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Bioeconomy future: Green transition in Europe from the perspective of life-science students

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Abstract

As European societies transition from fossil-based to circular bioeconomies, new demands arise for skills, entrepreneurship, and inclusive pathways in the green labour market. This study investigates how life-science students – future professionals in sustainability-oriented sectors – envision bioeconomy futures across regions in nine European countries – Finland, Poland, Czechia, Germany, Belgium, the Netherlands, Portugal, Spain, and Romania. Drawing on a comparative web-based survey combined with contextual policy data, the research examines students' understanding of the bioeconomy, their motivations for engaging in sustainability-driven careers, and the barriers shaping their entrepreneurial intentions. Findings reveal substantial regional variation in familiarity with the bioeconomy concept. While many students associate it with nature-based solutions and sustainable land use, concrete awareness of entrepreneurial and career trajectories remains limited. Yet, strong interest in bioeconomy entrepreneurship persists, motivated by its potential to create environmental and social value. Persistent obstacles – such as lack of business knowledge, financial insecurity, and fear of failure – constrain engagement. By integrating student perspectives into the discourse on just and desirable futures, this paper contributes to futures thinking on green transitions, skills development, and bioeconomy entrepreneurship. It highlights how circular and forest-based bioeconomies can act as vehicles for equitable, locally grounded, and future-ready transformations.

Keywords: bioeconomy futures; green skills; entrepreneurship; student attitudes; sustainable business models; forestry

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1. Introduction

There is an urgent need to move societies into an operating space within planetary boundaries (Steffen et al. 2015), and this requires societal transformations. In the European Union (EU), changes are coordinated through the European Green Deal (EGD) policy agenda and holistic framework (European Commission 2019). The aim is to reduce environmental degradation and contribute to the global sustainability transition in a way that is fair and just (Rakovic et al. 2020). Forestry is no longer perceived as a biological field only but plays central role in bioeconomy and sustainable solutions. Study conducted among European universities in 2020 even emphasized that forestry students perceive forestry as the Bioeconomy sector with the highest importance (Masiero et al. 2020). Bioeconomy, understood as an economic system moving from linear fossil-based resource utilization towards using efficient and circular use of biological resources within planetary boundaries, significantly contributes to the EGD (European Commission 2018). At the same time the concept of circular economy which is very much connected with bioeconomy, represents a transformative response to environmental and economic challenges by promoting resource efficiency, waste minimization, and sustainable development through the decoupling of growth from environmental harm (Sassanelli et al. 2019; Alnafrah et al. 2025). To achieve positive outcomes during these changes, it is also necessary to focus on enterprise education, which must reflect the needs of sustainability, social justice and the principles of the bioeconomy (Dodd et al. 2022).

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The EGD is underpinned by many EU-level strategies (e.g., the Bioeconomy Strategy, Forest Strategy, Biodiversity Strategy, Farm-to-Fork Strategy, EU Forest strategy 2030), action plans (e.g. Circular Economy Action Plan, Bioeconomy: The European way to use our natural resources – Action plan 2018), and updates to legislation. Moreover, according to EU (2025), member states are encouraged to promote bioeconomy-related education, and it will be supported also through already existing initiatives (e.g. European Bioeconomy University, BIOEAST Uninet, Global Bioeconomy Alliance, Global Bioeconomy Youth Champions.). Collectively, these provide a roadmap for action at the level of the EU and individual Member States. Bioeconomy principles are being gradually introduced into relevant national (Rinn et al. 2022) and regional level strategies (Papadopoulou et al. 2022; M'barek & Wesseler 2023; Szarka et al. 2023; Mosley & Van Brusselen 2024). The success of bioeconomy relies on the social acceptance and involvement and understanding of stakeholders (Sadeghzadeh et al. 2025).

The discourse on bioeconomy is primarily framed around economic growth and job creation (Kleinschmit et al. 2017) and needs to consider local context and stakeholders' engagement (Grilli et al. 2024). At the same time, entrepreneurs are put forward as a group that act as enablers, introducing innovations and exploiting new opportunities created through policy (Fuller & Warren 2006; Kuckertz et al. 2020). Wensing et al. (2019) presented research on the factors influencing farmers' adoption of bioeconomy-related practices. This study brings interesting insights from farmers' perceptions of contextual conditions supporting the bioeconomy. Briers et al. (2024, 2025) brought information about public and private sector perceptions across different European regions. But it makes more sense to influence future stakeholders already during the study period, i.e., during their main training. Information about bioeconomy can be gained from different sources (media, books, policy documents etc.), however among university students, content of the study programme remains the main source (Marcineková et al. 2023). Understanding students' – the future professionals' – views of bioeconomy and entrepreneurship is therefore important for ensuring policy outcomes. In this study, we focus especially on life-science students' perceptions, as they are the most potential future professionals to work in the interface of bioeconomy and entrepreneurship.

Previous studies among students emphasized mostly the students' perceptions on bioeconomy, and/or awareness and acceptance of bioeconomy principles in general (see e.g. Halder 2011; Drejerska 2017; Stern et al. 2018; Hempel et al. 2019; Golowko et al. 2019; Vainio et al. 2019; Masiero et al. 2020; Výbošťok et al. 2022; Marcineková et al. 2023). The level of awareness and perceived importance of bioeconomy amongst students varies between countries (Masiero et al. 2020), and many studies have pointed out a gap in knowledge (Drejerska 2017; Golowko et al. 2019). Despite the lack of deeper awareness, bioeconomy perceptions are rather positive in general (Stern et al. 2018; Farstad 2021; Gaffey 2021). Less attention has been given to the connection of bioeconomy and entrepreneurship. On a general level, OECD survey found that almost 50% of young people, and around 40% of university students expressed interest in starting their own business after graduation (OECD and EC 2021).

Starting one's own business can also be a real-life solution, as the unemployment rate among young people (aged 15–29) is higher than the general unemployment rate in Europe. It also varies significantly among countries – the least in Germany with 5%, more than 20% in Spain and Greece (Eurostat 2025).

