

# Education for Advancing the Implementation of the Bioeconomy Goals: An Analysis of Master Study Programmes in Bioeconomy

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**Abstract** – Bioeconomy in Europe has become one of the leading courses for sustainable and resource-efficient development. Main aspects of bioeconomy: development of new technologies and processes, development of markets and competitiveness for bioeconomy can be implemented through higher education and transformative knowledge for building a sustainable bioeconomy. Over the past year, new bioeconomy-related Master study programmes have been created and have integrated bioeconomy goals into their research, programme aims and learning outcomes. During the research the set of competences based on sustainable development competences and bioeconomy competences have been created. The integration of competences for bioeconomy development in higher education can be seen as an important step in transformation towards knowledge-based bioeconomy. On this basis, 10 Master study programmes across Europe were analysed in order to find out the actual integration of competences in different study programmes for bioeconomy. Results of the analysis show that transdisciplinary competence, learning competence, interdisciplinary competence and system-thinking competence are strongly integrated into the study programmes. The analysis also shows that the integration of other competences, like anticipatory competence, normative competence, strategic competence and interpersonal competence can be improved in the future.

**Keywords** – Sustainable higher education; competences; green innovation; bioeconomy integration assessment

## 1. INTRODUCTION

Bioeconomy in Europe has become one of the leading courses for sustainable and resource-efficient development. Main aspects of bioeconomy: development of new technologies and processes and development of markets and competitiveness for bioeconomy [1] can be implemented through higher education and transformative knowledge for building a sustainable bioeconomy. Intellectual capital gained through the knowledge-based bioeconomy became crucial for the development agenda of the European Union [2]. Therefore, the implementation of bioeconomy in Europe will be in a short loop with education and research [3]–[6]. The successful

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development of bioeconomy requires new skills from graduates of higher education based on revised model of intellectual improvement and knowledge-based technology innovation [7], [8].

The Green deal [9] set ambitious targets for European Member states to strive for with the goal to reach the climate neutrality by 2050, with a special attention to a number of sectors crucial to fulfil its ambitious aims: clean energy, sustainable industry, building and renovating, sustainable mobility, biodiversity, farm to fork and eliminating pollution. As bioeconomy instead of fossil fuels rely on renewable biomass for the production of value-added products and these products will be produced in accordance with a cascade principle, the development of bioeconomy can help to reach The Green deal goals and targets.

Golembiewski *et al.* [10] identified three main bioeconomy challenges: knowledge base, converging technologies and commercialization issues. The role of higher education in crucial for all three of these challenges, cause innovation and intellectual capital development can be achieved only with adequate skills and knowledges. In accordance with Val Lancker *et al.* [11] five factors impacting implementation of innovation development in bioeconomy:

1. Radical innovation.
2. Complex knowledge base.
3. Intense cooperation.
4. Commercialization and adoption.
5. Complex and fragmented policy schemes [11].

The implementation of bioeconomy goals should be absorbed from the systematic perspective, considering different stakeholder's groups. Working on overcoming of bioeconomy challenges special attention should be paid to environmentally sustainable economy development, because ecologically correct business practices [12], [13] can reduce the impact on environment and speed up the achievement of Green Deal goals. Montalvo *et al.* [14], [15] pointed out that the creation of greener technologies includes technological capabilities through well prepared high-quality human resources, equipment and laboratories. Different authors have carried out studies, according to which development of environmentally sustainable innovation and green innovation requires innovation-oriented learning and acquisition of specific skills [16]–[19]. Considering the above mentioned, the best practices for teaching bioeconomy, environmental responsibility and green innovations in Europe should be discussed and analysed.

## 2. METHODOLOGY

A research was conducted to propose an effective framework to evaluate the effectiveness of Master study on Bioeconomy with a focus on competence-based education and development of sustainable innovations.

During the first and second step of the research the research definition, objectives and research questions were defined. Conduction of the research started with data collection and analysis. During this step the systematic review of scientific literature on teaching bioeconomy in higher education, competences for sustainable development and bioeconomy, innovation indicators was conducted.

During the next step of the research most significant innovation indicators for bioeconomy were identified and selected.

The integration of competences for bioeconomy development in higher education can be seen as an important step in transformation towards knowledge-based bioeconomy. During the next step key competences for bioeconomy have been defined. During the research the set of competences based on sustainable development competences and bioeconomy competences have been created.

