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OBRAZOVANJE PROFESIONALACA ZA BIOEKONOMIJU I ULOGA UNIVERZITETA I ISTRAŽIVAČKO-RAZVOJNIH MREŽA

Apstrakt: U radu se polazi od toga da u savremenom svetu postoji potreba za bioekonomskim ekspertima i predstavlja se profesija bioekonomiste. Glavni cilj rada je da se analiziraju osnovna znanja, veštine i kompetencije koje profesionalci za bioekonomiju treba da poseduju. Sagledava se uloga univerziteta u kreiranju i razvoju kompetencija koje odlikuju bioekonomske profesionalce. Na primeru šest vodećih evropskih univerziteta analiziraju se studijski programi master i doktorskih studija u ovoj oblasti. Predstavljani su i analizirani i odgovarajući kratki on-line kursevi. Poseban deo rada bavi se saradnjom između univerziteta, kompanija i nevladinih organizacija putem istraživačkih aktivnosti i projekata iz oblasti bioekonomije. Na kraju rada su izvedeni odgovarajući zaključci.

Ključne riječi: bioekonomija, profesionalci za bioekonomiju, kompetencije, univerziteti, saradnja.

EDUCATION OF BIOECONOMY PROFESSIONALS AND THE ROLE OF THE UNIVERSITIES AND RESEARCH AND DEVELOPMENT NETWORKS

Abstract: The paper starts from the fact that there is a great need for bioeconomic experts in the modern world; accordingly, the profession of a bioeconomist is presented. The main goal of the paper is to analyse the basic knowledge, skills and competences that bioeconomy professionals should possess. The role of universities in the creation and development of competences that characterize bioeconomy professionals is discussed. The study programs of Master and Doctoral studies in this field are analysed on the example of six leading European universities. Relevant short open online courses are also presented in more detail and analysed. Additionally, one part of the paper is devoted to collaboration between universities, companies and non-governmental organizations through research activities and projects in the field of bioeconomy. Appropriate conclusions are drawn at the end of the paper.

Keywords: bioeconomy, bioeconomy professionals, competences, universities, collaboration.

1. INTRODUCTION

In the area of South-eastern Europe countries, the state of the environment is not at a satisfactory level. Moreover, air, water and river pollution in this area often reach the highest levels, both at the European and global levels. Public policies of these countries do not necessarily contribute to alleviating/resolving this worrying situation. Desirable breakthroughs in this area include, however, specific expertise and competences, financial support, preparation/implementation of appropriate projects, strengthening the bioeconomic component of the existing economy, and, especially, the development and building of a new economy based on bioeconomic business.

Bioeconomy is a discipline that deals with the sustainable and innovative use of biomass and biological knowledge to provide food, feed, industrial products, bioenergy, and ecological and other services. Hence, its main function is to provide sufficient food of adequate quality and renewable resources to a growing population and, at the same time, to make/secure sustainable use of natural resources. Bioeconomy is expected to drive the transition towards a more sustainable economy by addressing some of the major global challenges, including food security, climate change and resource scarcity. The globally increasing demand for food in particular, but also materials and renewable energy, calls for innovative developments in the primary sectors. Innovations will have to generate more resource-use-efficient technologies and methods for increasing productivity in agriculture, forestry and aquaculture without harming the Earth's carrying capacity and biodiversity. Bioeconomy makes use of new resources by building on renewable biomass. Therefore, through the introduction of

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innovative and resource-use-efficient production technologies and the transition to a sustainable society, it assists in substituting or reducing the use of limited fossil resources, thereby helping the climate change mitigation.

The basic assumption for the use and development of bioeconomy in the area of Southeast Europe is the introduction of appropriate higher education (university) curricula in these countries in order to provide the necessary knowledge, skills and competences of specific experts for these purposes. In this context, it is important to look at the achievements and experiences of the six European universities, as well as research and development units and companies when it comes to the concept of bioeconomy.