Paris et al. (2023) has identified existing bioeconomy entrepreneurship-specific education and training. From the perspective of sustainability transitions, the role of entrepreneurship has been investigated for example by Kuckertz et al. (2020) and highlighted by the EIT Strategic Innovation Agenda (2021). They mention that studies addressing the bioeconomy and entrepreneurship exist, but just few of them address the topic directly. Kuckertz (2020) also defines determinants of entrepreneurship in bioeconomy strategies. A wider range of literature exists that focuses on 'ecopreneurship' and factors influencing Small and Medium Enterprises (SMEs) in the bioeconomy (e.g. Rodríguez-García et al. 2019; Urbaniec et al. 2022).

There are multiple regional initiatives that support entrepreneurship. Business incubators can help entrepreneurs, particularly SMEs, to bring their ideas to the market and lower market entry barriers (Haapasalo & Ekholm 2004). Business incubators can provide suitable business development premises and specialized coaches to help with developing and implementing a realistic business plan, mediating possible public and private financing, intellectual property management and further. They also often have a networking role and provide institutional mediation, or a link between academia and industry (Pettersen et al. 2016). Several regions have such business incubators, while these may be organized by different administrative levels. There are also other supporting and enabling factors for young entrepreneurs (innovative vouchers, consultancy, job shadowing, international exchange, targeted courses etc.), but financial point of view and promotion of entrepreneurs are among the most important.

The existing traditional businesses, and the internal culture of established bioeconomy companies do not accommodate the rapid changes needed for renewing the industry (Hansen 2016). For example, firms in forest harvesting and primary manufacturing tend to concentrate on process innovation rather than the development of new products (Hansen 2006; Hansen & Breede 2016). Entrepreneurship and start-ups could therefore play a crucial role in this transition.

In addition, it is appropriate to take into account the influence of the regions. Regions and regional actors play a key role in interpreting international and national policy goals and translating them into action on the ground, as well as offering entrepreneurial and start-up support structures (e.g. business incubators or accelerators). In this context, entrepreneurs and SMEs are crucial driving forces in the development of the bioeconomy (Reim et al. 2017), SMEs in agriculture, food and beverage and manufacturing are large employers (Dietershagen & Bammann 2023).

With regard to the literature review, we discovered a niche that lies in the lack of research on students' regional perspectives and their links to the principles of bioeconomy. In order to analyze these relationships, we started from the methodological approaches of previous studies (e.g. Marcineková et al. 2023; Briers et al. 2024; etc.). We dived deeper into exploring entrepreneurship in bioeconomy and how students as future professionals approach it. Ultimately, we aim to answer the following research question: What are life-science students' perceptions of bioeconomy entrepreneurship? The specific research questions are the following:

1. How do life-science students view the concept of bioeconomy?
2. What are the attitudes of life-sciences students toward entrepreneurship for tackling sustainability issues?
3. How do the students' attitudes vary between selected European regions?

Therefore, we assumed that there is a variety in the students' familiarity with bioeconomy. Following this assumption, we expected that there should be a different attitude of students towards bioeconomy entrepreneurship. We adopted an exploratory approach to analyze the aspects of bioeconomy entrepreneurship further in the context of European regions.

The aim of this paper is to provide new information about bioeconomy entrepreneurship and its perception among specific target group – students in 9 European regions. The paper brings especially practical implications of the relationship between bioeconomy transition and bioeconomy entrepreneurship.

2. Material and methods

2.1. Survey design

As the aim of the survey was to explore students' perceptions of bioeconomy and bioeconomy entrepreneurship, both of which are topics studied to a very limited extent, the formulation of a number of detailed, predefined hypotheses was not meaningful for the objectives of this study. Instead of testing such hypotheses, the study aimed at gaining new insights into the previously understudied topic based on an exploratory research approach. Therefore, the survey design was based on the literature review presented above, as well as a previous survey by Briers et al. (2024). Briers et al. (2024) explored public and private sector actors' perceptions of the bioeconomy and the concepts, value chains, benefits and risks linked to it. For this study, relevant questions from the survey developed by Briers et al. (2024) were replicated to allow future comparisons of the results of the two studies. Questions regarding bioeconomy entrepreneurship were drafted based on previous literature and surveys on entrepreneurship in general (e.g. Mandel & Noyes 2016). The questions were further developed and clarified to meet the objectives of this study based on expert opinions through multiple feedback rounds among authors.

2.2. Data collection

To examine the attitudes and viewpoints toward bioeconomy and entrepreneurship among students, a web-based survey was created. The survey was written in English taking approximately 10 minutes to finish. The survey included 24 questions regarding students' viewpoints on bioeconomy and entrepreneurship as well as demographic questions, consisting of multiple-choice and Likert scale items. The survey was disseminated through the networks of European Forest Institute (EFI), specifically utilizing EFI's Bioregions Facility. Higher level educational institutions (universities and universities of applied sciences) in Europe were contacted directly, along with various other relevant organizations and networks (such as the International Forestry Students' Association IFSA). Moreover, several social media (Twitter, Facebook, LinkedIn) channels were used to improve the outreach of the survey, by choosing a communication medium that connects with the primary audience.

The main target group of the survey was students at universities that are primarily oriented at the education in the field of life science studying in institutions of higher education in Europe, however all students older than 18 were welcome to answer the survey. All study levels (bachelor, master and doctoral) were included in the survey. The relevance of the target group stems from fact that bioeconomy is built on biological resources and the field of life sciences provide the necessary knowledge base; life science universities provide research and education activities that are essential for further bioeconomy deployment (FAO 2021; ICA 2025). The completion rate of the survey was 78%. The survey was opened on 4.11.2022 and closed on 16.2.2023.

2.3. Data analysis

Statistical analyses were conducted using IBM SPSS statistics version 29. Standard descriptive and summary statistics (mean, range) were initially used to explore data. To test the statistical significance of differences between regions, Kruskal-Wallis H Tests for comparing multiple groups (Guo et al. 2013) were used ($\alpha = 0.05$).

