Chapter 6
The Bioeconomy Perspectives in Transformation Towards a Circular Economy in Poland

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Abstract Development of the bioeconomy is one of the strategic tasks introduced in The Polish Circular Economy Roadmap and National Smart Specialization. The food sector is one of the most important and fastest growing branches of the Polish economy. 10.5% (1.7 million) of all employees employed in industry are involved in it. The increasing demand for eco-friendly products and packaging and at the same time focusing of the EU policies on carbon neutrality and ensuring resource and energy efficiency in a holistic approach creates new challenges and opportunities for food and beverage sector. Most of the companies start to analyse the economic and environmental impact from a value chain perspective to identify the environmental "hot spots" and value added from material supply to distribution from store supply to the customer and waste management. The paper analyses challenges and obstacles for turning bio-waste, residues and discards into valuable resources taking into account economic, environmental and social aspects based mainly on an example of Maspex (https://maspex.com/) which is one of the largest companies in the segment of food products in Central and Eastern Europe.

Keywords Bioeconomy · Circular economy · National specializations · Food and beverage sector

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1 Introduction

A circular bioeconomy is an important part of the European sustainable development strategy. According to the European Commission, the bioeconomy comprises those parts of the economy that use renewable biological resources from land and sea to produce food, materials and energy.[1] Therefore bioeconomy should strengthen the connection between economy, society and the environment.[2] The updated bioeconomy strategy is part of the Commission's efforts to create a boost for employment, growth and investments in the EU. According to the strategy the main challenge for the future is to increase the sustainable use of renewable resources, to face both global and local challenges, such as climate change and sustainable development. The European Commission underlines that it is absolutely crucial to implement the systemic changes in the way products are being produced, consumed and utilized and brings attention to the fact that the development of the bioeconomy (a renewable segment of the circular economy) will be and should be a way of reaching innovative ways of providing food, clean water and energy in the future.

Implementation of the priorities by the European Bioeconomy Strategy is based on five strategic goals:

- Ensuring food and nutrition security due to the changing needs of consumers in the field of sustainable food production and consumption practices
- Managing natural resources in a sustainable manner, aimed at preventing soil
- degradation, restoring degraded ecosystems and ensuring their resilience to climate change and valorisation of natural resources and secondary raw materials
- Reducing dependence on non-renewable resources, which is key to achieving EU energy and climate policy goals
- Mitigation and adaptation to climate change, which is recognized as the global challenge of the present generation
- Strengthening European competitiveness and job creation by providing a framework for innovation and implementation and supporting the development of markets for biotechnology-based products.[3]

The diagnosis of the bioeconomy indicates that many regions in the Europe still have a low level of bioeconomic maturity, which means they cannot fully use their potential such as creating new jobs, use resource efficiently or plan a sustainable rural. Five main areas which leads to more effective implementation of the bioeconomy at both regional and national level are pointed out in the document Bioeconomy development in EU regions Mapping of EU Member States, and those are:

[1] https://ec.europa.eu/research/bioeconomy/index.cfm

[2] A sustainable Bioeconomy for Europe: strengthening the connection between economy, society and the environment. Updated Bioeconomy Strategy, 2018.

[3] A sustainable Bioeconomy for Europe: strengthening the connection between economy, society and the environment. Updated Bioeconomy Strategy, 2018.

- More effective strategic planning and bioeconomy management at national and regional level
- Support for value chains/circularity and in particular the involvement of SMEs
- Development of research and innovation in technology, knowledge transfer and new skills in the field of bioeconomy
- Coordinated financing and synergy between support instruments
- Increased social awareness and acceptance[4]

According to the report the progress in implementation of bioeconomy will have a significant impact on the planning of activities towards further development of the circular bioeconomy, as well as on the development of recommendations for the implementation of the BIO concept in the circular economy.

2 Strategy of Bioeconomy Development in Poland

2.1 Overview

The Polish Strategy for Responsible Development (SRD) is a recommendation for the future development of the country. Strategy follows the development vision contained in the 2030 Agenda. According to the document the circular economy should play an important role in achieving the goals of sustainable development in Poland, combining social, environmental and economic issues. Sustainable development requires fulfilment of some boundary conditions such as efficiency of raw material consumption, the use of renewable energy, waste management and reduction of greenhouse gas emissions. According to Bio-Based Industries Joint Undertaking (BBI JU), there is a strong correlation between three specific objectives of the Sustainable Development Goals (SCGs) and the bioeconomy:

sustainable economic growth based increasingly on knowledge, data and organizational excellence; socially sensitive and territorially sustainable development; and an effective state and institutions for growth and social and economic inclusion. Pursuant to the assumptions of the strategy, the main goal of all activities and undertakings envisaged in it is "to create conditions for the growth of income of Polish residents, while increasing cohesion in the social, economic, environmental and territorial dimensions[5]".

[4] Bioeconomy development in EU regions Mapping of EU Member States' Final Report 2017.

[5] The 2030 Agenda for Sustainable Development – Implementation in Poland.

2.2 Road Mapping

The Road Map Towards the Transition to Circular Economy in Poland is based on the Ellen MacArthur model of circular economy which assumes the existence of two cycles: biological (renewable raw materials) and technical (non-renewable raw materials). The aim of the Circular Economy Road Map, on the one hand, is to indicate horizontal actions which would affect the largest possible section of social and economic life. On the other hand, the Circular Economy Road Map prioritizes the areas in which development will allow for taking advantage of the opportunities facing Poland and at the same time will address the currently existing or expected threats. This document refers to five general areas: (1) *Sustainable industrial production* attention was drawn to the important role of industry in the Polish economy and new opportunities for its development; (2) *Sustainable consumption* the need to take action on this stage of the life cycle, so far often underestimated in the context of its contribution to the transition to CE, is justified; (3) *Bioeconomy* outlines the management of renewable raw materials (the biological cycle of CE), which seems to have an unexploited potential in Poland; (4) *New business models* discusses the opportunities for reorganizing functioning of various market participants based on the idea of CE; (5) the implementation, monitoring and financing of CE.[6]

