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Bioeconomy and the Modern Challenge of Sustainable Production and Consumption of Biomass and Biofuels

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Abstract: The bioeconomy encompasses the whole economy's reliance on biological and renewable resources, appears as a response to the global challenges confronting the present civilization. This paper explains the genesis of this concept, focusing particularly on its fundamental components, i.e. the sustainable utilization of biomass and the production of biofuels. It offers an overview of global policies and strategies in this domain, alongside the potential applications of biomass. A large number of studies highlight the great potential of biomass, surpassing the current human needs. However, its application has to be examined through three aspects: supply, demand and sustainability. The increase in biofuel production also imposes challenges such as the competitive use of land for biomass and food production, which is a particular problem, and in this regard, various technologies have been developed that use inedible biomass in the production of biofuels and valuable chemicals. Recognizing the importance of the bioeconomy, as an inevitable element in achieving sustainable development, the European Union adopted a strategy and action plan for the bioeconomy in 2012. Also, many countries that are important players in the global economy, such as the United States, Germany, Canada, Japan, etc. have adopted their national strategies that promote the bioeconomy. It is clear that there is a global interest in research and investment in supply chains for biomass and biofuels, which gives an optimistic picture of the future use of biomass as the basis of a future global bioeconomy.

INTRODUCTION

Today we live in a world of limited resources, with numerous global challenges such as climate change, land and ecosystems degradation, with a steady increase of population. All of this forces us to look for new ways of production and consumption that respect the ecological boundaries of our planet, while achieving sustainability. Facing such challenges gives a strong incentive for the modernization of the industry, a new approach to research and development of processes, and a general shift and orientation towards renewable, biological raw materials. This new approach to production and consumption is often called the bioeconomy.

The bioeconomy encompasses all sectors and systems that rely on biological resources, such as plants, animals, microorganisms and waste of organic origin, and their functioning and principles (EC, 2018a). It can be said that these are economy sectors that derive most of their market value from biological products and/or processes derived from natural materials, as opposed to products and processes based on nonrenewable resources and purely chemical processes (UNIDO & SEI, 2005). Bioeconomy services accounted for between 5.0–8.6% of EU gross domestic product and 10.2–16.9% the EU labor force (Ronzon et al., 2022). From this point of view, the bioeconomy itself is not new, as various economies, before the industrial revolution and the massive use of fossil resources, oil and coal, were mainly based on biological raw materials. Thus, biomass was used for a very long time, for example in the production and processing of various wood-based materials such as cellulose, cellulose derivatives, paper, in the production of biomass-based fibers or in the production of various oilseeds or biomass materials with a high starch or sugar content (Tong et al., 2017; Marques et al. 2017; Klemm et al., 2005; Woodings, 2001). Biomass has also been used for energy purposes for a very long time, primarily for heating, but also in the production of charcoal, electricity, bioethanol, etc. (Lewis, 1981; Rodrigue, 2020), and offers an extraordinary potential as a substitute for fossil fuels (Perišić al., 2022). According to the Renewable energy statistics there were over 13.7 million renewable energy-related jobs worldwide in 2022 (Statistics, 2023a). Currently, with a renewable energy installation capacity of about 1,161 gigawatts, China is the leading country in the world, far ahead of other countries including the US, which is in second place with an installed capacity of 352 gigawatts (Statistics, 2023b).

Bioeconomy and the modern use of biomass, as its constituent element, implies the production of various materials based on biomass, the so-called bioproducts, as well as the production of advanced biofuels, especially transport biofuels (bioethanol, biogas, Fischer-Tropsch fuels, biodiesel, biohydrogen, etc.). In this sense, the technologies for the production of various biofuels, i.e., energy from biomass in general (bioenergy), are integrated with the technologies of bioproduct production into a unique concept of biorefineries. Biorefineries are used to produce energy in combined heat and power plants and biofuels, along with the production of chemicals and all with reduced or minimal negative impacts on the environment.

According to the definition given by the U.S. National Renewable Energy Laboratory (NREL), a biorefinery represents a plant that integrates biomass conversion processes and technologies in the production of fuels, energy, and chemicals (Kamm et al., 2007). A similar definition is given by the International Energy Association (IEA), according to which a biorefinery represents the sustainable processing of biomass into a number of marketable products (food, raw materials, materials, chemicals) and energy (fuels, electricity, heat) (IEA, 2014a). So, it can be said that biorefineries are similar to petrochemical refineries in which different chemical products and energy are obtained from oil as feedstock, while biorefineries use biomass as feedstock to produce various industrial products. This includes large amounts of transport fuels, e.g., biodiesel and bioethanol as products of relatively lower value, and small amounts of special chemicals or products of higher value. Some types of biorefineries may also include the production of food for human and animal consumption (Clark, Deswarte, 2015). To ensure the sustainable use of biomass, an approach has been developed that allows the highest value product to be obtained first, then the second highest, and so on (Celiktas et al. 2017).

In general, the limited fossil fuel resources as well as the constant increase of their price are the triggers for the development of the bioeconomy, in which biorefineries, as a counterpart to existing oil refineries, are a necessary element that enables the sustainability of overall production. In this regard, Kamm et al. (Kamm et al., 2016) cite the need for a gradual transition of a large part of the global economy to a sustainable economy based on biological principles, with biofuels, bioenergy and biomaterials as its supporting pillars. Also, the new situation with the Russian-Ukraine crises poses new struggles worldwide, in regard to supply chains, resource insecurities, energy poverty, etc. (Benton et al. 2022). Therefore, each country needs to ensure independent energy resources; reduce dependence and application of fossil fuels and conventional methods for energy production. Sustainable bioeconomy strategies support the achievement of some of the United Nations Sustainable Development Goals and open up new opportunities for innovation, job creation etc.(D'Amico, et al., 2022; Calicioglu, et al., 2021)

The purpose of this paper is, on the one hand, to provide additional explanations and insight into "bio-related" things that often intersect and complement each other, such as biomass, biofuel, bioenergy, biorefinery and bioeconomy.

