as in health, and environmental applications, to minimise discrepancies.
Funding institutions	• Develop funding models specifically targeting SMEs to ensure that co-funding or matching fund requirements do not prohibit smaller companies from accessing support. • Provide long-term investment instruments that support the entire lifecycle of high-TRL innovations, from prototype to full-scale commercialisation. • Offer alternative funding instruments such as convertible loans, innovation vouchers, and equity investments that can complement traditional grant funding. • Foster collaborations between public & private sector investors to create blended finance models that de-risk investment in high-TRL technologies. • Encourage private investors to align with public funding mechanisms to scale innovation in strategic sectors like biotechnology, clean energy, and advanced biomanufacturing.
Investors (Private and venture capital)	• Engage in public-private partnerships to co-invest in high-TRL bioeconomy projects, leveraging public grants to de-risk early-stage development and attract private capital for scaling and commercialisation. • Use public funding success stories as validation arguments to attract private investment, demonstrating and supporting the scaling of bioeconomy innovations. • Promote long-term financing strategies to ensure sustained investment in high-TRL technologies, recognising the extended timelines required for their de-risking and commercialisation. • Ensure flexible and responsive investment in high-growth bioeconomy sectors, such as bio-based industries, circular economy technologies, and food tech. • Align investment strategies with the growth journey of bioeconomy companies by providing tailored financial and business support across all stages, ensuring deep tech and sustainability-focused innovations receive the necessary resources to scale despite longer return timelines. • Introduce targeted incentives, such as tax benefits, co-investment schemes, and risk-sharing mechanisms, for early-stage investors (e.g., angel investors) to encourage funding at critical growth stages. • Consider integrated co-funded piloting and scaling as a validation and de-risking for next investments.

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6. Driving Bioeconomy Innovation: A Synthesis of Findings and Future Outlook

The overall ShapingBio project aimed to analyse initiatives, structures, policy instruments, and key gaps within four specific topics of the bioeconomy, with the goal of formulating recommendations for better policy alignment and improved stakeholder actions at various levels. To achieve this for this report on applied R&D and technology transfer specifically, it was essential to establish a clear framework, focusing on Technology Readiness Levels (TRLs) and stakeholder integration. The analysis specifically addressed a range of TRLs, from early applied research to higher levels of technology demonstration and market readiness. The primary objectives of the analysis included understanding the needs and challenges of stakeholders at different TRLs, developing strategies to facilitate research-to-market transitions, identifying best practices, fostering stakeholder collaboration, enhancing TRLs, and providing policy recommendations.

This report, D2.2, has provided a comprehensive exploration of applied R&D and technology transfer within the EU bioeconomy, guided by the insights and collaborative spirit of the ShapingBio project's Multi-Actor Group (MAG). Through meticulous analysis across different Technology Readiness Levels (TRL), we have illuminated key challenges and opportunities for fostering innovation and driving impactful outcomes. Our journey began with a detailed understanding of the motivation behind Task 2.2, recognizing its crucial role in strengthening the bioeconomy innovation ecosystem. We delved into the TRL framework, highlighting its significance in navigating the complex landscape from early-stage research to market-ready solutions. Recognizing that stakeholder needs vary across different TRLs, we adopted a tailored approach for each stage, ensuring inclusivity and relevance in our findings. By meticulously examining low TRL applied R&D (TRL 3-4), medium TRL pilot & demonstration projects (TRL 4-5; TRL 6-7) and high TRL demo cases (TRL >7), we have uncovered valuable insights into best practices, successful case studies, and potential areas for improvement. These findings provide a solid foundation for developing actionable guidelines that can empower researchers, industry players, policymakers, and civil society to effectively translate innovative ideas into tangible solutions.

Collaboration between research and industry for technology transfer

A key theme that emerged across all three sub-tasks was the importance of collaboration and the relationships between various stakeholder groups, particularly between research and industry, as well as between public and private funding sources. Understanding these relationships is beneficial at the macro, meso, and micro levels. Therefore, the report lists several key strategies to enhance collaboration between researchers and industry. First, it emphasizes the need to apply a broader set of indicators beyond publications and citation rates for academic careers (e.g. patents, industry collaborations, ….) to help them collaborate more with industry and enabling them to engage more freely with industry partners without the concern of prioritizing publication over commercialization. Second, it advocates for interdisciplinary teams of lawyers and scientists or engineers in intellectual property (IP) agreements, in using standardized contracts and procedures, so that contracts can be swiftly tailored to the specific case. This increases speed, quality and reduces potential barriers to collaboration. Another crucial point is the importance of building trust and understanding. Intermediaries can play a significant role in bridging the gap between academia and industry, facilitating communication and helping each party better understand the other's needs and perspectives. The report also highlights the need to address funding challenges, suggesting that policymakers should lower co-funding requirements for smaller companies, ensure funding conditions are clear and accessible, and streamline the application process to make it easier for businesses to secure

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support. Lastly, the report calls for improving administrative efficiency by reducing delays in R&D activities. This can be achieved by reviewing and shortening approval timelines for publicly funded collaborative R&D projects of academia and industry, ultimately fostering a more collaborative and effective environment for innovation. The findings underscore the importance of collaboration in driving job creation and generating broader economic impact. It also acknowledges the challenges researchers face when balancing academic goals with industry engagement and suggests solutions to overcome these obstacles.

