Chapter

Introductory Chapter: Objectives and Scope of Bioeconomy

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1. Introduction

As a result of the review of the implementations and research works conducted in many countries aimed at intensifying the processes of using RES, it turned out that these works are dispersed and do not bring the expected effect, both in the environmental aspect and in terms of energy conversion savings. For this reason, the vision of an industry based on raw materials of biological origin was created in the European Union, which also included waste substances from primary and secondary processes of biomass utilization and processing, as defined in Directive No. 28. The implementation of this vision should lead to the transition toward the so-called "post-oil" society, by clearly separating economic growth from resource depletion and environmental impact.

After consultations conducted in the member states, the need to separate a new industrial branch defined as a bio-based industry ("Bio-Based Industries") [1] was defined, which should strive to optimize land use and food safety through sustainable, efficient (effective) raw materials and to a large extent limit the amount of waste generated and industrial processing of the European renewable raw materials into a wide range of products of biological origin such as:

- Advanced transport fuels
- Chemicals
- Materials
- Food and feed ingredients
- Energy

As a result, "bio-industry," which is one of the core elements of the EU economy known as "bioeconomy," will play an important role in stimulating sustainable growth and making Europe more competitive through the reindustrialization and revitalization of rural areas, thus providing tens of thousands of jobs in the areas of research, development, and production over the next decade.

The bioeconomy program for Europe is going to be an evolutionary program. It is planned to develop the so-called value chains, whose implementation will eventually lead to the so-called biorefinery, which will process biomass in a comprehensive and waste-free manner. Thus, the most important technological, political, and market challenges will be before the commercialization of innovative solutions on a full scale. These challenges cannot be overcome by individual companies or the dispersed industry, so a systemic approach to the entire biomass management

system is necessary. This is important due to the need to reverse the current trend of significant bioeconomic investments in non-European regions where conditions seem to be more attractive. A long-term research and innovation program jointly funded by public and private entities can help solve this problem. This process will be implemented through the creation and implementation of appropriate value chains, which will lead to a reduction of investment risk in demonstration projects in the field of implementation of innovative processes.

This study is the result of analytical work of the Author's Team, completed with an internal report [2] and publication [3].

2. The concept of bioeconomy

Bioeconomy is defined in various ways. Therefore, the definition of the bioeconomy included in the Communication of the European Commission on 13 February 2012 of the European bioeconomy was adopted as a basis. According to this definition, the bioeconomy involves the production of renewable resources of biological origin on land and in the sea and the use of these resources and waste streams to produce value-added products such as food, feed, bioproducts, and bioenergy. Bioeconomy based on the use of renewable resources of biological origin is to gain a new character due to:

- Renewable resources
- Resources with low greenhouse gas emissions or neutral in this respect
- Resources repeatedly used (cascade) in production processes
- Resources with high potential for beneficial properties with respect to end products, such as lower or no toxicity, higher stability, higher durability and strength, limited water consumption, etc. [4]

The bioeconomy should include the agricultural, forestry, and fisheries sectors and all related sectors of the economy (production of food, feed, wood and paper, biofuels, etc.). The new approach to this economy should strive to implement innovation (research and innovation at the interface of many different sectors and industries) in combination with the industrial application of biotechnology [5]. The priority of the bioeconomy should be the economic growth achieved on the basis of traditional and new (emerging) industries based on biosurants. This increase will be realized through the creation of new value chains based on resources of biological origin that will provide high value-added products to the market.

The activities necessary for the development of the bioeconomy include, above all, research and innovations going beyond particular sectors, a coherent policy, and defined bioeconomy strategies at the level of countries and regions as well as international and intersectoral cooperation. The basis for the development of the bioeconomy should be intensified primary production. The goal and tool will also be the creation and development of new markets and the likely increase in the competitiveness of the entire economy. **Figure 1** presents the optimistic evolution of the economy in relation to the resources on which it is based [6].