Also, the purpose of this paper is to give a brief overview of some recent studies in the above-mentioned areas and to refer the reader to the importance of both local and global applications of the bioeconomy.

Therefore, this paper explains the origin, importance and potential of biomass as an integral element of the bioeconomy, current consumption and future projections in the context of a global perspective and current policies in this sector. It also analyzes different aspects of the origin and production of biofuels depending on the availability of different types of raw materials. Special attention is given to contemporary challenges of consumption and production, in which the bioeconomy with all its constituent elements, namely the sustainable use of biomass, the production of biofuels and raw materials, and biorefineries appears as a necessary mechanism for achieving sustainability.

BASIC TERMS AND DEFINITIONS

The bioeconomy, as a broader concept of the entire economy based on biological/renewable materials, emerges as a consequence of the long-term development of the concept of sustainable and knowledge-based progress. As with any other new sector of the economy, especially one that involves the transformation of society, understanding the appropriate progress of the bioeconomy is a challenge, primarily due to the lack of appropriate international/common databases, publications summarizing impact measurements, but also certain definitions (Schieb et al., 2015). Considering that the concept of bioeconomy is still in the development phase, there are a number of definitions that describe the term bioeconomy (Lago et al., 2019). The European Commission originally defined the bioeconomy as an economy in which renewable resources from land, sea, agriculture, fisheries and related public goods are used efficiently and sustainably to produce food, raw materials, fibers, bio-based products and bioenergy (EC, 2012). This definition was later somewhat modified to include efficient and sustainable production and processing to meet industry requirements and consumer needs, while taking into account environmental challenges, such as climate change (EC, 2018a). The bioeconomy in the United States is defined in a similar way. Thus, according to one paper, which refers to the White House National Bioeconomy Plan, it is stated that it is an economy based on the use of research and innovation in the biological sciences to create economic activity and public benefit. Furthermore, it is added that the American bioeconomy is all around us: new drugs and diagnostics to improve human health, high yields of food crops, new biofuels to reduce dependence on fossil fuel/oil and various chemical and other biologically based raw materials (Youmatter, 2020). Also interesting is the definition according to Serban, who defines bioeconomy as "the science of the dynamic integration of humanity into the environment". The same author, in the context of bioeconomy, cites the integration of economics and biology, the activities of studying market dynamics through the perspective of evolutionary biology, as well as a set of economic activities designed to optimize the production and use of biological products (Paşnicuet al., 2019).

It can be said that the bioeconomy covers a set of economic activities related to the innovation, development, production and use of biological products and processes, which will lead to significant benefits in the future in terms of improving agricultural production, increasing industrial productivity while increasing sustainability and improving public health (OECD, 2009). According to the European Bureau for Conservation and Development, the bioeconomy has the potential to mitigate climate change, between 1 billion and 2.5 billion tonnes of carbon dioxide equivalents per year by 2030 (EBCD, 2015).

Biomass is often used to obtain energy, and in this sense biomass is usually defined as any material of plant and animal origin that can be used for energy purposes. In this context, EU legislation defines biomass as a biodegradable part of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable part of industrial and municipal waste (Directive 2009/28EC). In the context of the bioeconomy, the term biomass refers to renewable biological materials that are used as raw materials in the conversion into value-added products, such as food, various materials, chemicals or energy. In this case, biomass includes both edible (food) and non-edible biomass derived from plants, animals or waste streams (Sánchez et al., 2019). It is therefore important to avoid partial definitions, such as definitions that focus exclusively on the energy use of biomass or purely biological definitions, but biomass should be viewed in a broader context. From a biological point of view, biomass is defined as the total mass of living organisms, including plants, animals and microorganisms, or from a biochemical perspective, the total mass of cellulose, lignin, sugar, fat and protein materials in a given specific area (Houghton, 2008).

Some authors divide biomass into eight categories according to common, or similar, methods of measuring and determining their potential (Rosillo-Calle et al., 2007). However, biomass is often classified in one of the following categories (Bajapai 2022; Sivabalan et al. 2021; Goyal et al., 2006):

- Wood biomass - waste and residues from forestry and the wood industry, fast-growing trees (e.g., willows, poplars, eucalyptus), waste wood from other activities and wood generated as a by-product in agriculture;
- Non-wood biomass - waste, residues and by-products from the cultivation of various plants (e.g., corn, straw, cobs, stalks, shells, seeds, etc.), biomass obtained from the cultivation of oilseeds, plants rich in sugar and starch and various algae and grasses (so-called energy crops) and biodegradable part of municipal and industrial waste;
- Animal biomass - waste and residues from livestock or farms (animal faeces, mat, carcasses, etc.).

Given the wide spectrum of raw materials involved, it is impossible to speak of a typical biomass composition. For example, wood and woody plants and their residues are mainly composed of cellulose, hemicellulose and lignin in varying percentages, and are often referred to as lignocellulosic biomass (Figure 1). On the other hand, manure is rich in proteins, while cereals are rich in starch. The different chemical compositions of different types of biomass determine their different chemical properties (Tursi, 2011). Nevertheless, it can be said that biomass consists of carbohydrates, lignin, proteins, fats, oils in varying proportions, with the presence of numerous substances such as vitamins, pigments, aromas and aromatic essences.

