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Analysis of training in Bioeconomy in farming sector

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Executive summary

The goal of this RELIEF project report is to offer an overview of the development of the education and training initiatives and programs associated with the bioeconomy sector, across the European Union. We address our overarching goal from different angles. Firstly, we present the results of a critical review focusing on the bioeconomy education and training practices, in the context of the increasing importance of this sector. Secondly, we present a catalogue of professional areas associated with the bioeconomy sector, based on the European Skills, Competences, Qualifications and Occupations (ESCO) framework. Thirdly, we map and summarize important competencies for professionals working in the bioeconomy sector, according to EntreComp and DigComp frameworks. We then move on to display a mapping of education and training opportunities across the European Union. Finally, we present the result of a Training Needs Analysis (TNA) conducted with both training providers and learners across the four partner countries of the RELIEF consortium (Greece, Italy, Portugal, and Sweden). We further interpret our results according to a conceptual framework of megatrends, trends, and weak signals which can help to set future priorities for bioeconomy-related education and training. Based on our multiple data points and sources we reach three main conclusions. To being with, education and training in bioeconomy reflects megatrends associated with the green transition in terms of generating hybrid and emerging knowledge subfields, often embedded in traditional scientific disciplines such as farming or forestry that require a fast adaptation to new and promising professional profiles. Moreover, our results also reflect digitalization megatrends. Specifically, education and teaching institutions are still biased towards in-person teaching methods, while learners show a significant preference for blended or online learning methods, especially among those with higher qualifications (agronomists, consultants, and policymakers). Importantly, significant trends in bioeconomy education and training were also detected. For instance, due to its novelty, bioeconomy education and training is becoming more relevant across the European Union, but developments are not homogeneous. Importantly, secondary education programs and VET supply seem to be slowly adapting to the demand for competencies and skills in this sector. Finally, it is also important to highlight that according to the learners involved in our TNA it is vital to disseminate comprehensive curricula in the bioeconomy sector, targeting technical, but also digital, entrepreneurial, soft, and transversal skills to address current professional requirements. Based on our conclusions, we offer some recommendations which may improve the quality and effectiveness of programs, in this field. Our recommendations cover issues such as curricula content, skills update of teachers and trainers, human-centred approaches to training design or appropriate use of digitalization.

Keywords: bioeconomy; education; training: VET; secondary education; tertiary education; green transition; digitalization; megatrends; trends; weak signals.

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Introduction

Bioeconomy is the production, utilization, conservation, and regeneration of biological resources, including related knowledge, science, technology, and innovation, to provide sustainable solutions (information, products, processes, and services) within and across all economic sectors and enable a transformation to a sustainable economy [1]. Bioeconomy corresponds to a complex, hybrid subfield of knowledge, stemming from the inputs of several scientific fields. It is also a sector strongly informed by major driving forces of current societies and economies. The dual transition, namely the green transition, and digitalization are certainly among some of these drivers that help shape the bioeconomy's present and future.

In this context, the future of bioeconomy strongly depends on how education and training informing the sector is able to adjust to this complex intersection of knowledge expansion, multidisciplinary, and important societal transformations. Bearing this in mind, this report issued by the RELIEF project aims at offering an overview of the education and training associated with the bioeconomy activities in the European Union. Our research effort is driven by the principles of blending multiple data points and addressing multiple informants. These principles were translated into four main work steps which correspond to different sections of this report.

In the first section, we present the results of a critical review focusing on the bioeconomy education and training practices, in the context of the increasing importance of this sector. This critical review has been published in a scientific peer-reviewed journal and is included here as it constitutes an important framework to further understand the information presented in the following sections of the report.

In the second section of the report, we present a catalogue of professional areas associated with the bioeconomy sector, based on the European Skills, Competences, Qualifications, and Occupations (ESCO) framework. This systematic identification of professional areas is vital for the reader's understanding of the opportunities in the bioeconomy field, as well as to better assess potential mismatches between training supply and demand.

In the third section, we present and summarize competences for professionals working in the bioeconomy sector, according to EntreComp and DigComp frameworks. The identification and mapping of the core competences and progression levels is of the utmost importance for the professionals working in the bioeconomy sector to self-evaluate their

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EntreComp and DigComp needs and to match them with the current requirements and demands of the context.

In the fourth section, we describe the results of our mapping of education and training opportunities across the European Union, based on official data sources. This section allows the comprehension of some trends as well as the geographic scope of the most prominent education and training opportunities according to the official records.

In the fifth section, we present the result of a Training Needs Analysis (TNA) conducted with both training providers and learners across the four partner countries of the RELIEF consortium (Greece, Italy, Portugal, and Sweden). This survey included 196 respondents and offers multiple insights that be triangulated with the information collected in the previous three sections resulting from desk research.

In the sixth section, we systematize our main findings and organize them according to the concepts of megatrends, trends, and weak signals. These concepts are time- and data-driven and, therefore, help to establish a prospective analysis of education and training programs in the bioeconomy sector.

In the seventh section, we present the limitations of this report in terms of data collection and generalization.

Finally, in the eighth section, we list some recommendations inspired by our findings covering topics such as curricula content, skills update of teachers and trainers, human-centred approaches to training design or appropriate use of digitalization.

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1.Critical review of the bioeconomy education and training practices[1]

1.1. Contextualization

In recent years the Bioeconomy has become a central topic in EU policymaking, especially in the context of the Green Deal, and is expected to continue to receive increased national and EU-wide policy support in the coming years [1]. In this context, the bioeconomy is expected to underpin the transition from a linear economic model that is based on non-renewable resources, to a circular, low-carbon economy that relies heavily on the production and consumption of renewable, organic-based resources. Such a transition requires both a mentality change of the population and a practical transformation of its skillset; as the standards and the needs change, new job types arise across entire value chains. In order to effectively support such a transition, a comprehensive bioeconomy education and training system needs to be developed, one that will take into account the special needs and the interdisciplinary approach that the bioeconomy entails. Such a system requires a transformation of existing education methods and training approaches, as well as the development of new ones [2–5].

Considerable gaps exist in our understanding of the existing practices around bioeconomy-related training and education. This can partly be explained due to the relevant newness of the bioeconomy as a concept [6], but also because multiple educational practices and approaches, that are clearly located within the bioeconomy conceptually, are not explicitly labelled as such. A range of previous projects and studies have investigated bioeconomy education programs and approaches [7–10], however a critical review of training methods and approaches across higher education (HE) and vocational education and training (VET) is lacking. This is especially relevant as previous studies have highlighted that education, training and knowledge development on bioeconomy sectors vary widely across Europe. According to the European Commission, there is a particular lack of training on bioeconomy for small enterprises and at low levels [2,6,11,12]. In addition, there is a

[1] This section includes the full version of a paper developed by the RELIEF project. Minor editions were made to fit the paper into the structure of this report. Full reference of the report is the following: Paris, B., Michas, D. , Balafoutis, Nibbi, L., Skvaril, J., Li, H 3,Pimentel, D., Silva. C., Athanasopoulou, E., Petropoulos, D., & Apostolopoulos, N. (2023). A Review of the current practices of bioeconomy education and training in the EU. *Sustainability*, *15*(2), 954. https://doi.org/10.3390/su15020954

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concern that the labour force is not trained adequately for this transition to a bioeconomy, especially as it requires expertise that originates in different disciplines and combines a variety of skills across and along value chains.

This section of the report aims to fill this gap by conducting a critical review of the current practices of bioeconomy education and training, as well as the associated methodologies, techniques and approaches. This will contribute to our understanding of how bioeconomy education and training is conducted, evaluate the different approaches, and provide the background for the development of additional and necessary bioeconomy curricula. This is relevant as, in order to create an effective and comprehensive curriculum, an overview of the current status is necessary, i.e. an overview of the current practices of bioeconomy education and training, and the training methodologies, techniques and approaches used within these.

This section is structured as follows: the rest of this section provides an overview of previous studies on bioeconomy training and education; section 2 discusses the methodology used in this critical review; section 3 presents the results of this study; section 4 provides a discussion and macro analysis of trends in bioeconomy training and education in the context of previous studies; and section 5 provides concluding remarks.

There are a range of bioeconomy policies and strategies developed at EU level and country level that support related bioeconomy training and education processes. At EU level, the 2012 European Bioeconomy Strategy, which was updated in 2018 with the addition of a Bioeconomy Action Plan, which calls for the new education processes and the testing of new HE and vocational training curricula [13]. Beyond this, the bioeconomy is supported by other major EU policies and strategies, including the Green Deal, the Circular Economy Action Plan and the Farm to Fork Strategy [14,15]. There are also a few EU Member States with a national bioeconomy strategy, including Finland, Germany, Latvia, France, Spain, Italy, Ireland, Austria and the Netherlands, while Norway and the UK also feature their own strategies. Estonia, Hungary and Lithuania are in the process of developing national strategies [16]. Similarly, all these policies tend to include and promote relevant bioeconomy education and training in their strategies. In September 2022 the EU released the report on ‘Promoting education, training and skills across the bioeconomy,’ which assesses expert insights on current bioeconomy education practices and the future needs for bioeconomy related education until 2050 [17].

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Various recent publications exist that investigate bioeconomy-related education and programmes. Pubule et al. (2020) analyse 10 Master programmes in bioeconomy and highlight the interdisciplinary nature of the approaches used [6], while Kalnbalkite et al. (2021) look more widely at education for the bioeconomy [1]. Ruxandra et al. (2018) investigate the role of the University in developing human capital for a sustainable bioeconomy [18], and Masiero et al. (2020) look into bioeconomy-related perceptions among 1400 students in 29 Universities [19]. Less recently, Watkinson et al. (2012) conducted a review of advanced bioenergy education and training in Europe [11], and Ray et al. (2016) highlighted the importance of linking bioeconomy development with education in developing countries, emphasising the potential of e-learning courses [20].

A common theme among relevant journal publications is the importance of interdisciplinarity in any method or approach with the bioeconomy education [21]. Sacchi et al. (2021), investigate the educational processes required for a bio-based economy, and highlight that the main challenge for education related to the bio-based economy is the development of an effective framework that bridges the life sciences and the social sciences [22]. Onpraphai et al. (2021) argue for the importance of creating new education approaches that are able to support the shift to a sustainable bioeconomy [23].

Lask et al. (2017), in looking at academic approaches to education for the bioeconomy, find that most HE programs, in particular at university level, are designed with I-shaped profiles whereby students specialise in one discipline and research field. However, bioeconomy programs are inherently interdisciplinary and aim to create a T-shaped profile, i.e., where integrative professionals are ideally also disciplinary experts, educated to incorporate and connect different disciplinary knowledge domains and methods. Therefore, this section of the report makes the case for a bioeconomy education that is multi- and transdisciplinary as well as practice-oriented in order to create bioeconomy professionals who, although specialised in one specific field, have an understanding of other related disciplines and are able to manipulate scientific jargon [24].

Moreover, a range of European and national projects are focused on supporting education and training in the bioeconomy. Examples of such projects include the European Bioeconomy Library [10], BIOEAST, The BRANCHES PROJECT [7], BE-Rural [8], MPowerBio [9]. Many of these projects include knowledge exchange and capacity building programmes for the bioeconomy. The ERASMUS+ project VET4BioECONOMY, which was completed in 2021, focused on VET programmes on forest bioeconomy, while the

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ERASMUS+ project FIELDS has a database on VET related programmes in the bioeconomy [25]. Extending the horizon beyond the EU landscape, the ERASMUS+ Capacity Building project BBChina established a 120 ECTS equivalent Master Program on Bioeconomy in three Chinese Universities by means of a cross collaboration between European and Chinese Higher Education Institutions [26].

In recent years, a host of platforms have already proliferated that support education processes often by hosting and sharing relevant bioeconomy knowledge, including the Rural Bioeconomy Portal, the European Bioeconomy Network, the European Bioeconomy Library, the Bio-based Industry Consortium's (BIC) bioeconomy platform, the European Bioeconomy University, the European Bioeconomy Alliance, and the Circular Bioeconomy Alliance. These platforms, at times overlapping, generally support bioeconomy knowledge and information sharing and development, stakeholder collaboration, policy development and provide tools and support for relevant stakeholders.

These publications provide relevant insight into bioeconomy education but none of them conducts a critical review of the entire bioeconomy education theme. Additionally, as the bioeconomy is such a wide concept, there are many educational programmes that are not labelled as ‘bioeconomy’ but clearly belong in this theme. For instance, a range of studies investigate training and education within the bioeconomy themes – the farming and agricultural sectors, water-based bioeconomy, forestry, bioindustry, bioenergy. However, these studies do not include courses in the bioeconomy per se – there are few curricula that are focused on the bioeconomy but there are many more that are related to the bioeconomy. This is an important finding, especially given the established significance for interdisciplinarity within bioeconomy-related courses, potentially entailing that bioeconomy education is inherently inter- and trans-disciplinary.

A common point between the relevant policies and strategies, the papers and the projects is that existing education and training approaches need to be transformed and new ones need to be developed to effectively train individuals for a sustainable bioeconomy – the bioeconomists. Relevantly, a recent report by the Global Bioeconomy Summit 2020 investigates how to shape education for a sustainable bioeconomy and identifies the relevant needs; “The expertise required in the [sustainable circular bioeconomy] SCB workforce in the industry by 2030+ was identified as: Knowledge transfer from lab to industry; critical thinking and problem-solving abilities, knowledge in business models and project management; knowledge about the principles of sustainable development and the

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circular economy; knowledge in bio-based markets and techno-economic expertise." This conclusion convincingly demonstrates the need for bridging theory with practice, life with social sciences, and cognitive with technical skills [27].

1.2. Methodology: Materials and methods

1.2.1. Conceptual approach

1.2.2. The bioeconomy

There are a variety of definitions and approaches to 'bioeconomy' ranging from a broader, inclusive definition that focuses on biological resources and processes in general to narrower and more specific definitions that focus on particular sectors. The European Commission defines the bioeconomy as "using renewable biological resources from land and sea, like crops, forests, fish, animals and micro-organisms to produce food, materials and energy [28]." A more in-depth definition provided in the EU Bioeconomy Strategy is that the bioeconomy includes all systems that are dependent on biological resources (biomass, animals, plants, organisms), their functions and principles. This includes land and marine ecosystems; primary production sectors (agriculture, forestry, fisheries and aquaculture) and; all economic and industrial sectors using biological resources to produce food, feed, biobased products, energy and services [13].

Considering this definition, the bioeconomy can be conceptually categorised along 5 themes, and in line with the EU bioeconomy strategy. These are:

- Food/agriculture systems, which encompass the value chains related to farming, the production of food and biological feedstocks within the 10.5 million farms in the EU [29].
- Forestry/natural habitats systems, which are a source of environmental public goods, raw materials and services, and refer to processes of managing and utilising the EU's 182 million ha of forests [30].
- Water systems, which refer to all aquatic systems and respective economic activities (such as fisheries, aquaculture, aquatic biomass production, etc.).
- Bioenergy, which refers to all energy derived from organic sources, being the largest RES in the EU (12% of total energy demand).

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- Biomaterials/bio-based products, which are derived from renewable biological feedstocks and are processed creating conventional products (e.g. timber and textiles) and advanced products (bio-plastics and pharmaceuticals).

It is important to note that the bioeconomy is interdisciplinary [12] and both transcends and interlinks between the themes (food/agriculture, forestry/natural habitats and aquatic/water system bioenergy and biomaterials), sectors (primary, secondary, tertiary) and the wider economy. The bioeconomy is inherently an inclusive concept as it is a response to the unsustainability of current economic processes that are often based on unsustainable production models and contribute to environmental degradation and societal fragmentation [3].

1.2.3. Educational approaches and methodologies

Bioeconomy education is generally distinguished by a number of characteristics. It is clear that education for the bioeconomy needs to adopt interdisciplinary learning and teaching approaches that are often focused on bringing together and integrating the STEM disciplines with the SSH (social sciences and humanities) disciplines.

This section of the report investigates training methodologies, techniques and approaches that are prevalent within bioeconomy education. A range of labelling of methodologies exists by different projects and studies. For this study, we prefer a relatively simple conceptual categorisation of educational approaches and methodologies, combining the insights and expertise from the RELIEF consortium as well as the research outputs of the Erasmus+ FIELDS project [31].

Training and education approaches are wide concepts that aim to broadly describe the pedagogical approaches to teaching. Based on a variety of sources, and in the framework of the RELIEF project, we categorise our research and findings along four main approaches: (i) the higher education and academic approaches, (ii) the VET and practical approaches, (iii) short-term approaches, and (iv) other approaches. Academic approaches are mainly based on cognitive approaches to education and learning knowledge and theory. This approach is often central to higher education institutions, such as universities, and teaching and learning generally occur over a number of years. Practical approaches are mainly centred around ‘learning by doing’ methods and are focused on supporting the development of an individual’s skills, abilities and knowledge around practical, real-life (as opposed to theoretical, hypothetical) issues. This approach is often used in VET institutions and learning

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duration ranges from a number of months to multiple years. This generally includes training in skills and knowledge for a trade or occupation and may be part of secondary or tertiary education programs or training for specific employment. Short-term approaches are time-bound, ranging from less than a day to a couple of months. These approaches are generally intensive, compressing large amounts of knowledge and learning in short time periods and may adopt an academic, practical or hybrid approach. Other approaches refer to other learning methodologies encountered in the literature, including do-it-yourself (DIY) learning, lifelong learning and informal education.

It is important to note that these are conceptual categorisations and that there exists a considerable overlap between approaches, while each individual approach often adopts learning practices and methods that are favoured by another approach. The categorisation has been determined based on the 'focus' of the given approach. For instance, in practice an academic bioeconomy University program may have a focus on theoretical concepts but generally also includes parts that are centred around problem or project or challenge-based learning and include practical learning and training.

Each approach adopts and favours a range of training methodologies and techniques. Training methodologies and techniques refer to those used in designing and implementing education and training, i.e., the pedagogical methods used to impart knowledge and skills in the context of each educational setting. These methodologies and techniques are explored as a sub-category of the four main training and education approaches identified. The training methodologies and techniques that were identified and referred to in the existing literature include: lecture and classroom-based formats, e-courses, virtual learning tutorials, on-the-job training, work placements/traineeships, practical workshops, in-person class, focus groups, panel discussions, mentoring, peer learning, participatory learning, on-site demonstration, gamification [31]. (See Figure 1.) These methodologies and techniques are not mutually exclusive, meaning that more than one can be used in one education setting and overlap within one approach, while they are also not assigned specifically to any of the main approaches. For instance, a lecture/classroom-based University course may make use of participatory learning techniques, as can a VET course.

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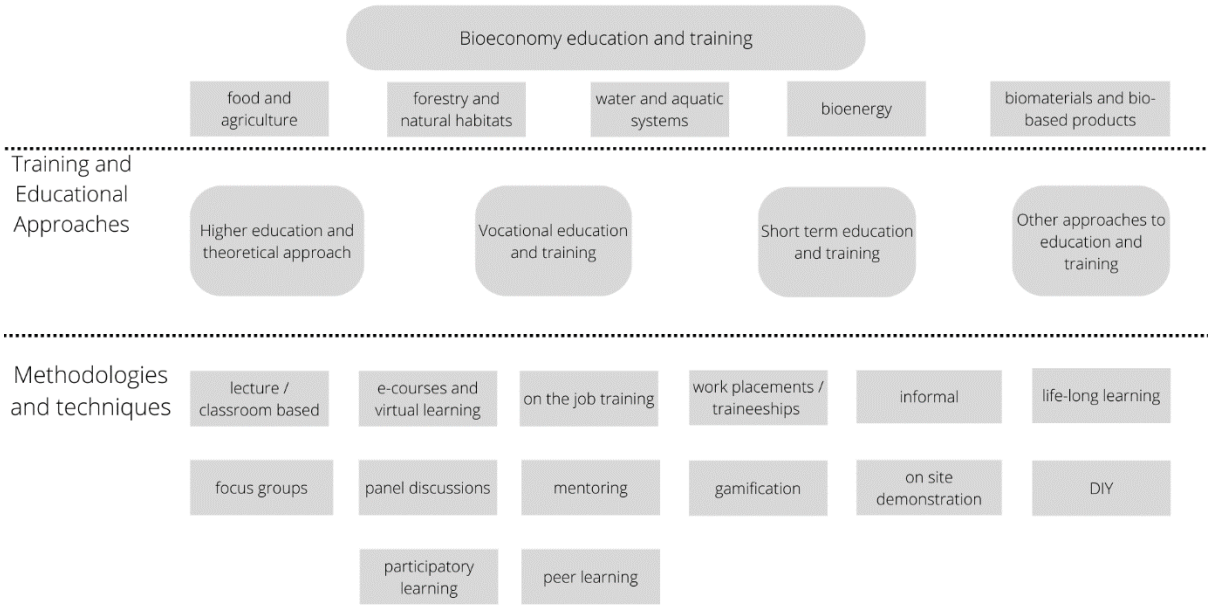
Figure 1. Conceptual Educational Approach



1.2.4. Data sources, Selection Criteria, Search Strategy and Data Collection

This study conducts a critical review of the current practices of bioeconomy education and training. Data was collected from a range of sources including peer-reviewed publications, reports, results from previous projects, national policies. Our search strategy followed a number of key steps: on the one hand, all partners of the RELIEF consortium were asked to participate in the data collection process by providing relevant information and data on educational approaches in their respective countries as well as the EU. On the other hand, relevant studies were identified through key word searches through google scholar and SCOPUS and desk-based research. Keywords used in these searches included ‘bioeconomy education’, ‘bioeconomy training,’ and ‘bioeconomy learning,’ these searches identified a total of 259 publications (175 in Scopus). The publications identified show considerable increase in recent years until October 2022 (Figure 2).

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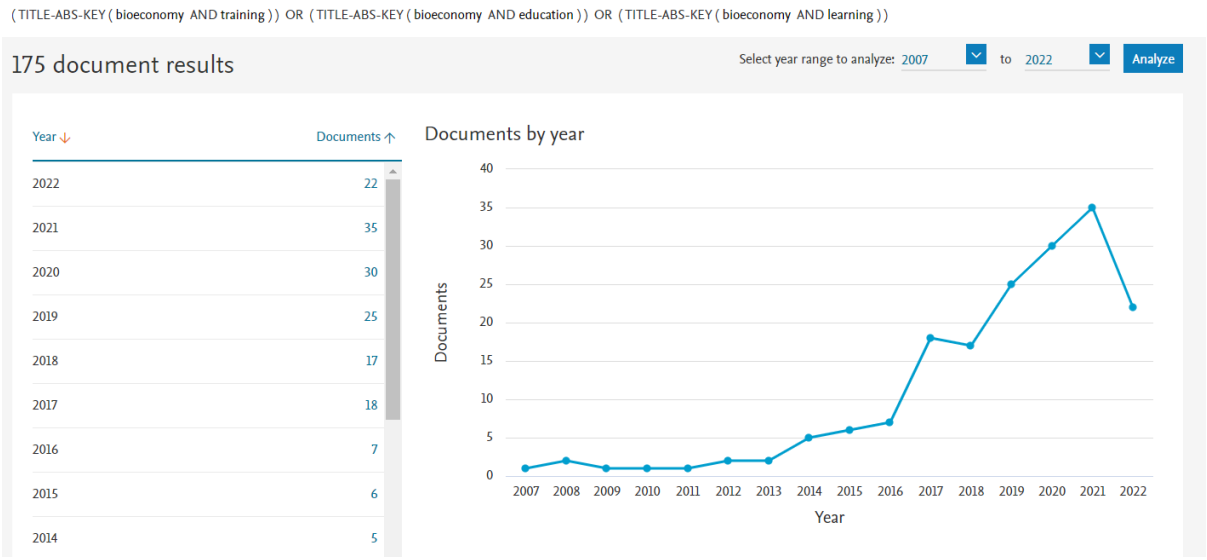
Figure 2. Number of bioeconomy education publications in Scopus by year



The studies included here, and in particular journal articles, were screened for relevance and applicability, the reports and projects used came from respected publication sources, while the journal articles had to be published in well respected and peer-reviewed journals. 72 studies were found relevant and selected for further analysis. Information and data were extracted, compiled and categorised along a number of categories for each bioeconomy theme. Due to the descriptive nature of the data and the goal of this study, data was analysed in a qualitative manner whereby different educational approaches were compared and contrasted.

1.2.5. Bias Risk and Limitations

There are a number of key limitations to the present study. Bioeconomy is a general concept with varying interpretations. In this sense, there is a risk of losing specific answers/results when discussing the bioeconomy [4] as they might be found under different terms. In addition, and due to these variations, authors and studies mean different things when they refer to ‘bioeconomy education’. Moreover, as the bioeconomy is a relatively new concept there are relatively few studies and approaches that focus solely on the bioeconomy or use the term ‘bioeconomy’. This is a limitation as some educational approaches adopt lenses other than the bioeconomy. Due to this newness, there is relatively little research available on existing bioeconomy education approaches and techniques and there are considerable data gaps. Future research is needed on more specific aspects of each education approach in the bioeconomy. There are also a number of bias risks when

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conducting a critical review. As the study is based on data and knowledge that has been shared with the authors and on keyword searches in google scholar and Scopus, the inclusion of knowledge and data is at risk of bias.

1.3. Results

1.3.1. Higher Education and academic approaches

In recent years, many higher education programs centred around the bioeconomy and its components have been developed throughout the EU. These exist at a range of higher education levels, including at bachelor, master/postgraduate and PhD level as categorised in Table 1. Common characteristics amongst these programs include: (i) interdisciplinary design, often bridging STEM and SSH disciplines, (ii) focus on the bioeconomy as a whole and/or on one or more bioeconomy-related themes, (iii) priority is given on academic approach, and (iv) teaching and learning approaches are predominantly classroom/lecture-based formats. These programs tend to be geared around supporting the development of a knowledge economy and have a strong sustainability-related dimension. This sustainability dimension appears in many forms throughout the available courses, for example there could be a focus on the study of the circular economy, the design of eco/efficient bio-products or on sustainable practices in general [32].

Further, there is a variety of designs and focus attached to these programs and they can generally be categorised along three main lines: (i) programs focused on a scientific discipline that emphasise on specific bioeconomy themes (e.g. Bio-technology) [33–36] (ii) general Bioeconomy programs that provide a general overview of the Bioeconomy and all its components [32,37], and (iii) programs that give equal emphasis in two disciplines, usually combining a STEM and a SSH discipline [38], and that focus on the relevant aspects of the bioeconomy (e.g. a course combining Bio-technology with Economics or with Ethics). In recent years, there has been a rapid increase in all of these programs, and specifically the interdisciplinary design, and this trend is likely to continue [24]. Such study designs are increasingly accepted within academia and higher education programs, while inclusive and interdisciplinary approaches are favoured as being paramount to the creation of a circular and sustainable bioeconomy, which is inherently interdisciplinary. Such courses approach the subject with a holistic and critical understanding in order to accommodate the multidisciplinary character of the bio-economy which, as explained above, requires a re-designing of the traditional educational methodologies which are fragmental.

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Regarding bachelor level programs, several were identified in a number of countries and can broadly be split into either general bioeconomy programs or specific theme-based programs. The design of these general bioeconomy programs has a focus on learning and education across the entire bioeconomy value chain, while some of them may include an additional focus on particular aspects of the bioeconomy. These programs generally adopt an academic approach; although the teaching methods vary somewhat, they appear to use traditional approaches to higher education centred around an on-campus lecture format combined with problem-based learning with some or limited access to field-work and laboratory programs [32,37,39].

Regarding the bachelor programs that are focused on specific bioeconomy themes, this study located several Bachelor of Science, including on biotechnology, biomaterials, bioenergy, agricultural sciences and agricultural engineering, forestry and bioeconomy. These programs are likely to incorporate more of a hands-on approach than the general programs discussed above, with access and use of laboratory facilities and research infrastructure. In many instances, these programs also have close links with industry and can provide relevant work placements for the students. Course descriptions often mention approaches centred around problem-based or challenge-based learning or experiential learning, as well as hands-on learning through lab experiments, field trips, and a capstone project [33,34,36,40].

Regarding Masters programs, these tend to have a closer focus on specific themes of the bioeconomy and generally adopt a mixed education approach that combines academic and practical methodologies [11]. The course descriptions of such post-graduate programs often appear to include a more general, foundational module focused on the bioeconomy/bio-circular economy as a whole, followed by more focused modules on, for instance, biobased industries, management of biobased feedstocks, etc. Often, in addition to the course modules which are generally lecture-based and emphasise on theory, there is a more practical component as part of the program. This practical component may include carrying out experiments, either in lab or real-life conditions, or a work placement, or some independent research [6]. Similarly, to bachelor programs course descriptions are also often centred around problem-based or challenge-based learning [38,41–46].