The emergence of the post-oil society is, however, subject to many conditions related to the current state of the technology of converting fossil resources into

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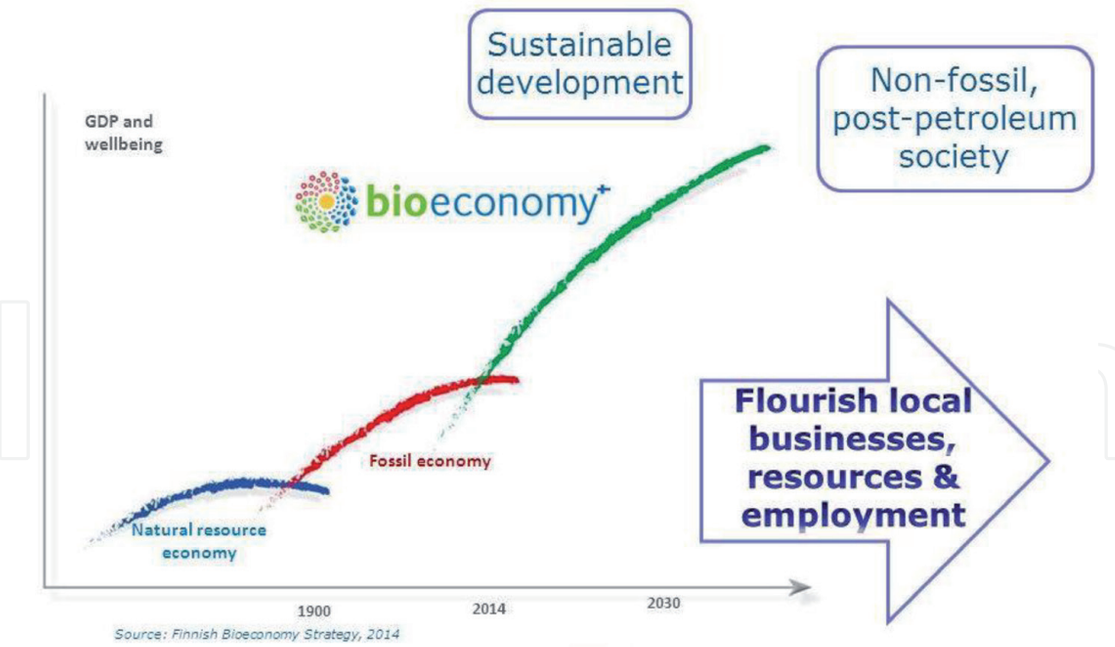

Figure 1.
The concept of transition through successive stages of economic development in relation to resources [6].

widely used products, as well as the continuous development of these technologies in terms of obtaining protection of growing social needs. Processing of fossil resources is a huge area of the global economy, whose transformation or extinction of specific sectors of this economy may be difficult or even impossible. Biomass resources as the basis for the bioeconomy, and more broadly the so-called "green economy," can be a substitute for fossil fuels, not only for energy applications but also for the production of chemicals and materials. However, biomass is also of great importance in natural environmental processes. Estimates of biomass availability for industrial purposes usually do not take into account environmental needs and are definitely overestimated. Biomass is traditionally used as a raw material for the production of, for example, wood products, in the cellulose-wood industry, and natural fibers, and as a raw material in the biofuel industry (oily, starchy, and sugar raw materials). Therefore, taking into account the environmental needs necessary to meet environmental needs, only waste from the above areas of biomass utilization should be used, and substitute materials in these industries should be considered to reduce the demand for primary biomass. Therefore, the vision presented in **Figure 1** will probably be shifted on the timeline, and the shape of the bioeconomy curve will probably be significantly flattened. Nevertheless, in a modern bioeconomy, one should strive to ensure the sustainability of biomass production and utilization processes, the efficiency of these processes, and the scaling effect in relation to mobilizing possible environmentally safe resources [5].