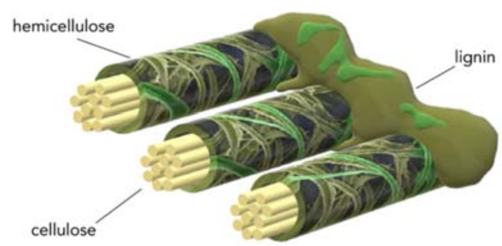

Figure 1. Complex structure of lignocelullosic biomass (Tursi, 2011)

Non-wood biomass, compared to wood biomass, is widely available, and has a more open structure, which makes it easier and cheaper to process compared to woody biomass. Also, the less energy-intensive production of bioethanol is often mentioned as an advantage of non-wood biomass. Non-wood biomass includes various plant and agricultural residues, with non-wood fibers. Some of the agricultural residues, whose bioethanol production capacities have been specifically investigated, are: corn, cassava residues, cereal straw, sugar cane residues, potato peel and oil palm biomass (Mohapatra et al., 2019; Pandey et al., 2000).

Biofuels are fuels produced directly or indirectly from biomass (Directive 2009/28EC). The main reason for processing biomass into various types of solid, liquid and gaseous fuels is to obtain fuels with a higher energy density compared to unprocessed raw biomass, and to facilitate storage and transport (Vukić and Papuga, 2014). Primary biofuels are unprocessed biomass, such as firewood, wood chips, briquettes, pellets, while secondary biofuels are fuels obtained by processing biomass, such as bioethanol, biodiesel, dimethyl ether, etc. (Nizami, et al., 2016; FAO, 2004). Biofuels are often classified from the point of view of the origin of the biomass from which they are produced into first, second and third generation biofuels (Janda and Banes, 2022; Preradovic et al. 2021; Nizami et al., 2016;), and more recently into fourth generation biofuels (Hoyos-Sebá et al. 2024; Seay and You, 2016).

Biomass is the largest renewable energy source, so the energy obtained from biomass is defined as bioenergy. It can be said that bioenergy is the energy that is contained in the organic matter of biomass. Essentially, it is the energy of the Sun that is “stored” in biomass during its biological growth, and through the process of photosynthesis (Sánchez et al., 2019; Sharma and Arya, 2019).

The total use of biomass for energy purposes is fundamentally difficult to measure, especially since most biomass is not involved in commercial transactions. However, in 2017, biomass energy is estimated to have accounted for 70% of the total renewable energy used that year, globally. However, it is important to note that most of the biomass energy relates to the traditional use for cooking and heating in developing regions. Thus, it is estimated that 86% of the primary energy of biomass in 2017, was used in the form of primary solid biofuels, including wood chips, wood pellets, and as an energy source for cooking and heating, and that only 7% of biomass energy was used as liquid biofuel (WBA, 2019).

BIOFUEL TECHNOLOGIES

The great diversity of biomass-based raw materials and products requires a wide range of different approaches and technologies for their processing. Some technologies have been present in the industry for a long time, but are also in the development phase. These advanced technologies enable the conversion of biomass into various forms of secondary energy, including electricity, gaseous and liquid biofuels, but also into various chemicals. All these technologies, or the corresponding processes, can be divided into three groups in principle (Papadokonstantakis and Johnsson, 2017; Kaltschmitt, 2017; Tursi 2011

- Thermochemical conversions (carbonization, gasification, pyrolysis),
- Physicochemical conversions (transesterification, pressing, extraction, etc.),
- Biochemical conversions (alcoholic fermentation, enzymatic hydrolysis, anaerobic fermentation, composting, etc.).

These processes yield biofuels in the form of solids (mainly charcoal), liquids (mainly alcohol and biodiesel) or gases (mainly mixtures with methane or carbon monoxide), and as schematically presented in Fig. 2. the resulting biofuels can be used for a wide range of applications, including transport or various high-temperature industrial processes.

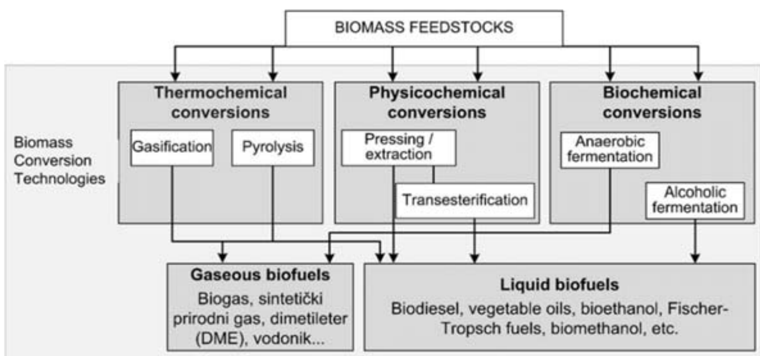

Figure 2. Different biomass conversion technologies, based on (Kaltschmitt, 2017)

Thermochemical conversions

Thermochemical processes of biomass processing include those transformation processes that are primarily caused by the action of heat, and under different process conditions (temperature, presence or absence of an oxidizing atmosphere or gasifying agent, etc.), (Vukić, Papuga, 2014). These include the processes of gasification, pyrolysis, and carbonization and, more recently, torrefaction processes. Usually, fuels produced by thermochemical processes are called synthetic biofuels. The most promising liquid synthetic biofuels, also called BtL (biomass-to-liquids), are biomethanol and Fischer-Tropsch fuels. Gaseous synthetic biofuels include dimethylether (DME) and Bio-SNG. Bio-SNG is also a form of biomethane and can be used in a similar way as a natural gas substitute, such as biogas. Alternatively, the cleaned and conditioned product gas can be converted into hydrogen. (Kumar et al. 2022; da Rosa and Ordóñez, 2022).

Among thermochemical conversions, the production of synthetic gas (syngas) by gasification of biomass is distinguished. Synthetic gas is primarily a mixture of carbon monoxide and hydrogen, but also contains smaller amounts of carbon dioxide, methane, water and other by-products, as well as nitrogen, which depends on the process conditions, the type of raw material and the performance of the gasification system. Although syngas can be used as a stand-alone fuel, its energy density is approximately half that of natural gas. Therefore, synthetic gas is mainly used as an intermediate block of molecules, for the production of transport fuels and other chemical products (Capodaglio and Bolognesi, 2021).