Despite these commonalities bioeconomy Masters programs and their development generally follow country specific developments. For instance, in Italy, Master degrees are intended as in-depth thematic studies offered independently by universities. The first

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example of a Master program related to the Bioeconomy was the “IMES Master in Bioenergy and Environment”, set up in 2004 with the support of the “EU/US Programme for Cooperation in Higher Education and Vocational Education and Training” [47]. The 60 ECTS equivalent course run in three US Universities and in two EU Universities and was mainly focussed on the Biomass to energy chain. It was held in ten editions until 2019 at the University of Florence, while at the Universidade Nova de Lisboa, it was transformed into a Master Degree at the end of the 2010's. In this Master, the multidisciplinary approach was developed all along five different axes: Biomass Production (Agriculture, Forestry, and Energy crops), Energy conversion (Renewable Energies and Bioenergy Generation), Biofuels (Conventional and Advanced) and Biorefineries, Environmental Impact (modelling and LCA), and Legislation & Economy. Another important example, started in 2016 and presently running, is the 2nd level Master “Bioeconomy in the Circular Economy BIOCIRCE”. It is an interdisciplinary program jointly offered by four Italian Universities (University of Bologna, University of Milano-Bicocca, University of Naples Federico II, and University of Turin), by 4 non-academic partners (Intesa Sanpaolo, Novamont SpA, GFBiochemicals SpA, and PTP Science Park di Lodi), and 2 Italian Technological Cluster (Cluster SPRING and Cluster CLAN agrifood) providing skills and expertise necessary to deal with the full range of issues in the complex bioeconomy field [48].

Regarding PhD and further higher education programs, these are not prescribed, and they are variable depending on the topic, however, the general trend shows that there are an increasing number of PhD programs around the bioeconomy [49]. Such programs can be practical, academic or hybrid, including a mix of educational approaches. They are research-focused with the goal of advancing bioeconomy-related research and development, and they often go in-depth on one more specific topic within the sectors of the bioeconomy [49–51].

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Table 1. Current higher education practices for the bioeconomy

Type of Program	Description	Typical Learning Method	Time Period (years)	Geographical Locations	Prevalence	Qualifications
General Bioeconomy Bachelor	Theory-based learning with some practical elements.	lecture / classroom based, e-courses and virtual learning, participatory learning, some practical elements/on site demonstration	3-4	Germany [37], Finland [52], Norway [32], Poland [39]	Several	Undergraduate degrees
Bachelor on specific bioeconomy themes	Mixed learning approach	lecture / classroom based, e-courses and virtual learning, participatory learning, many practical elements/on site demonstrations	3-4	Germany [33,34], Spain [40], Finland [36], UK [35]	Several	Undergraduate degrees
Masters	Mixed learning approach	lecture / classroom based, e-courses and virtual learning, participatory learning, many practical elements/on site demonstrations	1-2	Greece [38,41], UK [42], Austria, Ireland, France [31], Germany [43], Netherlands [44], Italy [45], Sweden [46]	Many	Postgraduate certificates and degrees
PhD, Post-doc	Research oriented	Self-learning, some lecture / classroom based	2+	Ireland [50], Switzerland, Spain, Italy, Sweden, Netherlands, Germany, Austria, Belgium [49], France [51]	Several	Degree

With regards to connections between these more practical VET courses and the academic higher education courses described above, there seems to be a considerable overlap between the two; the VET courses usually include a theoretical aspect, albeit smaller than the practical part of the course, often in the introductory modules, while in the higher education courses there often is a module that requires more practical skills, possibly in the form of lab experimentation or work placement.

1.3.2. VET and Practical Approaches

The EC defines VET as “the training in skills and teaching of knowledge related to a specific trade, occupation or vocation in which the student or employee wishes to participate. Vocational education may be undertaken at an educational institution, as part of secondary

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or tertiary education, or may be part of initial training during employment, for example as an apprentice, or as a combination of formal education and workplace learning" [53].

VET programs that are focused on specific themes of the bioeconomy are prevalent across the EU. This study has located a multitude of agricultural courses, forestry courses, energy/electrician courses. Relevantly, the EU ERASMUS+ project FIELDS has created a database on VET related programs in the bioeconomy [31]. VET programs are generally not standardised across the EU in terms of education and training methodologies and there are a wide range of approaches and learning methods used. In practice, different countries have different approaches to VET education and the training is linked differently with secondary and tertiary education systems. For instance, it is common for VET education to be centred around education institutions but in some countries VET education and certification can also be achieved through apprenticeships, which is the case in France.

VET courses are predominantly focused on training and teaching of skills and knowledge for employment. In this sense, in VET courses on the several bioeconomy themes, the typical learning methods are centred around the teaching of practical skills, achieved through experiential learning and hands-on practice [54]. A common VET course description is likely to include a short theoretical overview of the relevant topic/bioeconomy theme, followed by a range of practical training directed towards the specific topic and the practical skills attached to it. There is a large variation in the types of practical training offered, which can come in the form of lab work, traineeship, apprenticeship, etc.

Common thematic focuses for the courses located (Table 2) are agricultural technicians, digital/technological expertise combined with a bioeconomy theme and forest management expertise. A commonality amongst all VET courses located is that they all involve some level of practical training, usually done through on site/farm demonstration and learning activities and students receive a certificate at the end of their studies. This may also be combined with a work placement, generally towards the end of the program. Amongst the VET courses located there are considerable differences in terms of the time period of all courses ranging from a couple of weeks and/or hundreds of hours to 2+ years and/or 2000 hours [54–60].

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Table 2. Approaches and Methodologies in VET Education and Training for the Bioeconomy

Course Title	Description	Typical Learning Methods	Time Period	Location	Qualifications
Smart Farming and Bioeconomy Technician [54]	Training to become a smart farming technician following a range of courses, field learning and cv related training	Lecture / classroom and on-farm demonstration activities	800 hours (400 on site, 400 classroom)	Italy	Certificate
Professional Higher Technician in Agrotechnology [61]	Agrotechnology technician training for the management of a small-medium agricultural enterprise	Lecture / classroom and on-farm demonstration activities	2 years	Portugal	Certificate
Technicians in rural areas [55]	Focused on creating entrepreneur with thematic focuses on innovation in agriculture, the viability of farms, irrigation	Lecture / classroom and on-farm demonstration activities	1 year	Spain	Certificate
Data-Driven Agri-Food Business [62]		Online learning	10 weeks	Netherlands	Certificate
Agrogardening [57]	Vocational training with job placements	On-farm demonstration activities and job Placements	2000 hours	Spain	Certificate
Forest Harvesting [56]	Training on forestry use and management with associated job placements	Lecture / classroom, on-site demonstration activities and job placements	2 years	Spain	Certificate
Environmental Technician [58]	Technical training as an environmental technician through training and job placements	On-site demonstration activities and job placements	2 years	Belgium	Certificate
Technician in agricultural production [63]	Technical training on producing agricultural products	Lecture / classroom and on-farm demonstration activities	2000 hours	Spain	Certificate

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Technician in Forest Management and the natural environment [64]	Technical studies for forestry and environmental work in mountainous areas and nurseries	Lecture / classroom and on-farm demonstration activities		Spain	Certificate
Entrepreneur Biodynamic agriculture [60]	Training for sustainable agricultural production technician integrated with high school	Lecture / classroom and on-farm demonstration activities		Netherlands	Certificate
Agricultural Technician [59]	Technical training as an agricultural technician through training and job placements	Classroom/lecture and participatory learning	Up to 6 years	Belgium	Certificate
Agricultural Production Technician [65]	Training for Agricultural Production Technician Integrated with high school	Lecture / classroom and on-farm demonstration activities	1 year	Portugal	Certificate

1.3.3. Short term training and education approaches

A number of short-term education and training approaches for the bioeconomy have been located and are summarised in Table 3. They have been categorised according to workshops, short courses, and SME training. These categories generally adopt varying and mixed learning approaches and methods, depending on the goal and the scope of the training, they last for a short period of time and are generally knowledge-intensive. These courses are run by a number of bodies and various funding modes, including national and EU projects, universities, research institutes, NGOs and for-profit enterprises. Most of these courses either focus on general knowledge sharing on the bioeconomy or the development of specific skills for specific topics within the subject.

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Table 3. Short term education and training approaches for the bioeconomy

Category	Typical learning approach	Methods	Description	Example Courses
Workshops	Mainly academic, possible some practical	Panel Discussions Focus groups Lecture based	Short events ranging from a few hours to a few days. Focused on specific themes around the bioeconomy or general bioeconomy. Condensed knowledge transfer. Often are organised in the context of EU and/or national bioeconomy related projects	Unlocking Regional bioeconomy transitions. State of the art and ways forward [66] Sustainable Production of Biobased Products in the Bioeconomy Era [67]
Short Courses	Mix between academic and practical	Lecture based Tutorials Practical teaching E-learning courses	Range from a few days to Some assessment. Students with bioeconomy background or not. Generally, a mix of lectures, lab and field visits. Online courses	Training course for farmers: non-food crops (NFC) for bioeconomy in Italy [68] Summer School: Towards a Biobased Economy [69] Bioeconomy school [70] ELLS Summer School on Bioeconomy [71]
SME Training	-	Mentoring	Generally centred around capacity building and supporting SME developments in the bioeconomy	Bioeconomy Ventures [72] MPowerBio [73] DigiCirc [74]

1.3.4. Other approaches

A range of other bioeconomy education approaches are also mentioned by various actors. These approaches are often informal and/or are not attached to educational institutes and are centred around individual and lifelong learning schemes, though are often dependent on open-source data published by educational institutes. These approaches are generally characterised as self-motivated and voluntary, for personal and professional reasons, and can be practiced by a range of methods, including both academic and practical, depending on the relevant scope and goals [24,27,75]. A range of education techniques are practiced but are generally based around on the job training and participatory

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learning techniques, mentoring and self-learning through audio-visual material but can also include learning appropriated through informal means such as through discussions with other relevant stakeholders. It is important and multiple authors argue that these self-motivated processes are crucial for supporting a society wide transition towards a circular bioeconomy and need to be supported by educational material and scientific research that is available to the general public [20,27].

1.4. Analysis and discussion

The findings presented in this report illustrate that education approaches attached to the subject of the bioeconomy vary considerably across the EU, with a range of academic, practical, hybrid, short term, and other approaches. There are some important commonalities in the methodologies used within these approaches; the education offered is generally problem-based, interdisciplinary and combines academic and experiential learning. While the teaching methods vary, traditional lecture based, and lab-based formats are popular while in recent years online-learning has also become popular [31] replacing and/or adding to the more traditional lecture formats.

Courses focused around academic and higher education have proliferated, especially in recent years. These have also been centred around creating increased collaborations between existing institutions, for instance, In 2022 the European Bioeconomy University was launched as a collaboration between 6 European universities to promote bioeconomy education [76]. The main learning approaches used in these educational systems are based around traditional, campus-based lectures and tutorials, sometimes with slight variations in the format [24]. There is some focus on problem-based and experiential learning within relevant courses. More specifically, there is a relatively high selection of masters' courses that combine bioeconomy with a thematic focus. Pubule et al. (2020) highlight that bioeconomy master programs are designed around thematic focuses that aim to facilitate long-term employment in the bioeconomy sector. They also highlight that most of these programs are currently concentrated in Western Europe though they predict a likely spread to other areas around the world as the bioeconomy becomes more and more prevalent [6].

Regarding VET programs, in the research process of this study, it was relatively easy to locate higher education courses but harder to locate practical VET courses. This is in line with the study by Ciriminna et al. (2022) who highlight that in recent years university courses on the bioeconomy have proliferated but that there is a need for more practical courses [12].

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However, it is important to note that the distinction between the various education approaches is not always clear when it comes to VET programs, while the categorisations between VET and HE programs appear increasingly blurred. On the one hand, this is likely to be due to the newness of the bioeconomy as a concept but also due to the inherent interdisciplinary nature of bioeconomy education that generally requires and includes a mix of academic and practical approaches to education. The lack of data around specific design of VET courses is a major data limitation this study, and as more practical courses become available, our understanding of the approaches used, and their effectiveness will become clearer. A key recommendation coming out of various studies is that there is a need for considerably more practical bioeconomy education approaches, especially vocational ones, that support the development of relevant skills across a variety of economic sectors [77].

Given that a thriving bioeconomy is the foundation for the transformation towards a circular economy, there is a need for more bioeconomy programs [3]. It is clear, that on a policy level, the importance of bioeconomy education is now widely recognised [12], however our understanding of what transformative bioeconomy training approaches are and how they fit into supporting the transition towards a circular economy remains limited. There is a need for bioeconomy experts across the economy, within research, the public sector and private sector [12]. Considerable attention is now being put towards mapping and creating new approaches to training for the bioeconomy and these can build on the research presented in this section. Such programs, courses and modules are necessary to support knowledge-wise this transition and the training approaches and methodologies need to also be transformative and need to combine higher education, VET and industry in each of the themes of the bioeconomy, in order to approach the concept in an interdisciplinary manner that supports an understanding of the complexities of a sustainable bioeconomy. Indeed, various studies [3,11,27,78,79] argue that bioeconomy educational programs need to be designed to create a knowledge-based economy and to provide the new skills needed for the new and upcoming bioeconomy [17]. To fulfil this, relevant programs need to be innovative, interdisciplinary, holistic and open to advancements.

A considerable drawback of current bioeconomy related research is that there is no concrete accepted definition of what bioeconomy education entails. A recent study found that some programs still have a tendency to be discipline oriented and that this can hinder the capacity of students to dealt with complex issues [80]. In the design of educational

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programs and pedagogical practices ways need to be found to overcome learning boundaries [80] whilst ensuring an interdisciplinary approach to bioeconomy education [81].

Box 1. In the spotlight: Key conclusions stemming from the critical review.

- Bioeconomy is inherently an inclusive concept as it is a response to the unsustainability of current economic processes that are often based on unsustainable production models and contribute to environmental degradation and societal fragmentation.
- To reflect the essence of bioeconomy the existing education and training approaches in this field need to be transformed and new ones need to be developed to effectively train individuals for a sustainable bioeconomy – the bioeconomists.
- The main commonalities amongst the analysed educational approaches (higher education, VET and practical approaches, short-term training and education and other approaches) are that they are generally problem based, interdisciplinary, combine academic and experiential methods.
- Higher education approaches are generally based around traditional lecture/campus-based formats with some experiential approaches integrated.
- In contrast, VET approaches often combine academic and practical learning methods while focusing on developing practical skills.
- A key recommendation coming out of various studies is that there is a need for considerably more practical bioeconomy education approaches, especially vocational ones, that support the development of relevant skills across a variety of economic sectors.

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2. Identification of the existing ESCO occupations associated with the bieconomy sector

2.1. Framework

The promotion of bioeconomy is a priority of political agendas in more than fifty countries. Bioeconomy cuts across several scientific disciplines offering a unique opportunity to comprehensively address interconnected societal challenges such as food and nutrition security, fossil-resource dependence, natural resource scarcity, and climate change while achieving a sustainable economic development. This complexity of the sector requires, therefore, up-to-date, hybrid education and training packages. Our critical review shows that for past two decades there was an overwhelming expansion across Europe of educational and training packages in the bioeconomy domain. However, our research also reveals shortcomings, such as the lack of sufficient practical VET in the area.

Several jobs are deeply connected with the bioeconomy sector. Thus, it is crucial to systematize the economic activities and related skills/competences which are relevant to this realm of economic activity. This adds layers of understanding to our critical review, while further substantiating the findings of the RELIEF survey presented in the subsequent sections. Specifically, this section provides a systematic identification and mapping of the activities associated with bioeconomy using ESCO (European Skills, Competences, Qualifications, and Occupations) [82]. ESCO is the European multilingual classification of Skills, Competences, and Occupations that provides a much more detailed functional description of those occupations. Indeed, ESCO works as a dictionary, describing, identifying, and classifying professional occupations and skills relevant to the EU labour market and education and training. Those concepts and the relationships between them can be understood by electronic systems, allowing different online platforms to use ESCO for services like matching jobseekers to jobs based on their skills, suggesting training to people who want to reskill or upskill, etc. Our mapping approach is two-folded. Firstly, we offer some examples of jobs/activities relating or overlapping with bioeconomy from research to practice in the following subsection using a descriptive approach. Secondly, we summarize the full results of this mapping approach in one table (Annex 1), combining ESCO codes with occupations and expected skills and competences for each occupation. This descriptive and summarized overview will further inform educational institutions and relevant stakeholders in the field of bioeconomy (e.g., companies, research institutions) about the educational needs and priorities in the sector.

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2.2. Bioeconomy activities

To start a project that has the bioeconomy as its principle, it is first necessary to have good planning of the whole process. For this, it is essential to have a research and development manager (ESCO 1223.2). This professional is responsible for coordinating the efforts of scientists, academic researchers, product developers, and market researchers towards the creation of new products, the improvement of current ones, or other research activities, including scientific research. They manage and plan the research and development activities of an organization, establish goals and budget requirements and manage the staff. In parallel, a leader production planner (ESCO 2141.6) is much needed. This professional is responsible for planning and following production planning, working with the production manager to follow progress of the schedule and together with the warehouse to ensure that optimum level and quality of materials are provided, and with the marketing and sales department to meet customer order requirements.

For each intended production, it is necessary to have a team leader. Thus, depending on the purpose of the exploration, we may have:

1 - Agronomic crop production team leader (ESCO 6111.1) who is responsible for leading and working with a team of crop production workers. This professional is responsible for organizing the daily work schedules for crop production and participate in the production.

2 - Tree and shrub crop growers (ESCO 6112) plan, organize and perform farming operations to grow and harvest trees and shrubs such as fruit and nut trees, tea and coffee bushes, grape vines, berry-bearing bushes, cocoa trees and rubber trees, and to collect sap, for sale or delivery on a regular basis to wholesale buyers, marketing organizations or at markets. Within this group we can find many occupations, such as arboriculturist, fruit production, hop farmer, among others.

3 - Gardeners, horticultural and nursery growers (ESCO 6113) plan, organize and perform operations to cultivate and maintain trees, shrubs, flowers and other plants in parks and private gardens, and to produce saplings, bulbs and seeds or grow vegetables and flowers, by intensive cultivation techniques for sale or delivery on a regular basis to wholesale buyers, marketing organizations or at markets.

4 - Mixed crop growers (ESCO 6114) plan, organize and perform farming operations to grow and harvest specific combinations of field crops, field vegetables, tree and shrub crops, and garden, horticultural and nursery products, for sale or delivery to wholesale buyers, marketing organizations or at markets.

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5 - Animal producers (ESCO 612) plan, organize and perform farming operations to breed and raise domesticated animals, poultry, insects and non-domesticated animals for the production of meat, dairy products, honey, skins, textiles and other products, or for use as working, sporting or recreational animals, for sale or delivery to wholesale buyers, marketing organizations or at markets.

After planning the intended production, whether it be agriculture, forestry or even fishery, it is necessary to have a professional who manages it so that everything works as planned, while anticipates any problems that may occur (Farm manager – ESCO 6130.1; Production managers in agriculture, forestry and fisheries – ESCO 131). Production managers plan and organize the daily operations, resourcing and business management of animal and crops producing farms. In parallel, the production managers plan, direct and coordinate production in large-scale agricultural, horticultural, forestry aquaculture and fishery operations such as plantations, large ranches, collective farms and cooperatives, to grow and harvest crops, breed and raise livestock, fish and shellfish and to catch and harvest fish and other forms of aquatic life.

Agronomists (ESCO 2132.2) provide consulting services to companies, agricultural cooperatives, agronomical crop growers and horticultural crop growers on the cultivation of food crops. They study the science, technology and business related to growing plants. They examine crops and perform experiments in order to improve crop yields and farms' production. Agronomists also examine the most effective ways to harvest and cultivate plants.

The control of the energy applied in the production and processing of all products obtained through the bioeconomy is monitored by energy managers (ESCO 1349.12) and energy consultants (ESCO 3112.7).

While the energy managers coordinate the energy use in an organization, and aim to implement policies for increased sustainability, and minimization of cost and environmental impact, the energy consultants monitor the energy demands and use, developing improved strategies, as well as researching the most beneficial sources of energy for the organization’s needs. On the other hand, the energy consultants advise clients on the advantages and disadvantages of different energy sources. They help clients to understand energy tariffs and try to reduce their energy consumption and carbon footprint by using energy efficient products and methods.

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In a world threatened by climate change, the drive towards a more environmentally friendly economy is not an option, it is an obligation. To achieve such sustainable development, the bioeconomy, which the FAO defines as "knowledge-based production and the use of biological resources, processes and methods to provide goods and services in a sustainable manner in all economic sectors", becomes essential [83]. For this reason, environmental protection manager is a fundamental occupation related to bioeconomy (ESCO 1349.13). This professional provide advice on the development of environmental policies to governmental and official institutions, while analysing possible threats to the well-being of the people and the environment in a region and managing campaigns aimed at tackling problems such as waste collection, landfills, and preservation of green areas.

Other occupations relating with the environment care side of bioeconomy are biologists, botanists, zoologists, and other related professionals (ESCO 2131). These professionals study living organisms and their interactions with each other and with the environment and apply this knowledge to solving human health and environmental problems. They work in diverse fields such as botany, zoology, ecology, marine biology, genetics, immunology, pharmacology, toxicology, physiology, bacteriology, and virology, relying on agricultural scientists to be able to take and advise correctly (Agricultural scientists – ESCO 2132.1). These scientists research and study soil, animals, and plants with the objective of improving agricultural processes, the quality of agricultural products or the impact of agricultural processes on the environment. They plan and implement plans such as development projects on behalf of clients or institutions. Bioengineers (ESCO 2149.5) also play an important role because they combine state of the art findings in the field of biology with engineering principles in order to develop solutions aimed at improving the well-being of society. They can develop improvement systems for natural resource conservation, agriculture, food production, genetic modification, and economic use.

The result of all present and possible future interventions in the environment is controlled by environmental protection professionals (ESCO 2133). These professionals study and assess the effects on the environment of human activity such as air, water, and noise pollution, soil contamination, climate change, toxic waste and depletion and degradation of natural resources. They also develop plans and solutions to protect, conserve, restore, minimize, and prevent further damage to the environment. Alongside these professionals, natural resources consultants (ESCO 2133.8) play a fundamental role in bioeconomy as well because they provide advice on the protection and management of

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natural resources, namely fauna, flora, soil and water to companies and governments, which exploit these resources. They strive to guide companies on an appropriate policy for exploiting natural resources in industrial contexts, raise awareness on health issues, and ensure the conservation of ecosystems for sustainable interventions in natural habitats.

Sustainability managers are responsible for ensuring the sustainability of business processes (Sustainability managers – ESCO 2133.12). They provide assistance in the design and implementation of plans and measures to ensure that the manufacturing processes and products comply with given environmental regulations and social responsibility standards. Alongside, they monitor and report on the implementation of sustainability strategies within the company supply chain and business process. They also analyse issues linked to manufacturing processes, use of materials, waste reduction, energy efficiency, and product traceability to improve environmental and social impacts and integrate sustainability aspects into the company culture.

Although some have already been mentioned, there is still a large number of professionals who interfere directly or indirectly with the bioeconomy in relation to the environment: 1) environmental programme coordinators (ESCO 2133.6) who develop programmes for the improvement of environmental sustainability and efficiency within an organisation or institution. They inspect sites to monitor an organisation's or institution's compliance with environmental legislation, also ensuring education for the public on environmental concerns; 2) environmental engineers (ESCO 2143.1) who integrate environmental and sustainable measures in the development of projects of various natures. They seek to preserve natural resources and natural sites. They work together with engineers from other fields to envision all the implications that projects might have to design ways to conserve natural reserves, prevent pollution, and deploy sanitary measures; 3) environmental experts (ESCO 2143.2) search for technological solutions to tackle environmental problems. They detect and analyse environmental issues and develop new technological production processes to counter these problematic issues, as well as researching the effect of their technological innovations and present their findings in scientific reports. A very important aspect in agriculture and even more so in the bioeconomy is waste treatment. Waste treatment engineers (ESCO 2143.1.4) design processes, facilities and equipment used in the collection, treatment, and distribution of waste. They research environmental standards and policies in order to optimise waste treatment procedures and ensure minimal strain on the environment by analysing and classifying the processed waste.

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Related with the environment are also the soil scientists (ESCO 2133.11) because they ensure its conservation by studying scientific concerning disciplines. They advise on how to improve soil quality to support nature, food production or human infrastructure using surveying and irrigation techniques as well as erosion reduction measures. They make sure to conserve and restore land suffering from intense farming or human interaction.

Nowadays, communication networks are extremely important for the success of any project in the bioeconomy sector. Green Information and Communication Technology (ICT) (ESCO 2511.7) consultants advise organisations on their green strategies and its implementation in the most effective and efficient manner allowing the organisation to reach their short, mid, and long-term ICT environmental objectives.

For a good trade to occur, there is the need for export/import specialists to manage all surplus products as well as to import what is missing in the local market. To perform these tasks, we have the import export specialists (ESCO 3331.2.1) who apply deep knowledge of import and export goods including customs clearance and documentation. They declare goods that cross the border, inform customers about customs' regulations, and give advice concerning disputes related to legislation. They also prepare the documents needed and make sure they are delivered to customs, checking and processing duty, making sure VAT payments are done as applicable. These professionals may operate in specific domains, according to the examples provided below:

-Import export specialists in agricultural machinery and equipment (ESCO 3331.2.1.1).

-Import export specialists in agricultural raw materials, seeds and animal feeds (ESCO 3331.2.1.2).

-Import export specialists in fish, crustaceans, and molluscs (ESCO 3331.2.1.12).

-Import export specialists in flowers and plants (ESCO 3331.2.1.13).

-Import export specialists in fruit and vegetables (ESCO 3331.2.1.14).

-Import export specialists in live animals (ESCO 3331.2.1.19).

A very important professional domain that has very significant repercussions on all professionals in the bioeconomy includes teaching professionals (ESCO 2.3). These professionals teach the theory and practice of one or more disciplines at different educational levels; conduct research; improve or develop concepts, theories, and operational methods, as well as prepare scholarly papers and books. Within this group, we can find the vocational teachers specialized agriculture, forestry, and fishery (ESCO

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2320.1.1) which instruct students in their specialised fields, which is predominantly practical in nature. They also provide theoretical instruction in service of the practical skills and techniques the students must subsequently master for an agriculture, forestry or fishery profession. These teachers monitor students' progress, assist individually when necessary, and evaluate their knowledge and performance on the respective subjects through assignments, tests and examinations.

As in any other activity, there must be someone responsible for creating and enforcing the legal rules. Agricultural policy officers (ESCO 2422.12.1) analyse and identify agricultural policy issues and develop plans for improvement and new policy implementation. They write reports and presentations in order to communicate and acquire support for the policies from government officials and the public. They also communicate with professionals in agriculture for research and information purposes and perform administrative duties. Agricultural inspectors (ESCO 3359.1) monitor agricultural operations in farms and other agricultural facilities, inspecting activities such as health and safety measures, costs and production processes to ensure that workers and their activities comply with proper legislation and standards. Agricultural inspectors also analyse and report on their findings.

To make sure all tasks are duly performed there must be a set of workers who do all the hands-on tasks, such as: Scientific laboratory technicians (ESCO 3141.2) who provide the technical support to life science professionals undertaking research, analysis and testing of living organisms, and development and application of products and processes resulting from research in areas such as natural resource management, environmental protection, plant and animal biology, microbiology, and cell and molecular biology; Agricultural technicians (ESCO 3142.1) who perform tests and experiments, and provide technical and scientific support to agricultural scientists, farmers and farm managers; Forest technicians (ESCO 3143.1) who perform technical and supervisory functions, supporting research and forest management and harvesting whose actions allow for resource conservation and environmental protection; or Veterinary technicians and assistants (ESCO 3240.2) who carry out advisory, diagnostic, preventive and curative veterinary tasks more limited in scope and complexity than those carried out by veterinarians. They care for animals under treatment and in temporary residences at veterinary facilities and assist veterinarians to perform procedures and operations.

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Mixed farmers (ESCO 6130.2) are also a different group involved in the bioeconomy sector. These professionals are responsible for managing all aspects of livestock and crop production as a small enterprise or for self-sufficiency.