Over the past year, new bioeconomy-related Master study programmes have been created and have integrated bioeconomy goals into their research, programme aims and learning outcomes.

A systematic review [20]–[22] of existed Master study programmes on Bioeconomy was required. For identification and selection of the most significant indicators in teaching of bioeconomy in higher education, study programmes in Europe, including joint programmes and Erasmus Mundus joint programmes were investigated.

Based on this examination, ten Master study programmes across Europe were analysed in order to find out the actual integration of competences in different study programmes for bioeconomy.

The methodological algorithm of the research is shown in Fig. 1.

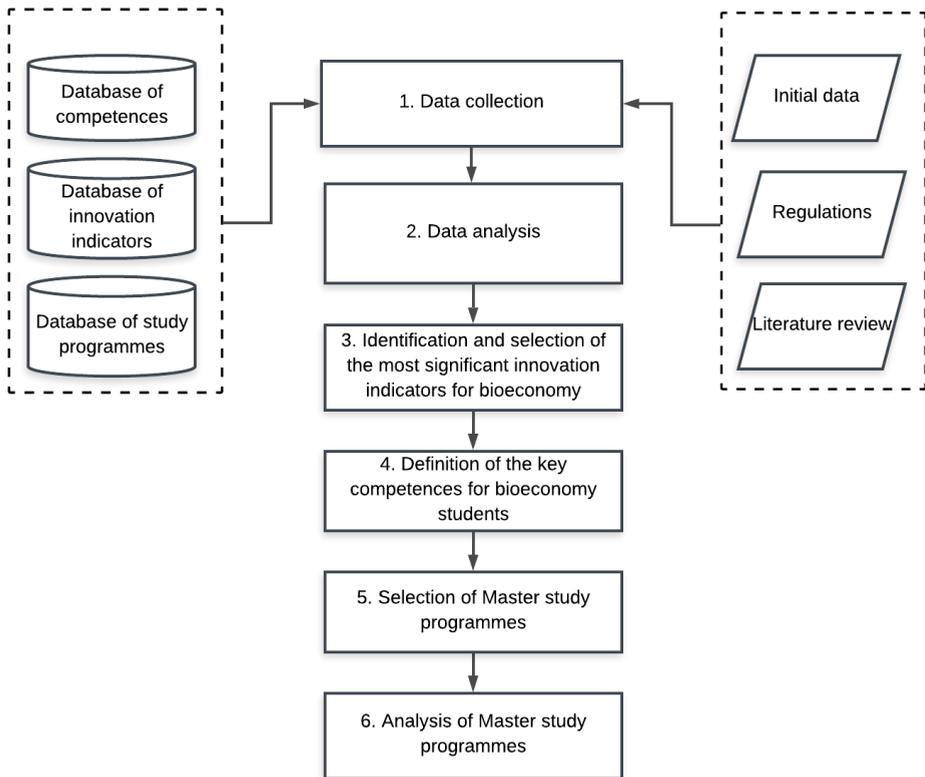


Fig. 1. Methodological algorithm.

### 3. RESULTS AND DISCUSSION

#### 3.1. The Role of Higher Education in Innovation Development in the Bioeconomy

The development of the bioeconomy is related with the promotion of innovation. The interaction of innovation with the bioeconomy context should be defined. Through innovation and use of

knowledge-based technologies bioeconomy provide entirely new products, at the same time adapting the existing technologies and products to reach the demands of sustainable economy [23].

How to measure innovation in the bioeconomy? Wydra [24] had analysed innovation indicators in bioeconomy, including research and development activities, bibliometrics and patents, human resources and commercialization and the impact of innovation. Ribeiro and Cherobim [25] described stages of the innovation process and Van Lancker *et al.* [11] analysed the role of universities in innovation in the bioeconomy. Fig. 2 shows the innovation process in bioeconomy, including innovation process, stages, involvement of university and innovation indicators. Universities play the core role in the innovation process.