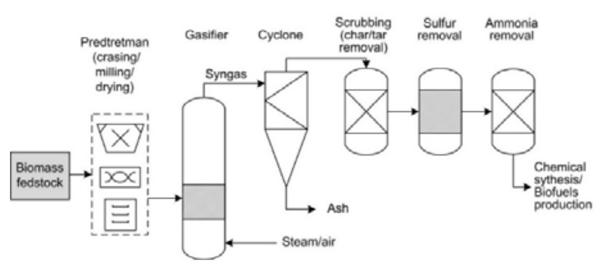

Figure 3. Syngas cleaning for downstream applications

Figure 3 shows the basic stages of synthesis gas purification used for chemical syntheses, for example for Fisher tropsh syntheses. Cyclone separators are used to remove floating particles, as well as different types of filters, such as bag filters made of textile materials. Sulfur compounds, ammonia and tar are removed using wet scrubbers. Despite the existence of various synthesis gas purification technologies, the commercial application of gasification on a large scale is still challenging, primarily due to the presence of numerous pollutants in the synthesis gas (Lotfi et al. 2021).

One of the possibilities of using cleaned synthesis gas is in the fermentation process, in the production of alcohol. The process itself is extremely challenging, and significant research efforts are being invested in the further implementation of these processes (Ellacuriaga, 2023).

Torrefaction has gained increasing attention recent years, as it produces the solid biofuels with improved properties (durability, grindability, bulk density, calorific value and energy density) compared to the untreated biomass. The process takes place under inert conditions, whereby oxygen is being removed, moisture reduced and the chemical composition changed (Olugbade and Ojo, 2020 10.1007/s12155-020-10138-3).

In general, the production of synthetic biofuels and new materials from biomass is a wide subject. Among the different processes, a special focus is on pyrolysis, which is a widely used technology and one of the most promising for the synthetic fuel production (Gvero et al., 2017).

Pyrolysis as a chemical recycling technique for plastic materials is attracting an increasing interest as an environmentally and economically acceptable option for the processing waste materials. Studies of these processes are carried out under different experimental conditions, in different types of reactors and with different raw materials (Papuga et al., 2016; Gvero et al., 2016; Papuga et al., 2013; Papuga et al. 2022; Gutierreza et al. 2022). In general, a review of recent studies on thermochemical conversion of the biomass could be find in numerous papers (Ambaye et al. 2021; Jha et al. 2022; Gonzalez and Roug, 2019; Zhang et al. 2010).

Physicochemical conversions

Physicochemical transformations of biomass include transesterification, pressing and extraction processes, which are processes used to produce high-density biofuels primarily biodiesel from triglycerides. A detailed overview of recent technologies on biofuel production from triglycerides is given by Long et al. (2021).

Basically, these processes convert different types of animal fats and vegetable oils, or triglycerides, into fuels that are similar to diesel fuel in terms of their physicochemical parameters. The transesterification process can be realized in different ways. A typical transesterification technology is shown in the process diagram in Figure 4.

Pressing and extraction processes release oils from plant raw materials, while chemical reactions of transesterification convert triglycerides with methanol or ethanol into methyl or ethyl esters, or biodiesel. These reactions take place in the presence of alkaline catalysts (KaOH or NaOH). A co-product of biodiesel production is glycerol, which can be used as a starting material for the production of a range of value-added compounds for various industries such as the food and pharmaceutical industries (ETIP bioenergy 2024; Tursi, 2019).

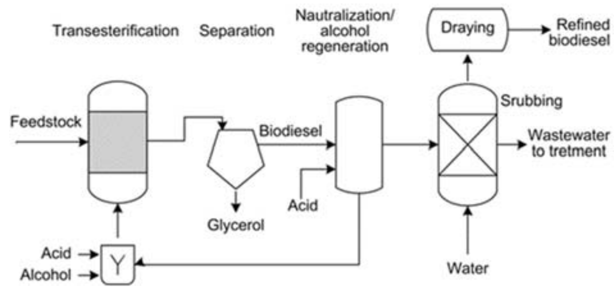

Figure 4. Process diagram of typical biodiesel production technology

Biochemical conversions

Biochemical conversions involve the transformation of biomass by microorganisms, such as yeasts, bacteria, etc. This type of biomass conversion can be processed into biofuels, which can be both liquid (e.g. bioethanol and biomethanol) and gaseous (e.g. biogas as a product of anaerobic digestion). Most bioethanol is still produced from sugar raw materials (the simplest process), but the problem of food shortage is becoming increasingly pronounced , so the development of bioethanol production is mainly directed towards the production of inedible, lignocellulosic. The main limiting factor in the use of this raw material is the complexity of its processing, due to the complexity of its structure.

Biomass needs to be subjected to a certain pre-treatment process. The production of bioethanol from lignocellulosic raw materials passes through four basic steps (Figure 5): pre-treatment, which has the task of preparing the lignocellulosic raw material for the next process; enzymatic hydrolysis, during which the polymers of lignocellulosic raw materials are converted into fermentable sugars; fermentation of sugars formed by enzymatic hydrolysis of lignocellulosic polysaccharides using appropriate microorganisms into ethanol; purification and concentration of ethanol by distillation (Balat, 2011).

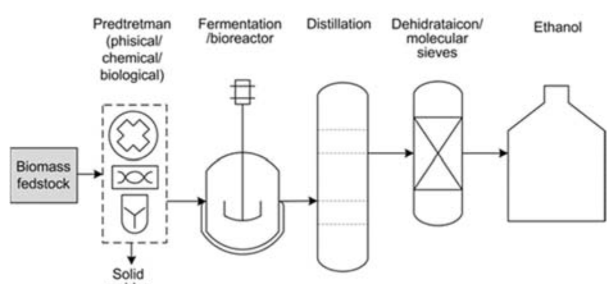

Figure 5. Process diagram of celullosic ethanol production

The enzymatic hydrolysis required to convert lignocellulose into ethanol is an expensive and technically challenging process. Today, various physical, chemical, and molecular-biological methods are available to modify the side chains of proteins in enzymes, thereby achieving more efficient use of biomass. It is expected that the widespread application of these methods will further advance this field (Fülöp et al. 2020). Recently, a series of researches have been carried out in an attempt to obtain an ideal microorganism that will be able to produce ethanol directly from any carbohydrate (Bušić, et al. 2018). The sustainability of cellulosic ethanol depends on the cost involved in each step of the bioconversion process (Devi et al., 2022).