In addition to the quantitative survey, representatives of all countries involved in the study were consulted to confirm and add information on the regional and national situation regarding bioeconomy (Table A2). This included information on the bioeconomy-related strategies in place, as well as specific features and focal points on each region included in the study.

3. Results

3.1. Sample description and descriptive statistics

The total number of responses collected was N = 764. The respondents were divided into categories based on the location of their university. Grouping was done based on NUTS (Nomenclature of territorial units for statistics) classification system at the level of NUTS 3, referring to small regions for specific socio-economic analyses (Eurostat 2022). However, two NUTS 3 regions from Belgium, namely Gent and Leuven, were analysed together due to their small size and immediate proximity. To examine regional differences in a meaningful way, only regions with more than 15 responses per region were taken into account. Therefore, the final sample consisted of 405 responses from nine selected regions. Regions and universities included in the analysis are presented in Table A1.

Most of the respondents were either Bachelor's (41%) or Master's (41%) level students, with 5% of respondents studying for a Doctoral degree and 13% responded "Other". The main field of study for most (64%) respondents was agriculture, forestry, fisheries or veterinary, while 11% studied natural sciences, mathematics or statistics. In Warsaw 40% of respondents were studying business, administration or law, but in all the other regions, respondents were predominantly life science students. The age of the respondents varied between 19 and 65 years.

3.2. Bioeconomy in regions

When exploring the role and importance of bioeconomy in the regions included in this study, notable differences can be detected. On a country level, five out of nine countries studied have a general bioeconomy strategy in place (Table A2). Romania, Poland and Czech Republic do not have official bioeconomy strategies in place; however, dedicated bioeconomy strategies are being developed. Belgium has only regional strategies dedicated to bioeconomy. Moreover, some countries have sector-specific or other relevant strategies that include some bioeconomy content. For example, the National Forest Strategy of Romania briefly addresses bioeconomy related goals despite the country not having a bioeconomy strategy (Giurca et al. 2022).

After looking into the national strategies, we explored relevant regional bioeconomy strategies. The scopes of the regional strategies vary, most of them reflecting NUTS 1 or NUTS 2 regions. Stuttgart, Lleida, Warsaw, and Gent and Leuven have regional strategies fully dedicated to bioeconomy. Lisbon and North Karelia have regional strategies where bioeconomy is one of the key elements. Prague, Veluwe and Brasov have general development strategies with some bioeconomy content.

Sectors and biomass sources included in the strategies are manifold; all five national strategies discuss agriculture, aquaculture, and forests. Similarly, regional strategies fully dedicated to bioeconomy include a variety of aspects and biomass resources. On the other hand, regional development strategies are often narrower: for example, the Smart specialisation strategy (RIS3) East Netherlands 2021–2027 involves only agrifood, food and beverages as well as bio-based materials and plastic; and the Smart Specialisation in North Karelia strategy focuses on forest and wood-based biomass.

Many strategies see the private sector as a key factor in driving the transition to sustainable bioeconomy and aim to support innovation and entrepreneurs for developing bioeconomy in the region. For example, Lleida, Gent and Leuven have more specific targets for bioeconomy entrepreneurship, including targets relating to bioeconomy start-ups and scale-ups. Another commonality in the regional bioeconomy strategies is the principle of circularity, cascade and hierarchical use of resources.

Cross-sectoral collaboration and community building is recognized as an important factor in sustainable bioeconomy in many strategies (Stuttgart, Lleida, Gent and Leuven). The aim of this cooperation is to develop expertise and share knowledge locally as well as boost the image and vitality of the regions. In many cases, the development of rural areas and socio-economic benefits are in the special focus. Regions and nations aim to grow sustainably, generate business, and foster innovation and technological development.

3.3. Bioeconomy perceptions

The results show that students in general are not very familiar with the concept of bioeconomy (Fig. A1). On

a scale of 0–100, students rated their familiarity with the concept to be, on average, 55 (± 27.5).

A Kruskal-Wallis Test shows that there are statistically significant differences in the rating of bioeconomy familiarity between regions ($p < 0.001$, $\chi2 = 69.168$, $df = 8$). Students from Warsaw recorded the lowest average familiarity of 37.26 (± 23.1) whereas North Karelian students rated their familiarity highest, 73.3 (± 19.9).

Students were asked which concepts they link with bioeconomy. Most often linked concepts were nature-based solutions (69%), ecosystem services (61%), and circular use of resources (59%). The opinions on linkages between bioeconomy and sustainable land management (perceived to be linked by 54% of respondents), sustainable consumption (49%), carbon neutrality (48%) were more divided. On the other hand, most respondents did not associate bioeconomy with technological advancement and digitalization (perceived to be linked by 27% of respondents), economic prosperity (25%), community resilience (24%), or rural development (30%). Moreover, 35% link bioeconomy with the concept of degrowth (the reduction of global consumption and production), and only 20% with decoupling (separating economic growth from environmental impacts).

Most students in Lleida, Gent and Leuven, Lisboa and Brașov find that the biggest bioeconomy benefit is the conservation of biodiversity and ecosystem services (Fig. A2). While this is also a popular view in other regions, the two other options also received high scores. The highest rated option in Stuttgart, Prague and Warsaw was the potential to reduce material consumption and waste, increased reuse and recycling. Providing renewable alternatives to non-renewable materials was the most popular amongst students in North Karelia, and tied first place in Lisboa and Veluwe. Least votes were attributed to "Boosts technological innovation" and "Job creation and economic growth".

Interestingly, most students find that the biggest risk of bioeconomy is the degradation of biodiversity and ecosystem services. Only in Lisboa was "Higher cost of essential goods" ranked higher. The rest of votes were distributed amongst the remaining options, and increasing biomass cost was seen to be the least important risk.