According to the Polish Statistic Office, in 2017 the area of agricultural land in Poland amounted to 14,620 thousand ha (i.e. ca. 47% of the size of the country), which translates into a significant potential for the development of bioeconomy based on this source of biomass. Currently, apart from food production, biomass is most often used for energy purposes – mainly for direct combustion and, to a relatively small extent, for the production of liquid fuels. According to Polish Investment and Trade Agency, the food sector is one of the most important and fastest growing branches of the Polish economy. 10.5% (1.7 million) of all employees employed in industry are involved in it. Poland is the sixth largest market in Europe, with a capacity of 38.5 million inhabitants. Polish producers are characterized by high competitiveness both in the EU and in the world. 80% of all exports, in 2017, went to the EU's internal market, which after accession became one of the main driving forces for the sector with a potential of over 508 million consumers. Strengths of the Polish food sector are many years of tradition, high-quality product, competitive production and labour costs, qualified staff, solid educational base and R&D potential and well-developed network of suppliers.[7]

The CE Road Map focuses, on the one hand, on general actions aimed to create conditions for the development of bioeconomy in Poland and, on the other hand, on activities concerning the development of bioeconomy in selected areas, i.e. creating local value chains, in industry in general, and in the power industry in particular. Due to the cross-sectional and inter-sectoral nature of bioeconomy, there is no single ministry in Poland responsible for shaping this framework and defining its

[6] The Road Map Towards the Transition to Circular Economy, 2019.

[7] https://www.paih.gov.pl/sectors/food_processing

development directions at the central level. The implementation of individual actions provided in the CE Road Map will be carried out with competence of individual ministries. According to the document "development of bioeconomy contributes to the reduction of pressure on the natural environment, as well to creating new jobs, in rural areas in particular. The production of innovative materials and products within bioeconomy requires a continuous supply of quality biomass. Therefore, it is important to build local value chains in the areas around local biorefineries, which will be able to produce high quality bio-residue material in the quantities consistent with entrepreneurs' needs".[8]

Biomass is currently one of the most popular renewable energy sources in Poland. According to the assumptions biomass should be cascading, based primarily on its use for food production and as a raw material for the chemical, pharmaceutical, paper and building materials industries as well as for the production of organic fertilizers. Only residual biomass and waste from the final stages of recycling should be used for energy purposes, with priority given to the production of biofuels and biogas. Bioeconomy can provide a strong stimulus for increasing the innovation and competitiveness of entire industries; however, the use of biomass by industry in Poland is still not widespread. To support the development of the bioeconomy in the industrial sector, the principle of the cascading use of biomass is important, favouring the use of higher value-added technologies that allow the reuse and recycling of products and raw materials.

2.3 Bioeconomy as a Strategic Area of National Smart Specializations

According to the European Union innovation is a driving force for future economic growth and social development in Europe, and therefore better conditions for innovative processes should be created. This goal is to be achieved through the use of the concept of smart specialization. Smart specialization is a key element of EU efforts to support countries and regions in developing their own path of economic growth. The goal of smart specialization is to create new areas of economic activity and to increase the competitiveness of regions. The development of the European economy is to be based on knowledge and result from investments in the sphere of education, research and innovation. Smart specialization is a key element of the European Union's efforts to support this development model. It refers directly to the "Innovation Union" flagship project, which is the basic instrument for achieving the goals of the Europe 2020 strategy.[9]

In Poland, the bioeconomy plays an increasingly important role, being an important element of the National Smart Specializations (NSS). National specializations

[8] Road Map towards the Transition to Circular Economy, 2019, p. 21.

[9] Europe 2020 Flagship Initiative Innovation Union.

indicate preferences in providing support for the development of research, development and innovation (R & D & I) under the financial perspective for 2014–2020 which are specified in the government document entitled "National Smart Specializations". Issues related to bioeconomy are widely covered in two NSS: (1) innovative technologies, processes and products of the agriculture and food and forest-based sector and (2) biotechnological and chemical processes, bioproducts and products of specialist chemistry and environmental engineering.

The bioeconomy has become one of the economic priorities in the area of R & D & I that may contribute to the transformation of the national economy towards a circular economy by modernizing it, structural transformation, diversification of products and services and creating innovative socio-economic solutions, also supporting transformation towards a resource-efficient economy, including natural resources.

In the case of bioeconomy, a broad interdisciplinary profile of this key area of specialization has been outlined, which creates enormous opportunities for creating mutual cooperation links based on NSS for the development of integrated value chains. The bioeconomy is perceived as an area with a large potential of raw materials and technologies; all the more it seems necessary to strengthen the efforts to increase the technological readiness of bioeconomy solutions aimed at developing business initiatives.

In the Entrepreneurial Discovery Process, activities are carried out to continuously activate, update and absorb national specializations to implement strategic research and innovation development plans in the country. In the process of monitoring National Smart Specializations, periodic assessment of the activity of individual specializations is carried out, including data based on applications submitted and co-financed in operational programs. Based on this data, the NSS is periodically prioritized. In the area of bioeconomy for NSS 2 and NSS 3 in the first half 2019, there was quite a large variation in the number of submitted and co-financed projects, for NSS 2 mainly in the agri-food and forestry-wood areas and for NSS 3 in the development of bioprocesses and specialized chemistry. Thematic evaluation of the achievement of the national smart specialization goals carried out as part of the NSS monitoring provided information on the research and development potential of scientific units and its impact on the implementation of the NSS 19 goals. As part of the study, scientific units were assigned to individual NSS, and the strength of their links with specializations was assessed. NSS 2, being a specialization in the field of bioeconomy, came second to NSS 1 Health with the largest number of science institutions that reported membership in this specialization.[10]

As part of the evaluation of national smart specializations carried out by PARP, an assessment was made of the internationalization of national enterprises (Maciej Piotrowski, 2019). The aim of the study was to characterize the level of internationalization of Polish enterprises taking into account the specificity of individual NSS and non-NSS groups with significant internationalization potential and

[10] Ecorys Polska, Taylor Economics, 2019.

identification of activities, which should be implemented by the public sector to strengthen the internationalization potential of Polish enterprises, in particular under the NSS. The obtained data confirmed that NSS 2 is in the range with the highest potential for internationalization as well as in the range with the highest import intensity.