Table 1. Review of the biomass conversion technologies

Type of the conversion technology	Classification of technologies	Reference
Thermo-chemical	Gasification	Ibarra-Gonzalez et al. 2019, Shahabuddina et al. 2020, Kirubakaran et al. 2007, Kumar et al. 2022
	Pyrolysis	Demirbas & Arin 2002, Djurdjevic et al. 2024, Wang et al. 2020, Amenaghawon et al. 2021
	Torrefaction	Preradovic et al. 2023, Djurdjevic & Papuga 2023, Olugbade & Ojo 2020, Chen et al. 2021
	Carbonization	Qin et al. 2022, Amer & Elwardany 2020, Samaniego et al. 2022
Physico-chemical	Transesterification	Vasaki et al. 2022, Hamza et al. 2020, Singh et al. 2022, Karpagam et al. 2021
	Pressing & Extraction	Show et al. 2020, Armenta et al. 2023
Biochemical	Alcohol fermentation	Kang & Lee 2015, Hwang et al. 2016,
	Anaerobic digestion	Prasad et al. 2017, Guiot & Frigon 2012, Song et al. 2015
	Enzymatic hydrolysis	Vasic et al. 2021, Santos et al. 2012, Saini et al. 2022
	Composting	Dutta & Kumar 2021, Vakili et al. 2015

Adjusting the optimal enzyme and substrate concentrations is crucial from the point of view of future industrial application. Low enzyme and substrate concentrations result in low concentrations of the obtained sugars and significantly prolong the time required to achieve a satisfactory degree of hydrolysis. On the other hand, high substrate concentrations allow the processing of larger amounts of biomass during a single cycle, but can lead to reduced hydrolysis yields due to problems related to diffusion limits caused by reduced of water content and problems in achieving homogeneity of the enzyme-substrate mixture (Kristensen, 2009; Ivetić, 2012). Recent advances in the processing of lignocellulosic biomass from agricultural waste were presented by Mujtaba et al. (Mujtaba et al. 2023). Table 1. provides an overview of the recent literature references representing all types of biomass conversion technologies.

GLOBAL POLICY AND PERPSECTIVES

The energy and material need of human society will reach a critical point in the near future. This will be primarily due to the rising costs and demand for fossil resources on which we have become dependent in terms of energy, fuels, materials and chemicals. The world's population continues to grow, and development is unprecedented in our recent history, especially in areas that have traditionally had very low demand for fossil resources (OECD, 2009). In proportion to these growing demands, it has become apparent that continuous greenhouse gas emissions and ozone depletion are affecting the global climate (De Bhowmick et al., 2018). The main strategy proposed for reducing dependence on fossil raw materials, as well as mitigating the effects of climate change, i.e., reducing carbon dioxide emissions, is the greater and more efficient use of biomass (Wiloso et al., 2012). There are three main reasons why biomass is considered an extremely important raw material. First, it is a renewable resource that could be sustainably managed in the future. Second, biomass is also considered an environmentally friendly resource. Namely, the amounts of carbon dioxide that plants absorb during their life through photosynthesis and the amounts that are released during their thermal decomposition are approximately equal, so biomass is assumed to be a "CO_2 or carbon neutral fuel" (WBA, 2012). Also, biomass has a negligible content of sulphur, nitrogen and ash, which results in lower emissions of SO_2, NOx, and soot compared to conventional fossil fuels (Zhang et al., 2007; Strehler, 2000). Third, it seems to have significant economic potential, given that fossil fuel prices will inevitably rise in the future (Demirbas and Demirbas, 2010). All this leads to the conclusion that biomass provides a positive solution for safer and more environmentally friendly production of renewable energy, including heat, electricity, and transport fuels, which can reduce emissions of carbon dioxide, sulphur and heavy metals into the atmosphere, while potentially improving rural incomes and energy security by replacing coal, oil and natural gas.

The international bioenergy market is expected to have a wide range of suppliers from several regions of the world, and bioenergy will not be affected by geopolitical issues such as oil or natural gas. Noticeable climate changes as well as environmental regulations encourage the accelerated development of the use of energy from renewable sources in meeting all energy needs, including the use of biofuels in the transport sector. Also, other legislation, such as the Regulation on Registration, Evaluation, Authorization and Restriction of Chemicals (REACH EC 1907/2006), will lead countries to reassess the feasibility of using biomass as a feedstock for chemical production using different biotechnologies. Although this is a European example (REACH regulation), it is expected that similar regulations will affect producers and consumers worldwide (IEA, 2014b).

In 2012, the European Commission adopted the document: "Innovation for Sustainable Growth: A Bioeconomy for Europe", which presents the EU Strategy and Action Plan for the Bioeconomy. According to the aforementioned document, the orientation of the European economy towards greater use of renewable resources is defined, while respecting the principle of sustainability (EC, 2012). Thus, the document clearly states that Europe must fundamentally change its approach to the production, consumption, processing, storage, recycling and disposal of biological resources, in order to be able to manage a growing global population, the rapid depletion of many resources, increasing pressures on the environment and climate change. The strategy emphasizes that the cross-cutting nature of the bioeconomy offers a unique opportunity to comprehensively solution of interrelated societal challenges, and identifies five goals to which the strategy and action plan should contribute:

1. Ensuring food safety,
2. Sustainable management of natural resources,
3. Reducing dependence on non-renewable resources,
4. Climate change mitigation and adaptation, and
5. Creating jobs and maintaining EU competitiveness.