Finally, there is a group of producers who can also be included in the bioeconomy sector including the subsistence farmers, fishers, hunters, and gatherers (ESCO 63). These subsistence producers can be:

- crop farmers (ESCO 6310) who are dedicated to grow and harvest field or tree and shrub crops, vegetables and fruit, in order to provide food, shelter and, in some cases, a minimum of cash income for themselves and their households.

- livestock farmers (ESCO 6320) who breed, raise and tend livestock in order to provide food, shelter and, in some cases, a minimum of cash income for themselves and their households.

- mixed crop and livestock farmers (ESCO 6330) who grow and harvest field or tree and shrub crops, vegetables and fruit; gather wild fruits, medicinal and other plants; tend or hunt animals; and/or catch fish and gather various forms of aquatic life in order to provide food, shelter and, in some cases, a minimum of cash income for themselves and their households.

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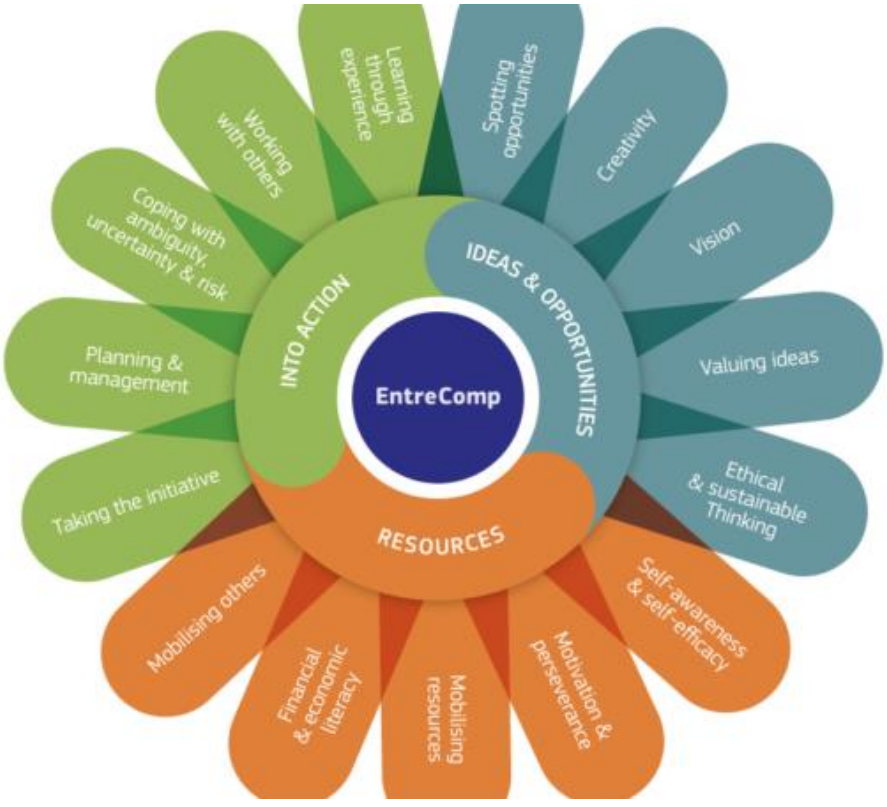
3. Identification of the EntreComp and DigComp associated with the bieconomy sector

In a rapidly changing society, it is of utmost importance for everyone to have the capacity to act upon their innovative ideas and take on opportunities that may arise in order to manage their careers and shape their future in a dynamic way. It is with that goal in mind that the European Commission has deemed the entrepreneurial mindset as the core of what is necessary for organisations and teams in order to develop. With regard to society's demands as well as what it actually means to have an entrepreneurial mindset, the European Commission has generated EntreComp: the European Entrepreneurship Competence Framework. The EntreComp framework consists of 15 competences on entrepreneurship, and each of those competences caters to one of three identified areas: Ideas & opportunities, resources and into action. The EntreComp Competences are visualised on the Wheel of competences (see Figure 3). They are of equal importance, and even though they are numbered, numeration has nothing to do with hierarchy. An activity or a tool that wants to adapt EntreComp may focus on only one competence or on all fifteen.

Figure 3. The EntreComp Competences framework.



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3.1. The EntreComp Framework

Based on the way EntreComp is utilised, it is expected that more emphasis will be given to specific competencies than others, depending on the target's specific needs, the external and internal environment in which they operate and their field of expertise. For professions related to bioeconomy, the following competences mapped and presented in Annex 2 have been recognised as the mosct relevant to their work, in order to build an entrepreneurial mindset. By developing a strong entrepreneurial mindset and skill set, bioeconomy professionals can take advantage of new opportunities, manage resources effectively, and navigate the industry's challenges. (Bacigalupo, M. et al, 2016). EntreComp has the flexibility to be adapted and tailored according to the needs of its specific audiences. Each competence includes learning outcomes that should be fulfilled, but the level at which they are adapted depends on the learner's autonomy, as each individual has different starting point and priorities. Thus, a progression model has been developed and adapted according to the circumstances. The progression levels that have been mapped are eight and range between foundation to intermediate, advanced and expert levels. Considering the profile of our audience, we focused on the "foundation" competences, referring to the progression levels 1 and 2. An explanation of what these levels mean can be found in the table below (Bacigalupo, M. et al, 2016):

Table 4. The EntreComp foundation competences

FOUNDATION RELYING ON SUPPORT FROM OTHERS	
Under direct supervision. (Includes, for example, support by teachers, mentors, peers, advisors, or consultancy services)	With reduced support from others, some autonomy and together with my peers
Level 1- Discover Focuses mainly on discovering your qualities, potential, interests and wishes. It also focuses on recognising different types of problems and needs that can be solved creatively, and on developing individual skills and attitudes.	**Level 2- Explore** Focuses on exploring different approaches to problems, concentrating on diversity and developing social skills and attitudes. (Bacigalupo, M. et al, 2016)

3.2. The DigComp framework

DigComp, or the Digital Competence Framework, is a framework developed by the European Commission to define the digital competences required for individuals to use digital technologies effectively and responsibly in various domains. While DigComp is not specifically tailored for professionals working in the bioeconomy sector, it can still be applied to their context as it was created with applicability as a factor. (Vuorikari, R., et al., 2022). The DigComp framework has identified five areas, referred to as Dimension 1, with identified key components. The five areas are the following:

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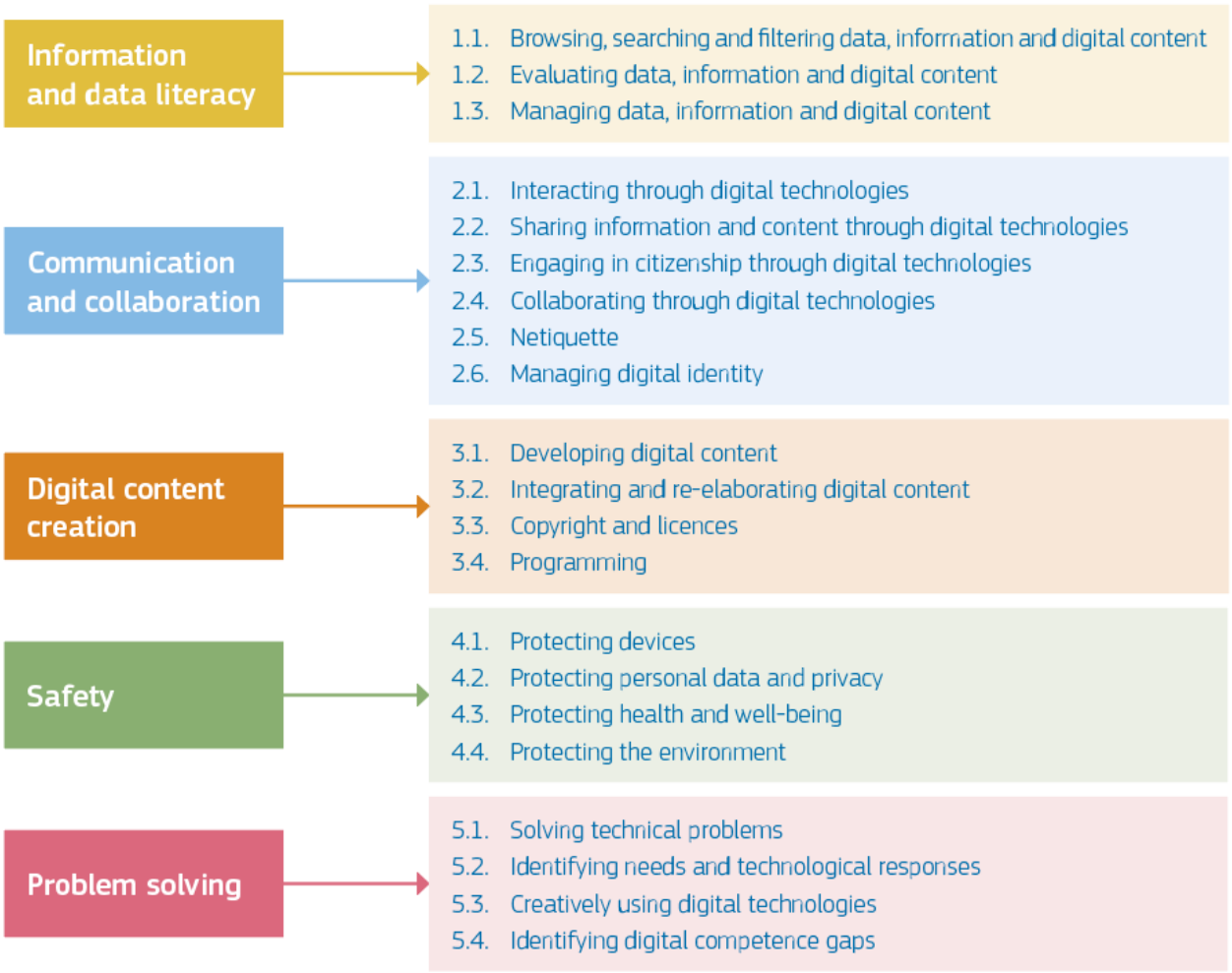
1. Information and data literacy: articulate information and locate data, check the relevance of the sources and content, manage digital data and store them.
2. Communication and collaboration: communicate through digital means, public participation, and participatory citizenship. Managing their digital presence.
3. Digital content creation: create and edit digital content, understand rules of copyright and license, and give understandable instructions on the use of computer systems.
4. Safety: safeguard personal data, devices, content, and privacy in digital environments; have knowledge of the digital technologies available for social well-being and inclusion, thus protecting physical and phycological health.
5. Problem-solving: identification of problems and needs, resolving conceptual situations in digital environments, using digital tools and products and staying up to date with digital evolution.

For all areas, 21 competences have been mapped, outlined as Dimension 2. Dimensions 1 and 2 together form the DigComp conceptual reference model. (Vuorikari, R., et al., 2022)

Figure 4. The DigComp conceptual reference model



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Professionals working in the bioeconomy sector can benefit from digital technologies in various aspects of their work, such as precision agriculture, data analysis, farm and crop management, marketing, and communication. By leveraging digital tools, these professionals can enhance their productivity, optimise resource usage, make data-driven decisions, and improve their overall efficiency.

Next, we present some key areas of DigComp that can be relevant such professionals:

1. Information and Data Literacy: A significant part of the professionals working in the bioeconomy sector need to develop skills in finding, evaluating, and managing agricultural information, as well as analysing and interpreting data from various sources, including sensors, weather stations, and agricultural databases.

2. Communication and Collaboration: Effective communication and collaboration skills are essential for professionals working in the bioeconomy sector to connect with suppliers, customers, agricultural experts, and fellow farmers. This includes using digital communication tools, social media platforms, and online marketplaces.

3. Digital Content Creation: Professionals working in the bioeconomy sector can use digital technologies to create and share content related to their farming activities, such as maintaining a website, writing a blog, or sharing educational videos. Skills in creating and editing digital content are valuable in reaching out to a wider audience and promoting their products or knowledge.

4. Problem-Solving: Digital technologies can present challenges to professionals working in the bioeconomy sector, and the ability to identify and solve technical issues is crucial. Farmers should develop problem-solving skills to troubleshoot digital equipment, software, or network-related problems.

5. Safety and Security: Professionals working in the bioeconomy sector need to be aware of cybersecurity risks and take measures to protect their digital assets, such as farm data, financial information, and online accounts. Skills in data backup, password management, and recognising potential threats are important to ensure the security of digital systems.

Those who are interested in diversifying their income streams or exploring new market opportunities can benefit from digital entrepreneurship skills. This includes understanding e-commerce platforms, digital marketing strategies, and online business models. While there is no specific DigComp profile designed exclusively for farmers, these areas can provide a general framework for professionals working in the bioeconomy sector to assess and develop their digital competences. For this project, competences can be developed on the Foundation level. More specifically the DigComp conceptual reference model can be mapped as presented in Annex 3.

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Both EntreComp and DigComp frameworks were created and developed with the purpose of being adapted to several different contexts and cases. The key components and competences they identify are flexible, depending on the target audience that wishes to implement them and can be adapted according to their needs. That is the reason why all identified competences of both frameworks can be developed either on the foundation level, or the intermediate, advanced and proficient. In a society and world that keeps evolving, there are a lot of opportunities available for professionals working in the bioeconomy sector in order to implement digital ideas and have an entrepreneurial mindset. Considering the potential audience target groups of this project, the report focused mostly on the foundation level of EntreComp and DigComp competences. The foundation level is built upon the ability to identify their needs, and the tools they need, building basic knowledge and communication skills, but also relying on support from others and implementing those basic skills with guidance from an expert.

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4. Mapping the education and training trends and needs in the bieconomy sector

In the previous sections of this report, we have defined bioeconomy in the context of the green transition. We have also targeted the main opportunities, as well as the caveats associated with bioeconomy-related training (e.g., shortage of VET courses/programs). In addition, we have mapped the different types of training areas intersecting with the bioeconomy sector, using the ESCO framework. Overall, we have demonstrated that bioeconomy is an emerging sector intersecting knowledge from multiple scientific disciplines. Unsurprisingly, this hybrid condition of the bioeconomy sector has outstanding implications for training design that need to be better understood. On the one hand, training providers must mobilize different skills and expertise while ensuring that training programs are useful and attractive for potential learners. On the other hand, learners must fulfil their learning and skills expectations which are rather complex. The match between training offer and demand is one of the oldest questions in formal education. This will remain as an open-ended question, as formal education must continuously adjust to societies and economies development. However, matching training packages with learners needs and expectations is even more demanding in emerging sectors such as the ones aligned with the green transition [84].

Considering the main conclusions of our efforts to understand and map bioeconomy training requirements, the RELIEF project went a step further by conducting a mapping of current education and training provisions at VET and higher education levels in this sector (full courses or courses including bioeconomy dimensions) across the EU in the farming sector. This mapping procedure is described in this section. Afterwards, the consortium implemented a Training Needs Analysis (TNA) which is presented in section 4. Altogether, the mapping and the TNA aim at identifying and categorizing needs in knowledge-skills-competences in the bioeconomy sector. By doing so, the RELIEF project intends to: (a) further understand the catalogue of available education and training on bioeconomy or bioeconomy related sectors; (b) feed in the development of the learning objectives and curricula, as well as to (c) establish the pedagogical background required by those delivering education and training within the higher education and in the VET institutions, in the bioeconomy field.

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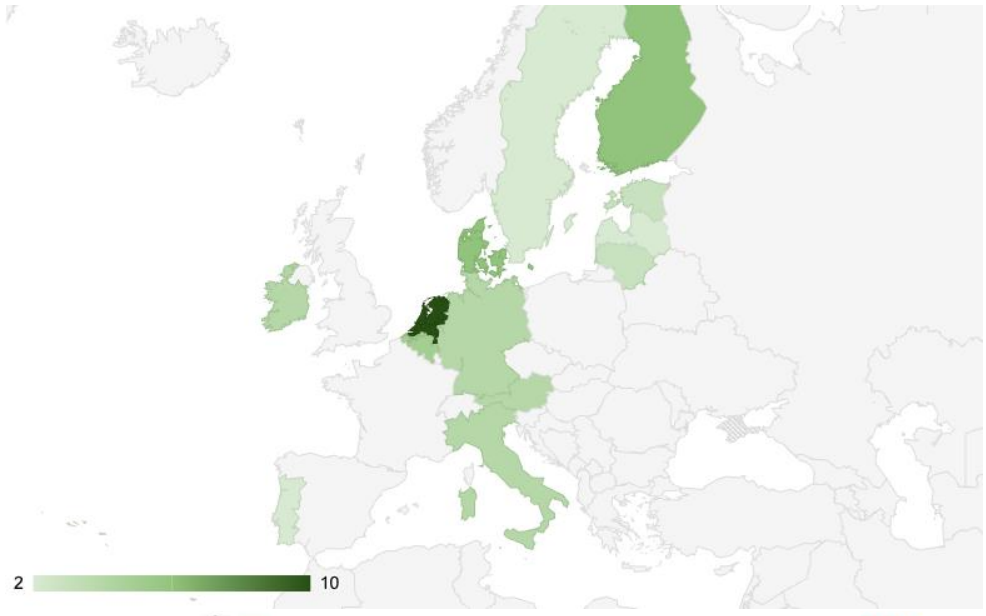
4.1. Training opportunities in bioeconomy at the EU level

4.1.1. Methodological note

The RELIEF project conducted an analysis of the current education and training provisions at VET and higher education levels in the field of bioeconomy in the farming sector across the EU countries. This task consisted of an online desk research approach involving two main steps. Firstly, using a pre-organized course-form developed and provided by P7 (TERINOV), P6 (CESIE) and P3 (OTC) the consortium gathered relevant information related with bioeconomy courses provision in the field of agriculture across European Union countries, expanding and including detailed information from training provisions available across EU countries that do not formally integrate the project's consortium. The main criteria to be include in this mapping was that the training offer must be currently active and/or accepting new learners. Afterwards, data was extracted directly from higher education institutions and VET providers curricula available at the institutional websites of each organization and from publicly available databases from official bodies responsible for the accreditation of training provisions (e.g., Direção-Geral do Ensino Superior and Direção-Geral da Educação, Portugal).

Figure 5 depicts education and training full programs and programs with curricular units on bioeconomy across the EU by country identified through the mapping procedure.

Figure 5. Training curricula on bioeconomy by EU country (count)



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The consortium identified in total 55 training curricula on bioeconomy or including curricular units on bioeconomy subjects in the farming sector across 13 countries. The distribution of curricular programs included in the RELIEF database ranged from 2 in Portugal and Sweden to 10 in The Netherlands. Importantly, of the 55 education and training curricula added to our database, 48 (87.2%) were delivered by public universities.

Figure 6 summarizes the identified curricula by type of course.

Unsurprisingly, the inspection of Figure 6 shows that most of the programs provided by education and training providers are higher education degrees. The biggest share of them are MsC (65.5%; *fi* = 36), followed by training courses with no specific awarded certification (9.1%; *fi* = 5), BsC (7.3%; *fi* = 4) and MOOC courses (7.3%; *fi* = 4), with all other types being available in residual numbers.

Figure 6. Distribution of education and training programs by type of course (%)

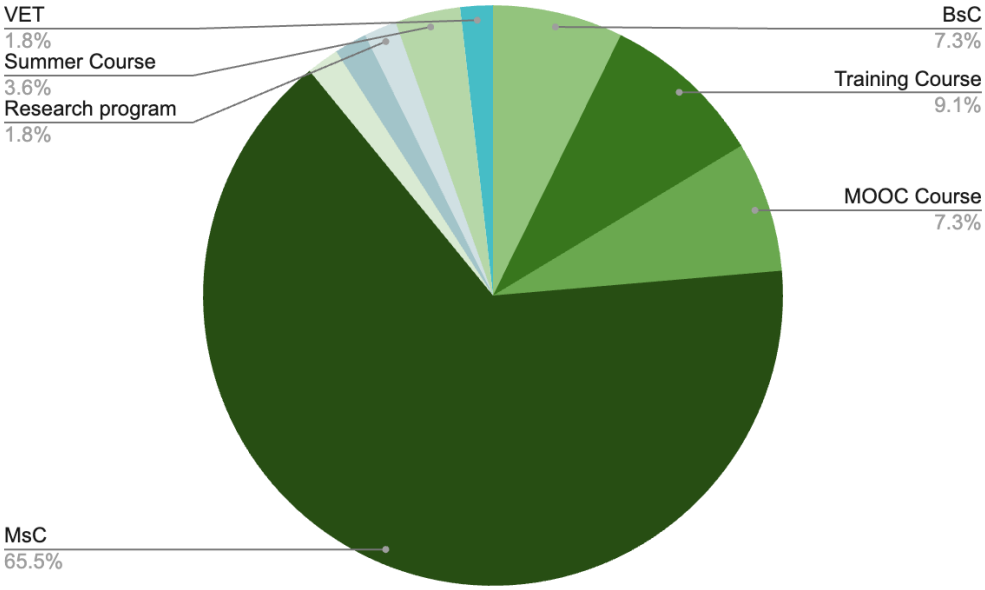

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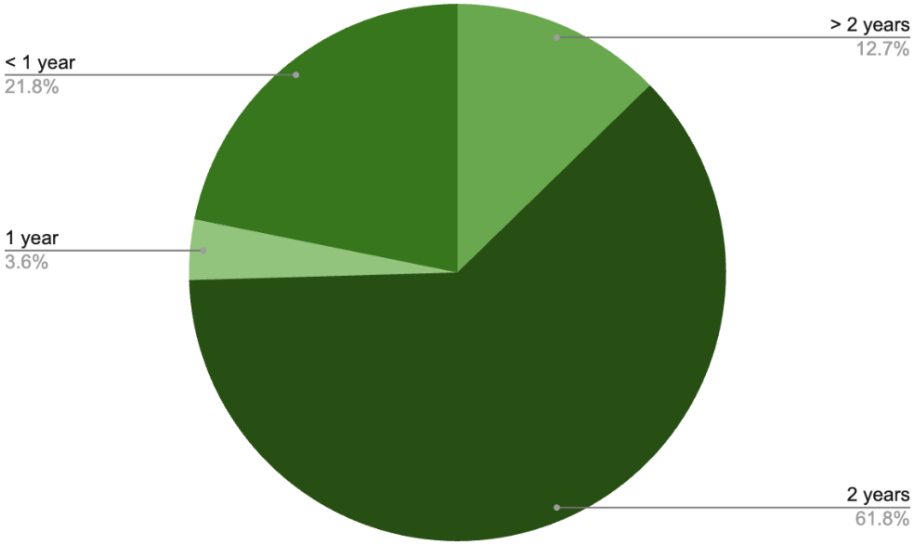
Figure 7 depicts the distributions of the selected education and training programs by duration.

Figure 7. Distribution of education and training programs by duration (%)



The inspection of Figure 7 shows that almost two thirds of the programs included in the project's database are two-years courses (61.8%; *fi* = 34), a figure that is well explained the proliferation MsC programs on bioeconomy or including bioeconomy dimensions. Less than 1-year programs (ranging from 10 days to 6 months) were somewhat frequent (21.8%; *fi* = 12), followed by programs lasting for more than 2 years (12.7%; *fi* = 7) 1-year programs (3.6%; *fi* = 2).

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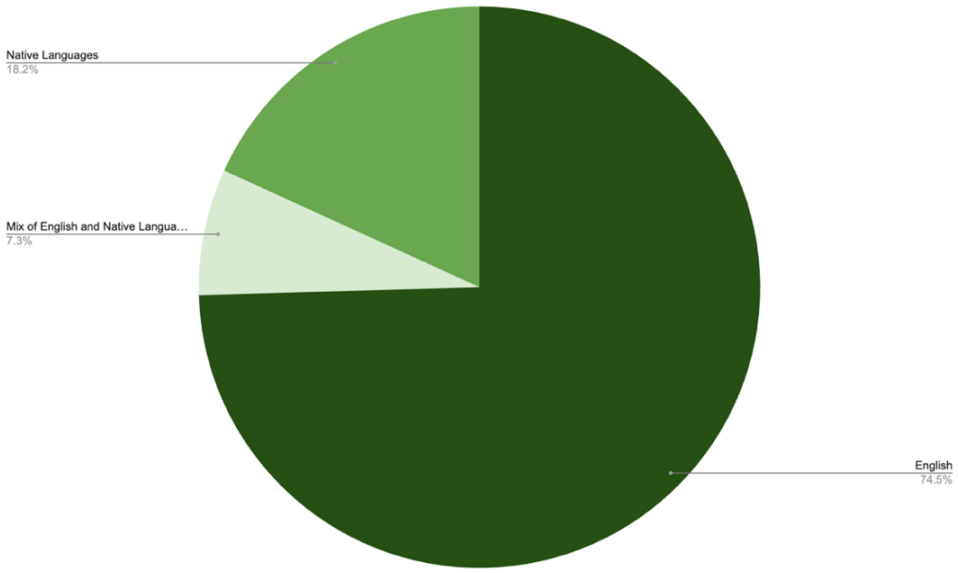
Figure 8 displays the distribution of the educational programs included in the mapping database of the RELIEF project by language.

Figure 8. Distribution of education and training programs by teaching language (%)



According to Figure 8, it is evident that a vast majority of the education and training programs are delivered in English (74.5%; *fi* =34). Less recurrent are programs delivered only in native languages (18.2%; *fi* = 10) or mixing English and native languages (7.3%; *fi* = 4).

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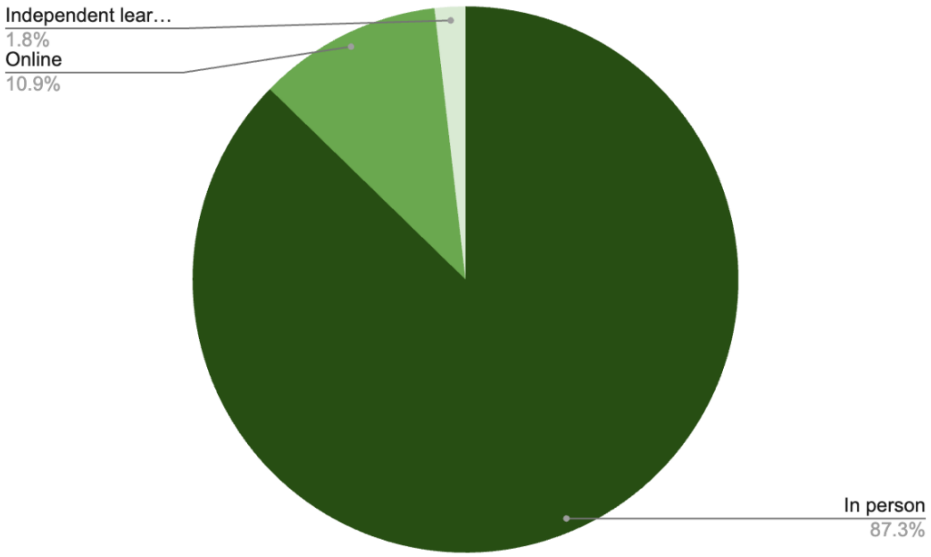
Figure 9, in turn, describes the methodological approach of these programs.

Figure 9. Distribution of education and training programs by methodological approach (%)



In this domain, it is evident that most of the courses are made available using in-person teaching methods (87.3%; 48), compared to a very scarce offer of online programs (10.9%; *fi* = 6) and independent learning approaches (1.8%; *fi* = 1).

Box 2. In the spotlight: Key conclusions stemming from the mapping.

- Fifty-five training programs were included in the RELIEF database, cutting across 13 countries.
- The programs were mostly long-term, advanced courses (e.g., MsC), delivered by tertiary education institutions.
- According to the mapping, most of the programs were based on in-person teaching methods and were delivered in English language.