Regulatory frameworks on applied R&D

Another key finding of the report highlights the significant impact of regulatory frameworks on applied R&D. Regulatory frameworks significantly impact applied research and development (R&D), especially when aiming for higher technology readiness levels (TRLs). Even at low TRL spectrum the interviewees (independently of being researcher or company) stressed out that to conduct research some form of certification needs to be provided or to prove regulatory compliance. Indeed, companies in the bioeconomy need to show the quality or characteristics of their products or technologies to satisfy certification purposes - this can range about safety, quality (e.g. water quality), or sustainability related (e.g. CO_2 emissions etc.) -, or regulatory purposes (fertilizing products or livestock feeds need to be approved before being placed on the market,), or to prove the efficacy of the product over other products. Early-stage developers stressed the need to anticipate and address regulatory challenges already very early in the innovation process due to lengthy approval processes and different requirements depending on the targeted application. This concern was echoed by those at higher TRLs who recognized regulation as a key factor shaping innovations and the targeted applications from the outset.

The ShapingBio report reveals a critical tension point across all TR levels: the impact of regulatory frameworks on applied R&D within the bioeconomy. While regulation is essential for ensuring safety and efficacy, it can also act as a significant barrier to innovation, particularly for companies operating in emerging sectors like biotechnology. Throughout interviews, researchers and industry representatives consistently highlighted concerns regarding lengthy approval processes, inconsistent regulations across different sectors (human health, animal applications, environment), and a lack of specialized knowledge among regulatory evaluators when assessing biotechnological products. This inconsistency creates confusion and additional work for companies that develop products with cross-sectoral applications. The report advocates for streamlining administrative processes, providing targeted training for regulatory personnel both in regulatory agencies and companies, and promoting greater consistency and clarity in regulations across sectors or applications. This push for a more supportive regulatory environment underscores the recognition that innovation thrives when balanced with robust but efficient oversight mechanisms. Interestingly, this focus on navigating regulatory hurdles intersects with another key finding: the need to balance researcher autonomy with commercial pressures. While encouraging industry engagement is crucial for translating research into real-world applications, the report acknowledges that researchers often face pressure to publish findings quickly. This tension between academic freedom and meeting commercial goals highlights the complex landscape of collaboration within the bioeconomy. Overall, the report doesn't present outright contradictions but rather highlights the complex interplay of factors involved in successful academic-industry collaborations. It suggests that finding the right balance between various stakeholder interests is crucial for fostering innovation while upholding ethical and scientific standards.

Importance of PDIs across the TRL spectrum

The ShapingBio project underscores the critical role of Pilot Demonstration and Innovation (PDI) facilities in accelerating bioeconomy innovation across Europe. Recognizing a widespread challenge faced by

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companies at all stages of technology development – the need for access to expensive, specialized equipment and technical expertise – PDIs emerge as essential bridges between research and commercialization. Interviews with industry representatives consistently revealed that scaling up technologies often requires access to cutting-edge infrastructure too costly for individual companies to justify investing in. This is where PDIs shine, offering a shared platform equipped with state-of-the-art technology and staffed by experienced personnel who can guide innovators through the complexities of process development and custom manufacturing. By providing this crucial support, PDIs de-risk innovation by enabling companies to test, refine, and optimize their technologies at scale. This collaborative approach fosters a more inclusive bioeconomy ecosystem where smaller players can compete alongside larger companies, ultimately leading to faster development and deployment of innovative biotechnological solutions. The project further emphasizes the need for ongoing investment in existing PDIs to ensure they remain state-of-the-art and flexible enough to accommodate the evolving needs of the bioeconomy. By supporting these crucial infrastructures, the EU can unlock the full potential of innovation and accelerate the development and deployment of biotechnological solutions across a wide range of sectors – from agriculture and food processing to biomanufacturing and biomaterials.

Demonstration sites – market deployment

Companies at high TRL stages (TRL 8 and 9) focus on scalability, market readiness, and regulatory compliance, requiring significant investment in manufacturing, marketing, and distribution. Across various sectors, including energy, bioplastics, and food production, companies are committed to sustainability, using advanced technologies to minimize environmental impact. Shared pilot and demonstration facilities play a crucial role in scaling technologies from the lab to industrial production, offering cost efficiency, flexibility, and access to specialized expertise, which helps companies overcome scaling and validation challenges. It highlights a significant commitment to sustainability across sectors such as energy, food production, biobased chemicals, and waste management. The findings emphasize the role of research and development (R&D) in driving innovations, with companies focusing on decarbonizing production processes, developing sustainable protein sources, and creating biodegradable alternatives to conventional plastics. Despite facing challenges in scaling technologies and navigating regulatory landscapes, companies have achieved critical milestones, including successful transitions from pilot to industrial-scale production and securing significant investments. The document underscores the importance of strategic planning, market expansion, and financial support in overcoming these challenges and achieving long-term growth and sustainability goals

D2.2 culminates in a powerful call to action, urging stakeholders to embrace collaboration, evidence-based decision-making, and targeted support across the TRL spectrum to unlock the full potential of the EU bioeconomy. This collective effort promises not only robust economic development but also paves the way for crucial environmental sustainability and enhanced social well-being. Building on these insights, the next critical step involves formulating concrete policy recommendations at various levels of the European Union. These recommendations should focus on fostering dynamic academia-industry collaborations and streamlining technology transfer processes. By addressing these key areas, we can create a thriving ecosystem where innovation flourishes and the benefits of the bioeconomy reach every corner of society.

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