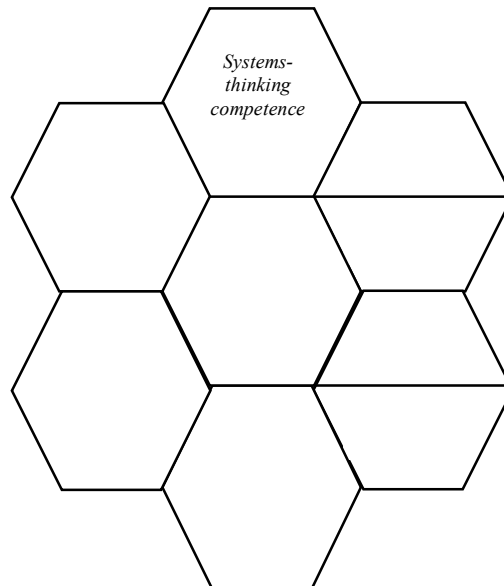
2. BIOECONOMY PROFESSIONALS

Bioeconomy, as an integral part of sustainable development, covers all sectors that rely on biological resources, from the primary sector that produces and uses biological resources to the industrial sectors which use these resources to produce food, bio-based products, energy and services. In addition to *positive environmental effects* (lower emission levels, reduction of emissions in the energy sector by using bioenergy etc.), the transition process to bioeconomy can provide various *positive socio-economic effects* at the local and global level, such as:

- employment growth in agriculture, fisheries and aquaculture, bio-based textiles, bio-based pharmaceuticals, bio-based plastics and rubber, bioenergy etc.;
- an increase in household income;
- an opportunity for farmers, foresters and fishermen to diversify their income sources;
- preventing of the rural exodus by the creation of new jobs associated with the development of new food and bio-based value chains, especially in remote rural areas;
- improvement of people's quality of life etc.

New bioeconomy professionals are required for the transition towards a sustainable and bio-based green economy. They are able to work effectively in different bioeconomy sectors due to specific expertise and the set of competences which they possess (Picture 1).

Picture 1. Profile description of the bioeconomy professional



Source: Adapted by the authors according to Lask et al. (2018), p. 345 – 346.

Bioeconomy professionals are expected to be specialised in one field, but also able to understand the scientific language of associated disciplines.⁴ Lask et al. (2018) use five key

⁴ Lask et al. (2018), p. 343.

competences for sustainability and one specific competence to describe the set of competences that bioeconomy professionals must have:

- *Systems-thinking competence* – ability to perceive and analyse the bigger picture of the global socioecological problems (climate change, pollution, energy supply etc.);
- *Anticipatory competence* – ability to analyse, evaluate and anticipate future from the point of sustainability;
- *Normative competence* – ability to identify sustainability values, principles, objectives etc.;
- *Strategic competence* – ability to create and implement sustainable strategies; and
- *Interpersonal competence* – communication skills that facilitate bioeconomy professionals to cooperate effectively.

Besides these five competences for sustainability, bioeconomy professionals must also be characterised with the *interdisciplinary competence*, which refers to:

- high level of expertise and knowledge of the whole biobased value chain;
- ability to understand and integrate different disciplines; and
- effective interdisciplinary teamwork and collaboration.

According to Lask et al. (2018) bioeconomy professionals have a *T-shaped profile*. In addition to *disciplinary expertise* (broad knowledge base in a specific bioeconomy field, the vertical stroke of the T), a bioeconomy professional also owns *interdisciplinary expertise* (collaboration competences that enable integration of different disciplines, the horizontal stroke of the T). European universities have created various bioeconomy education programmes in order to develop bioeconomy professionals with a T-shape profile.

3. THE ROLE OF UNIVERSITIES IN THE DEVELOPMENT OF COMPETENCES FOR BIOECONOMY PROFESSIONALS

Bioeconomy is a core area for education, research and innovation at many European universities.⁵ The most important objectives of the development of bioeconomy curricula in higher education across Europe include: the *development* of specific skills required by the growing bioeconomy industry and *strengthening* scientific research infrastructure, which is necessary for the development, promotion and implementation of knowledge-based bioeconomy. The six leading European universities in promotion and integration of the bioeconomy concept into education curricula across Europe are: the Paris Institute of technology for life, food and environmental sciences (*AgroParisTech*), the University of Natural Resources and Life Sciences in Vienna (*BOKU*); the University of Eastern Finland (*UEF*); the University of Hohenheim in Stuttgart (*UHOH*); the University of Bologna (*UniBo*) and the Wageningen University & Research (*WUR*).⁶

Developed international and interdisciplinary bioeconomy education programmes cover technical, economic, social and environmental aspects of bioeconomy, such as agriculture, sustainable forest bioeconomy, fisheries, aquaculture, food transformations and bio-products, biotechnology, bioenergy, sustainable management of natural resources and the environment, sustainable and healthy food systems, bio-based business models etc. In Table 1 are presented bioeconomy education programmes at the MSc level offered by the leading European universities.

⁵ Josipović, S. (2020), p. 224.

⁶ Josipović, S. (2020), p. 225.