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5. Bioeconomy training needs across the consortium partner countries

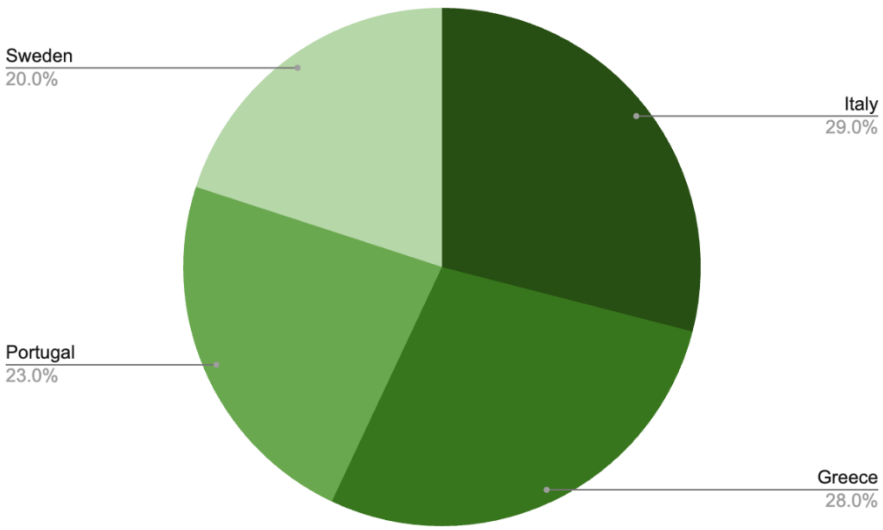
5.1. Methodological note

The TNA approach followed the principle of multiple informants to better understand the learning needs in the bioeconomy and, therefore, to target commonalities and differences among different stakeholders. Potential participants from higher education institutions and VET providers were identified and contacted to participate in the study directly by the partners of the consortium. Potential learners, namely farmers, agronomists, consultants, and policy makers were identified and contacted with the invaluable help of local, regional, and national farmers' associations, universities, and government bodies who kindly shared the questionnaires with their stakeholders. A total of 95 questionnaires for higher education institutions and VET providers and 230 questionnaires for potential learners were sent out via e-mail but also made available on paper-and-pencil format. The questionnaires were filled in between 20/10/2022 and 12/05/2023.

5.2. Participants

A total of 196 questionnaires were sent back (45 questionnaires for training providers and 151 questionnaires for learners), which represents a return rate of 85.2%. According to Figure 10, participants were distributed by countries in the following: 57(29%) from Italy; 55 from Greece (28%); 45 (23%) from Portugal; and 39 (20%) from Sweden.

Figure 10. Participants in the RELIEF Training Needs Analysis by country (%)



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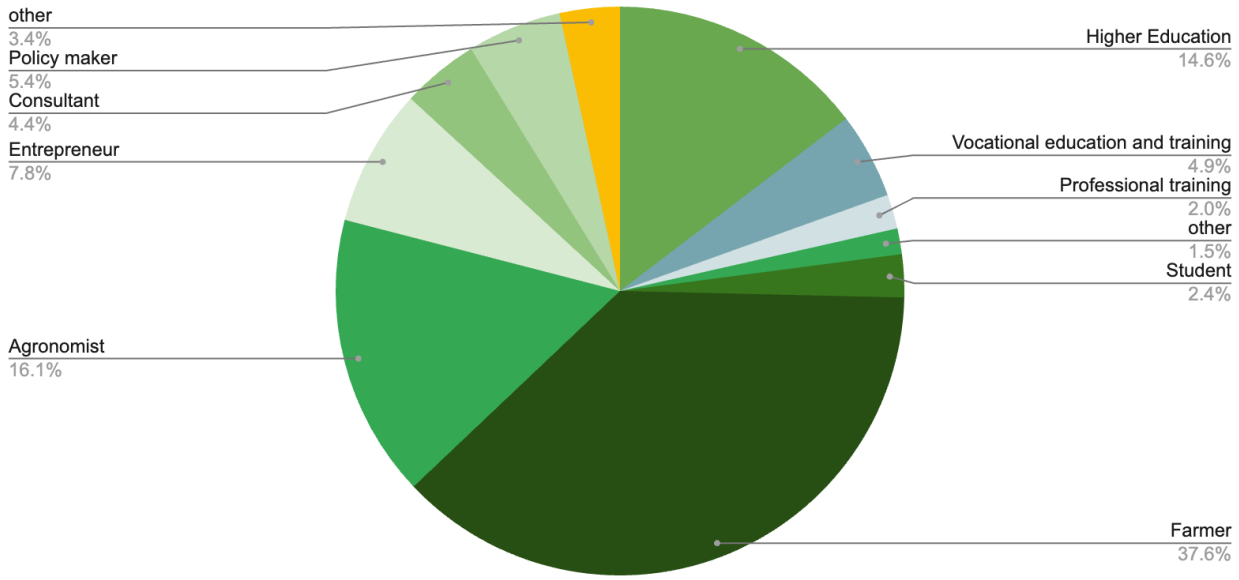
According to Figure 11 the most represented group in the survey was farmers (37.6%; *fi* = 77), followed by agronomists (16.1%; *fi* = 33), higher education training providers (14.6%; *fi* = 30), entrepreneurs (7.8%; *fi* = 16), policy makers (5.4%; *fi* = 11), vocational education and training (4.9%; *fi* = 10), and consultants (4.4%; *fi* = 9). All other groups covered by the survey have 7 participants or less. Nine participants identified themselves as being in more than one category leading to a total number of 205 replies in this question.

Figure 11. Type of participants (%)



5.3. Instruments

To conduct a comprehensive TNA, the RELIEF consortium developed two questionnaires.

The first questionnaire targeted **training providers** (Annex 3). The first part of this questionnaire aimed at characterizing the training providers in terms of active training fields associated to the bioeconomy sector, institutional typology (VET provider, professional training, higher education or other), and degrees awarded (if any). This part of the questionnaire also included a depiction of learning courses/programs offered by training providers, covering elements such as training types, duration, learning methods, or fees. In the second part of the questionnaire, the participants were asked about the opportunities and challenges of their training packages, including strengths and weaknesses, elements of effective training, or non-technical skills covered. The questionnaire also comprised some

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open-ended questions regarding expected training updates, improvements, or partnerships for programs' implementation.

The second questionnaire focused on **learners** (Annex 4). Learners covered by this questionnaire were farmers or farming companies, agronomists, farming consultants and policymakers. In many ways, this questionnaire mirrored the questionnaire for training providers to ensure comparability. The first part of the instrument covered personal information about the learners in terms of the highest educational qualification achieved, duration of the latest qualification, number of curricular units associated to bioeconomy attended, and professional identity (e.g., agronomist, farmer, etc.). The second part focused specifically on farmers' perceptions and expectations regarding bioeconomy learning needs. This section of the questionnaire included questions about the level the interest to learn more about the sector, preferred learning language or preferred learning methods. This section also encompassed a series of questions using a 5-points Likert scale (from 1 "not at all" to 5 "extremely important) to rate the relevance of promoting different entrepreneurial (e.g., creativity), digital (e.g., digital content creation) and transversal skills (e.g., self-efficacy). The third part of the questionnaire aimed specifically at agronomists, farming consultants or policymakers covering largely the same questions and items rated using the 5-points Likert scale. Both the second and the third section of the questionnaire for learners included some open-ended questions.

5.4. Data Analyses

The results from the questionnaires for training providers and learners were collapsed in three parts: (a) training supply description by training providers; and (b) learners' qualifications and learning needs We followed a descriptive statistical analysis using mostly two approaches. In the case of characterization questions, we depict response frequencies and percentages. In the case of Likert scale questions aiming at learners we present mean values. The results are presented in graphical displays in the results section.

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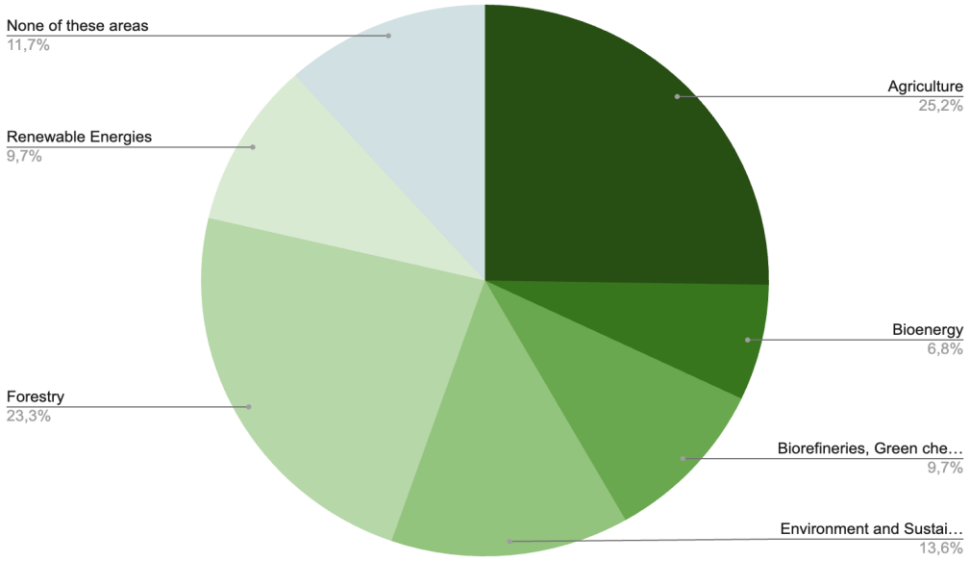
5.4.1. Results[2]

5.1.1. Training supply: Training providers

The survey aiming at training providers started by identifying the fields of education related to the bioeconomy sector offered by the institutions represented by these participants. Figure 12 summarizes the total of 103 fields of training identified by training providers.

Figure 12. Fields of education related with bioeconomy offered by training providers (%)



The results from Figure 12 show that training offers were more often made available in the agriculture field (25.2%; *fi* = 26), followed by forestry (23.3%; *fi* = 24), environment and sustainability (13.6%; *fi* = 14), biorefineries and green chemistry (13.6%; *fi* = 10), and renewable energies (13.6%; *fi* = 10). Importantly, a part of the training providers referred that they did not provide training in any of the proposed areas of the survey (11.7%; *fi* = 12).

Figure 13 provides information about the educational levels offered by the VET providers.

[2] Note: In several questions of the survey, the number of answers can be above of the number of participants (*n* = 196), due to the fact that the participants can provide more than one answer.

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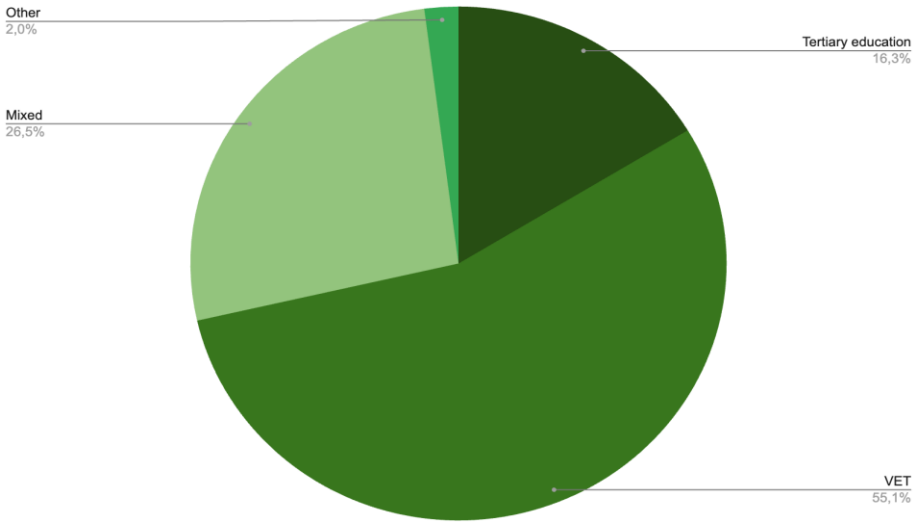
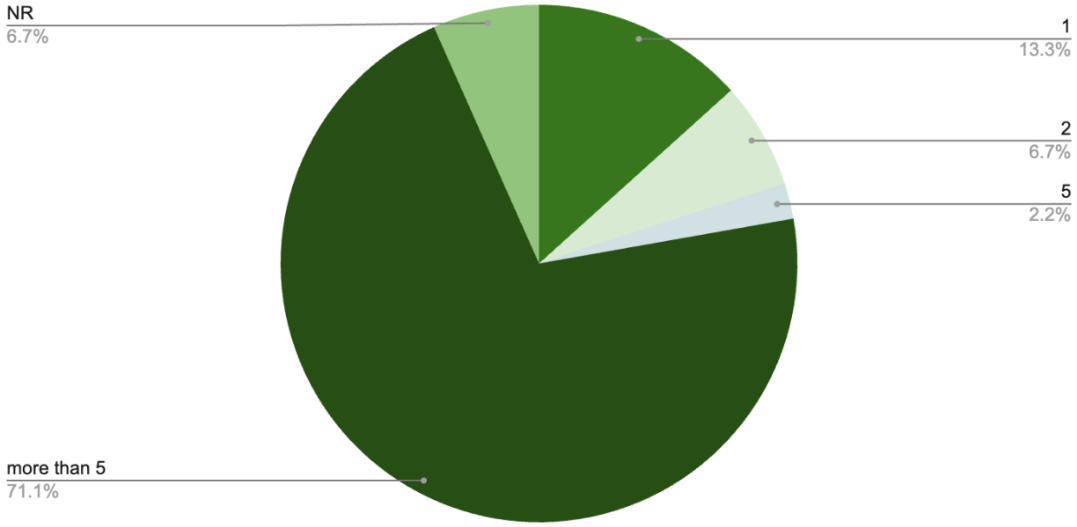
Figure 13. Education levels provided (%)



VET equivalent to different certification degrees (EQF 3 to 5) (55.1%; *fi* = 27) is the most often offered education level according to the institutions involved, followed by a mix of education levels (26.5%; *fi* = 13), tertiary education (16.3%; *fi* = 8), and other (2.0%; *fi* = 1).

The number of curricular units provided by the VET providers is described in Figure 14.

Figure 14. Number of curricular units (%)



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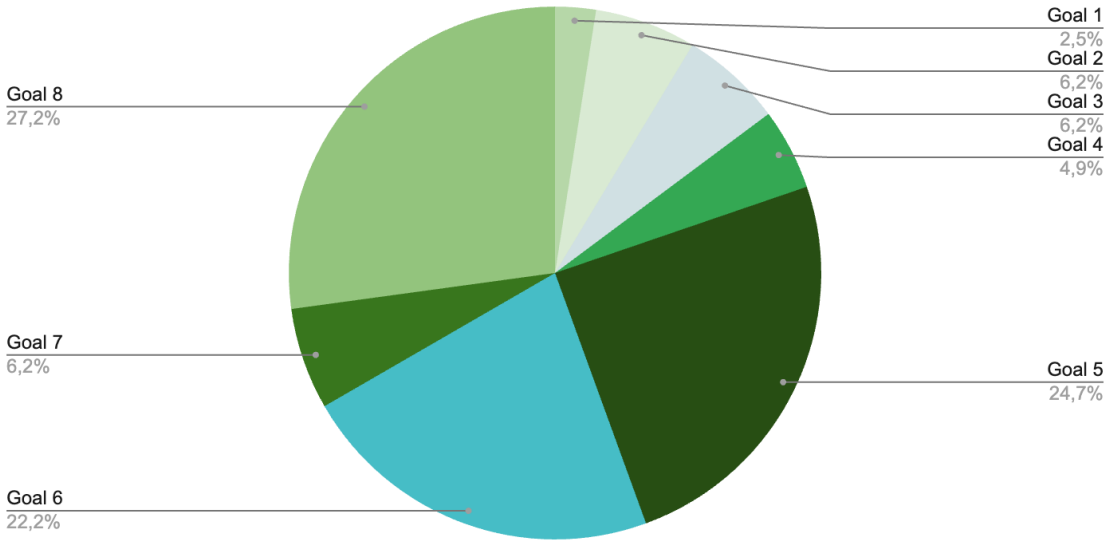
According to Figure 14, most of the VET providers courses offer more than 5 UC's on bioeconomy (71.1%; *fi* = 32), followed by those providing 1 UC (13.3%; *fi* = 6), 2 UC's (6.7%; *fi* = 3), and 5 UC's (2.2%; *fi* = 1). A part of the training providers did not provide any answer to this question (6.7%; *fi* = 3).

The results from Figure 15 show the main aims of the current bioeconomy-related course.

Figure 15. Main aims of the current bioeconomy-related course (%)



Notes: Goal 1: To provide the key concepts in microeconomics; **Goal 2:** Systematic approach to conduct economic analysis to evaluate costs and benefits; **Goal 3:** Knowledge on bioeconomy strategies; **Goal 4:** Knowledge on biomass markets; **Goal 5:** Methodologies for environmental impact assessment; **Goal 6:** Necessary skills to deal with the biomass to energy chain; **Goal 7:** Necessary skills to deal with the biorefinery and Green Chemistry topics; **Goal 8:** Other; training providers were allowed to provide more than one answer.

According to Figure 15, Goal 8 "other" (27.2%; *fi* = 22) was the most selected one by the participants, followed by Goal 5 "Methodologies for environmental impact assessment" (24.7%; *fi* = 20), Goal 6 "Necessary skills to deal with the biomass to energy chain" (22.2%; *fi* = 18), Goal 7 "Necessary skills to deal with the biorefinery and Green Chemistry topics" (6.2%; *fi* = 5), Goal 3 "Knowledge on bioeconomy strategies" (6.2%; *fi* = 5), Goal 2 "Systematic approach to conduct economic analysis to evaluate costs and benefits" (6.2%; *fi* = 5), Goal 4 "Knowledge on biomass markets" (4.9%; *fi* = 4), and goal 1 "To provide the key concepts in microeconomics" (2.5%; *fi* = 2).

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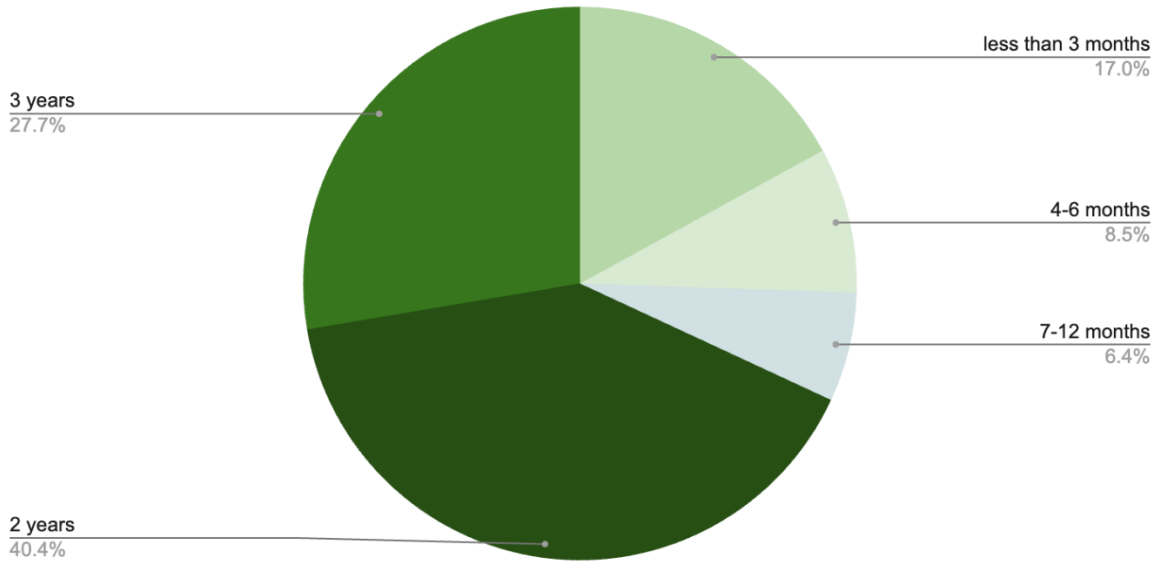
The most recurrent duration of the current bioeconomy-related course according to the training providers is presented in Figure 16.

Figure 16. Duration of the current bioeconomy-related course (%)



According to the surveyed training providers, bioeconomy related training lasted most often for 2 years (40.4%; *fi* = 19), followed by training courses with a duration of 3 years (27.7%; *fi* = 13). Short-term training courses were less recurrent, whether they lasted less than 3 months (17.0%; *fi* = 8), 4 to 6 months (8.5%; *fi* = 4) or finally 7 to 12 months (6.4%; *fi* = 3).

Figure 17 illustrates which is the preferred primary teaching language used in bioeconomy-related courses according to training providers. This question offers, thus, an idea about the internationalization of the training in this sector.

According to Figure 17 the primary teaching lesson of the current bioeconomy-related course, bioeconomy-related courses are more often delivered in English (29.8%; *fi* = 14), followed by a similar share of courses provided in Greek and Portuguese languages (both 21.3%; *fi* = 10). Courses in this area provided only in Italian (14.9%; *fi* = 7), and Swedish (12.8%; *fi* = 6) were less recurrent.

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Figure 17. Primary teaching language of the current bioeconomy-related course (%)

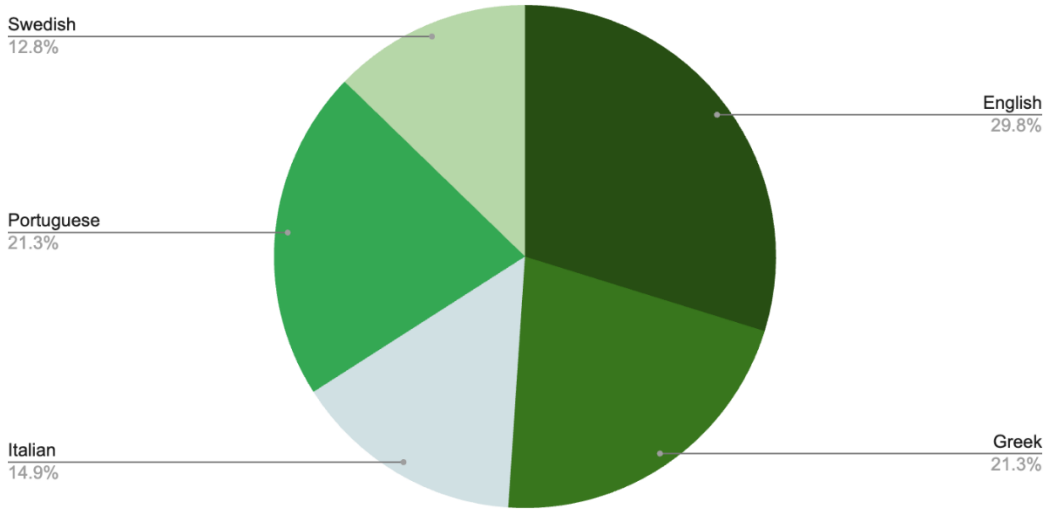
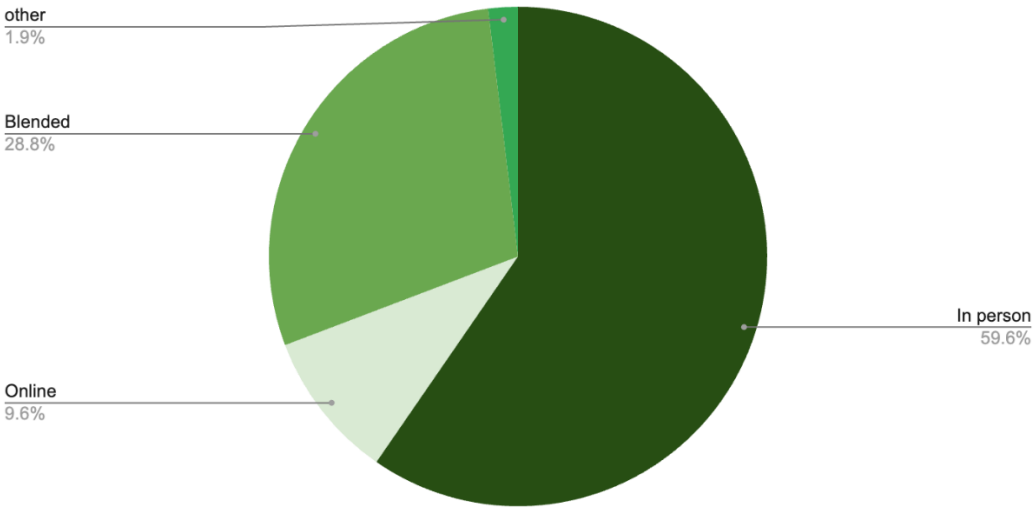


Figure 18 summarizes the most commonly used learning methods. Learning methods here stand for the use digital tools as for delivering bioeconomy-related training.

Figure 18. Learning methods of the current bioeconomy-related course (%)



The most common methodological approach to training in the bioeconomy-related training courses, according to the participants is in-person training in-person (59.6%; *fi* = 31), followed by the blended method (28.8%; *fi* = 15), online (9.6%; *fi* = 5), and other (1.9%; *fi* = 1).

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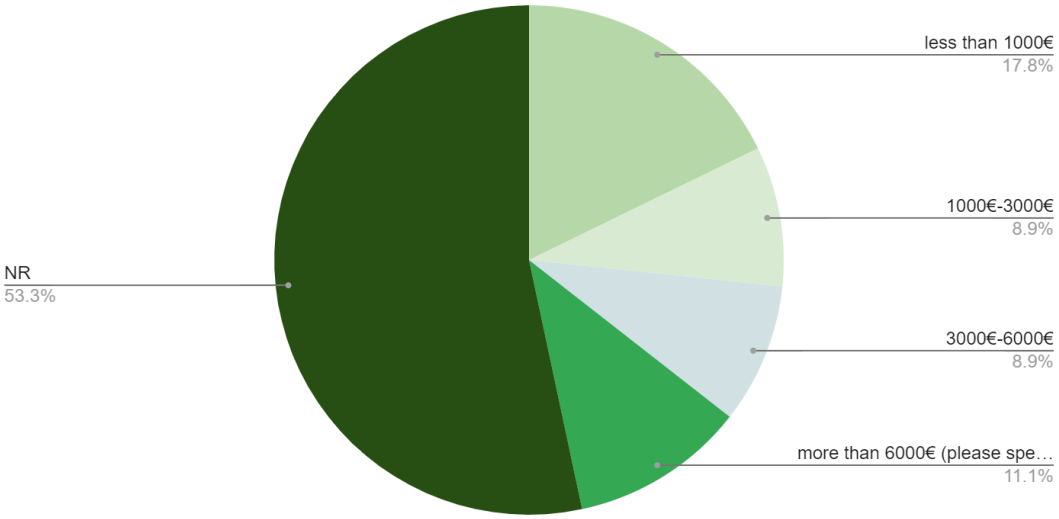
Figure 19 shows the tuition amount of the current bioeconomy-related courses (%) as indicated by the training providers.

Figure 19. Tuition amount (if any) of the current bioeconomy-related course (%)



Overall, tuition fees were implemented by half of the training providers (50.0%; *fi* = 23). Among these, tuitions ranged considerably from being less than 1000€ (17.8%; *fi* = 8), to more than 6000€ (11.1%; *fi* = 4), with some being in between1000€-3000€ and 3000€-6000€ (both 8.9%; *fi* = 4). It is important to note here, nevertheless, that tuition variability certainly overlaps with the variety of training opportunities provided by the surveyed training institutions, according to the results displayed in Figure 6. It is also important to note that most of the training providers did not provide any answer to this question (53.3%; *fi* = 24).

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Box 3. In the spotlight: Key conclusions stemming from the TNA: Training providers.

According to the training providers…

- Agriculture and forestry account for almost 50% of the training areas offered by VET providers. Interestingly, emerging areas associated with the green transition already account for almost 39.8% of all bioeconomy related training.
- VET is the predominant training approach to bioeconomy.
- In most cases, bioeconomy is nonetheless a relevant dimension of the training curricula. More than 70% of the training providers indicated that they offered at least 5 curricular units related to the sector.
- The goals associated with the provided bioeconomy training opportunities cover multiple targets, showing that the approach followed by the training providers inquired by the RELIEF project acknowledges the hybrid nature of the sector.
- Bioeconomy training is mostly provided as part of long-term curricula (lasting for 2 or 3 years). Short-term training is therefore less recurrent raising the question of how much specialization is offered in the sector.
- Almost a third of bioeconomy training is provided in English.
- Blended and online forms of training already account for almost 40% of the training delivered by the training providers enrolled in our survey.

5.1.2. Learners' qualifications and learning needs

The data analysed in the following subsection refers to the TNA conducted by the consortium with learners. Figure 20 summarizes the educational qualifications profile of the learners' involved in the study.