Students were presented with a set of true/false statements regarding bioeconomy and its impacts (Table A3). Interestingly, 91% of respondents stated that they believe bioeconomy provides business and innovation opportunities. Moreover, most students believe that the statements "The bioeconomy helps reduce our dependency on fossil fuels" and "The bioeconomy contributes to sustainable economic growth" are true (labeled as true by 90% of respondents). 43% of respondents stated that "The bioeconomy is a good idea, but there is not enough biomass to implement it" as true, and 38% that "The bioeconomy will significantly put pressure on natural systems". Only 27% believe that the bioeconomy contributes to deforestation.

Between different regions, the statement "The bioeconomy will significantly put pressure on natural systems" divided opinions. Less than one third of respondents believed this was true in four regions: North Karelia, Gent and Leuven, Lisboa, and Stuttgart. On the other hand, over 60% of respondents in Veluwe and Lleida thought this statement to be true.

3.4. Entrepreneurial perceptions in bioeconomy

The respondents demonstrated average interest in entrepreneurship. On a scale of 0–100, students rated their interest in becoming an entrepreneur (starting your own business), on average, 53 (± 30.8). A Kruskal-Wallis Test shows that there are small but statistically significant differences in the rating of entrepreneurial interest between regions ($p < 0.05$, $\chi2 = 18.926$, $df = 8$). The students from Prague rated their interest towards bioeconomy lowest (on average 38), while students from the Brașov had the highest interest towards starting their own business, on average 64 (Fig. A3).

In terms of university-level training on entrepreneurship issues, only 20% of respondents had attended such a course at their institution of higher education. 38% had not attended such courses or training even though their university offers them, and 17% stated that their educational institutions do not offer these types of courses or training. Moreover, it is important to note that over 20% of respondents chose "I don't know" as an answer to the question. Differences in responses between regions are presented in Fig. A4.

The students were asked what encourages them to try entrepreneurship in the field of bioeconomy, selecting up to three from given options (Fig. A5). Most common driver was "reducing environmental impacts", selected by 38% of respondents. The opportunities to realize one's ideas and the (positive) impacts on the life quality of communities as well as oneself were also selected by over 20% of respondents. Following family traditions, being in the management of an organization and difficulties in finding a job were the least common drivers for trying entrepreneurship, all selected by 5% of participants or fewer. Moreover, 11% of respondents stated that they are not interested in trying entrepreneurship.

In terms of barriers, financial risk discourages students from becoming entrepreneurs in the field of bioeconomy the most, as it was selected by 45% of respondents (Fig. A6). This is followed by the fear of failure, entrepreneurship being too stressful, and lack of funding. Gender stereotypes, impacts on the life quality of communities, lack of technical skills, and potentially causing harm to the environment were selected as barriers by fewer than 5% of respondents.

When asked about which resources students would find the most effective for helping them start a business in the field of bioeconomy, collaborating with someone who has business expertise was the most important resource (selected by 52% of respondents). Moreover, having a team would be effective for many respondents (40%). Less important resources were information on how to apply for funding (30%) and school courses on entrepreneurship (24%).

4. Discussion

4.1. Bioeconomy awareness and educational context

When discussing bioeconomy entrepreneurship, it should be noted that bioeconomy usually goes beyond individual disciplines and requires an interdisciplinary perspective. Here we find analyses that identify barriers that entrepreneurs may face. Examples include patenting issues and underdeveloped regulations linked to innovative products and technologies (Dietershagen & Bammann 2023). Knowledge and competencies related to sustainable valorisation of biomass, biobased products marketing and management of limited resources are key (Hinderer & Kuckertz 2022). In some countries, including Czechia, the biomass (resources, utilization and innovative products) is still among key topics when speaking about country's approach to the bioeconomy (MZe 2019). Vaz & Nijkamp (2009) created a literature review focusing on economic interactions at the local and regional level, where sustainability conditions play a key role. Knowledge and innovation are important drivers.

As the bioeconomy concept is closely connected to circular economy, it makes sense to compare findings that are related to circular economy. Authors Trevisan et al. (2024) in their study developed a gap analysis framework to identify skills currently missing from circular economy courses and to highlight the critical competencies that should be prioritized in future educational programs, serving as a guide for both higher education and vocational training providers.

Overall, the self-reported familiarity with the concept of bioeconomy was, on average, 55 on a scale from 0 to 100. This indicates that there is room for increased awareness, even though it is important to note that the concept is in the centre of a wider societal debate and there might not be a universally accepted definition and understanding of its meaning even within the scientific community, professionals, and policymakers (Bugge et al. 2016; Birner 2018). The results show that the general awareness of bioeconomy, as well as the interest towards entrepreneurship, varies between regions in Europe. This can be due to differences in the prevalence of bioeconomy in regions and in the university curricula. Moreover, in some countries bioeconomy as a topic is brought up already in schools and pre-schools more than in others, which may have an impact in the perceived familiarity. Across most regions, the impact of bioeconomy on biodiversity and ecosystem services was seen to be the biggest risk and benefit. In terms of other benefits, around 87% of respondents also found that the bioeconomy in fact will contribute to the creation of jobs. However, bioeconomy as a concept was not seen to be linked to economic prosperity. This suggests that the viewpoints are diverse and sometimes perhaps contradictory and can be due to the varying understandings on the term bioeconomy. Moreover, it was interesting to note that most respondents did not link technological development and digitalization with bioeconomy, even though multiple innovative technologies and technological solutions related to bioeconomy are currently being developed. There are also activities that should prepare the educators in the bioeconomy field (e.g. national and international projects, MOOC courses, forest pedagogy, etc.).