The bioeconomy should respond to the following challenges [4]:

- Feeding the growing population (9 billion people by 2050)
- Launch and use of the production potential of the seas and oceans
- Economic strengthening of coastal and rural areas
- Intensive development of markets based on resources of biological origin

3. Implementation of the concept of bioeconomic processes

The implementation of bioeconomic processes requires a change in the approach of both the industrial sector and the policy of governments in individual countries. It is also necessary to deepen the transformation of social awareness toward the need to consume products from these processes. In European Union countries, the implementation of bioeconomic processes through public-private partnership began. This partnership is to operate in the following areas, through:

1. Construction of new value chains based on the development of sustainable biomass collection and supply systems with increased efficiency and better use of biomass resources (including cogeneration and by-product management) while using and valorizing waste and biomass

2. Adaptation of existing value chains to a new level, by optimizing the use of raw materials and industrial side streams while offering innovative value-added products, thereby creating market demand and strengthening the competitiveness of EU forestry and industry

3. Bringing technologies to the state of advancement through research and innovation, as well as through the modernization and construction of demonstration and flagship biorefinery installations that are already processing biomass in the direction of obtaining innovative products of biological origin [7]

Taking into account the limited resources of biomass and the need for its processing by the agri-food industry, technological processes should be implemented in a way that does not limit the production of food of an appropriate quality and quantity.

In pursuing the set goals in accordance with the developed value chains, the partnership shall ensure the availability of sustainable and safe supplies of biomass, both for food and feed applications and for the production of chemicals, materials, fuels, and energy. It is also necessary to increase the productivity and efficiency of biomass from agricultural land and forests, but in a sustainable way, while taking advantage of the potential of residues and by-flows as well as waste. Currently, it is desirable to work on the optimization of the use of the existing raw material (forest and agricultural biomass), the development of new raw material supply chains (e.g., forestry waste, agricultural waste, lignocellulosic or special crops), and the use of side streams of organic industrial and municipal waste. Providing new markets for biomass producers will strengthen rural economies and allow for further development and investments in a sustainable production system. Because the efficient processes of biomass and biodegradable waste conversion have not yet been developed in a way that enables their commercialization, it is necessary to plan solutions to these problems by conducting further research and creating demonstration technologies.

4. Strategic Innovation and Research Agenda (SIRA) in the area of bioeconomy

As part of the preparatory work for launching European activities in the field of bioeconomy, the Strategic Innovation and Research Agenda (SIRA) plan was developed. This document proposes a coherent set of actions that should lead to an intensification of the implementation of the bioeconomy development concept:

- Implementation of projects aiming at the integration and implementation of technologies and results of scientific research and the introduction of technology on a commercial scale through the implementation of demonstration and flagship projects

- Implementation of development projects aimed at filling gaps in research and technological innovation

- Supporting projects addressing cross-sectoral challenges

Schematically, the value chains are shown in **Figure 2**.

In the Strategic Innovative and Research Agenda (SIRA), these chains have been defined as follows:

1. From the lignocellulosic feed to advanced biofuels, chemicals, and biomaterials, through the selection of raw material base and technology for the new generation of fuels, chemicals, and materials

2. Utilization of the full potential of forest biomass through rationalization of afforestation and rebasing as well as creation of new markets and value-added products

3. The use of agro raw materials enabling durability of production through effective agricultural production as well as new markets and value-added products

4. Waste management, through the implementation of sustainable technologies to transform waste into valuable products

5. Integrated biorefineries as a means of sustainable production of bioenergy, including biofuels, biomaterials, biochemicals, etc.

The first value chain includes new or improved profitable lignocellulosic biomass sources with higher efficiency in production (fertilizers, water use, logistics) and/or improved processing properties in biorefineries. This will reduce the amount of industrial waste and improve environmental impact, helping to reduce pressure on natural resources, as well as European dependence on imports, and increasing rural development. Financial incentives will be created that favor higher incomes for farmers and forest owners, producing biomass at a competitive price. This chain should end with a demonstration of advanced technologies for the hydrolysis and conversion of lignocellulose.

The goals of the second value chain will be achieved by creating new value-added products from the current raw material base by increasing the mobilization of raw materials (forest waste) and improving the use of by-products and waste streams. For this purpose, new innovative and efficient technologies will be implemented, and innovative products will be developed, as well as by-products and residues and valorization of side streams. This will improve the competitiveness of European value chains based on forest industry while reducing pressures on biomass resources. Products from this value chain have a much smaller impact on climate change by exchanging fossil materials for bio-based materials with positive social impact. It will meet both market and consumer requirements and will create new markets by demonstrating the paths and concepts of processing new innovative materials into new products.