2.4 Bioeconomy: A Strategic Area of Regional Smart Specializations (RSS)

A condition for support in operational programs of activities implemented under the two thematic objectives of the European Regional Development Fund (ERDF) was the regions' identification of smart specialization. Its improvement should be based on strategy setting priorities and tools for using the opportunities and potentials of a given region and achieving competitive advantages. Therefore, each region, which is a beneficiary of cohesion policy in the 2014–2020 financial perspective, was obligated to prepare its own research and innovation strategy for smart specialization (the so-called RSS3 strategy) and identify in it the areas in which it wants to specialize and increase its competitiveness.

Bioeconomy is an area of smart specialization with high potential in the context of increasing the competitiveness of Polish regions. Its essence lies in the innovative use and management of renewable biological resources in order to generate new types of products and production techniques, while meeting the requirements of sustainable development. Bioeconomy is one of the most promising economic sectors in which Polish regions intend to specialize. The concept of bioeconomy has become one of the areas of strategic planning, especially in the sphere of innovation. The development of bioeconomy means the need to make internal changes in the sector, including strengthening the integration of the economy with science and the sphere of business with the social environment. This means that the bioeconomy should be considered comprehensively, from the theoretical point of view in micro, meso and macroeconomic terms, and from the side of economic policy in regional, national and European terms.

From a microeconomic perspective, bioeconomy includes the production of various products and services related to living organisms for food and utility purposes by farms, processing plants and other business units. From the meso-economic point of view, bioeconomy is a sector or sphere of production of these products and services and creation of local and regional systems for the production and consumption of products and services. In macroeconomic terms, attention is paid to economic structures and processes that are the basis for the sustainable use of biological, renewable production resources to produce healthy food, feed, materials, energy and other products while respecting the principles of food, health, energy and environmental protection.

13 Polish voivodships have declared the production of agricultural raw materials and their processing into food as specialization. The importance of agriculture and food processing sectors was not taken into account by three voivodships: Małopolska, Pomorskie and Śląskie. Specializations related to biomass production and processing as well as waste to energy conversion are not much less common. More than half of the voivodships have adopted activities in the sphere of environmental protection and biodiversity as well as in sectors of the industry processing biological raw materials into non-food products as areas of specialization within the bioeconomy. Subspecialization covering knowledge gathering, scientific research, institutions as well as creating value chains and cooperation was indicated relatively least frequently.

3 Diagnosis of the Bioeconomy Potentiality in Poland

3.1 Potential Feedstock and Bioproducts Demands

According to the analysis of the Deloitte report entitled "Closed loop – open opportunities" (Report of Deloitte, 2018) in which development and growth prospects for the circular economy are presented, Poland is a prospective country for the development of the bioeconomy. According to the data, the food, feed and drink sectors account for the largest share in bioeconomy turnover in the EU and Poland, accounting for nearly half of the total turnover. In turn, the turnover of the bio-industry including the production of chemicals and chemical products, pharmaceutical products, plastics, paper, textiles, biofuels and bioenergy as well as the wood industry sector is worth EUR 600 billion.

The agricultural and forestry sectors are mainly responsible for the production of raw materials for processing industries using biomass. In Poland, this is a very rich base: the arable land in 2017 accounted for about 14.6 million ha, i.e. they occupy about 47% of the country's territory, by 10 pp. more than the average in the world.[11] Poland is also in the European lead when it comes to the area of forests – they grow on the area of 9.2 million ha, covering about 29.6% of the country's area.[12] Domestic extraction of biomass, i.e. biodegradable products, waste and residues from biological origin, in 2017, amounted to 191 million tonnes and was nearly 20% higher than in 2010.[13]

The structure of obtained biomass includes in % arable crops (except fodder), 34%; crop residues, fodder and grazing biomass, 53%; wood, 13%; and wild fish, plants and aquatic animals, 0.1%. In recent years, the turnover of Polish foreign trade in biomass and its products has been growing. Significant surpluses have been visible for many years, which have been gradually increasing over time. In

[11] Piotrowski S., Carus M., Carrez D., (BIC) European Bioeconomy in figures 2008–2015, 2018..

[12] Statistic Office, 2018.

[13] http://www.lasy.gov.pl/nasze-lasy/polskie-lasy

comparison with 2008, the tonnage of exported biomass in 2015 increased by 118%. In 2017, the value of agri-food sector exports reached a record EUR 27.3 billion, accounting for 13.4% of the value of Polish exports.[14]

An important source of raw materials for the bioeconomy is biomass resources from the biodegradable waste stream, which in the circular bioeconomy system should be used first in the production of new bioproducts and biomaterials (including those used in new bio-packaging) and then in the processes of transformation into biofuels and biogas. It is biomass coming from both agricultural activities, production and processing processes (pomace, sludge, decoctions, musts, fragments of raw materials, by-products, defective products, etc.), municipal waste (organic fraction) as well as wastewater treatment processes (primary and secondary).

In the cascade biorefinery concept, these processes are carried out in a fully integrated mode with bioenergy recovery to comprehensively and fully utilize the potential of biosurets. The same process assumptions may apply to the forestry/wood industry, which generates approx. 50% of biomass in the form of all types of forest waste associated with logging, all types of production residues related to wood processing and all types of wood waste obtained in recycling processes.