4.2. Barriers and drivers of bioeconomy entrepreneurship

The results present the perception of barriers and driving forces from life-science students' point of view with a strong element of reluctance and uncertainty towards entrepreneurship as a career, at least at their current point in life. The survey did not include a time dimension (e.g. whether respondents would consider entrepreneurship later in their careers) but rather focused on the current job, education and life education of students, which typically would include the entry in the job market and first professional experiences and the building of networks. Financial risk (45% of all respondents) was listed as the highest risk, followed by the fear of failure, stressfulness, and lack of funding were identified as the biggest barriers for entrepreneurship in the field of bioeconomy. Financial risks, lack of resources, insufficient knowledge and entrepreneurship skills were identified as the main barrier for entrepreneurship when investigating it at the European level in 2022 in relation of "social entrepreneurship and youth" (EU 2023).

As young people often need to build up both financial reserves and the necessary CVs and professional profiles with documented successes and networks, uncertainty in finances and success, along with the stigma and fear of failure are considerable stumbling blocks. More information on available financial support, funding schemes, and incentives can balance part of that risk. Salvador et al. (2022) addressed this topic from the perspective of companies operating in the bioeconomy sector. According to their findings, the obstacles include lack of financial resources needed to switch to circular practices, logistical

problems, insufficient technologies, low awareness and inadequate regulatory frameworks. Connection between institutional quality and bioeconomy performance, namely political stability, control of corruption, effectiveness of government, regulatory quality, rule of law, and voice and accountability were identified as having positive impact on European bioeconomy (Barra & Marcello Falcone 2024). Conversely, the factors that drive change and represent opportunities are mainly related to subsidies and financial incentives (whether from private sources or governments), advances in or better access to technology, and the potential to improve operations while adding value to the business.

Another, and maybe even more important factor to foster entrepreneurship, is support structures such as mentoring programmes and professional help and matchmaking for building teams. This element was highlighted in the survey responses and corresponds to assistance while entering new terrain. Similar as first jobs have an onboarding procedure and teams with peer-support and mentoring through senior colleagues or supervisors, similar structures across entrepreneurs would lower the entry threshold and risk of failure. Having role models, targeted training (especially in soft-skills) and mentoring schemes were identified as key elements for women who already work to support them on the labor market and to close the gender gap in the field of forestry (Fem4Forest 2021; Fem2forests 2025). Small start-up companies need to master multiple disciplines from the main business focus to admin and finance, to communications and marketing, and other areas, while operating in a rather isolated and/or competitive environment (e.g. Carbonell-Alcocer et al. 2025). Recent times saw a very recent and tentative increase in initiatives of university-based acceleration programmes such as Maria 1.0 (http://maria.io/). Oliveira et al. (2020) highlight the interest and potential for universities to connect with acceleration programs to promote open Innovation in startups, as well as traditional corporations. At the same time, they caution about possible disconnects between university research and start-up business activities, even within the same thematic domain.

4.3. Methodological considerations and future research directions

The aim of this study was to obtain a regional perspective of students on bioeconomy and entrepreneurship. The above-presented results about regional perception may show a deviation related to regional delineation. The survey was conducted among university students in selected regions; however, it needs to be noted that the regions represent the locations of the institutions of higher education; respondents may reside elsewhere. This is especially probable in smaller NUTS 3 regions where respondents might live in surrounding regions. We recognize that the views about concepts that we asked about depends on the personal preferences, which are influenced by the lived experience within specific social, cultural, political, and economic contexts. However, students that receive different training are expected to have different perceptions of concepts and therefore also preferences when it comes to ranking of alternatives. The biased outcome is highly dependent on the focus of their education, and how issued are framed i.e., "issue framing", which can be defined as "situations where, by emphasizing a subset of potentially relevant considerations, a speaker leads individuals to focus on these considerations when constructing their opinions" (Druckman 2004).

The questionnaire survey was conducted online, which is a common methodological approach enabling effective data collection (Ball 2019). The response rate was supported by a competition for wooden T-shirts that are also an example of innovative use of wood in bioeconomy. However, some studies suggest that incentives do not necessarily have a significant impact on survey response rates (Wu et al. 2022). The dissemination strategy used for sharing the survey with students causes certain limitations for the study. It is possible that students with mostly pre-existing interest towards bioeconomy and entrepreneurship answered the survey. Moreover, the survey may have reached only students from certain disciplines and study programmes. Therefore, it is not possible to generalize the results to concern the whole student population in any of the regions considered in this study. However, as the aim of the survey was to find implications on similarities and differences between regions instead of creating generalizable results, this is not seen as an issue. Another option to consider would be to use other data collection methods besides questionnaires, such as the Delphi method or structured interviews similarly to Lovrić et al. (2021). Although we could obtain more detailed information, it would certainly not be possible to obtain information from such a large number of respondents (Devaney & Henchion 2018).

The data was collected in 2023, however we can confirm that the operating environment has not changed as the updated European bioeconomy strategy comes earliest at the end of 2025 and there were no new national bioeconomy strategies published in the time period 2023–2025 in the surveyed countries (EC 2025a; EC 2025b). The questionnaire brough robust data (405 completed answers) that have been collected across Europe (9 countries) and allow presenting different viewpoints and allow international comparison.

Given that the field of bioeconomy includes a very complex view (e.g. Dietz et al. 2023) and the analysis presented by us reflects this general concept of bioeconomy, it would be appropriate to focus on individual parts of bioeconomy in the future. Due to the focus of the author's team, a detailed link between forest bioeconomy and entrepreneurship should be investigated. The

interface of entrepreneurship and bioeconomy is still an insufficiently researched topic (Kuckertz et al. 2020). Some authors have addressed the topic of forest bioeconomy (e.g. Lovrić et al. 2020; di Letizia et al. 2023), but the perspective of students could fill the existing niche in knowledge. Fostering entrepreneurship for sustainable and innovative bioeconomy is also a core of a project co-funded within ERASMUS+ initiative entitled FOEBE (AgroParisTech 2025). Another direction for future research could be a study presenting the required professional skills for a successful transition to a bioeconomy. A similar analysis was created by Trevisan et al. (2024) on the case of the circular economy, i.e., it brought an understanding of the critical skills of the transition to a circular economy and allows academics and training providers to better structure courses and curricula that meet the current demands of the markets. Current labour markets also support the inclusion and equality, and universities are adopting targeted approaches, e.g. gender equality strategies. There are also gender equality plans (GEPs) that come with tangible measures and are being continuously evaluated, including international perspective (e.g. AGRIGEP project for GEPs at life-sciences universities[1]). Disparities between genders, especially notable differences between countries in gender performance (e.g. European Commission 2024; EIGE 2025) can also impact on the attitudes and willingness to start and conduct their own business. To name a few, it is the gender pay gap, possibility for career advancement, and availability of childcare.