Table 1. Bioeconomy education programmes at the MSc level offered by the European universities

Universities	MSc bioeconomy education programmes
AgroParisTech	- <i>MSc in Engineering</i> - <i>Master of Science</i> - <i>European Master in Biological and Chemical Engineering for a Sustainable Bioeconomy - Bioceb</i>
BOKU	- <i>MSc in Biotechnology</i>
UEF	- <i>MSc Wood Materials Science</i> - <i>MSc European Forestry</i> - <i>Cross-Border University MSc in Forestry</i> - <i>Transatlantic Forestry MSc</i>
UHOH	- <i>Biobased Products and Bioenergy</i> - <i>Bioeconomy</i> - <i>Food Biotechnology</i>
UniBo	- <i>Low Carbon Technologies And Sustainable Chemistry (LoCaTe)</i> - <i>European Master in Bioeconomy in the circular economy (BioCirce)</i> - <i>Erasmus Mundus Master Course in Chemical Innovation and Regulation (EMMC-ChIR)</i>
WUR	- <i>Biobased Sciences</i>

Source: Table created on the basis of the analysis presented in Josipović, 2020.

Courses developed within the *Engineering* and *Master of Science* curricula offered by the AgroParisTech cover a wide range of topics related to bioeconomy: from agricultural production and forestry, management of land and natural resources, sustainable and healthy food systems, biotechnologies, bio-products to socio-economic dimensions of the bioeconomy. *Key competences* that students gain include: the ability to apply economic and engineering approaches to biology and forest ecosystems; knowledge and understanding of the sustainable and innovative food development; knowledge about industrial practices related to bioeconomy; the ability to use different research quantitative tools and methods and the development of specific personal, social, cultural, leadership and technical skills. AgroParisTech with the University of Reims-Champagne-Ardenne, the Aalto University, the Tallinn University of Technology and the University of Liège offeres MSc programme *Bioceb*. The *vision* of this programme is to promote the development of sustainable and circular European bioeconomy by connecting chemical and biological engineering with the design and development of bio-based products and processes. It consists of four semesters⁷: Agro-sciences and biorefinery (the first semester), Bioproducts & sustainable chemistry or Agro-resources & value-chain assessment (the second semester), Biomass engineering, Bioprocesses or Bio-based products (the third semester) and Master's thesis preparation (the fourth semester). The main *learning outcomes* of this MSc programme are the following: understanding and knowledge of the green chemistry principles, the ability to use tools for socio-economic and environmental assessment and development of the soft skills including project management.

The *vision* of the BOKU is to contribute to a sustainable and circular development in Europe by developing education curricula in different fields of bioeconomy and the innovations necessary for the creation of bio-based green economy. The developed curricula, under MSc programme *Biotechnology*, offer students the opportunity to choose one of six specialisations: Bioinformatics, Bioprocess Engineering, Medical Biotechnology, Plant Biotechnology, Environmental Biotechnology and Protein Engineering and Technology.

In order to remain an internationally recognised educational and research institution, the UEF offers four international and interdisciplinary MSc programmes specialised in the field of the Forest Bioeconomy:

- *MSc Wood Materials Science* - the curricula consists of Compulsory (97 ECTS) and Elective studies (23 ECTS) and provides specialised knowledge focused on the use of the wood biomass for the production of the bio-based products (bio-based materials, chemicals and bioenergy).

⁷ For more details see: <http://www.bioceb.eu>

- *MSc European Forestry* - offered by UEF in collaboration with the AgroParisTech (France), the BOKU (Austria), the University of Freiburg (Germany), the University of Lleida (Spain) and the Transilvania University (Romania);
- *Cross-Border University MSc in Forestry* - the programme is result of cooperation between the UEF and the Bauman Moscow State Technical University, the Mytischki Branch Petrozavodsk State University and the Saint Petersburg State Forest Technical University. The curricula comprise general and methodological studies (min. 7 ECTS), studies in language and communication (min. 3 ECTS), advanced studies in European forestry (min. 55 ECTS), elective courses (min. 10 ECTS) and obligatory advanced studies (45 ECTS).
- *Transatlantic Forestry MSc* - the programme is result of cooperation between the UEF and the University of New Brunswick (Fredericton), the University of Alberta (Edmonton), the University of British Columbia (Vancouver), the Albert-Ludwigs-University, Freiburg (Germany), the University of Bangor (Wales), the University of Padova (Italy) and the BOKU, Vienna (Austria). Education curricula, specialised in the field of sustainable forestry and environmental management, comprise coursework (120 ECTS, including internship in either Canada or Europe) and MSc thesis (30 ECTS).⁸

MSc programme *Bioeconomy* offered by the UHOH is taught in English and consists of three types of modules: Compulsory, Semi-elective and Elective. The topics covered by the curricula range from natural and agricultural scientific studying of the properties of bio-based resources to economic analysis and optimisation of production and processing across the entire bio-based value chain.⁹ The MSc programme *Food Biotechnology* offers an opportunity for specialisation in two fields: *Enzyme Biotechnology* and *Food Microbiology*.