The implementation of a circular economy in Poland may be highly beneficial from a macroeconomic point of view. The performing of this type of economy would definitely have a positive impact on economic growth – "the estimated effect in the form of added value from saving 1% in material and energy costs for Polish GDP can be as much as PLN 19.5 billion[15]". The implementation of a circular economy allows the use of a number of solutions related to the reduction of material consumption, the amount of waste and its recovery as well as the increase in energy efficiency. The impact on GDP of the reduction of material and energy consumption by 1% in individual sectors of the economy was estimated. The analysis is a preliminary approximation of macroeconomic effects for Poland. The input-output model focuses on relationships and dependencies between various branches of the economy, thanks to which it is possible to examine how the activities of a given branch of the economy affect the development of others.

According to the Report of Deloitte, the reduction of material and energy consumption costs in the case of bioeconomy can be achieved, among others, by:

- Using production (including packaging) materials that are biodegradable and easy to recycle
- Transition to an agricultural system allowing soil regeneration and revitalizing the ecosystem in agricultural areas
- The use of new technologies for the recovery of nutrients and energy from waste (e.g. anaerobic digestion).[16]
- Sustainable waste management according to UE should be based on the following principles:

[14] Eurostat, 2017.

[15] https://www2.deloitte.com/pl/en/pages/zarzadzania-procesami-i-strategiczne/articles/innowacje/raport-zamkniety-obieg-otwarte-mozliwosci.html

[16] Report of Deloitte, 2018.

- Waste prevention
- Preparation for reuse
- Recycling
- Other recovery methods
- Storage

The goal of EU regarding recycling by 2030 is 65% for municipal waste and 75% for packaging waste, as well as limiting the amount of landfill for municipal waste generated by 2030, to a maximum of 10%.

What is especially important in Polish ecological policy, which is closely related to raw materials and energy policies, is the subject of analyses and discussions, but still in many aspects it needs to be updated and clarified. The amount of generated waste in Poland (excluding municipal waste) has been in the range of 110–130 million tonnes/year since 2000. In 2017, 126 million tonnes of waste was generated, of which municipal waste was 12.5 0 million tonnes (9.5%). The amount of waste generated annually remains at a similar level, with a constant increase in GDP, which may indicate positive trends in waste management. According to Statistics Poland recently, the largest amount of waste was generated in the Dolnośląskie and Śląskie voivodships. Lubelskie, Podkarpackie and Warmiańsko-Mazurskie voivodships are those who generate the smallest amount of wastes. In Poland, on a regional scale, the amount of waste generated is in the range from about 190 to about 375 kg/inhabitant. In turn, the average amount of municipal waste generated per capita in the European Union in 2016 was 483 kg. The amount of municipal waste generated depends not only on the population density but also on consumption patterns determined by the standard of living of society. Between 2006 and 2017 from the total amount of municipal waste generated in the European Union, 29% was recycled, 27% was thermally neutralized, 26% was neutralized by landfilling, and 16% was composted.[17]

The methods of thermal processing of waste with energy recovery have been used in Poland since 2015. An important element conditioning the possibility of using waste for energy needs is the availability and transmission capacity of energy infrastructure, including heating. The highest values of the heat network density index were recorded in the Śląskie, Małopolskie and Łódzkie voivodships. The majority (approx. 77.2%) of heat produced is intended for the needs of heating residential buildings. The most heat for heating purposes was produced using solid fuel, followed by gas and liquid fuels. The share of waste as fuels used for heat production is marginal. There are eight waste incineration plants in Poland and one multifuel CHP plant using RDF fuel. Further RDF heating plants are under construction or at the planning stage. In 2016, the total amount of waste generated in the EU-28 in all sectors of the economy and households amounted to approx. 2.5 billion tonnes, while the share of individual countries in this amount varies. The highest levels of waste production were recorded for municipal services, households and manufacturing activities. According to Eurostat an overall increase (by around 10%) in the

[17] GUS Ochrona środowiska, 2018, Infrastruktura komunalna w 2017 r., GUS 2018, Infrastruktura komunalna w 2017 r., GUS 2018.

number of waste recycled and incinerated with energy recovery can be seen. There is a clear tendency to move away from landfilling municipal waste, mainly in favour of recycling and incineration, and to a lesser extent composting and other methods.

According to the United Nations, our production and consumption lead to large quantities of waste. "An important element on work on eco-cycles is therefore sustainable waste management. Articles that circulate in society contain large quantities of different materials. Many are energy-demanding to produce and contain substances that exist in limited quantities of different materials. Many are energy-demanding to produce and contain substances that exists in limited quantities. It is therefore necessary to manage common resources in long-term manner to achieve sustainable cycle". According to many scientists, current production of biofuels is rather unsustainable, so there is a strong need to improve current production methods. According to the framework, policy decisions concerning biofuels should take into account certain moral values. These include human rights and global justice, solidarity and the common good, sustainability and intergenerational justice. The five ethical principles and one ethical duty forming the core of the ethical framework are:

- Biofuels development should not be at the expense of people's essential human rights, including food, health and water.
- Biofuels should be environmentally sustainable.
- Biofuels should contribute to a net reduction of total greenhouse gas emissions.
- Biofuels should adhere to fair trade principles.
- The costs and benefits of biofuels should be distributed in an equitable way. It should not happen, for example, that the benefits occur in the developed world and the costs occur disproportionately in poor countries.

If these five principles are respected, depending on certain key considerations, such as absolute cost or whether there are even better alternatives, there is a duty to develop such biofuels.[18]

3.2 Bio-Inspired Industrial Potentiality in Poland

The analysis of the potential of companies interested in research in the bioeconomic area indicates the existing implementation potential in this area, which, however, requires quite intensive efforts to intensify activities related to the preparation of R&D potential that can be implemented in industrial practice. To this end, actions necessary to increase the technological readiness indexes of TRL solutions developed in scientific and research units are necessary, including investment activities in pilot installations for rescaling technological solutions with high financial risk, which include innovative solutions in the field of bioeconomy and industrial biotechnology. Good practices in the field of bioeconomy are implemented by some domestic companies (Table 6.1).