Moreover, exploring similarities and differences between various study programmes and educational pathways would be an interesting topic for future research. The number of responses in this study did not allow for meaningful statistical analysis to explain differences between programmes in depth. The concepts of bioeconomy are included in higher education at various levels, separately (topic/subject), but also as a full study programme and there should also be differences between students of life sciences and students from different study fields. It is natural to emphasize specific topics in the study plan according to the major study field, but detailed explanation of differences between perceptions and needs can in future frame the update of the university curricula to better suit the needs of young professionals and incorporate bioeonomy as a key topic irrespective of the study.

5. Conclusions

In the current transition from a linear fossil-based economy towards a more sustainable circular bioeconomy, entrepreneurship and small-scale innovations play an important enabling role (Martinez-Fernandez et al. 2010). Students as future professionals represent a key stakeholder group in this transition. This study provides insights into how life-science students perceive the bioeconomy and its entrepreneurial pathways. The results reveal considerable regional differences in familiarity with bioeconomy concepts, while many students associate bioeconomy with sustainability but have limited awareness of concrete career or entrepreneurial opportunities.

These findings indicate a gap between conceptual understanding of bioeconomy and the ability to translate it into entrepreneurial action. The results further show that students' entrepreneurial motivation is often driven more by environmental and societal values than by profit-seeking. However, perceived barriers – including financial risks, lack of training, and fear of failure – may discourage entrepreneurial activity at an early stage.

The findings therefore highlight the importance of strengthening entrepreneurship education, mentoring schemes, and access to early-stage financial support. Universities, policymakers and regional actors can play a key role by creating enabling environments where students can develop practical entrepreneurial skills and transform ideas into viable bio-based business initiatives.

From a policy perspective, the results suggest that regional bioeconomy strategies should more explicitly integrate youth entrepreneurship support, including access to networks, incubators and innovation ecosystems linking students with industry and research actors. Educational institutions can support this transition by embedding bioeconomy and entrepreneurship components into life-science curricula and by promoting practical learning environments such as start-up incubators or living labs.

Ultimately, the success of the European bioeconomy transition will depend not only on technological innovation or policy frameworks, but also on the ability of young professionals to see themselves as entrepreneurs and change-makers. Empowering students to transform sustainability values into entrepreneurial action may therefore become a key driver of a resilient and regionally embedded bioeconomy.

Acknowledgements

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[1] Universities' first Gender Equality Plans.

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Appendix

Table A1. Regions and universities selected for the final analysis.

NUTS 3 Regions	Country	Universities	N
Stuttgart	Germany	University of Hohenheim	45
Lleida	Spain	EA Vallfogona de Balaguer, University of Lleida	51
Prague	Czech Republic	Charles University, Czech University of Life Sciences Prague	34
Gent and Leuven	Belgium	KU Leuven, Hogeschool Gent	74
Veluwe	The Netherlands	Wageningen University and Research	28
Lisbon Metropolitan Area	Portugal	University of Lisbon, Instituto Superior de Agronomia	17
Warsaw	Poland	Warsaw University of Life Sciences	60
North Karelia	Finland	University of Eastern Finland	65
Brașov	Romania	Transilvania University of Brasov	31

Table A2. National and regional bioeconomy strategies in place (Sanchez Lopez et al. 2020; Haarich & Kirchmayr-Novak 2022).

NUTS 3 Region	Country	National bioeconomy strategy	Relevant regional bioeconomy or development strategy
Stuttgart	Germany	Yes; National Bioeconomy Strategy for a sustainable, circular and strong economy	Federal Strategy sustainable bioeconomy Baden-Württemberg
Lleida	Spain	Yes; Spanish Strategy on Bioeconomy	Bioeconomy Strategy of Catalonia 2030
Prague	Czech Republic	Under development; concept paper "Bioeconomy Concept in the Czech Republic from the Perspective of the Ministry of Agriculture (2019–2024)"	Strategic Plan of the City of Prague; Circular Prague 2030. Strategy for the transition to a circular economy Prague 2030
Gent and Leuven	Belgium	No; only regional strategies dedicated to bioeconomy	Flemish bioeconomy policy; Bio-economy in Flanders
Veluwe	The Netherlands	Yes; The position of the bioeconomy in the Netherlands	Smart specialisation strategy (RIS3) East Netherlands 2021–2027
Lisbon	Portugal	Yes; Action Plan for the Sustainable Bioeconomy (PABS) – Horizon 2025	Regional Agenda 2.0 for the Circular Economy in the RLVT
Warsaw	Poland	Under development	Bioeconomy development strategy for Mazowieckie Voivodeship 2030
North Karelia	Finland	Yes; The Finnish Bioeconomy Strategy. Sustainably towards higher value added	Roadmap Towards Oil-Free and Low-Carbon North Karelia by 2040; Forest Bioeconomy in North Karelia
Brașov	Romania	No national strategy dedicated to bioeconomy	Smart specialisation strategy 2021–2027 – RDA Centru

Table A3. True/false statements regarding bioeconomy.