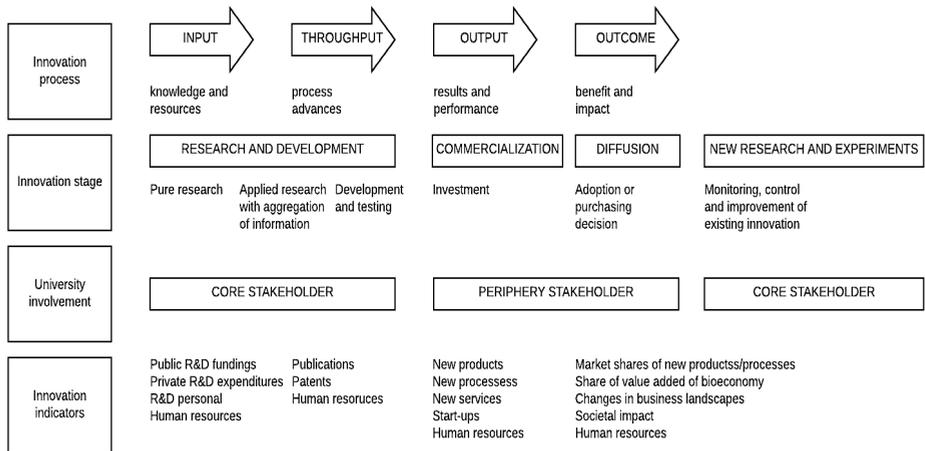


Fig. 2. Innovation process and indicators in bioeconomy.

### 3.2. The Integration of Competences for Bioeconomy Development in Higher Education

European Commission has defined the theoretical concept of Knowledge-Based-Bioeconomy (KBBE) as life science knowledge transformation process into eco-efficient, new and sustainable products [26]. The transformation process of the existing production system towards KBBE will increase demand for the high-skilled and highly qualified workers. To analyse the qualification needed, the competences and knowledge for building a sustainable bioeconomy were analysed. Due to the global changes and transition to bioeconomy and circular economy, new ways of knowledge production and decision-making at university level should be developed [27].

In accordance with Segalas *et al.* [28], education, although an important condition, does not guarantee a change to sustainability. Engineering students upon graduating should have systems thinking and transdisciplinary competence. The same statement can be addressed to bioeconomy. Transdisciplinary in contest of engineering education is considered a competence for sustainability [29]. Lambrechts *et al.* [30] analysed the integration of competences for sustainable development in higher education via a holistic, interdisciplinary and transdisciplinary approach and competence-based education. Authors analysed how competences for sustainable development, such as responsibility, emotional intelligence, system orientation, future orientation, personal involvement and action skills were integrated into bachelor study programmes in management. Weak *et al.* [31] defined system-thinking competence, anticipatory competence,

normative competence, strategic competence and interpersonal competence as main competences for sustainability.

The transition towards a bioeconomy requires well prepared bioeconomy professionals with basic and key competences acquitted through interdisciplinary educational process and new learning environments. Sustainability is considered to be a basic principle of bioeconomy; therefore, the competences for sustainability can be used as the basis for the competences for bioeconomy [32].

The programmes on bioeconomy are trying to integrate innovative learning and facilitate the development of interdisciplinary competence acquiring the ability to integrate and collaborate [33]. Learning competence include self-directed learning, collaborative learning and problem-oriented learning [34].

The integration of competences for sustainable development and bioeconomy competences can be seen as an important step in higher education for advancing the implementation of the bioeconomy goals.

There is a lack of information on the actual status of the integration of competences in existing Master study programmes on bioeconomy. The competences used for the analysis of Master study programmes on bioeconomy are shown in Table 1.

TABLE 1. COMPETENCES FOR BIOECONOMY USED FOR THE ANALYSIS

Competence	Discourse of Competence
<b>System-thinking competence</b>	The ability to collectively analyse complex systems across different domains of sustainability and bioeconomy [31].
<b>Anticipatory competence</b>	The ability to collectively analyse and evaluation in bioeconomy and sustainability issues [31].
<b>Normative competence</b>	The ability to collectively map, specify, apply, reconcile, and negotiate sustainability values, principles, goals, and targets [31].
<b>Strategic competence</b>	The ability to collectively design and implement interventions, transitions, and transformative governance strategies towards bioeconomy sustainability [31].
<b>Interpersonal competence</b>	Advanced skills in communicating, deliberating and negotiating, collaborating, leadership, pluralistic and trans-cultural thinking, and empathy [31].
<b>Transdisciplinary competence</b>	Advances skills in transcendence, problem solving, innovation, interdisciplinary research, transgression [28].
<b>Learning competence</b>	The ability to self-directed learning, collaborative learning and problem-oriented learning [33].
<b>Interdisciplinary competence</b>	The ability to integrate disciplinary perspectives and their insights to advance understanding of complex problems with the goal of applying the understanding to a real-world problem [30].