The MSc programme *BioCirce* was founded as a result of cooperation between the UniBo and three Universities from Italy¹⁰. This programme is also supported by four main Italian bioeconomy companies and associations (Intesa Sanpaolo, Novamont SpA, GFBiochemicals SpA and PTP Science Park di Lodi). During the course of the programme, students are introduced to the entire value chain of bio-based products (from the supply of biological resources and bio-technological and industrial processes that transform these resources into a bio-based product, to marketing and consumption of the final bio-based products). It lasts for one year and consists of four modules, each managed by one of the four participating universities. The key *learning objectives* include¹¹:

- knowledge and understanding of the technologies related to bioeconomy;
- the ability to analyse the principal components of the whole industrial production chain and understanding of the mechanisms behind successful technology transfer (*Milano Bicocca Module*);
- knowledge of the use of enzymes and microbial cells in industry and about theoretical and practical tools for the identification of new entrepreneurial innovative business ideas (*Napoli Federico II Module*);
- knowledge of the national and international regulations on access to genetic resources and about major economic and financial performance indicators (*University of Torino Module*); and
- knowledge of industrial biotechnological processes and economic characteristics of primary production of the raw materials for bioeconomy (*University of Bologna Module*).

The MSc programme *EMMC-ChIR* is managed by the Consortium which consists of four European Universities¹². In the first year of classes at the Host University (one of the four Universities which are members of the consortium), students choose 30 of 98 modules (each lasts for one week and it is worth 2 ECTS), which are grouped into five large disciplines: Design, Industry, Marketing, Assessment and International Regulations. During the second year, students work on a research

⁸ <https://www3.uef.fi/en/web/mdp-transform/studies>

⁹ For more details see: University of Hohenheim, Curriculum Bioeconomy, Master of Science, 2019.

¹⁰ The University of Milano-Bicocca, the University of Naples Federico and the University of Turin.

¹¹ University of Bologna, Master Biocirce, Bioeconomy in the Circular Economy.

¹² UniBo with the University of Algarve (Portugal), the University of Barcelona (Spain) and the Heriot-Watt University (UK).

project in order to finish their thesis dissertation. Research can be done at the University which is a member of the Consortium, at one of the non-EU partner universities (in Brazil, China, USA, India or Japan) or at one of 20 associate partner institutions. The *main learning outcomes* include: knowledge and understanding of the chemical safety international regulations; knowledge and understanding of the principles related to the design of new safe chemical products; ability to project a business plan for new chemical products; ability to evaluate potential environmental, toxicological, physical and chemical reactivity hazards of chemical substances and understanding of the global economy from the chemical industry perspective.

The MSc programme *Biobased Sciences* consists of two foundation courses (*Circular Economy* – 6 credits and *Principles of Bio-based Economy* – 6 credits), several interdisciplinary courses (12–18 credits) which belong to the chosen specialisation¹³, free optional courses (18–24 credits)¹⁴, the Academic Consultancy Training (12 credits), MSc thesis (36 credits) and an internship (24 credits) at a host organisation that fits the student specialisation and which is outside the WUR. The main *learning outcome* of this programme is to provide graduates with special knowledge in one of three bio-based disciplines (specialisations): *Biomass Production and Carbon Capture*, *Biorefinery and Conversion* and *Bio-based and Circular Economy*. After a successful completion of the programme, graduates will be able to design a new bio-based concept/product/process, assess technological, ethical, societal, and economic consequences of changes in the design of a bio-based concept, product or production process, cooperate in an interdisciplinary team, generate creative ideas and recognise the limits of scientific knowledge and develop and execute a research plan in order to meet the objectives of the bio-based research and development projects.

WUR offers two MicroMasters programmes in the field of Bioeconomy, *Economics and Policies for a Circular Bio-Economy* and *Business and Operations for a Circular Bio-Economy*. Each programme lasts for six months and consists of four courses¹⁵ that are taught in English. There are no formal requirements that a student must meet to enrol in these programmes, but it is desirable to have a BSc degree in social sciences (business or economics). Graduates of these programmes are usually (bio)chemical engineers, process engineers, top managers, supply chain managers, product managers, entrepreneurs, consultants and business developers in a bio-based business, bio-based researchers, bioprocess specialists etc.