Three basic fields of action have been defined for the implementation of the strategies, (Vidović, 2012):

1. Investments in research, innovation and training. This includes national and EU bioeconomy funds, national funds, private investment and enhancing synergies with other initiatives.
2. Market development and competitiveness in the bioeconomy sector by sustainably increasing primary production, transforming waste streams (products) into value-added products, while simultaneous learning about the mechanisms for improved production and more efficient use of raw materials. As an example, the costs related to food waste cost taxpayers in Europe between 55 and 90 Euros per tonne of waste, resulting in170 million tonnes of CO_2. This waste can be converted into bioenergy or other bio-based products, creating jobs and economic growth at the same time.
3. Strengthening the strategy of coordination and commitment of interested participants by organizing panels on the bioeconomy, monitoring the bioeconomy and organizing conferences of interested participants.

It is clear that there are different EU policies dealing with one or more of the above objectives, which cover the fields of action of the Strategy, such as: 7th Environment Action Program, Energy Union Strategy, Forest Strategy (Forest Strategy), Circular Economy Package, Common Agricultural Policy (CAP), etc.
In 2017, a review of the achieved goals envisaged by the Strategy was performed. The review concluded that the European Bioeconomy Strategy has largely met its objectives in recent years, through a wide range of actions, from the EU Framework Programs for Research and Innovation to the launch of a public-private partnership of bio-based industries (BBI JU, Bio-based Industries Joint Undertaking), which has led to the creation of several national bioeconomy strategies, dedicated regional platforms and stakeholder panels of interested sides, which promote the development of local bioeconomies by valuing local resources tailored to local needs (EC, 2017). The BBI JU is a €3.7 billion public-private partnership between the European Union and the Bio-based Industries Consortium BIC. Until today, the BBI JU has funded 123 bio-based innovation projects involving 924 beneficiaries from 37 EU Member States and associated countries (BBI JU, 2021).

In 2018, the European Commission updated the existing strategy with the aim of accelerating the implementation of a sustainable European bioeconomy by maximizing its contribution to the 2030 Agenda and its sustainable development goals, as well as to the Paris Agreement (EC, 2018a). The update of the existing strategy makes certain adjustments to the new European policy priorities, in particular with regard to the industrial policy strategy, the circular economy and innovation in the clean energy sector, all of which emphasize the importance of a sustainable circular bioeconomy to achieve their goals. This update proposes an action plan with 14 concrete measures to be launched in 2019, based on three key priorities:

1. Strengthen and scale up organic-based sectors . This implies launching a €100 million thematic investment platform for the circular bioeconomy to bring innovations in the bioeconomy sector closer to the market and make them less risky for private investments. This also includes the development of new sustainable biorefineries across Europe, as well as the promotion and development of various standards, labelling and acceptance of bio-based products, such as the EU Ecolabel.
2. Rapidly expanding the bioeconomy across Europe. This includes various strategic programs for sustainable agriculture, forestry, food and organic production, as well as supporting bioeconomy innovation through pilot activities in rural, coastal and urban areas. Support is also provided to EU member states to develop and implement their own bioeconomy strategies.
3. Respecting the ecological limits of the bioeconomy. This includes implementing systems to monitor progress towards a sustainable and circular bioeconomy, and providing some guidance on how best to manage the bioeconomy while respecting ecological boundaries.

The European Council asked the European Commission to report on progress in implementation the EU 2018 Bioeconomy Strategy. The Progress Report identified that the actions are on track in accomplishing the main goals of the Bioeconomy Strategy, i.e., a lot of national and regional bioeconomy strategies built up cross-sectoral cooperation and sustainability regulations, as well as investing in the bioeconomy. Central and Eastern European countries have made great achievements in advancing the bioeconomy, mainly due to the substantial contributions from EU funding and the creation of new platforms and networks for collaboration. There is also, a visible increase in the investments, research and innovations in the food and bio-based industries, which shows promising developments. On the other side, this Report also identified gaps in the Bioeconomy Action Plan. First, better land management is needed, and biomass demands must meet environmental and economic needs, aligning with the goal of achieving a climate-neutral Europe. And, second, more efforts are required to promote more sustainable consumption to improve environmental integrity.

So far, the European Union has supported the bioeconomy by funding research and innovation in this sector. €3.85 billion has been invested under Horizon 2020 (2014-2020) and a further €10 billion has been provided for projects involving natural resources, including the bioeconomy, and under Horizon Europe 2021-2027, (EC, 2018b).

There are large differences in policy goals and measures supporting the bioeconomy between individual countries, which is mainly determined by the dominant industrial and economic profiles of different countries, as well as the amount of resources (biomass) at their disposal. The way in which different countries approach this issue also varies greatly. Countries such as Germany, Japan, or the United States have adopted comprehensive and coordinated bioeconomy strategies, involving numerous government bodies dealing with the environment, agriculture, research, and economy, etc. (US WHO, 2012; BBF, 2011). Other countries, such as Italy or Canada, rely primarily on industrial or regional initiatives and limit themselves to creating framework conditions at the national level (Dieckhoff et al., 2015). The United States and Canada have large forest areas, long coastlines, and arable land. Both countries have traditionally engaged in the bioeconomy on a large scale, in terms of agricultural and forestry production. However, it is recognized that new technologies can further increase the value of the agricultural and forestry sectors, while promoting rural development. In countries with few natural resources and a strong industrial structure, such as Germany, Japan, France and Italy, the bioeconomy is viewed much more in terms of its innovative potential, and, more recently, its potential for an “industrial renaissance” (Dieckhoff et al. 2015).