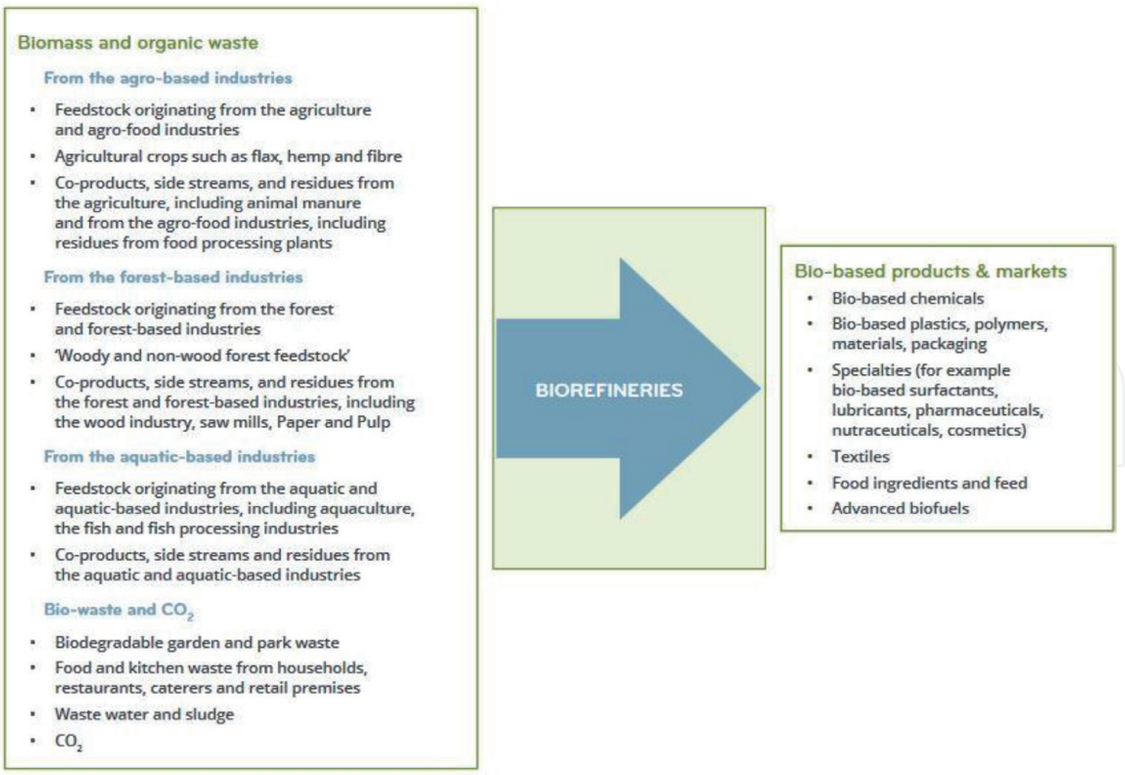

Figure 2.
Value chains in the bioeconomy [8].

The third value chain will be achieved by creating more value-added products from the current raw material base by increasing raw material production and flexibility and making better use of side streams and residues. In addition, new and improved profitable crops with higher productivity in production (use of fertilizers and water, logistics) will reduce industrial waste and improve environmental impact. Innovative and efficient cultivation, harvesting, and logistic technologies will be introduced for existing and new crops, and innovative products will be developed with the use of by-product and residue valorization.

The development and demonstration of value chains based on currently unused streams (side ones) and wastes from various sources of biological origin (agriculture, forestry, sewage management, sediments, municipal organic waste, garden waste, food processing waste, etc.) are the aim of the fourth chain value. The costs of implementing competitive value-added value chains will contribute to creating solutions for the environmental problem of ever-increasing waste flows (partly due to urbanization) while reducing the pressure on unprocessed natural resources and increasing the competitiveness of the industry.

The implementation of the fifth chain should demonstrate an improvement in the stability and economics of bioenergy production through the conversion and integration of biorefineries. The creation of a whole range of value-added products and bioenergy from raw materials will allow a full use of biomass, including unused biomass resources, and will increase the competitiveness of the bioeconomy.