The MicroMasters programme *Economics and Policies for a Circular Bio-Economy* provides students with the knowledge and skills necessary to understand the economic issues and policies that affect circular bioeconomy and evaluate costs, benefits and market impacts of the bio-based technologies.¹⁶ The MicroMasters programme *Business and Operations for a Circular Bio-Economy* provides students with the knowledge and skills necessary to understand and evaluate strategic, technological, operational and economic aspects of running a bio-based business and use quantitative methods in order to design and evaluate bio-based supply chains.¹⁷

In addition, WUR offers five massive open online courses (MOOCs) in the field of Bioeconomy. These courses are taught in English and are intended for students and professionals with a varied educational background (Table 2).

¹³ For more details see: <https://www.wur.nl/en/Education-Programmes/master/MSc-programmes/MSc-Biobased-Sciences/Specialisations.htm>

¹⁴ For more details see: <https://ssc.wur.nl/Handbook/Programme/MBS>

¹⁵ The MicroMasters program *Business and Operations for a Circular Bio-Economy* consists of the following courses: *Circular economy: an interdisciplinary approach*; *From fossil resources to biomass: a chemistry perspective*; *Business strategy and operations in bio-based economy* and *Capstone business and operations for a circular bio-economy*. The MicroMasters program *Economics and Policies for a Circular Bio-Economy* consists of courses: *From fossil resources to biomass: a chemistry perspective*; *Circular economy: an interdisciplinary approach*; *Economics and policies in a bio-based economy* and *Capstone economics and policies for a circular economy*.

¹⁶ <https://www.edx.org/micromasters/wageningenx-economics-and-policies-for-a-circular-bio-economy>

¹⁷ <https://www.edx.org/micromasters/wageningenx-business-and-operations-for-a-circular-bio-economy>

Table 2. Open online courses (MOOCs) offered by the WUR

Open online course	Learning outcomes	Subject	Length	Prerequisites
<i>From Fossil Resources to Biomass: A Business and Economics Perspective</i>	<ul style="list-style-type: none"> - Understand the concept of the bio-based economy and the value of bio-based products. - Understand the commercial, financial and organisational aspects of a bio-based business. - Understand the complexity of logistics of bio-based value chains. 	Science	5 weeks (20–28 hours per week)	BSc in technology, engineering (and applied) sciences
<i>Catalytic Conversions for Biobased Chemicals and Products</i>	<ul style="list-style-type: none"> - Understand how to efficiently convert bio-based feedstocks into desired products. - Identify pros and cons of a bio-based conversion route vs. a fossil-based conversion route. 	Chemistry	5 weeks (12–16 hours per week)	BSc in technology, engineering (and applied) sciences
<i>Biorefinery: From Biomass to Building Blocks of Biobased Products</i>	<ul style="list-style-type: none"> - Ability to conceptually design a biorefinery process. - Ability to evaluate a process design with respect to energy and feedstock efficiency 	Chemistry	7 weeks (12–20 hours per week)	BSc in technology, engineering (and applied) sciences
<i>Economics and Policies in a Biobased Economy</i>	<ul style="list-style-type: none"> - Explain the economic issues and policies affecting the bio-based economy at the EU and international level. 	Energy & Earth Sciences	4 weeks (12–20 hours per week)	no formal entry level requirement, preferably a BSc degree in social sciences (business or economics)
<i>Business Strategy and Operations in a Biobased Economy</i>	<ul style="list-style-type: none"> - Understand the dynamics in bio-based business investments and the supply chain challenges for bio-based businesses. - Ability to design and evaluate bio-based supply chains using quantitative methods. 	Business & Management	5 weeks (12–16 hours per week)	no formal entry level requirement

Source: A review created by the authors based on the analysis of the curricula for the presented open online courses available at: <https://www.wur.nl/en/Education-Programmes/online-education/MOOCs/Circular-and-Biobased-Production.htm>

Developed bioeconomy education programmes at the PhD level, offered by the leading European universities, are presented in Table 3.

Table 3. Bioeconomy education programmes at the PhD level offered by the leading European universities

Universities	PhD bioeconomy education programmes
AgroParisTech	<ul style="list-style-type: none"> - <i>Agriculture Food Biology Environment Health (ABIES)</i> - <i>Natural Resources, Science and Engineering (SIReNa)</i> - <i>Biodiversity, Agriculture, Food, Environment, Earth, Water (GAIA)</i>
BOKU	- <i>Advanced Biorafineries: Chemistry and Materials (ABC & M)</i>
UEF	- <i>PhD Programme in Forests and Bioresources</i>
UniBo	- <i>Erasmus Mundus Joint doctorate in Sustainable Industrial Chemistry</i>

Source: Table created on the basis of the analysis presented in Josipović, 2020.