Unlike North America, the EU does not classify medical and biotechnological innovations as part of the bioeconomy. Its focus is first on the replacement of fossil fuels and the associated reduction of greenhouse gases, and then on achieving technological advantages using new biomass processing methods to obtain new products. In countries with scarce resources, access to and use of "alternative biomass", such as waste or other residues, play a significant role. To ensure access to raw materials, Germany, Japan, and the United Kingdom are also trying to establish international technological and resource partnerships with developing countries, which have abundant biomass reserves (Dieckhoff et al., 2015).

The appropriate use of biomass can also be a driving force for the development of relatively underdeveloped countries, which have significant resources of biomass and other renewable energy sources, as is the case in Bosnia and Herzegovina (B&H)..Unfortunately, bioeconomy projects in the Southeast European countries have been co-founded on a much smaller scale than in North-Western Europe (Lovrić et al. 2020, Lovrić et al. 2021).

It is easy to show that small municipalities in B&H (with 10,000 to 20,000 inhabitants) with a centralized wood processing industry can satisfy all their energy needs from their own wood waste, on the other hand in the production of the new technologies, because “flash” pyrolysis or other thermochemical processes can activate new sustainable economic activities in the some specific local areas (Gvero et al., 2010). The increased deployment of modern biomass-based systems, as a reliable and affordable source of energy, could be part of the solution to overcome the current constraints concerning GDP growth in Bosnia and Herzegovina (Petrović et al., 2012).

Also, proper use and better management of biomass in developing countries has significant potential to reduce existing greenhouse gas emissions from the waste management, agriculture and energy sectors (Papuga et al., 2016a; Papuga et al., 2016b).

SUSTAINABILITY AND BIOECONOMY

In the context of sustainability, the bioeconomy can also be observed as a segment of the circular economy, which can convert biological waste into valuable resources, and create innovations and incentives that will help traders and consumers reduce food waste by 50% by 2030. (EC, 2018a). Innovations in the livestock sector are increasingly enabling the safe conversion of food waste into animal feed. It is estimated that land currently used only for animal feed could, with certain innovations, feed three billion people. Cities are seen as key hubs for the bioeconomy, delivering significant economic and environmental benefits through circular urban development plans e.g. the city of Amsterdam estimates that better recycling of high-value organic waste could generate €150 million per year, create 1,200 new jobs in the long run and save 600.000 tonnes of carbon dioxide per year (EC, 2018a).

However, it should be emphasized that the transition to a modern bioeconomy is not simple a matter of mastering efficient production technologies and markets for new bio-based products, but also implies challenges such as biomass sustainability, biomass efficiency and the economics of biomass mobilization. Biomass sustainability, i.e., the sustainable supply of biomass as a raw material, is one of the key challenges for the transition to a bio-based economy. Therefore, the source of the resource should be identified from a supply and demand perspective. The biomass that can be used is of very heterogeneous origin, whether it is purpose-grown crops or residues of various crops intended for food production, as well as forest residues or seaweed. Also, municipal waste, manure and other raw materials of animal origin are considered potential resources for biologically based products and services (UNIDO and SEI, 2005). A key step in understanding the sustainability of the bioeconomy is the assessment of biomass potential of, i.e., the total amount of biomass that can be sustainably managed.

Different studies of biomass potential have mainly focused on available biomass for the bioenergy sector, often overlooking the fact that it is the same feedstock that is increasingly used in the growing production sector of biomaterials industry (Brosowski et al., 2016; Karlsson, 2014; Chum et al., 2011; Berndes et al., 2003). The assessment of the energy potential of biomass is relatively complex, and the results can vary significantly, depending on the assumptions adopted, e.g., regarding agricultural yields and trends in food requirements, the methodology for assessing the potential, or the way in which the sustainability of biomass production is taken into account and certain social and political conditions are considered (Carlson, 2014; Chum et al., 2011; Kampman et al., 2010; Haberl et al., 2010). Thus, one paper analyses various studies of biomass potential, and shows how the possible contributions of biomass in the future global energy supply range from 100 EJ/year to over 400 EJ/year in the projected year 2050, with the highest estimated potential nine times greater than the lowest estimated potential (Berndes et al., 2003). For comparison, current global primary energy consumption is approximately 50 EJ/year (Bauen et al., 2009). The main reason for such differences is that the data for the two most important parameters in the assessment of biomass potential, namely the availability of arable land and the level of yield in the production of energy crops, are very unreliable and subject to different interpretations. Modern biomass use, as an integral part of the bioeconomy, combined with traditional uses such as food, energy, building materials, raw materials for pulp and paper, etc. will increase the pressure on existing biomass resources. Therefore, efficient use of available biomass resources is crucial to meet future requirements for biomass (Brosowski et al., 2006; Karlsson, 2014).

The current expansion of the biomass energy industry, accompanied by rising commodity prices, is raising public concern about the imposing a choice of land use , of which the areas are certainly limited, between use for food, raw materials or energy production. The impact of biofuels on food prices is attracting increasing attention. Industries that are strictly tied to biomass as a raw material, such as the pulp and paper industry, question policies that promote the production of energy from biomass (bioenergy), arguing that priority in the use of biomass should be given to the production of materials rather than energy (Hoeltinger, 2012). However, currently less than 1% of agricultural land globally is used for energy purposes, primarily for cereals, sugarcane, oilseeds and palm trees, which accounts for a relatively small part of the total land-use change associated with other activities. Perhaps the most significant impact of bioenergy on land use is related to the way forest management has changed in countries with large forest industries and where the use of biomass for energy has increased significantly, such as Finland and Sweden (Berndes et al., 2016).

The development of what are called "first generation biofuels", i.e., fuels produced from edible agricultural products, was a necessary step in advancing the technology into a more sustainable and environmentally friendly system. The biggest problem with first-generation biofuels is their competitiveness with food production, and the consequent increase in food prices (Khattar et al., 2016). This problem is partly solved by promoting second-generation biofuels, i.e., fuels derived from the inedible part of agricultural crops (e.g., flakes, ears, corn, straw, pruning residues), generally inedible biomass (e.g., different types of grass, waste) or from purpose-grown tree crops, inedible oilseeds, etc., i.e., from energy crops. However, in the general case, the raw material is more complex compared to the raw materials for first-generation biofuels, and therefore more sophisticated and complex for processing and production equipment is required (Nizami et al., 2016).