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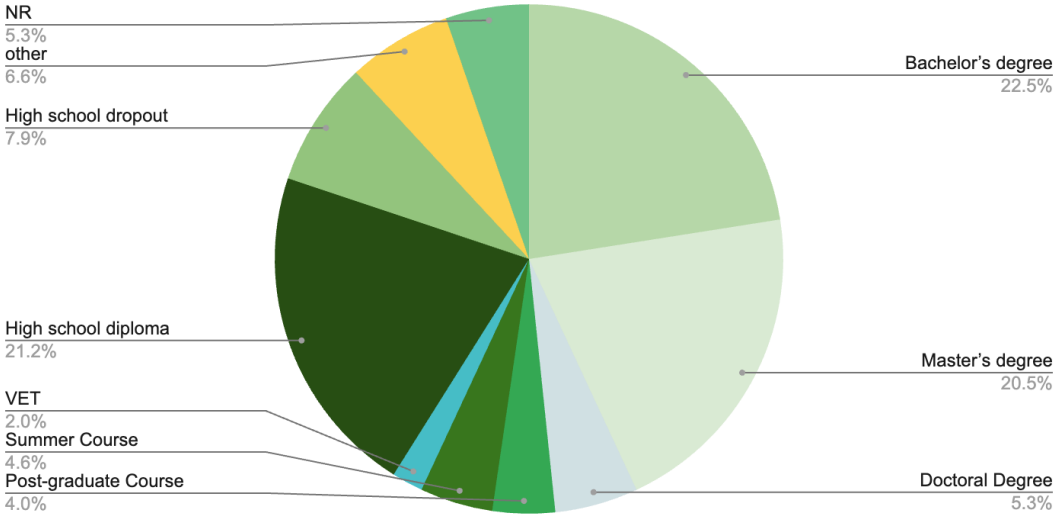
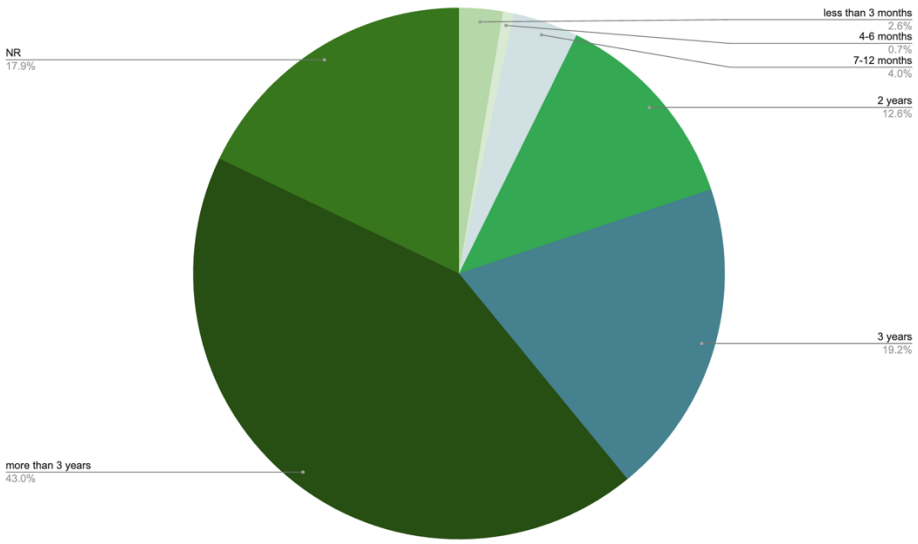
Figure 20. Learners' educational qualifications (%)



According to Figure 20, the participants were very diverse regarding their educational background. The most common qualification among the participants was bachelor's degree (22.5%; *fi* = 34), followed by high school diploma (21.2%; *fi* = 32), master's degree (20.5%; *fi* = 31), high school dropout (7.9%; *fi* = 12), other (6.6%; *fi* = 10), doctoral degree (5.3%; *fi* = 8), summer course (4.6%; *fi* = 7), post-graduate course (4.0%; *fi* = 6), VET (2.0%; *fi* = 3). Eight learners did not provide any answer to this question (5.3%; *fi* = 8). The graduation years range from 1976 to 2023.

Figure 21 depicts the duration of the latest qualification attained by the participants.

Figure 21. Duration of the latest qualification, course or degree attained (%)



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Unsurprisingly, and given the distribution by level of qualification, Figure 19 shows that the duration of the latest qualification, course or degree attained by the learners was a long-term one, whether it was more than 3 years (43%; *fi* = 65), 3 years (19.2%; *fi* = 29), or 2 years (12.6%; fi = 19). However, some of them were enrolled on 7-12 months (4.0%; *fi* = 6), less than 3 months (2.6%; *fi* = 4), or 4-6 months courses (0.7%; *fi* = 1). Importantly, 24 of the learners did not answer this question (53.3%; *fi* = 24).

Figure 22, in turn, depicts the number of curricular units/disciplines related to bioeconomy during the latest degree/qualification/course.

Figure 22. Number of curricular units/disciplines related to bioeconomy during the latest degree/qualification/course (%)

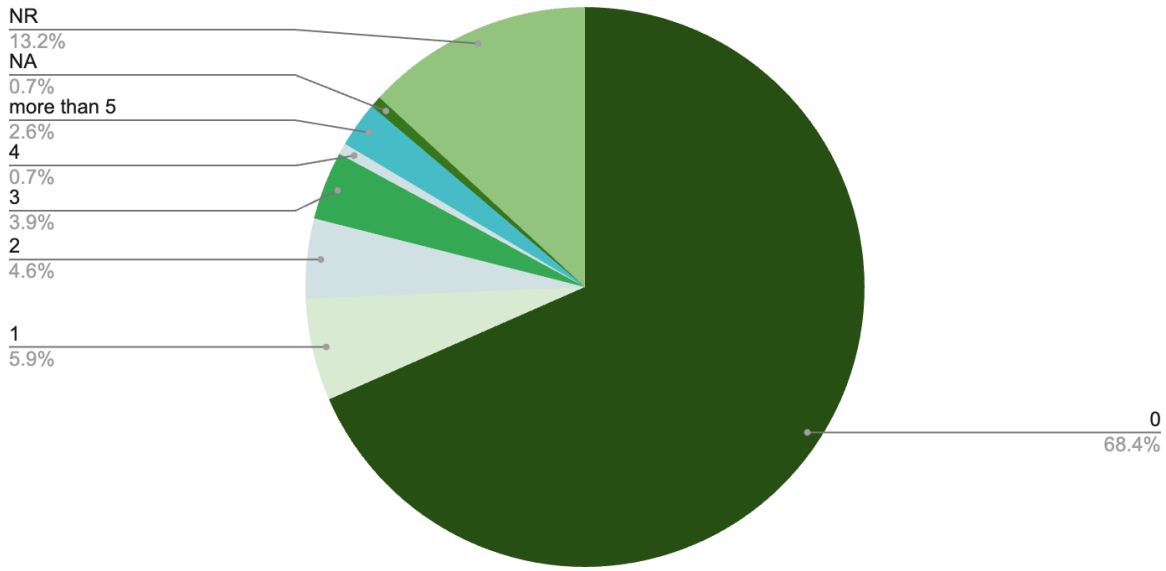

Figure 22 depicts the number of curricular units/disciplines related to bioeconomy the learners took during their latest qualification, course, or degree. Most of them reported 0 UC's (68.4%; *fi* = 104), followed by 1 UC (5.9%; *fi* = 9), 2 UC's (4.6%; *fi* = 7), 3 UC's (3.9%; *fi* = 5), more than 5 UC's (2.6%; *fi* = 4) and 4 UC's (0.7%; *fi* = 4). A part of the learners did not provide any answer to this question (13.2%; *fi* = 20). One of the learners considered this question not to be applicable (NA - 0.7%; *fi* = 1).

Figure 23 summarizes the learner's interests in bioeconomy areas for further training[3].

[3] Given the distribution of the professional background of the potential learners, and especially the low numbers of some professional categories (e.g., consultants) we organized the results by two main groups: farmers and agronomists/consultants/policy makers.

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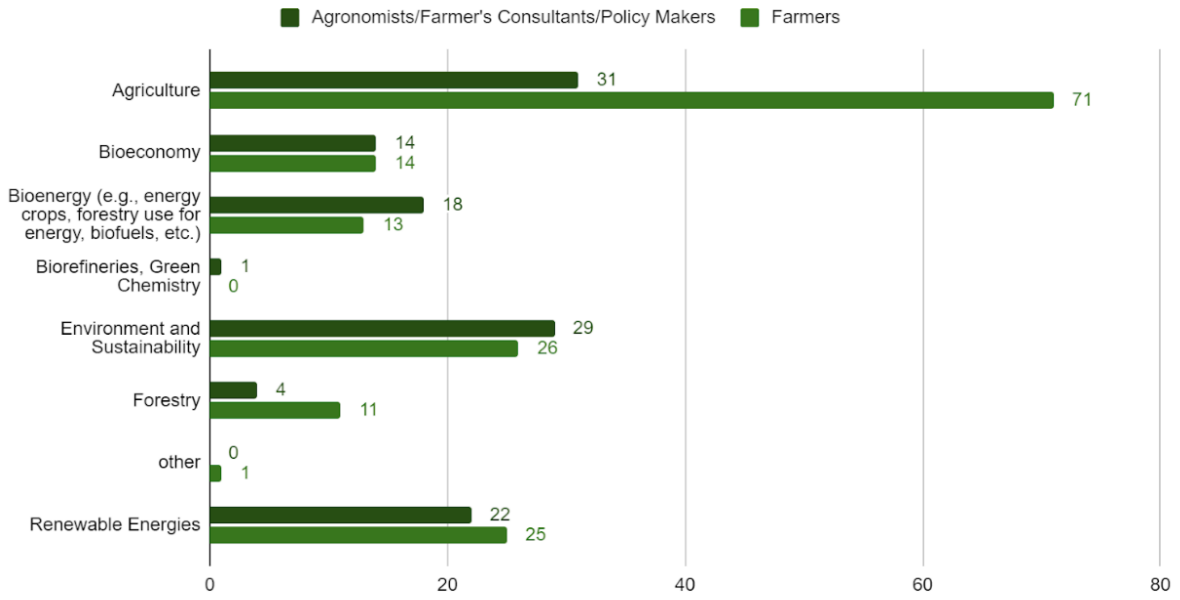
Figure 23. Most interesting bioeconomy areas for further training (count)



The participants clearly state a preference for agriculture as the most interesting area for promoting bioeconomy further training, irrespectively of being farmers (25.4%; *fi* = 71) or having another professional background (agronomists/farmer's consultants/policy makers) (11.1%; *fi* = 31). Training expectations associated to Environment and Sustainability (agronomists/farmer's consultants/policy makers - 10.4%; *fi* = 29; farmers - 9.3%; *fi* = 26) came second, followed by renewable energies, widely mentioned by farmers (8.9%; *fi* = 25) and agronomists/farmer's consultants/policy makers (7.9%; *fi* = 22). Bioenergy (e.g., energy crops, forestry use for energy, biofuels, etc.) also captured some attention among the respondents, although with different distributions among agronomists/farmer's consultants/policy makers' answers (6.4%; *fi* = 18) and farmers (4.6%; *fi* = 13). Bioeconomy was equally selected by both groups (5.0%; *fi* = 14); Forestry was selected mostly by farmers' (3.9%; *fi* = 11) compared to agronomists/farmer's consultants/policy makers' (1.4%; *fi* = 4). The option other areas was selected by only by one farmer (0.4%; *fi* = 1), while only one learner (i.e., agronomists/farmer's consultants/policy makers) answered Biorefineries, Green Chemistry (.4%; *fi* = 1).

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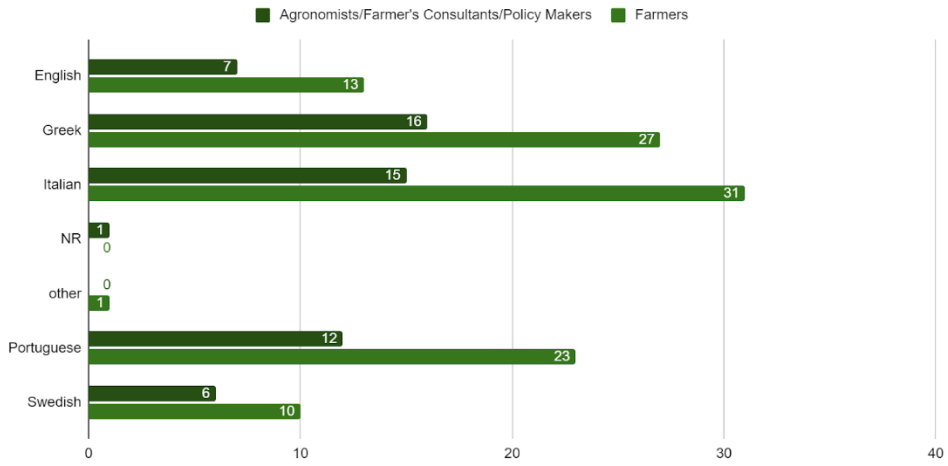
Figure 24 focuses on the preferred languages for conducting training.

Figure 22. Preferred teaching language for training (count)



According to Figure 24, the preferred teaching language for training differs depending on the country of the learner. Importantly, English is not the top preference for both farmers (8.0%; *fi* = 13) and agronomists/farmer's consultants/policy makers (4.3%; *fi* = 7). In general, both groups show a preference for their native languages as the most wanted teaching language for training.

Figure 25, in turn, focuses on the results of learners' preferred teaching methods.

Figure 25. Preferred learning methods and approach (count)

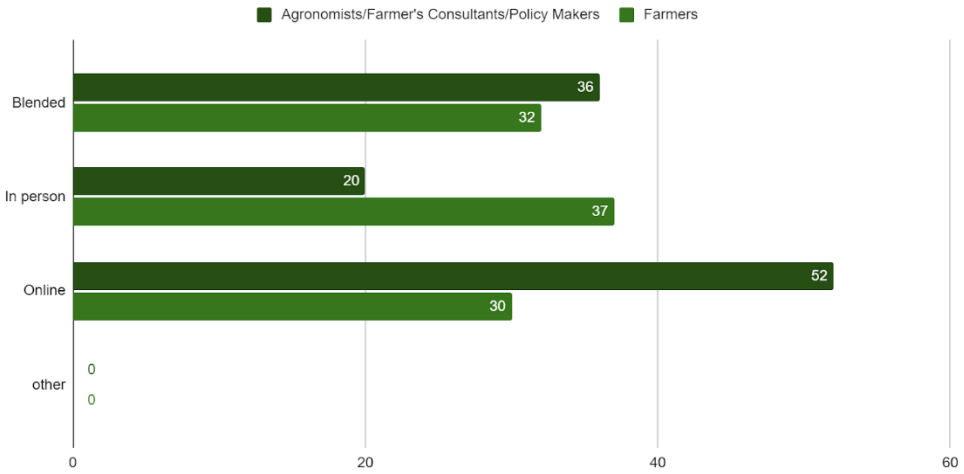


Figure 25 shows that the online method covers a great number of preferences in total. This was particularly true among agronomists/farmer's consultants/policy makers (25.1%; *fi*

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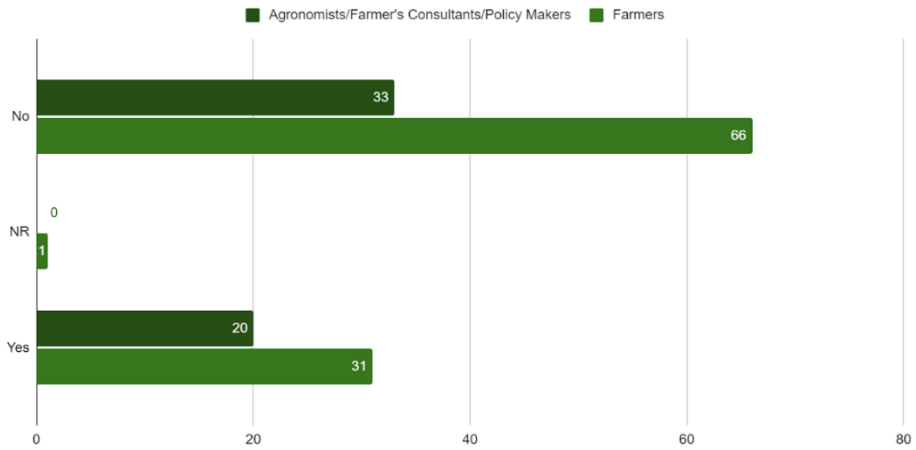
= 52) who more often preferred the online method when compared to farmers (14.5%; *fi* = 30). Blended method (in person+online) comes next and is preferred in almost evenly numbers by agronomists/farmer's consultants/policy makers (17.4%; *fi* = 36) and farmers (15.5%; *fi* = 32). Farmers showed more interest in learning in person (17.9%; *fi* = 37) than agronomists/farmer's consultants/policy makers (9.7%; *fi* = 20).

Figure 26 depicts the willingness of learners to pay tuition fees for bioeconomy-related training.

Figure 26. Willingness to pay tuition fees for bioeconomy-related training (count)



The inspection of Figure 26 reveals that most farmers are not willing to pay tuition fees for bioeconomy-related training (43.7%; *fi* = 66), seemingly to agronomists/farmer's consultants/policy makers (21.9%; *fi* = 33). A group of farmers (20.5%; *fi* = 31) were available to pay tuition fees, with a few more agronomists/farmer's consultants/policy choosing this option as well (21.9%; *fi* = 20).

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Figure 27 captures learners' perceptions regarding the most importance competences and skills to pursue a successful career in bioeconomy.

Figure 27. Most important competences and skills in pursuing a successful career as a "Bioeconomy specialist in Agriculture" (count)

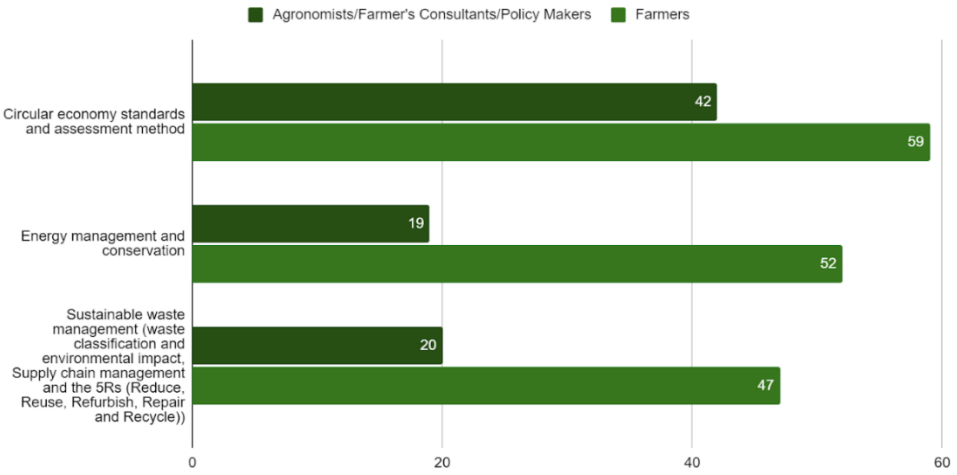

Figure 27 shows that circular economy standards and assessment method was the most often chosen option by both groups, especially by farmers (24.7%; *fi* = 59), compared to agronomists/farmer's consultants/policy makers (17.6%; *fi* = 42). Energy management and conservation came next among farmers (21.8%; *fi* = 52) and agronomists/farmer's consultants/policy makers (7.9%; *fi* = 19). Lastly, sustainable waste management (waste classification and environmental impact, supply chain management and the 5Rs (Reduce, Reuse, Refurbish, Repair and Recycle) among farmers (19.7%; *fi* = 47) and agronomists/farmer's consultants/policy makers (8.4%; *fi* = 20).

The final questions of the RELIEF survey for learners focused on the importance of different sets of skills to undertake bioeconomy activities. The selected skills are inspired by DigitComp and the EntreComp competences frameworks presented in section 3 of this report. Our inquiries are, thus, aligned with EU skills framework for digitalization and entrepreneurship. Mean results for the different items are presented – the adopted Likert scale ranges from 1 (not at all) to 5 (extremely important).

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Figure 28 specifically covers the items of the survey related with the perceived relevance of digital skills within the bioeconomy sector.

Figure 28. Importance of digital competences and skills to undertake bioeconomy activities (mean)

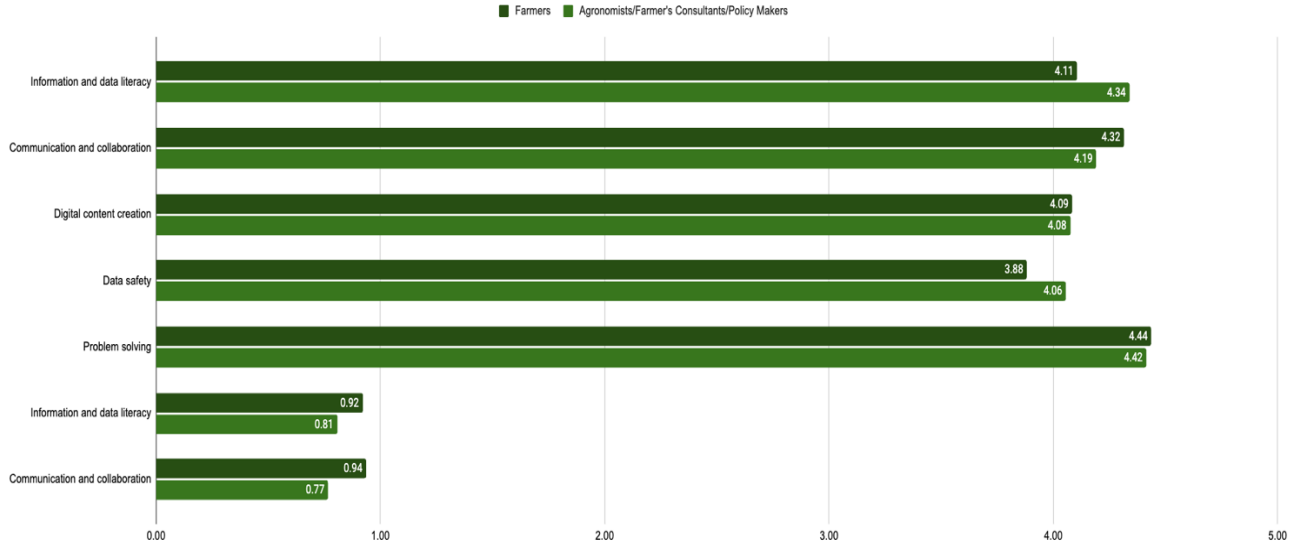

Figure 28 shows that, in general, both farmers and agronomists, consultants and policymakers give great a deal of importance to digital skills, with mean values above 4, contrary to information and data literacy and to communication and collaboration, with mean values below 1. It is also relevant to stress that mean values are similar across the two groups in each of the different digital competences/skills assessed.

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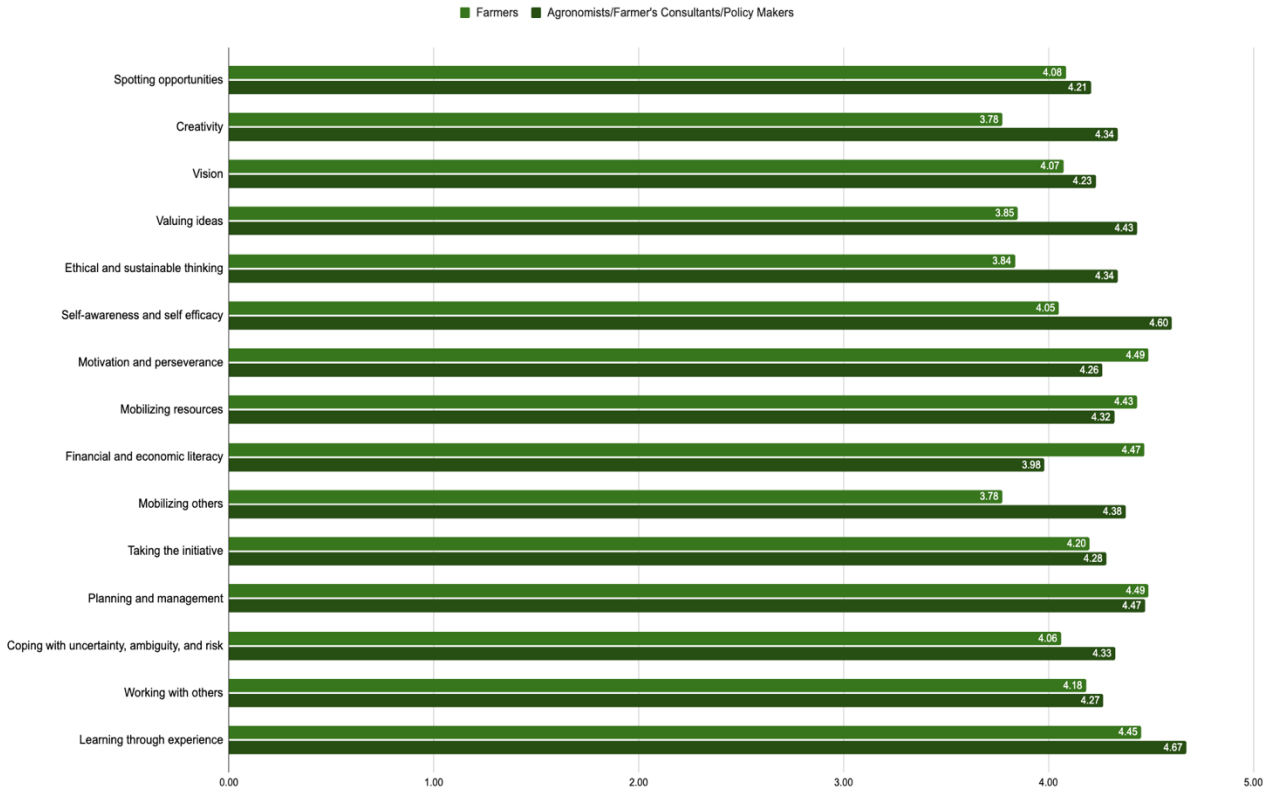
Figure 29, in turn, depicts the perceived importance of entrepreneurial and soft skills according to farmers and agronomists, consultants and policymakers.

Figure 29. Importance of entrepreneurial competences and soft skills to undertake bioeconomy activities (mean)



Overall, the pattern of mean results for both learners' groups found for entrepreneurial and soft skills depicted in Figure 29 is similar to the one found for digital competences and skills. Indeed, both farmers and agronomists, consultants and policymakers display considerably high values for all the proposed entrepreneurial and soft skills that might be relevant for the bioeconomy sector. There are, however, a few differences. For instance, farmers tend to give less importance, on average, to creativity, valuing ideas, ethical and sustainable thinking or self-awareness and self-efficacy compared to agronomists, consultants and policymakers. The reverse trend can be observed regarding financial and economic resources.

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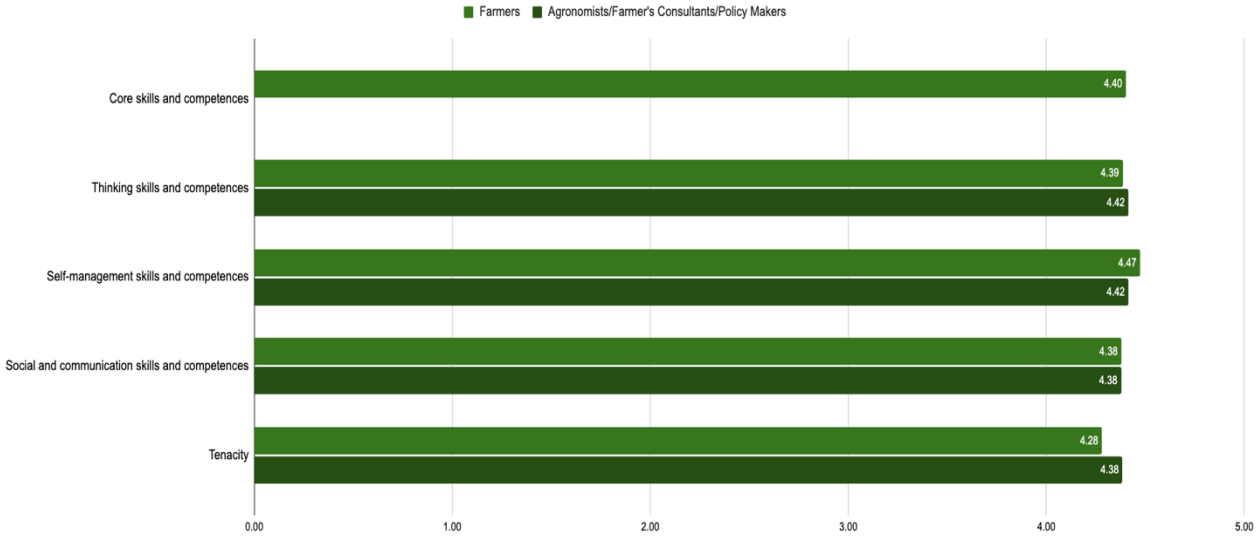
Figure 30 displays the average results from the importance of transversal skills to undertake bioeconomy activities[4].