Science and engineering for food and bio-products form an integral part of the developed curricula under all three PhD programmes that AgroParisTech offers with other universities in France. During the PhD programme *Advanced Biorafineries: Chemistry and Materials (ABC & M)* students

are introduced with the entire cycle of biorefinery. The programme is taught in English and intended for those who have an MSc or equivalent degree in Chemistry, Biochemistry, Biotechnology, Wood Technology and Management, Material Sciences or a related discipline. Also, other PhD programmes of the BOKU include various bioeconomy courses as well, such as Biochemistry, Biotechnology, Biotechnology specialisation in bioinformatics etc. PhD Programme in *Forests and Bioresources* is intended for postgraduate students who show interest in forest-based bioeconomy, renewable resources and biomaterials. All courses are taught in English and the programme offers the degrees of a Doctor of Science (Agriculture and Forestry), the Licentiate of Science (Agriculture and Forestry) with Forest Sciences as the major subject and a Doctor of Philosophy with Forest Sciences as the major subject. In order to accomplish its *mission*, to transfer sustainable/green chemistry from idea to innovation, the three year *Erasmus Mundus Joint doctorate in Sustainable Industrial Chemistry* programme is focused on four key sectors: Development of innovative catalysts and catalytic processes; Novel green solvents; Renewable energy and raw materials and Micro-reactors and membrane.¹⁸

4. COLLABORATION THROUGH BIOECONOMY RESEARCH ACTIVITIES AND PROJECTS

European universities conduct research activities and projects in the field of Bioeconomy which enable the collaboration between universities, companies and non-governmental organizations. They are aimed at understanding global socioecological problems. Research and development activities of the UEF are focused on the following bioeconomy topics: sustainable and multifunctional management; the use of forests for different ecosystem services; wood-based eco-innovations; sustainable processes, products and services; sustainable and integrated utilisation of aquatic resources; protection of aquatic biodiversity; management of waters; socio-ecological and spatial effects of transition processes; sustainable financing and management; analysis on regulatory and policy frameworks and the policy instrument practices etc. UEF participates in the project *Bioeconomy for Upper Secondary Schools* aimed at supporting and promoting the development of the bioeconomy education curricula. It also takes part in the project *Developing competitiveness of the regional bioeconomy companies* whose goal is to analyse the business of bioeconomy enterprises that operate in North Karelian.

EU bioeconomy projects in which participate lecturers and researchers of the AgroParisTech are:

- Projects implemented under *Horizon2020*¹⁹, with the goal to support the development of circular economy based on renewable biological resources;
- Projects implemented within the *Erasmus + multilateral projects*²⁰, with the goal to support development of international MSc programmes offered by an international consortium which consists of at least three higher education institutions;
- *Climate-KIC (Knowledge and Innovation Community) projects*²¹ which provide support for life-long training, entrepreneurship and innovations;
- *LIFE projects*²² which provide support for environmental and nature conservation and climate action projects throughout the EU countries, and
- *Interreg projects*²³ which promote economic and social development of the EU through cross-border, transnational and interregional cooperation.

¹⁸ For more details see: <http://www.sinchem.eu/>

¹⁹ RESOLUTE – High performing and safe solvent derived from cellulosic feedstocks – a collaborative project (Joint Undertaking Bio-Based Industries); FertiCycle – New bio-based fertilisers from organic waste upcycling; ZELCOR – Zero Waste Ligno-Cellulosic Biofineries by Integrated Lignin Valorisation – a collaborative project (Joint Undertaking Bio-Based Industries); LOGISTEC – Logistics for Energy Crops' Biomass; S2BIOM – Delivery of sustainable supply of non-food biomass to support a “resource-efficient” Bioeconomy in Europe etc.

²⁰ AgroParisTech is a Coordinator of the Erasmus Mundus Master in Biological and Chemical Engineering for a sustainable bioeconomy – Bioceb.

²¹ Project Voucher Biophenol.

²² Marine Habitats – Nature Integrated Project for effective and equitable management of marine habitats in France – Marha.

These bioeconomy projects are financed by the European Union Framework Programme for Research and Innovation (Horizon2020 projects) or by other European programmes and bilateral funding schemes (Erasmus + multilateral projects, Climate-KIC projects, LIFE projects and Interreg projects).