A special problem is the extraction of useful sugars from lignin and cellulose, and the need for appropriate enzymes to release sugar molecules from cellulose. In general, cellulosic ethanol currently costs two to three times more than the energy-equivalent amount of fossil fuel (Carriquiry et al., 2011). Third-generation biofuels, i.e., algae-derived biofuels, are considered to be an extremely promising approach in the biofuels sector (Dragone et al., 2010; Alam et al., 2015). Algae production is not competitive with food production, and a special advantage is the very high production in comparison to traditional agricultural crops. While traditional crops are harvested once or twice a year, depending on the culture and climate, microalgae can be harvested of every 10 to 30 days, which significantly increases the total yield of biofuels derived from algae (Schenk et al., 2008). A fairly high potential for carbon dioxide binding to useful biomass is often reported (Zhao and Su, 2014; Bai et al., 2017). Recently, there has been a lot of talk about fourth-generation biofuels, which relate to the use of genetically modified algae that have higher biofuel production (Shokravi et. al., 2022; Abdullah et al., 2019; Seay and You, 2016; Dutta et al., 2014). It is predicted that in the near future, the main sources of biodiesel will be third- and fourth- generation biofuels (Lugani et al., 2019). According to IEA projections, by 2035 these advanced biofuels will account for 20% of total global biofuel production (Seay and You, 2016).

CONCLUSION

Bioeconomy as a broader concept of the whole economy based on biological/renewable materials appears as a response to various challenges, such as climate change, resource scarcity and rapid population growth, that are imposed on modern civilization. Biomass as the resource on which the bioeconomy is based is today the only known renewable resource that can provide a number of positive solutions in the context of the mentioned challenges. Various studies show that the potential of biomass is extremely large and that exceeds the current needs of humanity, but this does not mean that it should be exploited to its fullest extent. The use of biomass should be viewed from the perspective of supply and demand, while respecting the limits of sustainability. An important segment of the bioeconomy is the production of various fuels from biomass, the so-called biofuels. Since biomass is a raw material of very heterogeneous composition and origin, there are different technologies for its processing into biofuels and various chemicals that can be used as raw materials in industry. A broad overview of these technologies is provided in this paper.

The increase in biofuel production also imposes challenges such as competitive use of land for biomass and food production. Currently, less than 1% of agricultural land globally is used for energy purposes, primarily cereals, sugar cane, oilseeds and palm crops, which makes a relatively small part compared to the total land use change associated with other activities. Also, if we take into account the negative effects of the use of fossil fuels, as well as certain chemicals and materials on the environment, we come to the inevitable conclusion that new production systems must be developed, based on renewable raw materials. Globally, the only such source of renewable raw material is biomass.

Recognizing the above issues, many countries have adopted their national bioeconomy strategies, such as the United States, Canada, Germany, Japan, including the European Union as a community of states. In 2012, the European Commission adopted the document: "Innovation for Sustainable Growth: Bioeconomy for Europe", which represents the EU strategy and action plan for the bioeconomy, which defines the orientation of the European economy towards greater use of renewable resources while respecting the principles of sustainability. In 2018, the European Commission updated the existing strategy with the aim of accelerating the implementation of a sustainable European bioeconomy, and maximizing its contribution to the 2030 Agenda and its sustainable development goals, as well as to the Paris Agreement. So far, the European Union has supported the bioeconomy through funding research and innovations in this sector. About €3.85 billion has been invested under Horizon 2020 (2014-2020) and a further €10 billion has been secured for projects involving natural resources, including the bioeconomy, and under Horizon Europe 2021-2027).

Given the previous considerations, it is clear that there is a global interest in research and investment in the biomass and biofuel supply chain, which gives an optimistic picture regarding the future use of biomass as the foundation of the future global bioeconomy.

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Summary/Sažetak

Bioekonomija kao širi pojam cjelokupne ekonomije zasnovane na biološkim/obnovljivim materijalima se javlja kao posljedica suočavanja sa brojnim globalnim izazovima današnje civilizacije. Ovaj rad objašnjava nastanak ovakvog koncepta, sa posebnim osvrtom na njegove sastavne elemente, odnosno održivo korišćenje biomase i proizvodnju biogoriva. Dat je pregled globalnih politika i strategija u ovoj oblasti, kao i potencijalno korišćenje biomase. Razne studije pokazuju da postoji ogroman potencijal biomase, koji prevazilazi trenutne potrebe čovječanstva. Međutim, korišćenje biomase treba posmatrati sa tri aspekta, odnosno, sa aspekta ponude, potražnje i održivosti. Povećanje proizvodnje biogoriva nameće i izazove kao što je konkurentno korišćenje zemljišta za proizvodnju biomase i hrane, što je poseban problem, pa su u tom pogledu razvijene različite tehnologije koje koriste nejestivu biomasu u proizvodnju biogoriva i vrijednih hemikalija. Prepoznajući značaj bioekonomije, kao neizbježnog elementa u postizanju održivog razvoja, Evropska Unija je 2012. godine usvojila strategiju i akcioni plan za bioekonomiju. Takođe, mnoge zemlje koje predstavljaju važne igrače u globalnoj ekonomiji, kao npr. Sjedinjene Američke Države, Njemačka, Kanada, Japan, itd., usvojile su svoje nacionalne strategije koje promovišu bioekonomiju. Jasno je da postoji globalni interes za istraživanje i ulaganje u lance snadbijevanja biomase i biogoriva, što daje optimističnu sliku u pogledu buduće upotrebe biomase kao osnove buduće globalne bioekonomije.