The concept of creating value chains in the "Bioeconomy for Europe" program is shown in **Figure 3**.

The implementation of these value chains should also contribute to the intensification of the so-called primary production, which may result in the potential development of the bioeconomy as a different industrial branch based on the resources of biomass, mainly waste.

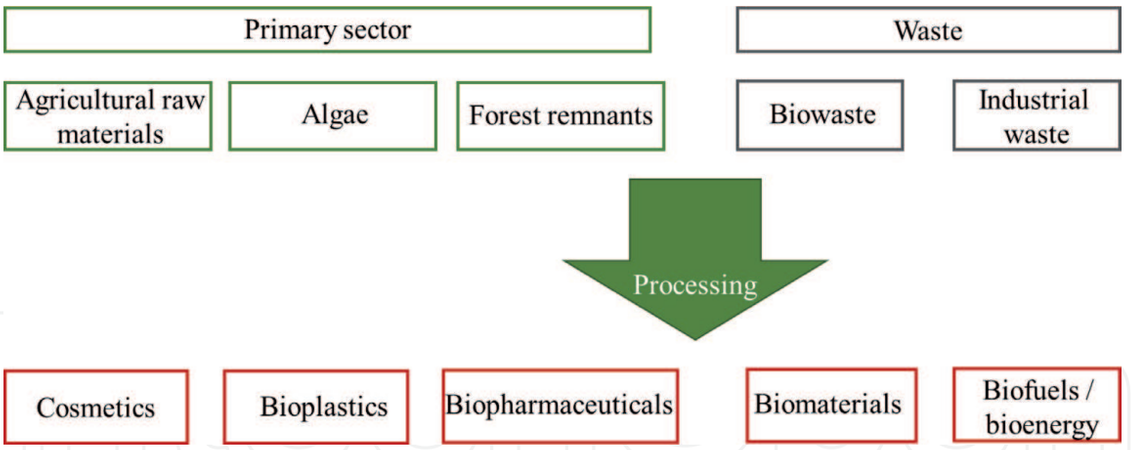

Figure 3.
Examples of value chains based on renewable energy resources [5].

As already mentioned, the proposed value chains capture biomass as the basic source of raw materials in the bioeconomy, also referred to as the "green economy." However, according to the International Energy Agency, the report "IEA Bioenergy, Task 42, Biorefineries" [9] shows that to ensure that the so-called National Indicative Targets can be met for the replacement of conventional fuels with biofuels from biomass, Europe is the second region outside the Japan, which must import biomass as a raw material for the production of these fuels. Irrespective of this, it is not clear what share of waste biomass from natural processes can be used as a raw material for bioeconomic processes, without creating environmental threats for the proper course of these processes. Also in the field of energy carriers, other sources of waste biomass as the main raw material are considered, i.e., waste biomass from industrial processes, including biodegradable waste from agriculture, wood management, food industry, etc. For the same reason, it is proposed intensifying the development of production technologies for other alternative fuels (other than biofuels), which may enable more efficient use of biomass as a shortage resource, mainly for the production of semifinished and high value-added products, replacing and then displacing petroleum and coal.

5. Bioeconomy in the circular economy cycle

In terms of the concept of economic development of highly industrialized countries, in order to meet the requirements related to sustainable development taking into account environmental requirements, it is proposed to create an economy with the so-called circular economy, which is to complete the life cycle of the product characterized by "life cycle assessment" (LCA) for this product. In short, you can define this cycle as a succession of processes: obtaining raw materials; production; operation; and utilization of post-mining waste, i.e., from cradle to grave (CtG). The closed cycle economy proposes the "cradle to cradle" (CtC) cycle, reusing post-mining waste to produce new (new products). This approach will result in reducing raw material consumption, reducing the amount of waste deposited and increasing the waste stream used for recovery and recycling. The course of such a cycle has been illustrated in several contemporary publications, while the economic closed loop can be considered interesting. In this perspective, the bioeconomy can mean much more than the circular economy, because agriculture, forestry, and fisheries or the primary sectors of the economy are the source of production of the raw material, i.e., biomass. In accordance with the anticipated value chains of bioeconomic

processes, waste biomass should be processed primarily for value-added products such as food and feed, chemicals, and materials from which bioproducts are produced, and biofuels and bioenergy should be obtained from the untraceable residue at today's level of technological profitability. However, it is not entitled that the bioeconomy means more than a circular economy, as shown in **Figure 4**.