[18] https://www.ncbi.nlm.nih.gov/books/NBK196458/

Table 6.1 Examples of good practices in Poland

Company	Internet link
BIOTECHNIKA Biotech solutions for modern industry in Lodz is a leading company on the Polish market, a company implementing industrial biotechnology projects, including: Production of ethanol for any purpose (consumption, bioethanol, technical ethanol, pharmaceutical ethanol) Bioenergetics, including mainly classic agricultural biogas plants Industrial biogas plants adapted to the characteristics of a specific industry (for ethanol production plants, breweries, starch plants, dairies, sugar factories and basically for every industry using biomass in its various forms in the production process) Sewage treatment plants (mainly industrial) – often associated with the previously mentioned installations (ethanol production or industrial biogas plants), for industrial processing of agricultural products (production of starch, starch hydrolysates) Biotechnology processes of small-scale products ("fine chemicals")	*http://www.biotechnika.net/*
BOWIL Biotech Sp. z o.o. in Władysławowo is the first factory in the world biocellulose made in accordance with pharmaceutical GMP standards. The production of biocellulose, a natural biomaterial that is used in medicine, biotechnology, pharmacy, dentistry, cosmetics, food industry and many other fields, is the result of scientific and industrial cooperation with the Institute of Technical Biochemistry of the Lodz University of Technology	*https://www.bowil.pl/produkty/bioceluloza/*
NapiFeryn BioTech company was established in 2014 in Łódź, awarded in the competition "Strong in business 2016". The Economic Award of the Łódź Voivodeship in the start-up category has developed an innovative technology for the production of high-quality protein from the residue after pressing oil from rapeseed. Protein isolates will be used by oil mills and food producers as food ingredients. The discovery of NapiFeryn BioTech corresponds to future civilization challenges in the scope of the possibility of feeding a larger population without adverse environmental impact processes. The company's goal is to ensure that at least 5% of the world's rapeseed crops are processed using NapiFeryn BioTech technology to form natural functional proteins	*http://www.napiferyn.pl*
ORLEN, south company from the ORLEN Capital Group, is working under the research and development project of the INNOCHEM Program on an innovative method of biotechnological transformation of biorefinery by-products and plant-derived raw materials into lactic acid necessary for the agricultural, food, medical and pharmaceutical industries. The substance plays a key role in the production of the most popular, fully biodegradable polymer, polylactide (PLA), which is used, among others, for the production of biodegradable packaging	*https://www.orlen.pl*
FLUID SA, a company from Sędziszów, is the only company in the world that sells biochar. The raw materials used for its production are, among others, straw, energy willow, animal droppings, municipal waste or sewage sludge. As a result, biochar can be used in energy, agriculture, environmental protection and industry	*https://innpoland.pl/*

In the current conditions, the competitiveness of the economy is increasingly based on research, development and innovation (R & D & I) and the ability to absorb dynamically and participate in the creation and development of new technologies. To meet the abovementioned challenges, cooperation between stakeholders representing various environments, industries or technologies is necessary. The key to achieving this goal is, inter alia, clusters, which thanks to the naturally established cooperation of enterprises, research institutions, business environment institutions, non-governmental organizations and local authorities are referred to as the catalyst for innovative processes. Cluster initiatives dedicated/related to the bioeconomy area are presented in Table 6.2

3.3 Bio Value Chain Model: Case of Food and Beverage Sector in Poland

Grupa Maspex Sp. z o.o. Sp. K. is one of the largest companies of the food segment in Central and Eastern Europe. It owns leading brands in the food industry and offers primarily juices, nectars, drinks, mousses, fruit cocktails, energy drinks, pasta, cereal products, sauces, instant products (teas, coffee whiteners, cocoa, etc.) diet supplements, vitamins and sweets. The company offers products of the highest quality, which invariably enjoy great recognition of consumers and traders. Since 2016 the Maspex Group has been a founding member of the EIT Food consortium, co-financed by the European Institute of Technology, whose aim is to change the methods of production, distribution and consumption of food, taking into account the needs and consumer expectations and the organization of the entire value chains of the food sector. EIT Food is to stimulate innovation, develop talents and engage consumers in the agri-food sector as well as support entrepreneurship of start-ups. The Company's R&D activity focuses on developing process and product innovations in the food industry, and at the same time it has great potential in conducting development projects in the field of logistics and marketing.

As part of the project, R&D works were carried out regarding the possibilities of using side products of pomace from fruit and vegetable processing in finished products which is related to bio-based innovated projects. Maspex Group in a scientific and industrial consortium with the Institute of Biopolymers and Chemical Fibers, COBRO Packaging Research Institute and the University of Humanities and Sciences of Jan Długosza (Częstochowa. Poland) has developed a patent-protected method of producing biodegradable, thermoplastic and barrier films as well as biopolymer injection moulds from starch and protein raw material derived from the by-product production line of the Lubella company of the Maspex Wadowice Group company. The developed technology is in line with the development trends of bioeconomy in the meaning of circular economy, namely, it covers activities related to the material management of biosources wastes and by-products of the food industry.