Figure 30. Importance of transversal skills to undertake bioeconomy activities (mean)



Again, as it happened with the digital and with the entrepreneurial and soft competences as skills, both farmers and agronomists, consultants and policymakers had strong average perceptions, above level 4, about the relevance of transversal skills for undertaking bioeconomy activities.

The RELIEF consortium also wanted to understand which were the strengths and weaknesses of the bioeconomy training programs. Therefore, the final part of the survey was dedicated to these two points, covering a wide range of factors which can constitute both pros and cons to implement educational and training programs in this emerging sector.

[4] Only farmers were questioned about core skills and competences.

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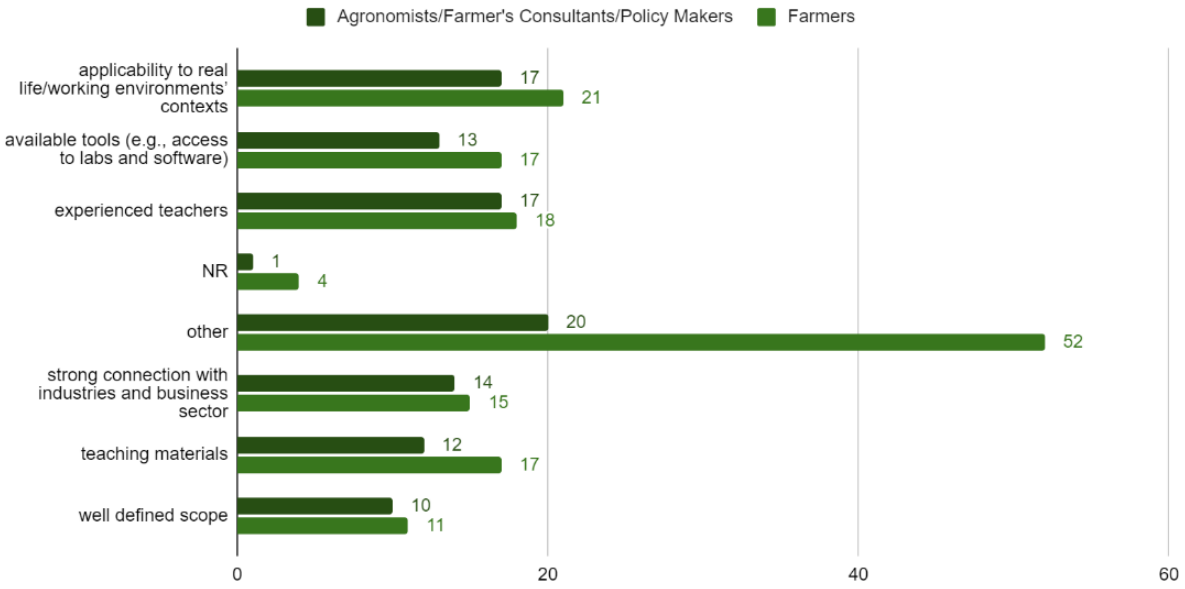
Figure 31 summarizes the results provided by the respondents regarding the strengths of the bioeconomy training programs.

Figure 31. Strengths of bioeconomy training programs (count)



According to Figure 31, there is not one of the proposed strengths that clearly stands out from the remaining others. Still, the most often selected strength among farmers (8.1%; *fi* = 21) and agronomists/farmer's consultants/policy makers (6.6%; *fi* = 17) was applicability to real life/working environments and contexts. Importantly, the most selected option was other, especially among farmers (20.1%; *fi* = 52) but also with a relevant number of answers among agronomists/farmer's consultants/policy makers (7.7%; *fi* = 20). Unfortunately, only rarely did the participants specified which other strengths did they have in mind.

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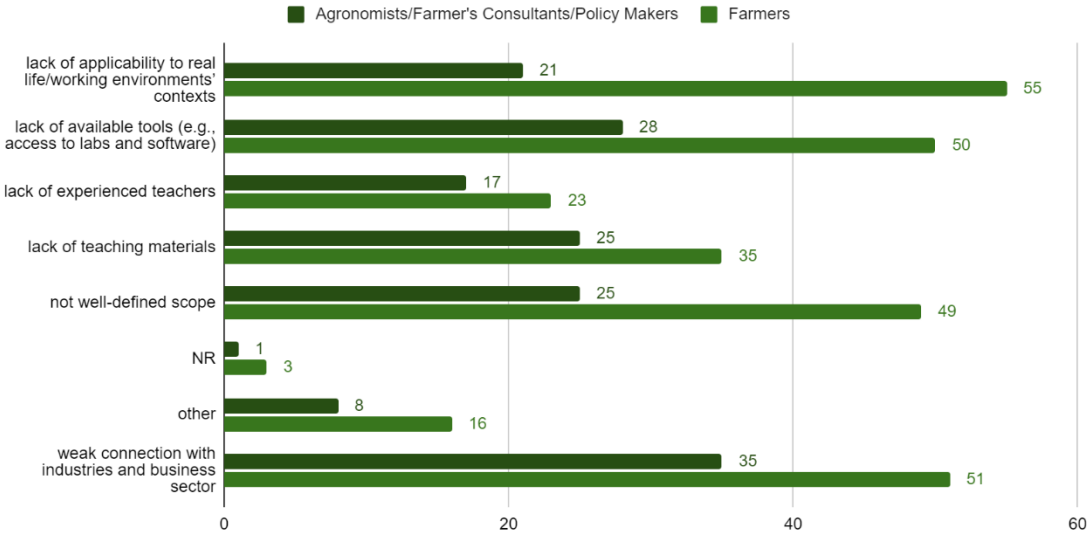
Figure 32 sums up the weaknesses of bioeconomy training programs.

Figure 32. Weaknesses of bioeconomy training programs (count)



One important trend emerging from Figure 32 is that farmers more often identify weaknesses compared to agronomists, consultants, and policymakers. That mismatch is clear regarding factors such as applicability to real life/working environments' contexts - farmers (12.4%; *fi* = 55); agronomists/farmer's consultants/policy makers (4.8%; *fi* = 21), followed by weak connection with industries and business sector - farmers (11.5%; *fi* = 51); agronomists/farmer's consultants/policy makers (7.9%; *fi* = 35), lack of available tools (e.g., access to labs and software), - farmers (11.3%; *fi* = 50); agronomists/farmer's consultants/policy makers (6.3%; *fi* = 28) - or not well-defined scope" - farmers (11.1%; *fi* = 49); agronomists/farmer's consultants/policy makers (5.7%; *fi* = 25).

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Box 4. In the spotlight: Key conclusions stemming from the TNA: Learners.

According to learners…

- The number of curricular units dedicated to bioeconomy is often low.
- The fact that farming is the main area of bioeconomy training indicates the need for training associated to practical knowledge (short-term trainings, upskilling/reskilling, VET).
- Programs delivered in English languages are not a priority among learners, whether they are farmers or agronomists/consultants/policymakers.
- Learners are somewhat open to the use of digitalization – although that seems to be more the case with agronomists, consultants and policymakers.
- The perceived importance of almost all digital skills is very high.
- High importance is given to all sets of skills beyond the technical skills, namely those covered by the DigiComp and the EntreComp frameworks. Still, it is relevant to underline that some skills related to direct management of these activities - funding - are more important, on average, for farmers.
- Weaknesses of training packages are very often selected by farmers.

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6. Discussion of results

6.1. Conceptual framework

In the following section we discuss in more detail the results of our report. Our discussion will combine three elements. First, we will specifically triangulate the results provided by RELIEF's critic review, with the identification of professional areas, the mapping of education and training opportunities and the training needs in the bioeconomy area according to training providers and learners. Second, the triangulation of data and informants will lead us to pinpoint the most relevant findings emerging from our different sources of information. Finally, and given the prospective nature of this report, we will further explore these findings by interpreting them according to the future-oriented concepts of **megatrends, trends, and weak signals**. Megatrends, trends, and weak signals are essentially conceptual instruments of prospective planning or social forecasting which help to anticipate socioeconomic developments, define management plans, resources allocation and establish impacts [85].

Megatrends correspond to forms of knowledge associated to mainstream developments that arise from environmental, social, and technological drivers and affect societies, policies, and markets and, thus, also education and training overall and in specific domains such as bioeconomy [86; 87]. Megatrends are an intersection of historical evolution with high objectivity- They are known for their potential to produce large societal impacts affecting large populations and territories – at a continental or even global scale [87]. Examples of megatrends relevant for the RELIEF aims are green transition, digitalization, or globalization. Of course, megatrends are not independent, producing multiple interactions, also known as synergies. These points of contact between megatrends are usually where major innovations occur producing large impacts for people and economies [87].

In turn, **trends** can be defined as a clear-cut social, economic, or technological development uphold by multiple credible sources as well as by relevant statistics. Trends can also be seen as a flow of changes that is not redirected easily. Trends usually are identified either by using longitudinal methodologies such as time-series analyses or by experts who have an in-depth knowledge of the latest changes within their fields. However, contrary to megatrends, which have a more decisive and widespread impact on whole

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societies and territories, trends are more localized and produce unequal impacts within a territory. Two good examples of some current trends are the development of sustainable consumption or rising populism in Western countries [87].

Finally, **weak signals** refer to current oddities, strange, unexpected issues that are thought to be in key position in anticipating future changes in organizations or more broadly in societies or environments. Identifying and using them in scenario work is thought to be relevant for looking further into the future and pertinent, in this case, to anticipate relevant prospects for bioeconomy education and training [88].

6.2. Bioeconomy education and training and megatrends

Some of the results presented by the RELIEF project in this report fit in well with some of the above-mentioned megatrends. Two intertwined megatrends that clearly intersect with the some of the results are the green transition and digitalization. The **green transition** refers to a shift towards economically sustainable growth and an economy that is not based on fossil fuels and overconsumption of natural resources. A sustainable economy relies on low-carbon solutions that promote the circular economy and biodiversity. In the EU context, the green transition is driven by the European Green Deal, a policy framework committed with a modern, resource-efficient, and competitive economy, ensuring: (a) no net emissions of greenhouse gases by 2050; (b) economic growth decoupled from resource use; and (c) no person and no place left behind [89]. Two findings stemming from our characterization of bioeconomy education and training main features are clearly aligned with the green transition megatrends.

Firstly, the ethos of the bioeconomy education and training programs is to tackle economic processes based on unsustainable production model that undermine environmental and social sustainability. This is demonstrated by both our critical review as well as by the mapping of available educational and training programs across the European Union and further extended by our TNA. Indeed, VET providers acknowledged that bioeconomy education and training programs more often aimed at fulfilling environmental sustainability goals (e.g., methodologies for environmental impact assessment) than to pure economic intentions, concepts or methods (e.g., systematic approach to conduct economic analysis to evaluate costs and benefits). Secondly, several of our data points show how education and training in the bioeconomy sector seems to be adjusting to the highly complex

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nature of the field as a response to the complex or “wicked” nature of the problems associated to the green transition. Indeed, our critical review started by demonstrating how bioeconomy and, consequently, bioeconomy education and training programs, correspond to interdisciplinary efforts stemming from the inputs of multiple scientific fields. The need for a high degree of complexity of bioeconomy education and training is further demonstrated by the ESCO catalogue of qualifications. New professional areas and demands associated to bioeconomy will require an increasing combination of different sets of knowledge in educational programs. Both training providers and learners add more details to this point. For instance, according to the training providers, while bioeconomy is by and large embedded in agriculture and forestry curricula, emerging areas associated with the green transition already account for almost 40% of all bioeconomy related training.

Two other findings emerging from this research effort of the RELIEF project are clearly aligned with another megatrend: **digitalization**. By digitalization we mean “a sociotechnical process of applying digitizing technologies to broader social and institutional contexts”, where digitizing refers to “a technical process of converting analogue signals into a digital form” [90]. To begin with, we found a relevant mismatch between the predominant teaching methodologies, according to our mapping of existing education and training programs and training providers, and the predominant teaching methodologies reported by learners in our TNA. Thus, while in the mapping and in the survey implemented with training providers, most of the education and training programs included in our database were delivered in person, learners showed a greater preference for online or blended teaching methods. Importantly, farmers are still those among learners that favour the least teaching methods other than in-person teaching. This finding deserves some thoughtful consideration. On one hand, there seems to be a gap between the teaching methods currently delivered by education and training institutions and the methodological approach expected by learners, which are more inclined towards the use of digital options. This contradiction is understandable after the COVID-19 pandemic as digitalized education has become widespread, particular in lifelong learning contexts. However, we must keep in mind that our mapping and survey is biased towards higher education programs and their representatives. Therefore, in-person teaching continues to the standard in this context, so this contradiction must be carefully considered. On the other hand, learners with higher professional qualifications (agronomists, consultants, policymakers) were more often open to the use of digital alternatives in education and training in bioeconomy than farmers. In principle, more

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qualified professionals are more exposed to the use of digital tools in their daily work routines and, therefore, are also more open to online education and training. This, of course, leads us to one additional though about farmers online learning experiences. In some cases, the use of digital tools might be a good way to reach out to them and to disseminate training experiences, especially in more remote areas, where training facilities and human resources are scarcer [84]. However, this option has significant limitations when digital literacy and connectivity (particularly in faraway rural areas) are low. These caveats are part of an extensive list of risks associated to digital inequalities which are relevant in this field of bioeconomy education and training [91]. Aside, one must also consider the importance given by learners in general to digital skills and competences in the RELIEF survey. Indeed, the average results are high in almost all the items dedicated to digital skills which here inspired by the DigiComp framework, described in section 3, showing that all types of learners do see the importance of digitalization in implementing bioeconomy activities. Interestingly, the low mean values in data literacy require two more comments. Firstly, people in general tend to overestimate their digital skills. Actual digital literacy – searching, finding, and purposively using information using digital tools – tends to be lower than perceived digital literacy. The needs to improve digital literacy are, in fact, one of the many requirements and emerging educational needs across EU countries (e.g., Portugal) [92]. That must be considered when designing new educational and training programs, both in terms of selecting the delivery or teaching methods, as well as on the inclusion of digital skills development as part of the curricular program. Moreover, the low average perception implying that collaboration is not embedded in the development of digital skills must be interpreted carefully, particularly in the case of farmers. Indeed, at least some qualitative studies [93] have shown that digital skills and tools are used by farmers to collaborate between each other, particularly to compensate the lack of support from official services in developing projects and skills in the farming sector. Thus, this result may not apply overall or, at least, in some rural areas.

Another finding stemming from the RELIEF project research efforts can be associated with another on-going trend, globalisation. Globalisation is defined in many ways. Overall, this notion encompasses as the spread of transplanetary – and in recent times also increasingly supraterritorial – connections between people. Globalisation depicts, thus, how the world has become a more connected and interdependent place through trade and technology exchanges [94]. One important element of globalisation is communication. It is

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evident how global exchanges demand greater communication between people and organizations. The use of common, standard language is, thus, essential to enable continued interactions between different geographic points, cultures, and groups of people at the planetary scale. In this context, the use of English is nowadays understood as a symbol of international exchanges, including in the education and training field. The RELIEF explored how much education and training in the bioeconomy domain is becoming more international by using English as the primary teaching language. Our results show different trends which only at the surface may reveal a tension. Our mapping reveals, for instance, that almost three quarters of the training programs included in our database are delivered in English. In turn, data arising from our TNA provided by both training providers and learners, show not only a lower proportion of education and training programs being delivered in English as well as a preference for native languages from learners. It is important to mention that our mapping ended up covering mainly advanced courses (e.g., MsC). The number of international programs taught in English is fast increasing in Europe across all knowledge domains, with bioeconomy and related areas being no exception. However, our TNA covered, as well, an important share of people without tertiary education and who may not master that well international languages. For them, it is of course more relevant to access learning environments in their native languages.

6.3. Bioeconomy education and training trends

As we have mentioned before, trends are emergent social, economic or technological developments supported by multiple data points and sources. In the case of education and training in the bioeconomy sector, trends are above all depicted by promising or relevant developments in the training supply and demand nexus.

A first trend emerging from the multiple data sources used by the RELIEF project and particularly from our critical review is that bioeconomy is becoming a more relevant area in curricula across Europe. Training providers involved in our survey also confirm this raising trend. Indeed, more than 70% of the training providers indicated that they offered at least 5 curricular units related to the sector. However, due to its complexity and novelty, bioeconomy education and training programs dissemination is not homogenous and more, important, is far from being an independent training field *per se*. Our TNA also shows that agriculture and forestry account for almost 50% of the bioeconomy-related training

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opportunities offered by training providers. Interestingly, however, emerging areas associated with the green transition already account for almost a big share of all bioeconomy related training. These education and training trends are to a great extent confirmed by different types of learners. Both farmers as well as agronomists, consultants and policymakers see bioeconomy as one important building block within the curricula of major, traditional knowledge fields such as farming, or of new, hybrid curricula driven by megatrends, such as the green transition. Curricula on environment and sustainability is a good example of this. Still, it is important to underline that a large share of learners also highlighted that the programs they have attained did not include any curricular units on bioeconomy topics. Given that many of the learners involved in our TNA had attained secondary education or less, it is feasible to think that many of them were enrolled in VET courses which did not comprise bioeconomy subjects. Most importantly, from the supply and demand perspective, our multiple data points show that education and training is a field going through a transition, showing unbalanced and even, somewhat, contradictory developments. Indeed, bioeconomy seems to be more and more relevant, especially in advanced training, where complex knowledge and skills are required. However, at the same time, the basics from bioeconomy seem to be less than a priority in VET training.

Another trend associated with the above-mentioned bioeconomy education and training transitional process is the lack of VET programs or curricular units in VET curricula in this area. This trend is particularly evident in our critical review but also in our mapping efforts (less the 10% of the programs included in the mapping were training programs). In addition, most of the learners that participated in our TNA did have a background in training rather than in higher education. In our survey they have confirmed the limited access to bioeconomy curricular units. VET is seen as a significant means of boosting educational attainment in all knowledge areas [84]. This view is embedded in the most recent strategic policies for the educational sector, such as the European Skills Agenda, which promotes the qualification of education and training as one of its three core axes [95]. This priority given to VET by the European Union authorities encompasses an increase of trainers' and trainees' mobility, greater cooperation between local/regional VET stakeholders, and the development of both technical and soft skills. VET is also a way to promote the rapid increase of the number of intermediate-level professionals, many of them described in the identification of ESCO qualifications related to the bioeconomy sector [96]. The proliferation of these professionals is key, especially in rural areas, where bioeconomy activities

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associated to farming, forestry or even new, emerging activities such as renewable energies are at the core of local economies. Overall, the share of these professionals, equipped with much-needed practical and problem-solving skills, is still low in these regions, hampering progress across several sectors, many of them included in the smart specialization regional strategies [96]. Filling in the gap of bioeconomy training supply in the VET sector is clearly a trend to be addressed in the years to come.

A third important trend emerging from RELIEF's research efforts is the one describing the framework of competences and skills necessary to undertake bioeconomy activities. Our survey does show that learners perceive that skills other than technical ones are key for being enrolled in the bioeconomy sector, in line with the EntreComp and DigiComp frameworks that were previously described. According to the collected data, this comprehensive catalogue of skills for bioeconomy professional success must include a high level of digital, entrepreneurial, soft, and transversal skills development. This general picture must, nevertheless, be nuanced by the types of learners and also by the fact that different levels of skills development (from foundational skills to proficiency) can be targeted by programs, according to their goals. Although more qualitative data here would be useful to fully support our interpretation, it seems that farmers are more clearly inclined to develop skills around managerial issues (e.g., funding) than agronomists, consultants, and policymakers. That is, of course, understandable, as they must manage their farms' challenges daily. Thus, monitoring and planning are key for them in order to balance profit with more sustainable production modes.

6.4. Bioeconomy education and training weak signals

Weak signals refer to current oddities or singularities which may help to anticipate future changes. We believe during our research efforts the RELIEF project has managed to capture some weak signals associated with bioeconomy education and training. These weak signals require further research but may be a starting point for further innovation and dissemination of bioeconomy educational programs, in the future.

One weak signal that we have detected is related with curricula duration. Bioeconomy training is mostly provided as part of long-term curricula (lasting for 2 or 3 years). Short-term training is therefore less recurrent raising the question of how much specialization is offered (and required) in the sector. However, considering the needs for upskilling/reskilling that are

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expected to increase in the years to come, due to groundbreaking technological progress, the preponderance of life-long learning paradigms as well as the European ambitions expressed in the European Green Deal, we anticipate short-term training opportunities will become more often available.

The assessment of weaknesses, particularly the one made by farmers, captured our attention as a potential weak signal. Farmers were quite keen in selecting several gaps in bioeconomy education and training packages. In a way, they seem to be capturing the unbalance between the high importance given to advanced training and the lack of short-term, problem-solving oriented training courses for professionals, as we have mentioned in the previous subsection. Our interpretation is that farmers represent a target group that will become more relevant to target in the years to come in the bioeconomy sector, something that does not seem to have been achieved until now.

Consequently, we must also consider the fact that an important part of the learners showed little to no motivation to pay tuition for training in bioeconomy. This weak signal coming from the data is very relevant if authorities want to consider expanding knowledge. If that is seen as a priority, then the allocation of public resources must be thoughtfully made, to ensure on-the-ground professionals, particularly farmers, are duly enrolled in educational packages.

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7. Recommendations

Based on the analysis of our results, according to the concepts of megatrends, trends and weak signals, we list below a series of recommendations for further supporting the development of the bioeconomy education and training. These recommendations are presented in no order of importance.

Balancing sustainability with economic dimensions in training and education | Matching the economic dimensions of the training programs with the sustainable environment principles, particularly to respond to the practical management needs that seem to be required by learners, especially by farmers in the bioeconomy-driven or bioeconomy-related education and training programs.

Complexity is and add-on for bioeconomy training packages, but also a challenge for selecting and updating technical skills of the teaching staff | The complexity of bioeconomy education and training with increasing overlaps between different scientific fields and multiple methodological approaches to programs delivery entails the need for training providers further supporting the development (upskilling and reskilling) of the technical skills of teachers and trainers.

Digitalization is not everything | Training providers must avoid an excessive techno-optimism. By this we mean that making bioeconomy training available online or using blended methods will not increase *per se* outreach and efficiency in delivering training programs. To avoid the problems associate to the digital divide that may affect potential learners in remote areas, especially farmers with lower digital skills, training providers must assess digital skills and literacy levels ahead of implementing any curricula. Training providers must also adjust content and structure to the targeted digital proficiency level.

English teaching is great, but it is not always good or better | Choosing the teaching language is an important aspect of setting an educational and training program in bioeconomy. Our results show that advanced courses are adopting English as the main teaching language as a standard. A continued effort to make advanced education and training in this area more international is required, to increase cross-borders cooperation and knowledge exchange. However, at secondary education levels and even at some intermediate training levels (EQF5), native language programs will continue to be needed,

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in order to increase the number of intermediate professionals in the field of bioeconomy, especially at the local/regional level.

Creating logical and linear education and training pathways, promoting coordination between the VET sector and higher education institutions | The development of bioeconomy-related education and training programs must look for a match between the learning of basic knowledge and skills at the secondary education level (especially in VET programs) and undergraduate levels that can, later one, be linked with advanced training courses on bioeconomy or in bioeconomy related fields. To achieve that, it is important that national training catalogues are reviewed and that a greater coordination between the VET sector and universities is achieved in terms of the curricular pathways offer.

The inclusion of bioeconomy in VET programs must be a priority | Bioeconomy is still far from being a relevant topic in EQF4 programs curricula. EQF5 programs specifically focusing on bioeconomy seem to be missing as well. Stakeholders must consider the dimension of VET bioeconomy curricula and curricular units as major priority for the sector.

Curricula (particular, non-standard ones) must adopt a person-centred approach | Our data shows suggests that curricula must adjust to different learners' profiles. This is a common place in education and training literature. It is, however, important to emphasize that curricula, particularly, non-standard ones which often have greater flexibility (e.g., MOOC courses, short-term courses) may benefit from co-creation design, putting potential learners at the centre stage of the process and, thus, ensuring the implementation of programs which are attuned with their expectations and needs. These approaches may more easily stream into the curricula the entrepreneurial and digital skills.

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8. Limitations

The RELIEF project tried to implement parallel data collection efforts and to involve different types of informers. This report combines, therefore, a critical review, with an identification of professional areas associated with the bioeconomy sector a mapping of training opportunities and TNA. This offered rich and nuanced data. However, we must highlight some limitations of our report. To begin with, our mapping task mostly identified education and training programs provided by universities. Training providers in our TNA were also, in most of the cases, representing the higher education sector. In turn, learners had a more diverse background, with some having concluded VET pathways. Thus, the data generated was at the same time extensive, but also somewhat contradictory. Future research efforts will expand our work by conduction specific research efforts at only secondary or tertiary education levels. This will increase the quality and specificity of conclusions and recommendations.

Another limitation had to do with the learners' distribution. While there was a clear intention of comparing on-the-ground professionals, namely farmers, with professionals with a more conceptual or decision-making profile (consultants, agronomists and policymakers), our consortium could have reached more nuanced conclusions if the four types of participants were enrolled in equivalent numbers. Intermediate professionals of specific fields associated with the bioeconomy sector (e.g., renewable energies) were also missing from the study.

Moreover, the open questions of the RELIEF TNA collected very few data points and could not be analysed in a proper way.

Finally, the unbalanced numbers of participants by country/type of profile (training provider, learner, type of learner) prevented country-based comparisons. Cross-country comparisons on the development of bioeconomy training and education packages is not only required but very informative as well.

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9. Conclusions

The picture of bioeconomy education and training across the European Union reminds us of someone going through adolescence. Indeed, the results seem to highlight growing pains typical of a transitional period full of opportunities, but also full of uncertainties.

It is undeniable that bioeconomy is an emerging sector. For the past few years, knowledge production, the number of professional occupations, and, consequently, the training packages associated with this sector have been increasing as our critical review and identification of professional pathways have underlined. Our mapping and TNA of bioeconomy educational and training programs further show that learning prospects in the sector are also becoming more relevant. These opportunities are being shaped by megatrends. The green transition leads to bioeconomy hybrid training packages or curricular units, often embedded in traditional scientific disciplines such as farming or forestry. These education and training programs and curricula seek to adapt to new and promising professional profiles stemming from the green transition.

Bioeconomy is also driven by digitalization megatrends. Specifically, learners are more and more inclined to be enrolled in online and blended teaching environments, although education and teaching institutions are still biased towards in-person teaching methods. This shift towards online learning methods is especially evident among those with higher qualifications (agronomists, consultants, and policymakers).

Aside, significant trends in bioeconomy education and training also stemmed from the RELIEF research efforts. For instance, due to its novelty, bioeconomy education and training are becoming more relevant across the European Union, but developments do not seem to be homogeneous across countries and educational levels. Importantly, the number of secondary education programs and VET associated with bioeconomy are still limited. Thus, education and training supply for practical seem to be slowly adapting to the demand for more practical competencies and skills in this sector.

Finally, it is also important to highlight that according to the learners involved in our TNA it is vital to disseminate comprehensive curricula in the bioeconomy sector, targeting technical, but also digital, entrepreneurial, soft, and transversal skills to address current professional requirements.

Our report suggests the need for balancing the core principles of sustainability with management requirements of training programs in the bioeconomy field, the need to support

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trainers and teachers' continuous professional development and updating, a thoughtful digitalization of learning programs, to avoid digital inequalities, especially among farmers, or the need to expand VET curricula associated with bioeconomy activities, in order to facilitate integrated training pathways from secondary education to advanced tertiary education.