As shown in **Figure 2**, all value chains lead to high value-added products through the so-called biorefinery processes. These processes lead to obtaining, through various technological variants, substitutes for hydrocarbon mixtures, which can be used to synthesize or compose the desired products using various technological processes. The analysis shows that it is possible to obtain many products with the desired and high added value, as shown in **Figure 5**. However, obtaining these products from waste biomass, coming from various industrial processes, may still generate waste substances, whose further processing is required. It will be the development of new technologies; in each case the processing of energy carriers causes emissions to the atmosphere, which in the full and real technical life cycle are usually greater than the absorption of carbon dioxide in photosynthesis processes. Regardless of the emission of carbon dioxide, it is also possible to emit other gases depending on the type of technological processes. Practically, a fully closed-loop economy lasted until the primitive human used natural stone or wooden branches as tools. From the stage of wood and stone processing, the era of waste generation began, and, therefore, the circular economy has ended. While the waste from woodworking was subject to natural biodegradation, wastes from stone processing and later from the manufacture and treatment of metals increased the effect of charging the environment with wastes resulting from the needs of humanity, up to the industrial era, which lasts until now. For these reasons, a fully circular economy seems to be impossible to achieve, because each new type of technology creates a new group of waste, for which another new technology is required for processing,

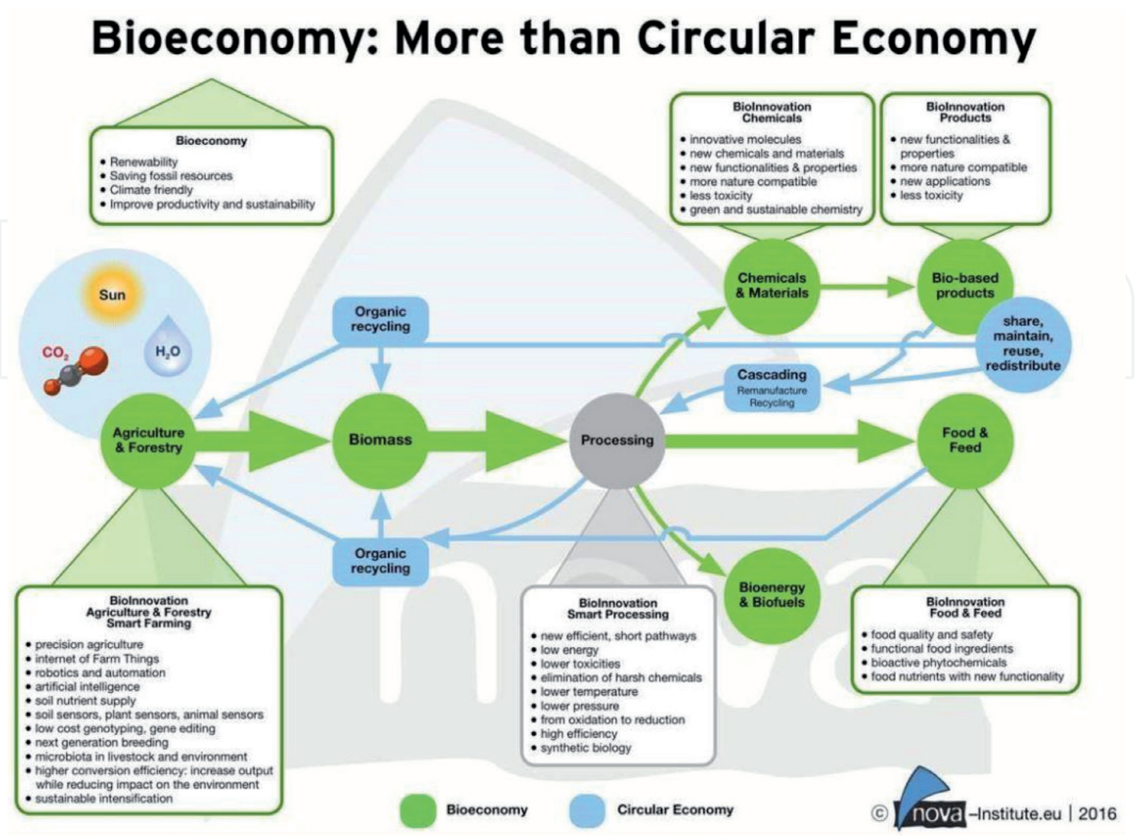

Figure 4.
Bioeconomy in the circular economy system [10].