### 3.3. Analysis of Master study programmes on bioeconomy

In the last years several universities in Europe have established programmes on topics related with bioeconomy. For the analysis from European master programmes on bioeconomy were selected. The study programme selection was done through the master study programmes search pages and through the search on specific home pages about bioeconomy.

Only full time Master Study programmes were selected. Search results have shown that study programmes on bioeconomy spread around Europe from North Europe (Finland and

Estonia), Western Europe (Germany, Austria, Netherlands, France Belgium), Eastern Europe (Rumania), Southern Europe (Italy, Spain) and the United Kingdom.

For the moment the most of the study programmes are in Western Europe. Netherlands are the leaders with four Master study programmes on bioeconomy. Germany, France, and the United Kingdom have more than one study programme on bioeconomy. Seven Master study programmes are University study programmes, two are joint Master study programmes and one is Erasmus Mundus Joint Master study programme. The overall focus of study programmes is on bioeconomy with specialization in different aspects of bioeconomy, such as forestry, biotechnology, circular economy, chemical engineering, biobased materials, bio innovations, etc.

The sampling resulted in the following 10 study programmes presented in Table 2.

TABLE 2. MASTER STUDY PROGRAMMES ON BIOECONOMY

University	The name of the programme	Study time	Description
Maastricht University (Netherlands)	Biobased Materials	2 years full time	Focus on discovery of new materials and sustainable production methods of bioresources [35].
Utrecht University (Netherlands)	Bio Inspired innovation	2 years full time	Focus on development of circular business-models and bio inspired research & innovations [36].
Wageningen University and Research (Netherlands)	Biobased Sciences and Biosystems Engineering (and Biotechnology)	2 years full time	Focus on biobased economy from an interdisciplinary perspective [37].
University of Edinburgh (UK)	Management of Bioeconomy, Innovation and Governance	2 years full time	Focus on such aspects of bioeconomy as sustainable innovation and bringing new technologies to existing and emerging markets [38].
University of Strathclyde (UK)	Industrial Biotechnology	1 year full time	Focus on understanding of the current developments in industrial biotechnology [39].
The University of Hohenheim (Germany)	Bioeconomy	2 years full time	Focus on biobased economy through inter- and transdisciplinary approach [40].
University of Helsinki (Finland)	Forest Sciences	2 years full time	Focus on forest bioeconomy business and policy [41].
Joint Study Programme: University of Eastern Finland, AgroParisTech (France), University of Freiburg (Germany), University of Lleida (Spain), University of Natural Resources and Life Sciences (Austria), Transilvania University of Braşov (Romania)	European Forestry	2 years full time	Focus on sustainable resource management with an emphasis on current bioeconomy issues [42].
Joint Master: University of Bologna, University of Milano-Bicocca, University of Naples Federico II, University of Turin (Italy)	European Master in Bioeconomy in the Circular economy	1 year full time	Focus on bio-based goods and services industry using biological resources and bio-technological processes [43].

Erasmus Mundus Joint Master: Paris Institute of Technology for Life, Food and Environmental Sciences (France), University of Reims-Champagne- Ardenne (France), Aalto University (Finland), Tallinn University of Technology (Estonia), University of Liège (Belgium)	European Master in Biological and Chemical Engineering for a Sustainable Bioeconomy	2 years full time	Focus on biotechnology, bioprocess design and upscaling, and biobased products engineering, with complementary focus on soft skills including project management [44].
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A framework of analysis was developed using competences for bioeconomy defined by Wiek *et al.* [31], Repko *et al.* [33], Barth and Burandt [34] and Tejedor *et al.* [29], and competences acquitted in the study courses of each study programme. The research used competences for bioeconomy as the basis for the analysis of study programmes. Each competence was interpreted in the competence scheme. For the analysis syllabus, study programmes descriptions and study course descriptions for each study programme have been used. The goal was to express the integration of the competences for bioeconomy in each study programme: (1) little or no integration, (2) minimal integration, (3) moderate integration, (4) good integration. Table 3 provides an overview of results of analysis of University of Edinburgh study programme “Management of Bioeconomy, Innovation and Governance”.