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Annex 1. The identification and mapping of the relative existing ESCO occupations

ESCO	Occupation	Skills & Competences
1223.2	Research and development manager	analyse business objectives analyse external factors of companies analyse internal factors of companies assess the feasibility of implementing developments carry out strategic research identify new business opportunities interact professionally in research and professional environments manage budgets manage intellectual property rights manage personal professional development manage research and development projects manage staff mitigate waste of resources perform market research perform project management report analysis results represent the organisation seek innovation in current practices speak different languages synthesise information think abstractly think analytically
131	Production managers in agriculture, forestry and fisheries	analyse business objectives analyse external factors of companies analyse internal factors of companies assess the feasibility of implementing developments carry out strategic research identify new business opportunities interact professionally in research and professional environments manage budgets manage intellectual property rights manage personal professional development manage research and development projects manage staff mitigate waste of resources perform market research perform project management report analysis results represent the organisation seek innovation in current practices speak different languages synthesise information think abstractly think analytically
1349.12	Energy managers	adhere to organisational guidelines advise on heating systems energy efficiency advise on sustainable management policies advise on utility consumption analyse energy consumption carry out energy management of facilities conduct energy audit create manufacturing guidelines define energy profiles define manufacturing quality criteria develop business case

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		develop energy policy develop manufacturing policies develop staff establish daily priorities follow company standards identify energy needs liaise with managers manage budgets manage logistics manage staff manage supplies meet deadlines prepare energy performance contracts promote environmental awareness promote innovative infrastructure design promote sustainable energy strive for company growth supervise daily information operations
1349.13	Environmental protection managers	advise on efficiency improvements advise on environmental remediation coordinate environmental efforts develop company strategies develop environmental policy develop environmental remediation strategies ensure compliance with environmental legislation ensure compliance with policies implement environmental action plans implement strategic planning integrate strategic foundation in daily performance liaise with government officials liaise with managers liaise with politicians monitor company policy promote environmental awareness provide training in sustainable tourism development and management report on environmental issues
2131	Biologists, botanists, zoologists and related professionals	
2132.1	Agricultural scientist	advise on efficiency improvements advise on soil and water protection apply for research funding apply research ethics and scientific integrity principles in research activities communicate with a non-scientific audience conduct research across disciplines create soil and plant improvement programmes demonstrate disciplinary expertise develop professional network with researchers and scientists disseminate results to the scientific community draft scientific or academic papers and technical documentation educate on recycling regulations evaluate research activities identify improvement actions increase the impact of science on policy and society interact professionally in research and professional environments manage findable accessible interoperable and reusable data manage intellectual property rights manage open publications

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		manage personal professional development manage research data mentor individuals monitor the farm environmental management plan operate open source software perform market research perform project management perform scientific research promote inclusion in research promote open innovation in research promote the participation of citizens in scientific and research activities promote the transfer of knowledge provide advice to farmers provide advice to hatcheries publish academic research report on environmental issues report pollution incidents research livestock production speak different languages synthesise information think abstractly think analytically write scientific publications
2132.2	Agronomists	apply horticultural standards and practices apply safety procedures in laboratory consult with business clients execute analytical mathematical calculations gather experimental data maintain laboratory equipment manage livestock manage nutrients perform laboratory tests research improvement of crop yields supervise hygiene procedures in agricultural settings use agricultural information systems and databases write work-related reports
2133	Environmental protection professional	
2133.6	Environmental programme coordinator	analyse environmental data assess environmental impact carry out environmental audits conduct environmental surveys develop environmental policy ensure compliance with environmental legislation implement environmental action plans implement environmental protection measures perform environmental investigations promote environmental awareness provide training in sustainable tourism development and management report on environmental issues
2133.8	Natural resources consultant	advise on environmental remediation advise on nature conservation analyse ecological data assess environmental impact conduct ecological research

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		conduct environmental site assessments conserve natural resources develop environmental policy ensure compliance with environmental legislation monitor nature conservation
2133.11	Soil Scientist	advise on nature conservation apply safety procedures in laboratory conduct soil sample tests gather experimental data perform laboratory tests write work-related reports
2133.12	Sustainability manager	advise on corporate social responsibility advise on sustainability solutions advise on sustainable management policies analyse business requirements analyse supply chain strategies assess environmental impact assess the life cycle of resources carry out training in environmental matters conduct qualitative research conduct quantitative research coordinate environmental efforts ensure compliance with environmental legislation evaluate company needs forecast organisational risks lead the sustainability reporting process manage environmental management system manage recycling program budget measure company's sustainability performance mitigate waste of resources monitor social impact perform risk analysis promote environmental awareness use sustainable materials and components
2141.6	Leather production planner	adapt to changing situations create solutions to problems execute working instructions exert a goal-oriented leadership role towards colleagues identify with the company's goals liaise with colleagues manage quality of leather throughout the production process manage supplies meet deadlines negotiate with stakeholders schedule production think analytically use IT tools use communication techniques work in textile manufacturing teams
2143.1	Environmental engineer	abide by regulations on banned materials address public health issues adjust engineering designs advise on environmental remediation analyse environmental data approve engineering design carry out environmental audits conduct environmental surveys

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		develop environmental remediation strategies ensure compliance with safety legislation perform scientific research process customer requests based on the REACh Regulation 1907 2006 use technical drawing software
2143.1.4	Waste treatment engineer	adjust engineering designs advise on waste management procedures approve engineering design assess environmental impact develop hazardous waste management strategies develop non-hazardous waste management strategies develop waste management processes maintain waste collection records monitor legislation developments perform scientific research use technical drawing software
2143.2	Environmental experts	advise on environmental remediation advise on pollution prevention analyse environmental data assess environmental impact carry out environmental audits collect samples for analysis conduct environmental surveys create solutions to problems develop environmental policy develop environmental remediation strategies investigate pollution measure pollution perform environmental investigations provide training in sustainable tourism development and management report on environmental issues report pollution incidents
2149.5	Bioengineer	adjust engineering designs approve engineering design perform scientific research
2320.1.1	Agriculture, forestry and fishery vocational teacher	adapt teaching to student's capabilities adapt training to labour market apply intercultural teaching strategies apply teaching strategies assess students assist students in their learning develop course outline facilitate teamwork between students give constructive feedback guarantee students' safety instruct on safety measures maintain students' discipline manage student relationships monitor developments in field of expertise observe student's progress perform classroom management prepare lesson content provide lesson materials work in vocational school work with virtual learning environments
2422.12.1	Agricultural policy officers	advise on legislative acts

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		create solutions to problems develop agricultural policies liaise with local authorities maintain relations with local representatives maintain relationships with government agencies manage government policy implementation promote agricultural policies
2511.7	Green ICT consultant	apply business acumen consult with business clients create project specifications define technical requirements ensure compliance with environmental legislation manage environmental impact of operations optimise choice of ICT solution promote environmental awareness provide ICT consulting advice report on environmental issues
3112.7	Energy consultant	define energy profiles
3141.2	Scientific laboratory technician	apply safety procedures in laboratory calibrate laboratory equipment maintain laboratory equipment mix chemicals operate scientific measuring equipment perform laboratory tests perform sample testing prepare samples for testing record test data test chemical samples use chemical analysis equipment wear appropriate protective gear work safely with chemicals
3142.1	Agricultural technicians	analyse environmental data analyse scientific data analyse test data apply safety procedures in laboratory conduct field work execute analytical mathematical calculations gather experimental data maintain laboratory equipment write work-related reports
3143.1	Forestry technicians	apply forest legislation apply prescribed herbicides conduct reforestation surveys coordinate timber sales maintain forest roads maintain forestry equipment manage forest fires monitor logging operations monitor work site operate forestry equipment perform tree thinning plant green plants provide first aid supervise forestry workers vegetation control
3240.2	Veterinary technicians	apply safe work practices in a veterinary setting assist in administering veterinary anaesthetics

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		assist in general veterinary medical procedures assist in the administration of fluids to animals assist in veterinary surgery assist the veterinary surgeon as a scrub nurse control animal movement deal with challenging people handle veterinary emergencies maintain work environments in a veterinary practice manage animal biosecurity manage infection control in the facility manage personal professional development monitor condition of hospitalised animals monitor the welfare of animals prepare animals for anaesthesia prepare animals for veterinary surgery prepare environment for veterinary surgery prepare veterinary anaesthetic equipment provide first aid to animals support veterinary diagnostic imaging procedures support veterinary diagnostic procedures
3331.2.1.1 3331.2.1.2 3331.2.1.12 3331.2.1.13 3331.2.1.14 3331.2.1.19	Import export specialists in agricultural machinery and equipment Import export specialists in agricultural raw materials, seeds and animal feeds Import export specialists in fish, crustaceans and molluscs Import export specialists in flowers and plants Import export specialists in fruit and vegetables Import export specialists in live animals	administer multi-modal logistics apply conflict management apply export strategies apply import strategies build rapport with people from different cultural backgrounds communicate with shipment forwarders create import-export commercial documentation create solutions to problems ensure customs compliance file claims with insurance companies handle carriers handle quotes from prospective shippers have computer literacy meet deadlines monitor merchandise delivery plan transport operations speak different languages
3359.1	Agricultural inspector	analyse business processes collect samples for analysis communicate health and safety measures conduct environmental surveys enforce sanitation procedures ensure compliance with legal requirements follow up complaint reports identify hazards in the workplace monitor work site perform inspection analysis undertake inspections write work-related reports
6111.1	Agronomic crop production team leader	ensure soil fertility execute disease and pest control activities execute fertilisation grow plants harvest crop maintain plant health maintain plant soil nutrition

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		maintain storage facilities maintain technical equipment manage agricultural staff monitor fields operate agricultural machinery prepare equipment for harvest prepare planting area propagate plants store crops store products supervise hygiene procedures in agricultural settings
6112	Tree and shrub crop growers	
6113	Gardeners, horticultural and nursery growers	
6114	Mixed crop growers	
612	Animal producers	
6130.1	Farm manager	assess new farming technologies manage farm products manage farm supplies manage production enterprise market farm products negotiate loan agreements operate farm equipment present the farm facilities supervise hygiene procedures in agricultural settings
6130.2	Mixed farmer	agronomical production principles crop production principles environmental legislation in agriculture and forestry health and safety regulations livestock farming systems livestock reproduction sustainable agricultural production principles
6310	Subsistence crop farmers	
6320	Subsistence livestock farmers	
6330	Subsistence mixed crop and livestock farmers	

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Annex 2. The EntreComp and DigComp framework competencies

1st Area- Ideas & Opportunities

Competence	Hint	Description for farmers
1.1 Spotting opportunities	Use your imagination and abilities to identify opportunities for creating value (Bacigalupo, M. et al, 2016)	Farmers need to be able to identify new market trends and opportunities to diversify their income streams. They need to be able to keep up with changing consumer demands and find new ways to meet their needs. Market research: By analysing market trends, consumer preferences, and the competitive landscape, farmers can identify gaps in the market and develop new products or services to fill those gaps. Networking: Networking with other farmers, industry professionals, and suppliers can help farmers stay informed about new developments in their field and identify potential partnerships or collaborations. Technology adoption: By adopting new technologies, farmers can increase productivity, reduce costs, and develop new products and services. Diversification: By adding value to their existing products or developing new products, farmers can increase their profitability and reduce their dependence on a single crop or commodity.
1.2 Creativity	Develop creative and purposeful ideas (Bacigalupo, M. et al, 2016)	Farmers need to be creative in developing new products, processes, and marketing strategies to stay competitive.
1.3 Vision	Work towards your vision of the future (Bacigalupo, M. et al, 2016)	Farmers need to have a clear vision of where they want their farm business to go and how they will get there. They need to be able to set goals and objectives and plan for the future.
1.5 Ethical and sustainable thinking	Assess the consequences and impact of ideas, opportunities and actions (Bacigalupo, M. et al, 2016)	Sustainable thinking enables farmers to make informed decisions that balance economic, social, and environmental concerns. It can be beneficial, for example, in the following ways:

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		Resource management: Farmers who think sustainably can better manage their resources, including water, soil, and biodiversity. By using sustainable practices, such as crop rotation, cover cropping, and reduced tillage, farmers can improve soil health, conserve water, and reduce the use of synthetic fertilisers and pesticides. Innovation: For example, farmers can use precision agriculture technologies to reduce inputs and optimise yields or use renewable energy technologies to power their farms. Risk management: By adopting practices that promote biodiversity and soil health, farmers can reduce the impact of climate change on their farms and increase their resilience to weather-related events. Branding: Consumers are increasingly concerned about sustainability and are willing to pay a premium for products that are produced in an environmentally friendly and socially responsible manner. By adopting sustainable practices, farmers can differentiate themselves in the market and attract environmentally conscious consumers.

2nd Area- Recourses

Competence	Hint	Description for farmers
2.3 Mobilising resources	Gather and manage the resources you need (Bacigalupo, M. et al, 2016)	Mobilising resources is essential for farmers to succeed in their businesses. Farmers need to access and manage various resources, including land, water, labour,

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		capital, and technology, among others. Financial management: includes creating and following a budget, monitoring cash flow, and keeping accurate financial records. Farmers may also seek financial support through loans, grants, or other financial instruments. Land management: Land is a critical resource that needs to be managed effectively to maximise productivity and profitability. This involves soil conservation, water management, crop rotation, and using sustainable farming practices. Labour management: This involves recruiting and training employees, managing work schedules, and ensuring safe and healthy working conditions. Technology adoption: This involves adopting new technologies, such as precision agriculture, crop monitoring systems, and automated machinery. Partnership and collaboration: This can involve sharing knowledge and expertise, pooling resources and equipment, and developing joint marketing and sales strategies.
2.4 Financial & economic literacy	Develop financial and economic know-how (Bacigalupo, M. et al, 2016)	Financial literacy a skill that should enable farmers to manage their finances effectively, make informed financial decisions, and achieve their financial goals. Budgeting and financial planning: By understanding their income, expenses, and cash flow, farmers can make informed decisions about investments, savings, and debt management. Risk management: By understanding financial concepts such as insurance, hedging, and diversification, farmers can protect their income and minimise their financial losses.

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		Access to finance: By understanding financial statements, credit reports, and loan requirements, farmers can present themselves as trustworthy borrowers and secure the financing they need to invest in their farms. Investment and wealth creation: By understanding investment concepts such as return on investment, net present value, and asset allocation, farmers can make informed decisions about allocating their resources for maximum financial benefit. Record-keeping and financial reporting: Financial literacy helps farmers to keep accurate records and prepare financial reports, such as profit and loss statements and balance sheets. These reports enable farmers to monitor their financial performance and identify areas for improvement.
2.5 Mobilising others	Inspire, enthuse and get others on board (Bacigalupo, M. et al, 2016)	Leadership: Farmers need to be able to lead and motivate their employees, and build strong relationships with suppliers, customers, and other stakeholders. Communication: Farmers need to be able to communicate effectively with a range of stakeholders, including customers, employees, suppliers, and regulators.

3rd Area- Into Action

Competence	Hint	Description for farmers
3.1 Taking the initiative	Go for it (Bacigalupo, M. et al, 2016)	Farmers need to be proactive in seeking out new opportunities and taking action to pursue them. They need to be willing to take risks and try new things.
3.2 Planning & Management	Prioritise, organise and follow up (Bacigalupo, M. et al, 2016)	Goal setting: Farmers should set clear and specific goals- long, medium and short-term goals, and defy their priorities, such as

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		increasing productivity, expanding operations, or improving profitability. This involves identifying key performance indicators, developing a plan of action, and tracking progress towards achieving these goals. Budgeting and financial management: A budget and financial plan should be developed in order to manage their cash flow and ensure they have the necessary resources to achieve their goals. This involves tracking income and expenses, monitoring financial performance, and adjusting as needed. Time management: Effective management of time for farmers should include prioritizing tasks, scheduling work activities, and delegating responsibilities to other farm members. Risk management: Weather conditions, market fluctuations or disease outbreaks should be identified and should lead to developing contingency plans, obtaining insurance coverage, and diversifying operations to minimize risks. Resource management: Farmers' resources such as soil, water, and energy must be managed to maximize productivity and minimize waste. This involves implementing sustainable farming practices, such as crop rotation, water conservation, and energy-efficient technologies.
3.3 Coping with uncertainty, ambiguity & risk	Make decisions dealing with uncertainty, ambiguity and risk (Bacigalupo, M. et al, 2016)	Farming is an employment that is very fickle and holds big risks as the outcome of farming depends not only on the farmer itself but also on external factors such as extreme weather conditions or physical

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		phenomena. Being able to handle fast-moving situations promptly and flexibly is a competence of much necessity for farmers. Coping with uncertainty, ambiguity, and risk is an important skill for farmers, as these factors are inherent in the agricultural industry. For farmers, dealing with uncertainty can be done through the following actions: Diversification: They can enhance their diversification by adding a variety of crops, raising different types of livestock, and exploring alternative revenue streams, such as agritourism. Risk management strategies: Implementing a risk management strategy is essential for farmers to protect themselves from losses due to adverse weather conditions, market fluctuations, or other unforeseen circumstances. Planning and preparation: This involves conducting risk assessments, developing emergency response plans, and regularly reviewing and updating them. Information and knowledge: Farmers can stay informed and up to date on industry trends, best practices, and emerging technologies by attending workshops, conferences, and training programs, as well as seeking advice and guidance from agricultural experts and other farmers.
3.4 Working with others	Team up, collaborate and network (Bacigalupo, M. et al, 2016)	Networking: Farmers need to be able to build and maintain a network of contacts in the agricultural industry and beyond. This can help them to access new markets, find new suppliers, and

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		stay up to date on industry developments. Teamwork: Farmers often work as part of a team, whether with family members, employees, or other stakeholders. They need to be able to collaborate effectively with others to achieve their common goals.

1. Information and data literacy

1.1 BROWSING, SEARCHING AND FILTERING DATA, INFORMATION AND DIGITAL CONTENT	At basic level and with guidance, I can: At basic level and with autonomy and appropriate guidance where needed, I can:	• identify my information needs, find data, information, and content through a simple search in digital environments, • find how to access these data, information and content and navigate between them, • identify simple personal search strategies. (Vuorikari, R., et al., 2022) Identifying Information Needs: Farmers should be able to recognise their information needs and understand what specific data or knowledge they require to make informed decisions in their farming practices. This involves identifying gaps in their current knowledge and determining the type of information that can help address those gaps. Searching and Retrieving Data: Farmers need to be proficient in searching for relevant data and information using online databases, agricultural portals, research papers, government reports, or other reliable sources. They should be able to use appropriate search terms, filters, and techniques to retrieve accurate and up-to-date data.

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1.2 EVALUATING DATA, INFORMATION AND DIGITAL CONTENT	At basic level and with guidance, I can: At basic level and with autonomy and appropriate guidance where needed, I can:	• detect the credibility and reliability of common data sources, information and their digital content. (Vuorikari, R., et al., 2022) Evaluating Information Sources: It is crucial for farmers to critically evaluate the credibility, reliability, and relevance of the information sources they encounter. They should consider factors such as the author's expertise, the publication's reputation, potential biases, and the currency of the information. This helps ensure that they rely on accurate and trustworthy data for decision-making.
1.3 MANAGING DATA, INFORMATION AND DIGITAL CONTENT	At basic level and with guidance, I can: At basic level and with autonomy and appropriate guidance where needed, I can:	• identify how to organise, store and retrieve data, information and content in a simple way in digital environments. • recognise where to organise them in a simple way in a structured environment. (Vuorikari, R., et al., 2022) Managing and Organizing Data: With the increasing use of digital technologies in agriculture, farmers must develop skills to manage and organize their data efficiently. This involves implementing appropriate data storage solutions, maintaining data integrity, and ensuring data security and privacy.

2. Communication and Collaboration

2.1 INTERACTING THROUGH DIGITAL TECHNOLOGIES	At basic level and with guidance, I can: At basic level and with autonomy and appropriate guidance where needed, I can:	• select simple digital technologies to interact with, and • identify appropriate simple communication means for a given context. (Vuorikari, R., et al., 2022) Digital Communication Tools: Farmers should familiarize themselves with various digital

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		communication tools and platforms that facilitate efficient and effective communication. This includes email, instant messaging applications, video conferencing tools, and online collaboration platforms. They should use these tools to connect with suppliers, customers, fellow farmers, agricultural experts, and other relevant stakeholders. Online Networking: Farmers can learn to engage in online networking activities by joining agricultural communities, forums, and social media groups related to farming. Participate in discussions, ask questions, and share experiences to learn from and connect with peers, experts, and industry professionals. Platforms like LinkedIn, Facebook groups, or specialized agricultural forums can provide valuable networking opportunities.
2.2 SHARING THROUGH DIGITAL TECHNOLOGIES	At basic level and with guidance, I can: At basic level and with autonomy and appropriate guidance where needed, I can:	• recognise simple appropriate digital technologies to share data, information and digital content. • identify simple referencing and attribution practices. (Vuorikari, R., et al., 2022) Sharing Knowledge and Experiences: Farmers should utilize digital platforms to share their knowledge, experiences, and best practices with others. This can include maintaining a blog, writing articles, creating educational videos, or contributing to online agricultural resources. Sharing their insights can contribute to the collective knowledge of the farming community and foster collaboration.
2.6 MANAGING DIGITAL IDENTITY	At basic level and with guidance, I can: At basic level and with autonomy and appropriate guidance where needed, I can:	• identify a digital identity, • describe simple ways to protect my reputation online, • recognise simple data I produce through digital tools,

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		environments, or services. (Vuorikari, R., et al., 2022) They should use digital platforms to promote their farm products or services, engage with customers, and build relationships. This can involve maintaining a professional website, utilizing social media for marketing campaigns, or participating in online marketplaces or farmer's markets.

3. Digital Content Creation

3.1 DEVELOPING DIGITAL CONTENT	At basic level and with guidance, I can: At basic level and with autonomy and appropriate guidance where needed, I can:	• identify ways to create and edit simple content in simple formats, • choose how I express myself through the creation of simple digital means (Vuorikari, R., et al., 2022) Text Documents: Farmers can use basic word processing software like Microsoft Word, Google Docs, or even simple text editors to create and edit text-based documents. These documents can include farm reports, field notes, crop plans, or written communications. Spreadsheets: Spreadsheets are useful for organising and managing data related to farm operations. Farmers can use software like Microsoft Excel, Google Sheets, or similar applications to create and edit spreadsheets for tasks such as crop inventories, budget tracking, yield calculations, or livestock records. Presentations: Creating presentations can help farmers effectively communicate information to stakeholders. Presentation software like Microsoft PowerPoint, Google Slides, or similar tools allows farmers to create slideshows with text, images, and charts to convey information about farm projects,

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		market analysis, or community presentations. Images and Graphics: Farmers can utilise simple image editing tools to modify and enhance photographs or graphics. This can be useful for creating visual content for marketing materials, social media posts, or website updates. Videos: Video content can be engaging and informative for sharing farm activities or demonstrating farming techniques. Farmers can use basic video editing software like iMovie (for Mac users), Windows Movie Maker (for Windows users), or online video editors to trim, merge, and add basic effects to video clips captured on smartphones or cameras. Social Media Content: Farmers can create and edit content tailored to social media platforms.
3.2 INTEGRATING AND RE-ELABORATING DIGITAL CONTENT	At basic level and with guidance, I can: At basic level and with autonomy and appropriate guidance where needed, I can:	• select ways to modify, refine, improve and integrate simple items of new content and information to create new and original ones. (Vuorikari, R., et al., 2022)
3.3 COPYRIGHT AND LICENCES	At basic level and with guidance, I can: At basic level and with autonomy and appropriate guidance where needed, I can:	• identify simple rules of copyright and licenses that apply to data, digital information and content. (Vuorikari, R., et al., 2022) Copyright Basics: Copyright is a legal protection granted to the creators of original works, including written content, images, videos, and more. It gives the creator exclusive rights to reproduce, distribute, and display their work. Generally, it should always be assumed that content is protected by copyright unless explicitly stated otherwise. Intellectual Property Rights: Respect the intellectual property rights of others. Avoid using or reproducing copyrighted material without proper permission from the copyright

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		holder. This includes photos, articles, videos, and any other content created by someone else. Public Domain: Public domain refers to works that are not protected by copyright or whose copyright has expired. These works can be freely used, shared, and modified without permission. However, it's important to verify the public domain status of a work before using it, as there may be certain conditions or limitations. Creative Commons Licenses: Creative Commons licenses allow content creators to grant permissions beyond what copyright law allows. These licenses allow others to use, modify, and share the work, subject to certain conditions specified by the license. When using content licensed under Creative Commons, ensure that you comply with the specific terms of the license, which may include giving attribution to the original creator. Open Data and Open Source: Open data and open-source licenses promote the sharing and collaborative use of data and software. Open data refers to datasets that are freely available and can be used, modified, and shared by anyone. Open-source licenses apply to software and allow users to view, modify, and distribute the source code. When utilizing open data or open-source software, adhere to the terms and conditions specified by the respective licenses.

4. Safety and Security

4.1 PROTECTING DEVICES	At basic level and with guidance, I can: At basic level and with autonomy and appropriate	• identify simple ways to protect my devices and digital content, and • differentiate simple risks and threats in digital environments.

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	direction where needed, I can:	• choose simple safety and security measures, and • identify simple ways to have due regard to reliability and privacy. (Vuorikari, R., et al., 2022) Farmers should be able to protect their devices by knowing how to use strong and unique passwords for their devices. They should know how to enable Two-Factor Authentication and install reliable antivirus software. It is also important to understand and tell apart simple risks and threats, such as data loss and losing important farm records, unauthorised access to their devices, and falling victim to phishing attempts where cybercriminals use deceptive techniques to trick them and get access to personal or financial details.
4.2 PROTECTING PERSONAL DATA AND PRIVACY	At basic level and with guidance, I can: At primary level and with autonomy and appropriate direction where needed, I can:	• select simple ways to protect my personal data and privacy in digital environments, • identify simple ways to use and share personally identifiable information while protecting myself and others from damage. • identify simple privacy policy statements of how personal data is used in digital services. (Vuorikari, R., et al., 2022) Farmers should use strong and unique passwords for their devices by using a combination of letters, numbers, and special characters. They should know how to enable Two-Factor Authentication (2FA): to add an extra layer of security by requiring a second form of verification. It is necessary to know how to update their software and devices and learn how to regularly install security patches and updates

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		to protect themselves against known vulnerabilities. They should also be cautious with emails and links when opening them, especially those from unknown senders. They can also secure their farm's wireless Network. Learning to be mindful of sharing personal information is also important. They should be cautious when sharing personal information online, particularly on social media platforms and should limit the amount of personal information they publicly share, such as their full name, address, or contact details, to minimise the risk of identity theft. They have also to be able to review basic privacy settings: Regularly review and adjust privacy settings on their online accounts and social media platforms. Using secure websites is another way to protect their data. When conducting online transactions or sharing sensitive information, they should ensure they are using secure websites like those who look like "https://" at the beginning of the website URL. Making regular backups of their important data and files is necessary to be protected against data loss from hardware failure, theft, or cyberattacks.
4.3 PROTECTING HEALTH AND WELL-BEING	At basic level and with guidance, I can: At basic level and with autonomy and appropriate direction where needed, I can:	• differentiate simple ways to avoid health risks and threats to physical and psychological well-being while using digital technologies. • select simple ways to protect myself from possible dangers in digital environments. • identify simple digital technologies for social well-being and social inclusion. (Vuorikari, R., et al., 2022) Digital Balance: Farmers can learn to maintain a healthy balance between

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		their digital activities and other aspects of their life. They can learn to avoid excessive screen time and make time for physical activity, rest, and social interactions. They should set boundaries for their digital use and prioritize self-care to prevent burnout and promote overall well-being. Online Mental Health Support: Farmers can learn to leverage digital resources and platforms to access mental health support. There are online communities, forums, and counselling services available that can provide guidance, coping strategies, and a supportive environment for farmers facing stress, anxiety, or other mental health challenges. Digital Detox and Mindfulness: Farmers should periodically disconnect from digital devices and engage in activities that promote mindfulness and relaxation; spend time outdoors, engage in hobbies, or practice mindfulness techniques to reduce stress and enhance their overall well-being. Online Safety and Cyberbullying: It is necessary for farmers to protect themselves from online harassment, cyberbullying, and negative experiences. They must learn to be cautious about sharing personal information online and maintain privacy settings on social media platforms.
4.4 PROTECTING THE ENVIRONMENT	At basic level and with guidance, I can: At basic level and with autonomy and appropriate direction where needed, I can:	• recognise simple environmental impacts of digital technologies and their use. (Vuorikari, R., et al., 2022) Environmental Impact Assessments: Farmers should recognise that they have to use digital tools and resources to assess the environmental impact of their farm operations. They should conduct life

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		cycle assessments, carbon footprint analyses, or water footprint assessments to identify areas for improvement and develop strategies to minimise your farm's environmental footprint.