including waste, etc. It is only possible to reduce the amount of waste by increasing efficiency of processes or modifications of technological processes toward the production of semi-products that can be directly used. One should therefore strive for an economy with a closed circulation so that the waste migration gap is as small as possible. For the above reasons, it can be concluded that the biorefinery processes presented in **Figure 5** are aimed at the so-called bioeconomy with a closing circle.

Biorefinery processes in terms of adherence to the principle of optimal use of resources from the so-called renewable sources have been widely discussed in [12]. In the current state of progress in the field of technology, assessed on the basis of bibliography [12, 13], the item [12] also includes thermodynamic aspects of biomass transformation as a natural source, and own works allow to determine the basic and desirable directions of technological use of biomass (waste) according to the initial LCA analysis carried out, as shown in **Figure 5**.

As can be seen in **Figure 6**, there are currently three paths for using waste biomass. The first of these paths proposes the transformation of biomass into

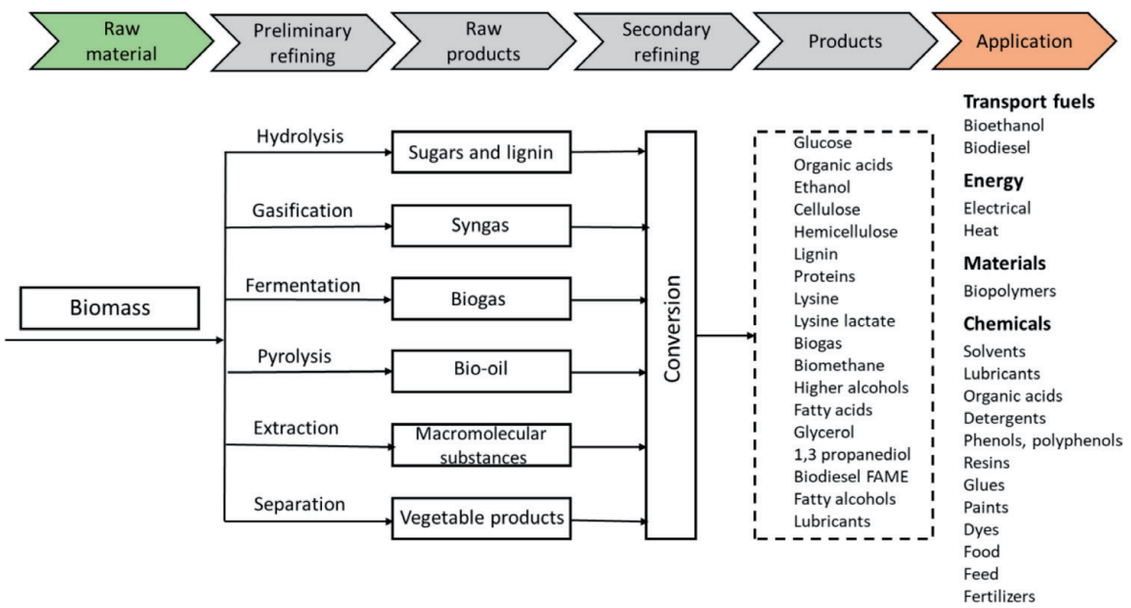

Figure 5.
Technological paths for obtaining products from biorefinery processes [11].