Table 6.2 Cluster initiatives dedicated/related to the bioeconomy in Poland

Cluster name	Internet link
Association Bioeconomy Cluster, whose aim is to integrate and concentrate the scientific and economic environment operating in the field of bioeconomy with particular emphasis on its cross-sectoral impact, covering the basic pillars of cooperation, i.e. innovation, education, entrepreneurship development and social communication	http://klasterbio.pl/
Natureef Association, which implements goals through webinars on packaging trends, resource efficiency technologies and financing, joint research projects mainly in the field of biomaterials, business missions, conferences and workshops, forward-looking projects for companies and associations opening new spaces of cooperation, i.e. circular economy , Industry 4.0, urban agriculture	https://natureef.pl/
NUTRIBIOMED Cluster, Wrocław Technology Park S.A., whose main idea was to build Poland's strong position in the industry offering dietary supplements, nutraceuticals and biomedical preparations, as well as using native, natural raw materials and modern technology for their production	http://www.nutribiomed.pl/
Klaster Life Science, Kraków Foundation, whose aim was to develop an innovation ecosystem in the field of biotechnology and life science, including creating cooperation networks, supporting entrepreneurship and innovation as well as combining and developing resources and competences in the area of Life Science	https://lifescience.pl/
Waste Management and Recycling Cluster RECYCLING COOPERATION CENTER, not for profit system sp. z o.o., which creates Polish enterprises providing a full range of management services for most categories of waste throughout the country as well as in most EU countries and outside the EU	https://www.clustercollaboration.eu/cluster-organisations/waste-management-and-recycling-cluster

Starch and protein compositions can be used for the production of (bio) packaging and bio-clays for paper products (*https://maspex.com/; https://www.eitfood.eu/; project NCBiR nr PBS1/A5/22/2012)*.

Maspex in the project "Development of innovative products based on processing pomace" comprehensively develops new effective methods for processing pomace, which are a side product of fruit and vegetable processing, and to develop recipes for innovative products based on carrot pomace or by adding pomace to traditional products. As a result of the project, new food products that meet the requirements of consumers are proposed, being a valuable source of vitamins and minerals, and – most importantly – a different perspective on the side products of vegetable and fruit processing. Fruit and vegetable waste from the processing industry is still a source of many valuable nutrients, because during the processing of the main raw material, many valuable ingredients remain in the pomace. There is still a lot of nutrients to be found in carrot pomace, including carotenoids, fibre, polyphenols, mineral salts, carbohydrates and protein. Carotenoids and polyphenols are primarily antioxidant. Dietary fibre has a positive effect on the human digestive system, intestinal peristalsis, carbohydrate and lipid metabolism, stimulates the growth of bacterial colon flora and plays an important role in the prevention of atherosclerosis and diabetes. Products developed on the basis of carrot pomace, or with its participation, will be enriched with valuable nutrients and will have a relatively low energy value. Especially pomace out of lactic acid fermentation will be very attractive for the consumers (including those not consuming animal products). Fermentation enriches vegetables with beneficial microorganisms and bioactive substances. Pickled vegetables are currently recommended by nutritionists and doctors because of their health promoting properties. Consumers are increasingly aware of the health problems associated with incorrect nutrition and are aware of the healthy potential of vegetables. They are also eager to look for low calories products due to the obesity risk (new products with added carrot fibre will have lower calorific value than traditional ones without such an addition). New products based on carrot pomace will broaden the range of vegetable products and will be able to satisfy consumer expectations and contribute to increased consumption of this food group. The research carried out as a result of the project will allow to determine the conditions for the production and use of biomass in the closed cycle and the conditions for the development of food use of agricultural products. Thanks to the implementation of the project, the Applicant acquired practical knowledge regarding the development of standards and norms conditioning sanitary safety of waste and side products of the agri-food industry, conditioning the implementation of the United Nations development goals for 2015–2030. As part of the pursuit of ensuring sustainable consumption and production patterns (objective 12), it is assumed to halve food waste at the stage of sales and consumption by 2030 and reduce losses at the stage of agriculture and processing.

Maspex in European consortium-industrial Group (Maspex; Roquette; University of Reading; Valio; VTT Technical Research Centre of Finland; Tymbark – MWS)

realized the project "Novel concepts for creating dietary fibre-rich foods from side streams (ColloidFibre)". The daily dietary fibre (DF) intake in Europe is way below the recommended level, arising partly from difficulties in creating appealing DF-rich food products for the consumers. The challenges are most pronounced in high-moisture foods where insoluble DF often gives rise to an unpleasant coarse mouth-feel and selling of the insoluble particles to the bottom of the container. High viscosity and unpleasant flavour are additional factors hampering the applicability of DF in foods. A common practice for DF enrichment in high-moisture foods has been to use only highly modified soluble DF to ensure proper sensory quality. The most common soluble fibre ingredients, such as inulin or various oligosaccharides, typically have a relatively low molecular weight and tend to cause intestinal discomfort in consumers. However, for maximized health effects and improved intestinal comfort, both soluble and insoluble DF of relatively high molecular weight would be beneficial. The utilization of more natural, less degraded DF is also driven by a recent regulatory change in the USA, which does not anymore allow labelling of "isolated, synthetic" fibre as DF in food products. This activity aims at creating better opportunities for the consumers to increase their DF intake by developing DF ingredients with improved properties that enable their addition to high-moisture food products not traditionally rich in DF. Side streams from wheat, oats and pea processing industry will be used as DF sources. These nutritious side streams will be modified by novel processing concepts not yet widely adopted in the food industry. The target is to reach an optimum ratio of soluble/insoluble DF in terms of technological functionality and sensory properties, without causing excessive intestinal discomfort often associated with the soluble DF alternatives existing on the market. The innovativeness of the chosen solutions is maximized by bringing together actors from academia and the industry with multidisciplinary expertise in food technology, material science, lignocellulosic biomass processing, flavour chemistry, sensory perception, nutrition, consumer understanding and business creation. As the outcome, this approach will generate positive societal impact by enabling ingredient, process and product innovations which helps the food industry to introduce new types of appealing and easy-to-consume DF-rich products on the market. This will improve consumers' possibilities to increase their DF intake, even for those people not aware of lacking DF in their diet. This will on longer term have a positive impact on public health and decrease health-care costs. This activity will also help in utilizing food resources more efficiently by enabling the application of side streams produced in vast quantities as food source for humans instead of as animal feed.