5. Problem-Solving

5.1 SOLVING TECHNICAL PROBLEMS	At basic level and with guidance, I can: At basic level and with autonomy and appropriate direction where needed, I can:	• identify simple technical problems when operating devices and using digital environments. • identify simple solutions to solve them. (Vuorikari, R., et al., 2022) Problem Identification is the first step of this skill. Farmers should clearly identify and understand the technical problem they are facing and be able to tell that it could be related to hardware, software, connectivity, or other digital tools used in farming operations. They should be able to gather as much information as possible to accurately describe the issue. Seek Expert Assistance: If the problem persists or requires advanced technical knowledge, farmers should seek help from experts or technicians. They can provide specialised guidance and support to resolve complex technical issues. Contact the manufacturer's support team or consult local IT professionals who have experience in agricultural technology.
5.2 IDENTIFYING NEEDS AND TECHNOLOGICAL RESPONSES	At basic level and with guidance, I can: At basic level and with autonomy and appropriate direction where needed, I can:	• identify needs, and • recognise simple digital tools and possible technological responses to solve those needs. • choose simple ways to adjust and customise digital environments to personal

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		needs. (Vuorikari, R., et al., 2022) Research Available Technologies: Farmers should explore the range of technological solutions available in the agricultural sector. This includes hardware devices, software applications, farm management systems, sensors, drones, precision agriculture tools, and livestock monitoring systems. Research their features, functionalities, and suitability for addressing your identified needs. Evaluate Compatibility and Integration: Farmers should consider the compatibility and integration of the technology with existing farm infrastructure and systems. They should assess whether the technology seamlessly integrates with their current equipment, software, or data management practices. Compatibility is crucial for ensuring smooth adoption and efficient use of the technology. Continuously Monitor and Adapt: Once the technology is implemented, farmers should regularly monitor its performance and impact, and assess whether it is effectively addressing the identified needs and achieving the desired outcomes and make necessary adjustments, adaptations, or upgrades as they gain more experience and learn from the technology's usage on their farm.
5.3 CREATIVELY USING DIGITAL TECHNOLOGY	At basic level and with guidance, I can: At basic level and with autonomy and appropriate direction where needed, I can:	• identify simple digital tools and technologies to create knowledge and innovate processes and products. • show interest individually and collectively in simple cognitive processing to understand and resolve simple conceptual problems and problem situations in

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		digital environments. (Vuorikari, R., et al., 2022) Farm Management Software: helps farmers organise and streamline their operations. These tools often include features for crop planning, inventory management, financial tracking, and record-keeping. Examples include FarmLogs, Farmer's Edge, or Agworld. Weather Apps and Sensors: provide real-time weather forecasts and alerts, allowing farmers to make informed decisions about planting, irrigation, or harvesting. Additionally, weather sensors can provide on-site weather data specific to the farm, enabling farmers to monitor temperature, humidity, rainfall, or wind conditions. Crop Monitoring Systems: utilise sensors and imaging technologies to gather data on plant health, soil conditions, and environmental factors. These tools can help farmers identify areas of improvement, detect pests or diseases, and optimise irrigation and fertilisation. Livestock Monitoring Tools: enable farmers to track the health, behaviour, and productivity of their animals. This can include wearable sensors, remote monitoring cameras, or automated feeding systems. Such tools provide valuable insights for managing livestock health, reproduction, and nutrition. Precision Agriculture Technologies: These technologies leverage GPS, drones, and remote sensing to optimize farming practices and resource allocation. These tools enable farmers to create detailed maps of their fields, assess crop variability, apply targeted treatments, and monitor yield performance. Examples include drone mapping software, GPS

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		guidance systems, or yield monitoring equipment. Online Marketplaces: They connect farmers directly with consumers, enabling them to sell their products and reach a wider customer base. These platforms facilitate product listings, order management, and payment processing. Social Media and Online Communities: Social media platforms and online communities provide opportunities for farmers to network, exchange knowledge, and showcase their products. These platforms allow farmers to connect with consumers, fellow farmers, and agricultural experts to learn, collaborate, and share experiences. Examples include Facebook farming groups, Twitter agriculture hashtags, or specialised online forums. E-commerce Platforms: E-commerce platforms enable farmers to sell their products online, expanding their market reach beyond local boundaries. These platforms provide features for product listings, inventory management, order processing, and shipping logistics. The selection of digital tools and technologies should align with the specific needs and resources of your farm. It's important to evaluate the features, ease of use, and compatibility of each tool with your existing systems and infrastructure.
5.4 IDENTIFYING DIGITAL COMPETENCE GAPS	At basic level and with guidance, I can: At basic level and with autonomy and appropriate direction where needed, I can:	• recognise where my digital competence needs to be improved or updated. • identify where to seek self-development opportunities and keep up to date with the digital evolution. (Vuorikari, R., et al., 2022) Assess Current Skills: Farmers should start by assessing their current digital skills and knowledge, evaluating their proficiency in

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		various digital areas, or using specific digital tools relevant to farming. Identify Desired Competences: They should determine the digital competencies that are necessary or desired for their farming activities, and consider the specific requirements of their farm operations, industry trends, and emerging technologies. For example, they may need to focus on data analysis, precision agriculture technologies, online marketing, or remote sensing.

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Annex 3. Questionnaire for training providers

Current education and training provisions questionnaire

This questionnaire is a research instrument intended to collect data regarding the current education and training provisions at the vocational education and training level as well as at the higher education level in the field of bioeconomy in farming sector in the European Union. This data collection process is framed within the RELIEF project, Work Package 2: RELIEF Training Approach Analysis. The RELIEF project, co-funded by the European Union, aims to develop and deliver an innovative approach for teaching bioeconomy in farming, by developing specific learning resources addressing higher education and vocational education and training students as well as farming practitioners.

Part I

This section of the questionnaire aims to collect general information about the course program(es) offered by your academic institution.

1. Country

☐ Cyprus

☐ Greece

☐ Italy

☐ Portugal

☐ Sweden

☐ other (_____)

Please indicate the region: _____

2. Does your institution provide any type of education in the field of:

☐ Agriculture

☐ Bioenergy (e.g., energy crops, forestry use for energy, biofuels, etc.)

☐ Biorefineries, Green Chemistry

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☐ Bioeconomy

☐ Environment and Sustainability

☐ Forestry

☐ Renewable Energies

☐ Presently my institution does not provide any educational program in any of the previous cited fields.

3. Title of the course program

_____

_____

Is the course active?

☐ Yes

☐ No, it was active from _____ to _____.

☐ No, it will be activated in 202_.

4. Name of the Institution / Provider

_____

_____

5. Typology of the institution

☐ Higher Education

☐ Vocational education and training

☐ Professional training

☐ other

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Please comment:

_____

_____

6. Education level (s) provided by the institution

☐ Bachelor's degree

☐ Master's degree

☐ Doctoral Degree

☐ Post-graduate Course

☐ Summer Course

☐ Vocational education and training

☐ MOOC Course

☐ other

Please comment:

_____

_____

7. Number of curricular units in the curriculum of the course program with reference to question 2.

☐ 1

☐ 2

☐ 3

☐ 4

☐ 5

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☐ more than 5

_____

_____

Total number of ECTS

☐ _____ ECTS

☐ Not applicable

8. Main aims and objectives of the current course program offered by your academic institution.

☐ to provide the key concepts in microeconomics provide the knowledge on bioeconomy strategies

☐ to provide a systematic approach to conduct economic analysis to evaluate costs and benefits

☐ to provide the knowledge on bioeconomy strategies

☐ to provide the knowledge on biomass markets

☐ to provide the methodologies for environmental impact assessment

☐ to provide the necessary skills to deal with the biomass to energy chain

☐ to provide the necessary skills to deal with the biorefinery and Green Chemistry topics

☐ other

_____

_____

9. Course program curriculum (please refer 3 main aspects of the program)

_____

_____

_____

10. Duration

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☐ less than 3 months

☐ 4-6 months

☐ 7-12 months

☐ 2 years

☐ 3 years

☐ more than 3 years (please specify _____)

11. Primary teaching language

☐ English

☐ Greek

☐ Italian

☐ Portuguese

☐ Swedish

☐ other (_____)

12. Learning methods and approach

☐In person

☐ Online

☐ Blended

☐ other

Please comment:

_____

_____

13. Tuition fees

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☐Yes

☐ No

If yes, specify the amount (total course program)

☐ less than 1000€

☐ 1000€-3000€

☐ 3000€-6000€

☐ more than 6000€ (please specify _____€)

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Part II

This section of the questionnaire aims to acquire more detailed information about the course curriculum that your institution is providing. Please consider your answer to question number 3, "course program", when providing the next answers.

14. Please briefly describe the strengths and weaknesses of the course program.

Strengths

☐ teaching materials

☐ available tools (e.g., access to labs and software)

☐ experienced teachers

☐ well defined scope

☐ strong connection with industries and business sector

☐ other

_____

_____

Weaknesses

☐ lack of teaching materials

☐ lack of available tools (e.g., access to labs and software)

☐ lack of experienced teachers

☐ not well-defined scope

☐ weak connection with industries and business sector

☐ other

_____

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15. **What are the challenges (technical, institutional and/or pedagogical) you experience while conducting the course program?**

☐ a broad topic

☐ rapid changes

☐ variations in geographic locations

☐ lack of available literature

☐ different needs from different perspectives

☐ other

16. **What are the key elements of conducting an effective course program? Explain it, please.**

☐ available literature (e.g., scientific publications, books, reports)

☐ available tools (e.g., access to labs and software)

☐ experienced teachers

☐ cooperation with industries and business sector

☐ effective examinations

☐ other

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17. Does the course curriculum cover topics related to the development of digital and entrepreneurial competencies. If yes, please indicate what are the main topics approached.

☐ invited lectures from industries and business sector

☐ online learning tools

☐ study visit

☐ formal curricular units

☐ other

Please comment:

_____

_____

18. Is your institution planning to include a new curricular unit in the course curriculum in the near future? If yes, what curricular unit and why?

_____

_____

19. Has the course curriculum been reviewed/updated recently? If yes, what efforts are made to answer future training needs in farming related to bioeconomy.

_____

_____

20. Is the training/educational offer provided by your institution developed in collaboration with business actors? If yes, from what fields.

_____

_____

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Annex 4. Questionnaire for learners

Current education and future training needs questionnaire

This questionnaire is a research instrument intended to collect data regarding the current education and training provisions at the vocational education and training level as well as at the higher education level in the field of bioeconomy in farming sector in the European Union. This data collection process is framed within the RELIEF project, Work Package 2: RELIEF Training Approach Analysis. The RELIEF project, co-funded by the European Union, aims to develop and deliver an innovative approach for teaching bioeconomy in farming, by developing specific learning resources addressing higher education and vocational education and training students as well as farming practitioners (i.e., farmers, farming companies, agronomists, farmer's consultants, policy makers). This questionnaire is composed by 3 parts: Part I, to be answered by all respondents; Part II to be answered only by farmers and farming companies and; Part III to be answered solely by agronomists, farmer's consultants and policy makers.

Part I

This section of the questionnaire aims to collect general information about the existing knowledge and qualifications.

1. **Country**

☐ Cyprus

☐ Greece

☐ Italy

☐ Portugal

☐ Sweden

☐ other (_____)

Please indicate the region: _____

2. **What are your educational qualifications?**

☐ Bachelor's degree

☐ Master's degree

☐ Doctoral Degree

☐ Post-graduate Course

☐ Vocational education and training

☐ High school diploma

☐ High school dropout

☐ other (_____)

3. Duration of your latest qualification/course/degree

☐ less than 3 months

☐ 4-6 months

☐ 7-12 months

☐ 2 years

☐ 3 years

☐ more than 3 years (please specify _____)

4. Title/name of your latest qualification/course/degree

_____

_____

5. Name of the Institution/Provider

_____

_____

6. What year did you graduate?

_____

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7. Number of curricular units/disciplines related to bioeconomy you took during your latest qualification/course/degree?

☐ 0

☐ 1

☐ 2

☐ 3

☐ 4

☐ 5

☐ more than 5

Total number of ECTS provided

☐ _____ ECTS

☐ Not applicable

8. Professionally, how would you identify yourself?

☐ Student

☐ Farmer

☐ Agronomist

☐ Entrepreneur

☐ Consultant

☐ Policy maker

☐ Other (Please specify)

_____

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Part II

TO BE ANSWERED BY FARMERS/FARMING COMPANIES

This section of the questionnaire aims to acquire detailed information about the knowledge, competencies and skills required for someone to become a "Bioeconomy Specialist in Agriculture"

The European Commission defines bioeconomy as "using renewable biological resources from land and sea, like crops, forests, fish, animals and micro-organisms to produce food, materials and energy." A more in-depth definition provided in the EU Bioeconomy Strategy is that the bioeconomy includes all systems that are dependent on biological resources (biomass, animals, plants, organisms), their functions and principles. This includes land and marine ecosystems; primary production sectors (agriculture, forestry, fisheries and aquaculture) and, all economic and industrial sectors using biological resources to produce food, feed, biobased products, energy and services.

1. **Are you satisfied with level of knowledge you have on bioeconomy, to do your job?**

☐ Yes

☐ No

☐ I am not sure

2. **Would you be interested in learning more on Bioeconomy?**

☐ Yes

☐ No

☐ I am not sure

3. **If the previous answer is Yes, which are the main obstacles for you?**

☐ I do not have the time to research on my own on bioeconomy

☐ I do not have the time to attend (a) relevant course(s)

☐ I do not have the money to pay for (a) relevant course(s)

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☐ I have not found relevant courses in my area

☐ I have not found learning material in my native language

☐ Other (please specify)

_____

4. Are you currently considering enrolling in a bio economy training course in the near future? If so, could you please provide some details on the specific theme(s) you are interested in, and why you are interested in pursuing this training?

_____

_____

5. What specific bio economy theme are you most interested in learning about?

☐ Agriculture

☐ Bioenergy (e.g., energy crops, forestry use for energy, biofuels, etc.)

☐ Biorefineries, Green Chemistry

☐ Bioeconomy

☐ Environment and Sustainability

☐ Forestry

☐ Renewable Energies

☐ other

6. Preferred teaching language

☐ English

☐ Greek

☐ Italian

☐ Portuguese

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☐ Swedish

☐ Other (_____)

7. Preferred learning methods and approach

☐In person

☐ Online

☐ Blended

☐ Other (_____)

Please comment:

_____

_____

8. Would you be interested in learning online (asynchronous education) that does not require payment of tuition fees?

☐ Yes

☐ No

☐ I am not sure

9. Would you be willing to pay tuition fees?

☐ Yes

☐ No

If yes, specify the total maximum amount.

☐ less than 500€☐ 501 - 1000€

☐ 1001€-3000€

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☐ 3001€-6000€

☐ more than 6000€ (please specify _____€)

10. In your opinion what should be the main aims and objectives of future course programs in bioeconomy in the farming sector?

☐ to provide the key concepts in microeconomics

☐ to provide the knowledge on bioeconomy strategies

☐ to provide a systematic approach to conduct economic analysis to evaluate costs and benefits

☐ to provide the knowledge on bioeconomy strategies

☐ to provide the knowledge on biomass markets

☐ to provide the knowledge on chain related technologies

☐ to provide the methodologies for environmental impact assessment

☐ to provide the necessary skills to deal with the biomass to energy chain

☐ to provide the necessary skills to deal with the biorefinery and Green Chemistry topics

☐ other (Please specify)

_____

_____

11. Please indicate the extent to which the following core competences and skills will enable you to successfully integrate the bioeconomy dimension within your agricultural practices.

☐ Circular economy standards and assessment method

☐ Energy management and conservation

☐ Sustainable waste management (waste classification and environmental impact, Supply chain management and the 5Rs (Reduce, Reuse, Refurbish, Repair and Recycle))

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12. **Using a scale from 1 to 5, where 1 means "Not at all" and 5 means "Extremely important", please indicate the extent to which the following digital competences and skills will enable you to integrate successfully the bioeconomy dimension within your agricultural practices?**

Information and data literacy (e.g., evaluating data, information and digital content, Managing data, information and digital content)

☐1 ☐2 ☐3 ☐4 ☐5

Communication and collaboration (e.g., Interacting through digital technologies, haring through digital technologies, Managing digital identity)

☐1 ☐2 ☐3 ☐4 ☐5

Digital content creation (e.g., Developing digital content, integrating and re-elaborating digital content, programming)

☐1 ☐2 ☐3 ☐4 ☐5

Data safety (e.g., Protecting devices, Protecting personal data and privacy)

☐1 ☐2 ☐3 ☐4 ☐5

Problem solving skills (e.g., Solving technical problems, identifying needs and technological responses, Identifying digital competence gaps)

☐1 ☐2 ☐3 ☐4 ☐5

13. **Using a scale from 1 to 5, where 1 means "Not at all" and 5 means "Extremely important", please indicate the extent to which the following entrepreneurial competences and soft skills will enable you to integrate successfully the bioeconomy dimension within your agricultural practices?**

Spotting opportunities (i.e., Use your imagination and abilities to identify opportunities for creating value)

☐1 ☐2 ☐3 ☐4 ☐5

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Creativity (i.e., Develop creative and purposeful ideas)

☐1 ☐2 ☐3 ☐4 ☐5

Vision (i.e., Work towards your vision of the future)

☐1 ☐2 ☐3 ☐4 ☐5

Valuing ideas (i.e., Make the most of ideas and opportunities)

☐1 ☐2 ☐3 ☐4 ☐5

Ethical and sustainable thinking (i.e., Assess the consequences and impact of ideas, opportunities, and actions and their implications to a sustainable development)

☐1 ☐2 ☐3 ☐4 ☐5

Self-awareness and self-efficacy (i.e., Believe in yourself and keep developing)

☐1 ☐2 ☐3 ☐4 ☐5

Motivation and perseverance (i.e., Stay focused and don't give up)

☐1 ☐2 ☐3 ☐4 ☐5

Mobilizing resources (i.e., Gather and manage the resources you need)

☐1 ☐2 ☐3 ☐4 ☐5

Financial and economic literacy (i.e., Develop financial and economic know how)

☐1 ☐2 ☐3 ☐4 ☐5

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Mobilizing others (i.e., Inspire, enthuse, and get others on board)

☐1 ☐2 ☐3 ☐4 ☐5

Taking the initiative (i.e., Go for it)

☐1 ☐2 ☐3 ☐4 ☐5

Planning and management (i.e., Prioritize, organize and follow-up)

☐1 ☐2 ☐3 ☐4 ☐5

Coping with uncertainty, ambiguity, and risk (i.e., Make decisions dealing with uncertainty, ambiguity and risk)

☐1 ☐2 ☐3 ☐4 ☐5

Working with others (i.e., Team up, collaborate and network)

☐1 ☐2 ☐3 ☐4 ☐5

Learning through experience (i.e., Learn by doing)

☐1 ☐2 ☐3 ☐4 ☐5

14. Using a scale from 1 to 5, where 1 means "Not at all" and 5 means "Extremely important", please indicate the extent to which the following transversal competences, attitudes and soft skills will enable you to integrate the bioeconomy dimension within your agricultural practices?

Core skills and competences

☐1 ☐2 ☐3 ☐4 ☐5

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Thinking skills and competences (e.g. critical thinking, problem solving, creative thinking, decision making initiative)

☐1 ☐2 ☐3 ☐4 ☐5

Self-management skills and competences (adaptability, organization, personal development, positive attitude, self-control, self- awareness, empathy)

☐1 ☐2 ☐3 ☐4 ☐5

Social and communication skills and competences (communication, collaboration, teamworking, negotiation, networking)

☐1 ☐2 ☐3 ☐4 ☐5

Tenacity (goal orientation, motivation, patience, resilience)

☐1 ☐2 ☐3 ☐4 ☐5

15. In your opinion, have academic institutions/providers made sufficient efforts to address the future training needs of farmers and agronomists/farmers consultants in topics related to bioeconomy?

_____

_____

16. Considering the previous question (15), what do you consider to be the main gaps and challenges? Your insights will help us understand the training needs.

_____

_____

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17. **In your opinion, have academic institutions/providers made sufficient efforts to address the future training needs of farmers and agronomists/farmers consultants in topics related to green, digital, entrepreneurial, and transversal competencies and skills?**

_____

_____

18. **Considering the previous question (17), what do you consider to be the main gaps and challenges?**

_____

_____

19. **Please select or briefly specify the current strengths and weaknesses of the available training in bioeconomy.**

Strengths

☐ teaching materials

☐ available tools (e.g., access to labs and software)

☐ experienced teachers

☐ well defined scope

☐ strong connection with industries and business sector

☐ applicability to real life/working environments' contexts

☐ other (Please specify)

_____

_____

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Weaknesses

☐ lack of teaching materials

☐ lack of available tools (e.g., access to labs and software)

☐ lack of experienced teachers

☐ not well-defined scope

☐ weak connection with industries and business sector

☐ lack of applicability to real life/working environments' contexts

☐ other (Please specify)

_____

_____

20. To what extent is collaboration between academic institutions/providers and business actors important to developing critical knowledge and skills in bioeconomy? If collaboration is important, which fields do you believe are particularly relevant for such collaboration?

_____

_____

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Part III

TO BE ANSWERED BY AGRONOMISTS/FARMER'S CONSULTANTS/POLICY MAKERS

This section of the questionnaire aims to acquire detailed information about the knowledge, competencies and skills required to for someone to become a "Bioeconomy Specialist in Agriculture"

The European Commission defines bioeconomy as "using renewable biological resources from land and sea, like crops, forests, fish, animals and micro-organisms to produce food, materials and energy." A more in-depth definition provided in the EU Bioeconomy Strategy is that the bioeconomy includes all systems that are dependent on biological resources (biomass, animals, plants, organisms), their functions and principles. This includes land and marine ecosystems; primary production sectors (agriculture, forestry, fisheries and aquaculture) and; all economic and industrial sectors using biological resources to produce food, feed, biobased products, energy and services.

1. **Are you currently considering planning to enroll in a bioeconomy training course in the near future? If yes, related to which specific theme and why?**

_____

_____

2. **What bioeconomy theme are you more interested in:**

☐ Agriculture

☐ Bioenergy (e.g., energy crops, forestry use for energy, biofuels, etc.)

☐ Biorefineries, Green Chemistry

☐ Bioeconomy

☐ Environment and Sustainability

☐ Forestry

☐ Renewable Energies

☐ Other

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3. Preferred teaching language

☐ English

☐ Greek

☐ Italian

☐ Portuguese

☐ Swedish

☐ Other (_____)

4. Preferred learning methods and approach

☐In person

☐ Online

☐ Blended

☐ Other (_____)

Please comment:

_____

_____

5. Would you be interested in learning online (asynchronous education) without tuition fee?

☐ Yes

☐ No

6. Would you be willing to pay tuition fees?

☐ Yes

☐ No

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If yes, specify the total maximum amount.

☐ less than 500€☐ 501 - 1000€

☐ 1001€-3000€

☐ 3001€-6000€

☐ more than 6000€ (please specify _____€)

7. Please indicate which of the following aims and objectives should be addressed within the course for "Bioeconomy Specialists in Agriculture"?

☐ to provide the key concepts in microeconomics

☐ to provide the knowledge on bioeconomy strategies

☐ to provide a systematic approach to conduct economic analysis to evaluate costs and benefits

☐ to provide the knowledge on bioeconomy strategies

☐ to provide the knowledge on biomass markets

☐ to provide the knowledge on chain related technologies

☐ to provide the methodologies for environmental impact assessment

☐ to provide the necessary skills to deal with the biomass to energy chain

☐ to provide the necessary skills to deal with the biorefinery and Green Chemistry topics

☐ other (Please specify)

_____

_____

8. In your opinion which of the following core competences and skills are most important in pursuing a successful career as a "Bioeconomy specialist in Agriculture"?

☐ Circular economy standards and assessment method

☐ Energy management and conservation

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☐ Sustainable waste management (waste classification and environmental impact, Supply chain management and the 5Rs (Reduce, Reuse, Refurbish, Repair and Recycle))

9. **Using a scale from 1 to 5, where 1 means "Not at all" and 5 means "Extremely important", please indicate how important are the following digital competences and skills in pursuing a successful career as a "Bioeconomy specialist in Agriculture"?**

Information and data literacy (e.g., evaluating data, information and digital content, Managing data, information and digital content)

☐1 ☐2 ☐3 ☐4 ☐5

Communication and collaboration (e.g., Interacting through digital technologies, haring through digital technologies, Managing digital identity)

☐1 ☐2 ☐3 ☐4 ☐5

Digital content creation (e.g., Developing digital content, integrating and re-elaborating digital content, programming)

☐1 ☐2 ☐3 ☐4 ☐5

Data Safety (e.g., Protecting devices, Protecting personal data and privacy)

☐1 ☐2 ☐3 ☐4 ☐5

Problem solving (e.g., Solving technical problems, identifying needs and technological responses, Identifying digital competence gaps)

☐1 ☐2 ☐3 ☐4 ☐5

10. **Using a scale from 1 to 5, where 1 means "Not at all" and 5 means "Extremely important", please indicate how important are the following entrepreneurial competences and soft skills in pursuing a successful career as a "Bioeconomy specialist in Agriculture"?**

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Spotting opportunities (i.e., Use your imagination and abilities to identify opportunities for creating value)

☐1 ☐2 ☐3 ☐4 ☐5

Creativity (i.e., Develop creative and purposeful ideas)

☐1 ☐2 ☐3 ☐4 ☐5

Vision (i.e., Work towards your vision of the future)

☐1 ☐2 ☐3 ☐4 ☐5

Valuing ideas (i.e., Make the most of ideas and opportunities)

☐1 ☐2 ☐3 ☐4 ☐5

Ethical and sustainable thinking (i.e., Assess the consequences and impact of ideas, opportunities, and actions)

☐1 ☐2 ☐3 ☐4 ☐5

Self-awareness and self-efficacy (i.e., Believe in yourself and keep developing)

☐1 ☐2 ☐3 ☐4 ☐5

Motivation and perseverance (i.e., Stay focused and don't give up)

☐1 ☐2 ☐3 ☐4 ☐5

Mobilizing resources (i.e., Gather and manage the resources you need)

☐1 ☐2 ☐3 ☐4 ☐5

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Financial and economic literacy (i.e., Develop financial and economic know how)

☐1 ☐2 ☐3 ☐4 ☐5

Mobilizing others (i.e., Inspire, enthuse, and get others on board)

☐1 ☐2 ☐3 ☐4 ☐5

Taking the initiative (i.e., Go for it)

☐1 ☐2 ☐3 ☐4 ☐5

Planning and management (i.e., Prioritize, organize and follow-up)

☐1 ☐2 ☐3 ☐4 ☐5

Coping with uncertainty, ambiguity, and risk (i.e., Make decisions dealing with uncertainty, ambiguity and risk)

☐1 ☐2 ☐3 ☐4 ☐5

Working with others (i.e., Team up, collaborate and network)

☐1 ☐2 ☐3 ☐4 ☐5

Learning through experience (i.e., Learn by doing)

☐1 ☐2 ☐3 ☐4 ☐5

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11. Using a scale from 1 to 5, where 1 means "Not at all" and 5 means "Extremely important", please indicate how important are the following transversal competences, attitudes and soft skills in pursuing successful career as a "Bioeconomy specialist in Agriculture"?

Thinking skills and competences (e.g. critical thinking, problem solving, creative thinking, decision making initiative)

☐1 ☐2 ☐3 ☐4 ☐5

Self-management skills and competences (adaptability, organization, personal development, positive attitude, self-control, self- awareness, empathy)

☐1 ☐2 ☐3 ☐4 ☐5

Social and communication skills and competences (communication, collaboration, teamworking, networking, negotiation)

☐1 ☐2 ☐3 ☐4 ☐5

Tenacity (goal orientation, motivation, patience, resilience)

☐1 ☐2 ☐3 ☐4 ☐5

12. Do you feel efforts have been made by the academic institutions/providers to answer future training needs of farmers and agronomists/farmers consultants in topics related to bioeconomy?

_____

_____

13. Considering the previous question (12), what do you consider to be the main gaps and challenges?

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_____

_____

14. In your opinion, have academic institutions/providers made sufficient efforts to address the future training needs of farmers and agronomists/farmers consultants in topics related to green, digital, entrepreneurial, and transversal competencies and skills?

_____

_____

15. Considering the previous question (14), what do you consider to be the main gaps and challenges?

_____

_____

16. Please select or briefly specify the current strengths and weaknesses of the available training in bioeconomy.

Strengths

☐ teaching materials

☐ available tools (e.g., access to labs and software)

☐ experienced teachers

☐ well defined scope

☐ strong connection with industries and business sector

☐ applicability to real life/working environments' contexts

☐ other (Please specify)

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Weaknesses

☐ lack of teaching materials

☐ lack of available tools (e.g., access to labs and software)

☐ lack of experienced teachers

☐ not well-defined scope

☐ weak connection with industries and business sector

☐ lack of applicability to real life/working environments' contexts

☐ other (Please specify)

_____

_____

17. To what extent is collaboration between the academic institutions/providers and business actors important for developing critical knowledge and skills in the field of bioeconomy? If collaboration is important, which fields do you believe are particularly relevant for such collaboration?

_____

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