Industrial Agro-Biotechnologies research and development center of the AgroParisTech is engaged in the realisation of multidisciplinary and transdisciplinary fundamental and applied research projects whose subject of research is the use of agro-resources for the development of the sustainable industrial processes and high value-added products.²⁴ The centre consists of three scientific teams (*Biotechnology, Green Chemistry and Process Engineering Team*) and one analytical platform. In order to support innovative solutions in different dimensions of bioeconomy, AgroParisTech has eight campuses in France and four business pre-incubators (Inn Labs).

Research activities of the Centre for Bioeconomy of the BOKU are focused on various areas related to bioeconomy²⁵:

- *Raw material production* (Production of agricultural, forestry and other raw materials, Plant management, Animal management, Waste and residue management etc.);
- *Converting and processing* (Harvest treatment, Biomass conversion technologies etc.);
- *Environmental aspects* (Sustainability criteria, Cascade use and circularity, Environmental accounting, Contribution to climate goals etc.); and
- *Social science aspects* (Macroeconomics, Microeconomics, Consumption behaviour, Monitoring etc.).

Through the *Bioeconomy Research Programme Baden-Württemberg*²⁶, the UHOH provides support for the development of an adequate bioeconomy research strategy in German and for the cross sectional research, innovations and networking in the field of bioeconomy. This programme, created in 2012, consists of research networks in three areas:

1. *Research network in biogas* focused on sustainable and flexible value added chains for biogas;
2. *Research network in lignocellulose* focused on development of an alternative commodity platform for new materials and products; and
3. *Research network in microalgae* focused on integrated use of microalgae for nutrition and feeding stuff industries.

The *Competence Network Modelling the Bioeconomy* is implemented within the programme. Its *objective* is to develop methods required for an integrated analysis of the potentials, risks and opportunities of the biomass use. A part of this programme is an interdisciplinary bioeconomy PhD programme *BioeconomyBaden-Württemberg: Exploring Innovative Value-Added Chains* (called BBW-ForWerts). The *main objective* of this three-year programme is to provide PhD students with knowledge of the entire innovative bio-based value chains, including the analysis of different ecological, economic and social aspects. At the end of the programme, they will be able to implement the acquired knowledge through cooperation with industrial partners and research institutions. The developed interdisciplinary curriculum includes summer schools, seminars, workshops, trainings, courses and excursions.²⁷

UHOH is also the founder of the *Research Center for Bioeconomy* whose *mission* is to connect researchers from different scientific fields (agricultural, natural, economic, business and social sciences) through large national and international projects²⁸.

²³ AgriWasteValue – transnational collaboration on the transformation of the agricultural by-products and residues into bioactive compounds; ALPO – cross-border collaboration on the development of polymeric materials based on microalgae.

²⁴ <http://www2.agroparitech.fr/ABI-Industrial-Agro-Biotechnologies-4248.html>

²⁵ <https://boku.ac.at/en/zentrum-fuer-biooekonomie/activities>

²⁶ <https://biooekonomie-bw.uni-hohenheim.de>

²⁷ For more details see: <https://www.biooekonomie-bw.de/en/articles/news/programme-to-train-bioeconomy-expert>; <https://biooekonomie-bw.uni-hohenheim.de/bbwforwerts-strategy>

²⁸ 10 projects in the field of the Competence Network Modelling the bioeconomy; 19 projects in the field of Optimizing lignocellulose-based value chains; 2 projects in the field of Substrate production and supply; 2 projects in the field of New technologies for the conversion of biomass; 3 projects in the field of Utilisation of conversion products; 6 projects in the field of Analyses of present and future economic, ecological, ethical and social implications of biogas production; 10 projects in the field of Analyses of potential of microalgae for the use in the food and feed sector.

Research Institute *Wageningen Food & Biobased Research* of the WUR conducts applied research with the aim of developing sustainable innovations in healthy food, fresh food chains and bio-based products. The main *research objective* of the Institute is to work on the creation of sustainable food chains and develop sustainable bio-based innovations in order to contribute to lower use of fossil resources. Currently, it is involved in the implementation of four bio-based projects.²⁹ WUR is also the founder of the *National centre for applied research on renewable energy and green resources ACRRES*³⁰, which is engaged in projects related to the use of renewable energy based on biomass.

WUR takes part in the Research programme *Circular and climate neutral* which covers three topics related to the transition process to the Circular society (Management of transition, New primary production systems and Biomass feedstock). WUR also currently participates in the multidisciplinary research programme on the production and biorefinery of microalgae *AlgaePARC*³¹ and the research programme *Connected Circularity*.