The project "EIT Food Digital Marketplace for Side Streams" performed by European consortium of 15 partners (ACESUR; Colruyt; Döhler; DSM; Givaudan Nederland; Maspex; Nestle; PepsiCo; Puratos; Technische Universität München; University of Reading; Givaudan Switzerland; Tymbark – MWS; Vlevico; RethinkResource) is aimed to strengthen the EIT's activity in Circular Economy/ Resource Stewardship by the following advances:

– Comprehensive platform that accelerates side stream valorization
– Generation of easily accessible information on available side streams and secondary materials
– Enablement of large scale sourcing of secondary resources
– Product innovation through upcycling
– Open up new application fields within and outside the food sector
– A fee-based accessible marketplace

Maspex is additionally connected with investments related to the policy of efficient economy of sources, energy and water. The Cogeneration (CHP) system in fruit and vegetable processing plant in Tymbark, Poland, was launched. The purpose of developing this system was to reduce the total demand for electricity and technological heat of the juice production plant through the use of biogas generated in the wastewater treatment plant (WWTP) and natural gas as the main fuel for electricity, process steam, chilled water and heating water production. In order to achieve the designated goal, the CHP system, based on the aggregate cogeneration with an electricity capacity of 1.0 MWe, fed with bi-fuel (biogas and high-methane natural gas). The industrial symbiosis aspect is also realized by the Tymbark processing plant agreement for wastewater treatment received from Tymbark municipality and a local dairy plant OSM Limanowa which corresponds in about 15% of the total wastewater flow in the WWTP (Fig. 6.1).

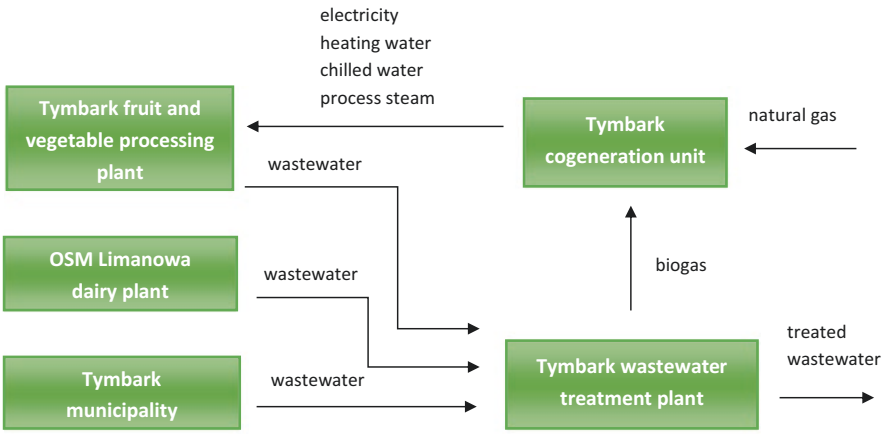

Fig. 6.1 The Cogeneration (CHP) system in fruit and vegetable processing plant in Tymbark. (On the base of Maspex own database)

4 Factors Conditioning Activities for the Development of Bioeconomy

The development of bioeconomy is inextricably linked to the use of an innovative approach, as well as the creation of new patterns of effective use of human capital. The potential inherent in human resources as well as financial and infrastructure capabilities should generate the development of new types of products and production techniques. It should also lead to the creation of an appropriate synergy of implemented policies, in particular scientific, scientific and technical, innovative, economic and social policies. Thanks to this impact, the economy should more effectively use both current and future resources in the production of basic raw materials, semi-finished and finished products in the food sector as well as industries and services processing or using biological resources. The key challenge for Poland in the macroeconomic dimension is to strengthen cooperation between science, entrepreneurs and public authorities, as part of the so-called triple helix, whose mission is to build an open and expansive economy. The positive impact on individual areas of the bioeconomy, the way it is shaped and implemented is ensured by the integration of the objectives of individual policies supporting finance, science, knowledge transfer and innovation. Less dispersion of development initiatives, concentration of public funds on science, research dissemination, knowledge transfer and innovation as well as activation and consolidation of extra-budgetary funds may become a key chain of sustainable activities to achieve positive effects conditioning the possibility of implementing bioeconomic innovations (Fig. 6.2). Creating a sustainable bioeconomy that fits into the idea of a circular economy requires coordinated efforts from public authorities and industry.[19]

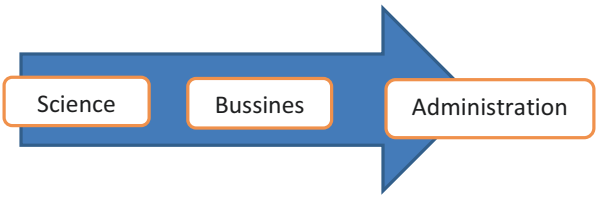

Fig. 6.2 Key structures conditioning the development of the bioeconomy

[19] Eugeniusz K. Chyłek, Monika Rzepecka „Biogospodarka – konkurencyjność i zrównoważone wykorzystanie zasobów", Polish Journal of Agronomy, 7, 3–13, 2011.

5 Recommendations for the Implementation of Bioeconomy in the Concept of Circular Economy

According to Wicki research and development until 2016 included in particular the following issues[20]:

- Developing processes for obtaining energy and chemicals with high added value from biomass from waste and vegetation using industrial biotechnological methods
- Obtaining new biomaterials and polymer composites with controlled biodegradability based on cellulose nanofibres and bio-nanocellulose
- Developing technologies for obtaining new biocatalysts and biocatalyst mimetics for the production of fuel and organic chemical compounds of significant industrial importance (from biomass)
- Developing biotechnological processes for the production of functional foods useful in the prevention and treatment of diet-related diseases
- Developing new ways to integrate fermentation and bioconversion processes with product separation, purification and dosing
- Development of biorefinery processes based on waste and renewable resources. While in the short term two further directions are envisaged: (1) strengthening innovation and competitiveness of the food industry and (2) developing technologies for the conversion of second generation biomass (residues from the food industry, household and municipal waste) into biofuels and raw industrial materials. The pressure on the food industry is well justified, given the importance of this sector in the Polish economy.