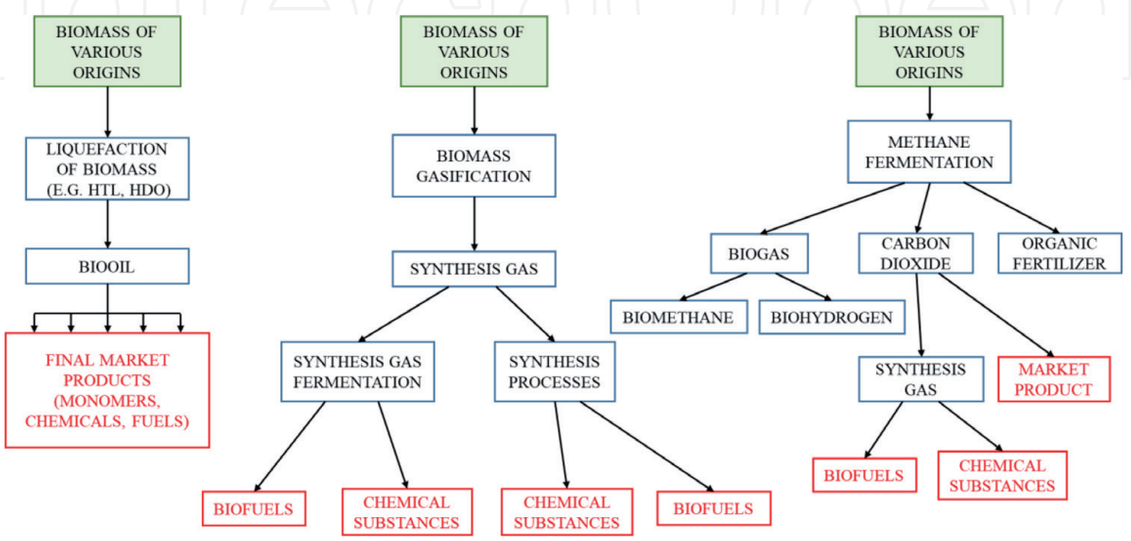

Figure 6.
Currently possible directions of biomass conversion in bioeconomic processes [14].

a so-called "biosurge," having characteristics of petroleum. Without going into the complexity of further processes, it is possible to convert bio-oil into products analogous to products obtained from crude oil, using comparable technologies. The second path is the path of biomass gasification, which results in synthesis gas fermentation processes leading also to the formation of isoprene structures and the possibility of further synthesis of various types of chemical compounds as well as biofuels in processes. The third track is based on the use of methane fermentation processes, which is important in many processes of using waste biomass from agricultural processes and wastewater management.

6. Conclusion

The concept of bioeconomy in the full range of potential possibilities of this industrial branch has not yet been clearly defined, especially as regards the availability of raw materials, their types, and technological possibilities of their processing while minimizing environmental impacts. In available sources, as well as in this monograph, the proposed paths of bioeconomic processes concern mainly biofuel technologies, not including identification of other bioproducts and technologies for their production. In the teams dealing professionally with the problems of the bioeconomy, two basic concepts are being clashed. The first one involves the transformation of biomass toward the production of biofuels or bioliquids, and post-process residues convert to biochemicals and other value-added products. This view is motivated by the already mastered technologies of "biomass to liquid" (BtL) and "waste to liquid" (WtL) processes, while biomass processing technologies for biochemicals, bio-plastics, and other products are just being developed. The second concept involves the implementation of processes leading to the separation of possible value-added products from biomass and the remainder subjecting WtL and "waste to energy" (WtE) processes to obtain energy carriers or directly energy for process purposes.

The economic efficiency of bioeconomic processes is still small. Due to the technological complexity, comprehensive technological processes, especially full biorefinery systems, still require research, which makes their implementation more expensive. It seems advisable to gradually adapt or retrofit existing oil refineries and petrochemical plants to the possibility of converting biomass to bio-oil [biosecure, e.g., in "hydrothermal upgrading" (HTU)] and further processing into fuels and value-added products using existing installations and technologies used, which would significantly reduce costs.

Bioeconomic processes may contribute to increasing the use of land, not yet used up to around 35% in 2030, which may cause an increase in biomass supply. The results of the implementation of the bioeconomy program may also contribute to the maintenance and further development of a competitive knowledge-based rural economy and the creation of new qualified jobs, including more than 80% in rural areas, relatively underdeveloped.

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