Statement	True, %	False, %
The bioeconomy provides business and innovation opportunities	90.7	9.3
The bioeconomy contributes to sustainable economic growth	90.2	9.8
The bioeconomy helps reduce our dependency on fossil fuels	89.6	10.4
The bioeconomy provides benefits to rural areas	85.5	14.5
The bioeconomy helps mitigate climate change	83.9	16.1
Developing the bioeconomy is a good way to protect forests and biodiversity	83.3	16.7
The bioeconomy contributes to the creation of new jobs	82.7	17.3
The bioeconomy provides benefits to urban areas	80.6	19.4
Social innovation and business services are part of the bioeconomy	79.2	20.8
Digitalization will advance the bioeconomy	78.7	21.3
Bio-based products are more easily recycled into new products and materials	71.9	28.1
The bioeconomy is a good idea, but there is not enough biomass to implement it	42.8	57.2
The bioeconomy will significantly put pressure on natural systems	38.3	61.7
The bioeconomy contributes to deforestation	26.6	73.4

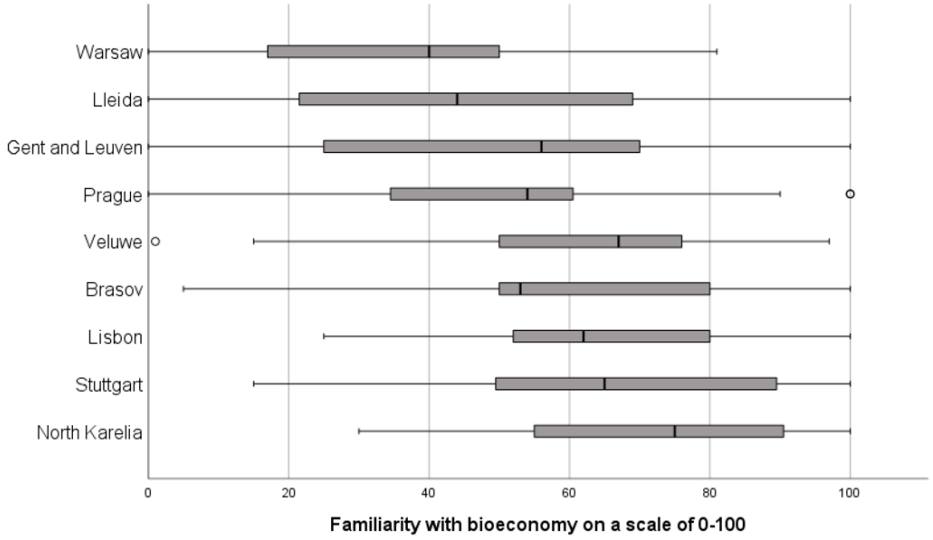


Fig. A1. Students' familiarity with the concept of bioeconomy on a scale of 0–100 in nine regions in Europe. Median values are indicated by the vertical line inside the grey boxes. The left boundary of the box is the 1st quartile (Q1) and the right boundary the 3rd quartile (Q3). The length of the box indicates the interquartile range, IQR. Whiskers represent the minimum (on the left) and maximum (on the right) values above Q1 – 1.5 × IQR and below Q3 + 1.5 × IQR.

What is the biggest bioeconomy benefit?

Stuttgart	Lleida	Prague	Gent and Leuven	Veluwe	Lisbon	Warsaw	North Karelia	Brasov	
28	53	20	43	21	38	11	19	52	Helping conserve biodiversity and ecosystem services
31	20	35	16	25	0	30	23	10	Reduced material consumption and waste, increased reuse and recycling
21	2	10	9	25	38	5	32	16	Providing renewable alternatives to non-renewable materials
5	9	30	11	13	0	29	11	6	Renewable energy to replace fossil fuels
10	4	5	9	13	8	5	7	0	Transition to a low-carbon economy
3	4	5	5	0	8	7	4	1	Providing wellbeing for people
0	2	5	4	4	0	2	2	0	Equality and fair chances
0	4	0	2	0	8	0	0	0	None of the above
3	0	0	0	0	0	9	0	10	Job creation and economic growth
0	0	0	2	0	0	2	4	0	Boosts technological innovation

What is the biggest bioeconomy risk?

55	38	29	50	46	38	26	45	53	Degradation of biodiversity and ecosystem services
11	11	48	21	8	0	26	10	17	Higher cost of essential goods (e.g. food, water, shelter, etc)
11	4	5	21	8	23	9	5	0	Impacts on poverty or food sovereignty
3	7	10	0	13	8	11	17	10	Not enough biomass to supply the bioeconomy
8	16	0	5	13	15	4	5	10	Increased imports of biomass to Europe may have dangerous impacts on developing countries
5	11	5	0	0	15	11	3	7	Limited access to forests and other protected nature areas
5	2	0	2	13	0	7	12	3	Increasing biomass costs
3	11	5	0	0	0	6	2	0	None of the above

Fig. A2. Perceptions of the biggest benefits and risks of bioeconomy in regions (per cent of total responses per region).

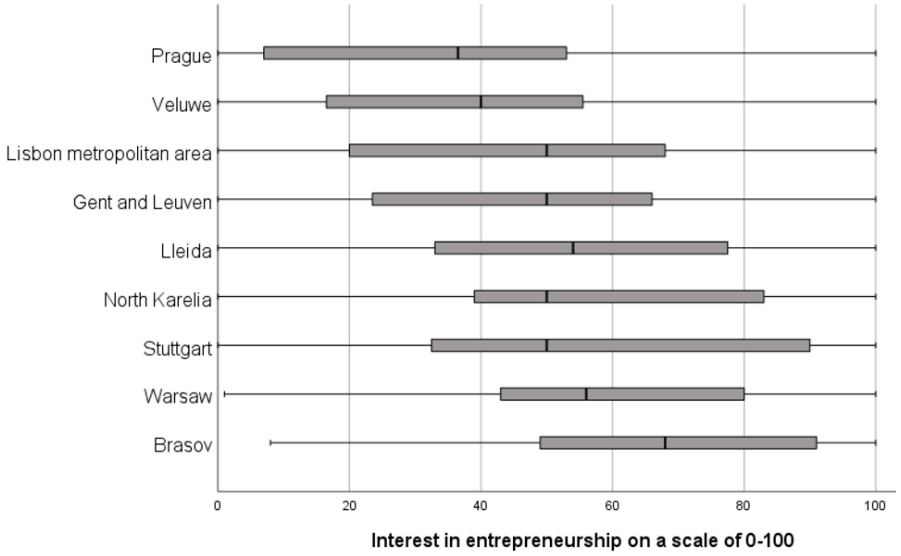


Fig. A3. Students' interest towards entrepreneurship on a scale of 0–100 in nine regions in Europe. Median values are indicated by the vertical line inside the grey boxes. The left boundary of the box is the 1st quartile (Q1) and the right boundary the 3rd quartile (Q3). The length of the box indicates the interquartile range (IQR). Whiskers represent the minimum (on the left) and maximum (on the right) values above Q1 – 1.5 × IQR and below Q3 + 1.5 × IQR.