The EU's involvement in the transition from the linear economy model to the circular economy model has accelerated the development of bioplastics in Europe. The EU has begun to appreciate the benefits of bio-based materials, and the amended EU Waste Framework Directive and Packaging and Packaging Waste Directive introduced in 2018 are an incentive for Member States to expand their use of packaging materials and improve packaging market conditions for these products.

In Poland, one of the key sectors in terms of socio-economic impact inscribed in the bioeconomy is the agri-food sector. Its economic impact, both on the domestic and international market, makes it one of the most important sectors requiring special attention in the development of the latest technological trends. At the same time, it is one of the key sectors in the biological raw materials supply chain.[21]

[20] Wicki L., A. Wicka, 2016, Bio-Economy Sector In Poland And Its Importance In The Economy, Proceedings of the 2016 International Conference "Economic Science For Rural Development" No 41 Jelgava, LLU ESAF, 21–22 April 2016, pp. 219–219).

[21] Ciechańska D., 2019. Raport 'Identyfikacja dobrych praktyk, barier oraz kierunków rozwoju obszarów badawczych ułatwiających wdrażanie w Polsce w obszarze biogospodarki koncepcji GOZ', w ramach projektu "GOSPOSTRATEG – otoGOZ".

In recent years, the importance of the chemical industry in the development of bioeconomic initiatives has increased, especially in the field of advanced biorefineries, which use bio-chem processes to transform renewable resources into sustainable chemical products, biomaterials and fuels. These processes are of particular importance in the circular economy due to the maximization of the use of all valuable components of biomass raw materials, both secondary and primary as well as in the future perspective of municipal bio-waste.

Strategies for bioeconomic activities to improve the innovation and competitiveness of innovative sectors of the economy, in particular the packaging industry, focus on several important aspects that fit into the circular economy, i.e.:

- Development of biorefining technology in accordance with the cascade concept that guarantees effective material recovery of each, significant by-product and waste component in combination with the rational management of raw material residues for the production of biofuels and energy
- Development of technologies for rational and sustainable management of natural resources
- Development of technologies extending the life cycle of biomass-based products (including intelligent packaging technologies – functional, barrier, biodegradable) which will allow for efficient management of waste biomass stream from the consumption of goods

The development and implementation of support systems focusing on these activities will allow the use of huge resources at the disposal of the Polish bioeconomy and develop circular economy systems based on biomass raw materials, biotechnology and bio-recycling.[22]

The analysis of EU strategic documents, regional strategies, national smart specializations as well as the identification of good scientific and business practices have created the basis for prioritizing research issues in the field of bioeconomy, including some following technological issues[23]:

- Improvement of existing industrial, agricultural and transport technologies in the aspect of elimination of negative climate changes
- Production of high-quality biogas (>90% methane)
- Construction of cascading biorefineries – maximizing the use of primary and secondary biomass raw materials
- Bioplastics in the circular economy
- Organic recycling of plastics

[22] Ciechańska D., 2019. Raport 'Identyfikacja dobrych praktyk, barier oraz kierunków rozwoju obszarów badawczych ułatwiających wdrażanie w Polsce w obszarze biogospodarki koncepcji GOZ', w ramach projektu "GOSPOSTRATEG – otoGOZ".

[23] Ciechańska D., 2019.Stanisław Bielecki, Beata Gutarowska, in Raport 'Identyfikacja dobrych praktyk, barier oraz kierunków rozwoju obszarów badawczych ułatwiających wdrażanie w Polsce w obszarze biogospodarki koncepcji GOZ', w ramach projektu "GOSPOSTRATEG – otoGOZ".

- Sewage sludge management (for bioplastics)
- H_2 and chemical building blocks from biogas
- CO_2 as a raw material in the economy
- Naturally produced biopolymers and their functionalization
- Ecological biopreparations for agriculture
- Combined production of biomethane and biohydrogen from waste from the agri-food industry
- Construction of biological, molecular tools and systems (biocatalysts, bioreactors) with new functions, for new processes in the bioeconomy
- Joint management of organic waste (kitchen with green), new farming techniques and modern genetic modifications in agriculture for the preservation of food and bio-based products
- Utilization of plastic waste (complex, contaminated) and sewage sludge for coal production for restoration of degraded soils and water purification
- Water management and soil quality improvement and horizontal actions to improve the commercialization of research and horizontal activities to improve the process of research commercialization as follows:
  - Digitization of the bioeconomy
  - New legal regulations for the bioeconomy
  - Cross-sectoral initiatives – optimal raw material and product management in integrated value chains
  - Concentrators of bioeconomic activities – Hub BIO-GOZ
  - Entrepreneurship accelerators – start-up initiatives related to national specializations in bioeconomy

On the base of the diagnosis of bioeconomy status, some recommendations could be defined as effected on the implementation of circular bioeconomy in practice[24]:

1. Development of pilot installations for upscaling R&D solutions in the area of circular bioeconomy from TRL at levels 3–5 to TRL at levels 6–9
2. Implementation of strategic documents for the development of the bioeconomy in Poland – Road Mapping
3. Focus and prioritization of bioeconomy activities based on regional strategies – Bioregions cooperation platform
4. Rationalization of biowaste management in the country
5. Research internationalization – cooperation within European platforms
6. Strengthening inter-cluster cooperation building integrated value and supply chains for various sectors related to the bioeconomy

[24] Ciechańska D., 2019. Raport 'Identyfikacja dobrych praktyk, barier oraz kierunków rozwoju obszarów badawczych ułatwiających wdrażanie w Polsce w obszarze biogospodarki koncepcji GOZ', w ramach projektu "GOSPOSTRATEG – otoGOZ".

7. Debate with various stakeholder groups on the prospects for implementing the bioeconomy in Poland
8. Bio-based industry needs of skills and competencies identification
9. Bio-based education at all levels of education

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