TABLE 3. EXAMPLE OF ANALYSIS OF STUDY PROGRAMME INDIVIDUAL COMPETENCE MATRICES

Competences for Bioeconomy  Study programme competences	System-thinking competence	Anticipatory competence	Normative competence	Strategic competence	Interpersonal competence	Transdisciplinary competence	Learning competence	Interdisciplinary competence
	Analysis of trends, opportunities and challenges along the life science innovation pathway [45]	4	4	3	3	2	4	3
Facilitating entrepreneurship and thinking creatively about the future of the bioeconomy [45]	3	3	4	4	4	4	4	4
Creating business plans and mapping routes to market for new technologies [45]	3	3	2	4	3	3	3	3
Foresight and scenario-based techniques for managing risk and uncertainty associated with emerging technologies [45]	4	3	4	3	3	4	2	4
Negotiation and communication skills in interdisciplinary teams [45]	4	4	3	4	4	3	4	4
Legend:	1	little or no integration						
	2	minimal integration						
	3	moderate integration						
	4	good integration						

Considering the fact that analysed study programmes are designed especially for the bioeconomy studies, overall bioeconomy and sustainable development competences are well integrated into the study programmes. In existing study programmes on Bioeconomy in Europe transdisciplinary competence, learning competence, interdisciplinary competence and system-thinking competence are strongly integrated into study programmes. The integration of other competences, like anticipatory competence, normative competence, strategic competence and interpersonal competence can be stronger. This illustrated that translation towards these competences for sustainable development and bioeconomy in a future must be intensified.

The result of the analysis on the integration of bioeconomy competences in study programme competences are shown in Table 4.

TABLE 4. THE INTEGRATION OF BIOECONOMY COMPETENCES IN THE STUDY PROGRAMME COMPETENCES

Competences for Bioeconomy		System-thinking competence	Anticipatory competence	Normative competence	Strategic competence	Interpersonal competence	Transdisciplinary competence	Learning competence	Interdisciplinary competence
Competence matrix of Master study programmes									
Biobased Materials		3	4	3	3	3	4	4	4
Bio Inspired innovation		4	3	3	3	4	4	4	4
Biobased Sciences and Biosystems Engineering (and Biotechnology)		4	3	3	4	3	4	4	4
Management of Bioeconomy, Innovation and Governance		4	3	3	4	3	4	3	4
Industrial Biotechnology		3	4	3	4	4	3	4	4
Bioeconomy		4	4	3	4	3	4	4	4
Forest Sciences		3	4	4	3	3	3	4	3
European Forestry		4	3	3	3	4	4	4	4
European Master in Bioeconomy in the Circular economy		4	3	4	3	4	4	4	4
European Master in Biological and Chemical Engineering for a Sustainable Bioeconomy		4	3	3	3	3	4	4	4
Legend:		3	moderate integration						
		4	good integration						

## 4. CONCLUSIONS

For the achievement of Green deal, new thinking, learning, teaching and acting strategies should be used. The transition towards bioeconomy is a challenging process and requires cooperation of different stakeholders. Universities, one of the main stakeholders in creation of innovation and sustainable invention, play an important role in implementation of bioeconomy goal through preparation of bioeconomy professionals. Bioeconomy programmes graduates will be the protagonists of a transformation to sustainable bioeconomy and will need to apply acquitted competences and knowledge in creation of new technologies and green innovations in general. This article has reviewed the indicators of sustainable innovation and bioeconomy and sustainable development competences for the education for bioeconomy. Defined competences include transdisciplinary competence, learning competence, interdisciplinary competence and system-thinking competence, anticipatory competence, normative competence, strategic competence and interpersonal competence. All of these competences have showed to be the most important for the implementation of bioeconomy goals and transformation to knowledge-based sustainable bioeconomy.

The analysis of 10 Master study programmes on bioeconomy revealed that the overall bioeconomy and sustainable development competences are strongly integrated into study programmes.

Authors state that more research is needed on the link between the integration of the competences and green innovations. Definition of competences is only one of the steps in the integration of sustainable bioeconomy and is only a part of a broader process, combined with knowledge, skills, intellectual capital and inventions for sustainable bioeconomy.

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