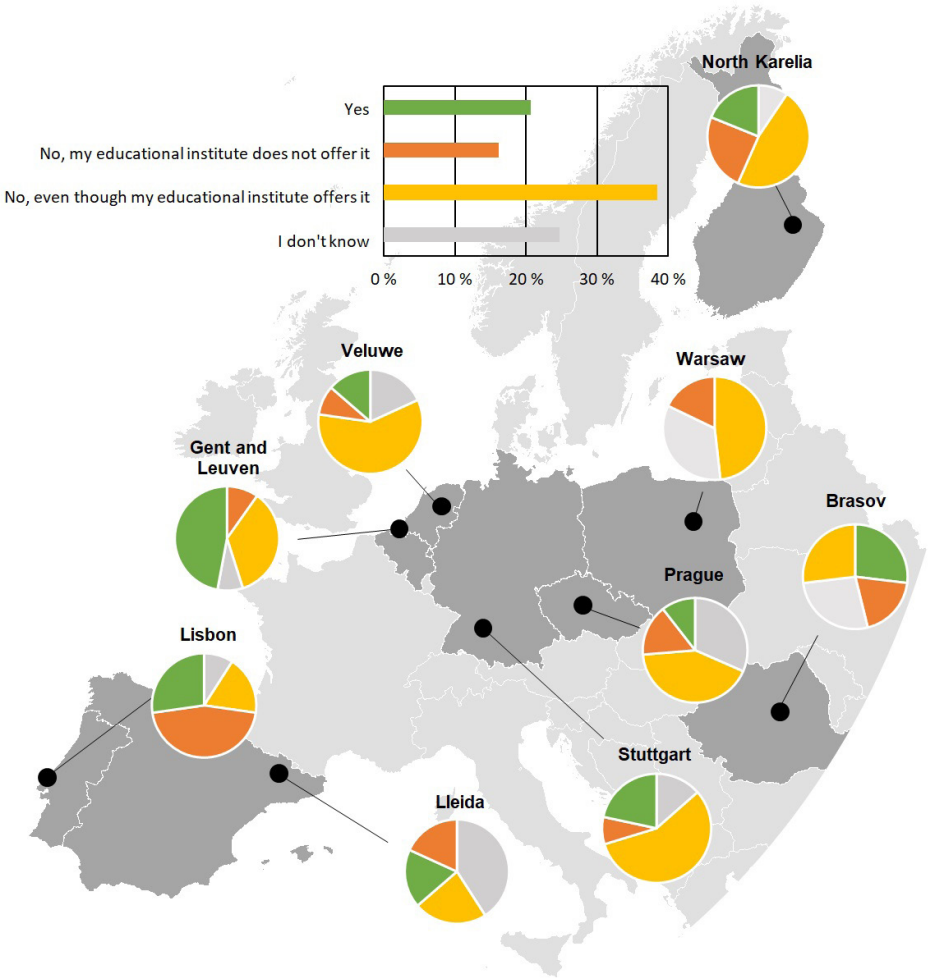


Fig. A4. Respondent participation in entrepreneurship-related courses in different regions. The bar chart shows results from all regions combined. Pie charts show regional results.



Fig. A5. Drivers for bioeconomy entrepreneurship as indicated by all respondents.

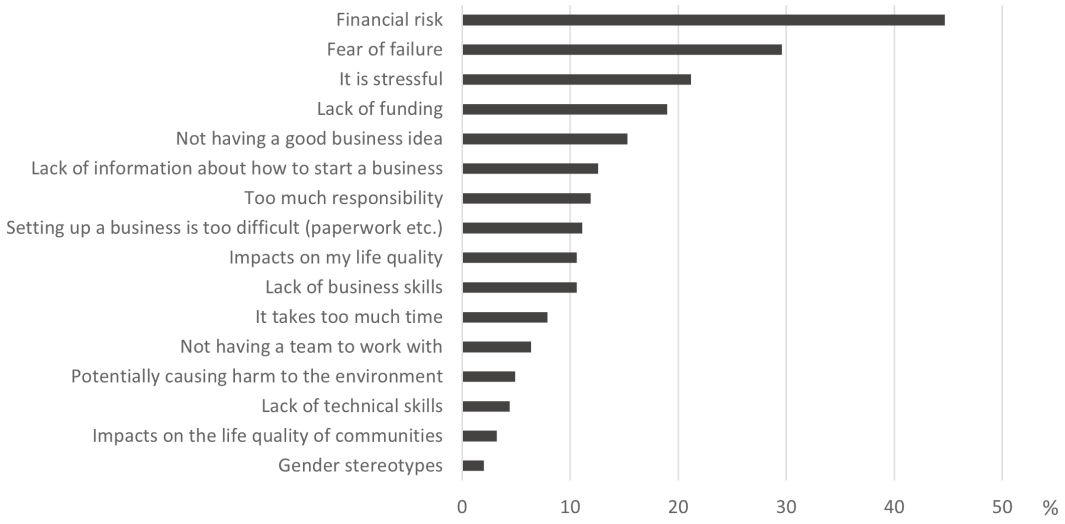


Fig. A6. Barriers to bioeconomy entrepreneurship as indicated by all respondents.