UniBo is a member of the Biobased Industries Consortium. Together with the European Commission, this non-profit organisation formed a public-private partnership called *Bio-based Industries Joint Undertaking* with the aim to promote and invest in the development of innovative bio-based industries. UniBo takes part in various projects related to Bioeconomy.³² As a member of the Coordinating Board of three bioeconomy-related clusters, the UniBo actively participates in achieving the goals defined by the strategy entitled “*A new bioeconomy strategy for a sustainable Italy*”. These three clusters include:

1. *National Agrifood Technology Cluster (CL.A.N.)*³³ – focused on bio-based innovations and growth of the Food industry with respect to the reuse of by-products;
2. *National Technology Cluster Blue Italian Growth (CTN-BIG)*³⁴ – focused on technological and innovation development of the national marine and maritime industrial system and on building of research infrastructures for the blue economy; and
3. *Italian Cluster of Green Chemistry (SPRING)*³⁵ – focused on the use of renewable resources as raw materials (such as scraps or dedicated crops, marginal and/or contaminated lands), on the creation of biorefineries and on the development of new bio-based products.

European Bioeconomy universities pay special attention to the development of entrepreneurial culture and skills. BOKU is one of the founders of the online interdisciplinary platform, the *Entrepreneurship Centre Platform*, which aims to promote and encourage the development of all aspects of entrepreneurship and foster cooperation between innovators, scientists and enterprises. UniBo provides support for launching and developing entrepreneurial initiatives through the digital workshop and co-working labelled *ALMALABOR* and through the Open Innovation Community for Entrepreneurship labelled *AlmaEClub*. WUR is the founder of a start-up incubator and educator, *StartHub Wageningen*, intended for students, PhDs and recent graduates with the aim of providing support in the development of entrepreneurial competencies.³⁶

5. CONCLUSION

New bioeconomy professionals are required for the transition towards a sustainable and bio-based green economy. They have a *T-shaped profile* and are able to work effectively in different bioeconomy sectors due to disciplinary and interdisciplinary expertise and a specific set of competences which they possess. Bioeconomy professionals must be characterised with *systems-thinking, anticipatory, normative, strategic, interpersonal and interdisciplinary competences*.

²⁹ Pulp2Value - European project realises new value chains for sugar beet; AF-SIP-14001 – Biorefinery for raw material and flexibility; PEFPACK – Developing new food and beverage packaging based on PEF; PANACEA – Network for use of non-food crops in European biobased economy.

³⁰ For more details see: <https://www.acres.nl>

³¹ <http://www.algaeparc.com/research-programs>

³² List of projects at: <https://www.unibo.it/en/research/projects-and-initiatives>

³³ For more details see: <https://boku.ac.at/en/zentrum-fuer-biooekonomie/activities>

³⁴ For more details see: <https://www.clusterbig.it>

³⁵ For more details see: <https://www.clusterspring.it>

³⁶ For more details see: <https://www.starhubwageningen.nl/>

In order to develop bioeconomy professionals with specific competences and expertise required by the growing bioeconomy industry, the six leading European universities (the Paris Institute of technology for life, food and environmental sciences; the University of Natural Resources and Life Sciences in Vienna; the University of Eastern Finland; the University of Hohenheim in Stuttgart; the University of Bologna and the Wageningen University & Research) have developed international and interdisciplinary bioeconomy education programmes at the MSc and PhD level. These programmes cover technical, economic, social and environmental aspects of bioeconomy. The vision, structure, the key competences and the main learning outcomes of these bioeconomy programmes were presented in the paper. Five relevant short open online courses in the field of Bioeconomy were also presented and analysed. In order to strengthen scientific research infrastructure, which is necessary for the development, promotion and implementation of knowledge-based bioeconomy, European universities conduct research activities and projects in the field of Bioeconomy. Collaboration between universities, companies and non-governmental organizations is strengthened through research & development networks.

The paper departed from the concept of bioeconomy as an important lever in achieving sustainable development, especially having in mind global challenges such as climate change mitigation, food security, as well as overcoming resource scarcity. In this context, significant aspects related to innovative and resource-saving technologies and methods to increase productivity in the primary activities (agriculture, forestry, aquaculture, etc.) were analysed. In addition, the paper took into account different participants and stakeholders in the field of bioeconomy, as well as the ways in which they were involved in interactive relationships and their divergent interests in practise. Therefore, it may be concluded that purposeful strategies and adequate instruments and tools are needed in the long run, as well as appropriate experts with specific bioeconomic knowledge, skills and competencies.

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