ECONOMICS WORKING PAPERS

VOLUME 6

NUMBER 1

ISSN 1804-9516 (Online)

2022

ECONOMICS WORKING PAPERS

Volume 6 Number 1 2022

Publisher: University of South Bohemia in České Budějovice
Faculty of Economics

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Edition: 2, 2022

ISSN: 1804-9516

ECONOMICS WORKING PAPERS

ECONOMICS WORKING PAPERS. Published by Faculty of Economics. University of South Bohemia in České Budějovice• The editor’s office: Studentská 13, 370 05 České Budějovice, Czech Republic. Contact: tel: 00420387772493, Technical editor: Markéta Matějčková, e-mail: matejckova@ef.jcu.cz • ISSN1804-5618 (Print), 1804-9516 (Online)

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FROM ENVIRONMENTAL THINKING IN ECONOMICS TO BIOPLASTICS: PROMISING MATERIAL FOR A SUSTAINABLE (BIO)ECONOMY

Nikola Sagapova

Abstract: The demand and concerns for sustainable production, environmentally friendly products, as well as conscious consumption are increasing, although environmental thinking in economics is nothing new. Bioeconomy is presented as a potential solution to overcome various challenges modern society faces. The power of the bioeconomy lies in replacing fossil resources with renewables to produce various goods. Even plastics, the essential materials of our time, might be made from renewable biological resources. However, bioplastics are often discussed when it comes to the sustainability of their production, but also concerning the proper waste management or even their circularity. The task is very complex, and it is needed to take both environmental and socio-economic impacts into consideration. Currently, we might perceive various prerequisites and barriers, that are typically of a socio-economic, technological, but also political character, which must be addressed to meet the full potential of viable bioplastics production and their introduction to the market. The purpose of this paper is to provide the theoretical basis for bioeconomy production, in particular, the bioplastics, based on a narrative literature review of topics ranging from environmental thinking in economics, through biotechnology to plastics, to be able to set research questions and determine gaps in the research for the upcoming dissertation thesis. Although I used mainly Web of Science, Science Direct, and Google Scholar, I also searched for books and reports to gather valuable information and achieve the complexity of this review. I found several gaps ranging from the financial perspective to a wider assessment of the potential of bioplastics and their production not only from the business perspective, but also environmental impact and sustainability, or even adequate policy support and regulatory framework that might help their production and market introduction.

Keywords: bioeconomy, biotechnology, plastics, sustainability, environment

JEL Classification: Q20, Q56, Q57

1. Introduction

As an animal species, man is distinguished by his ability to reshape nature and mould the environment in his own image in order to satisfy his needs. As early as prehistoric times, man burned down forests in order to use the landscape thus altered for agriculture. However, the industrial revolutions, characterised by the rapid development of technologies, production growth and consumption, led to unprecedented changes in the environment, as they began to alter not only the landscape but also the chemical composition of the individual components of the environment. Currently, humanity is not only changing the landscape and the environment, but thanks to the modern knowledge of biotechnology and the possibility of genetic modification, we are already changing various biological organisms from within. But while resources are limited, human needs are considered infinite. Modern society has undergone many improvements that have positively affected the lives of many people around the globe. These happened due to globalization, technological development, increase in productivity, and subsequent economic growth. However, the unprecedented level of production and consumption brings new challenges, some of which are considered global problems. These issues include global climate change, biodiversity loss, pollution, poor waste management, resource depletion, poverty, hunger, etc. The dynamic growth of consumption triggered by the socially accepted consumerism lifestyle leads not only to greater pressure on natural resources, but also to an enormous amount of waste generated, as well as inequalities.

Plastics are one of the most important materials that have contributed significantly to improving the quality of life of individuals and shaping the modern societies and economies of the world in recent decades. Conventional plastics are made from fossil sources, mostly petroleum. Currently, we are literally surrounded by various plastic products, moreover, microplastics and plastics can even enter the organisms of this planet and the food chains. They are part of our work tools, consumer goods, cosmetics, clothing, vehicles, homes, etc. The uses of plastics are limitless, but one of the previously admired properties of these materials, their incredible longevity, is now becoming one of the biggest environmental problems of our time. Not only state governments and associations, non-governmental organisations, companies, but also consumers who are not indifferent to the fate of our environment are now responding to this problem. One of the responses, supported by all the actors mentioned above, is the development and production of bioplastics. These can be made from biomass, be biodegradable or have both properties. This heterogeneity within the term "bioplastic" leads to different interpretations of what a bioplastic is in general and at the same time opens the way for the misuse of this term for marketing purposes. Finally, the conceptual discrepancy itself can lead to a mistrust of bioplastics, which is naturally prevalent due to the fact that these are relatively new materials that are presented to us as an ecological solution to the plastics problem.

This paper aims to provide the theoretical basis for bioeconomy production, in particular, the introduction of bioplastics to the market, to set adequate research questions, and determine gaps in the research for the upcoming dissertation thesis.

2. Methodology

This paper is conducted as a narrative literature review. I find it a relevant approach to be able to fulfill the aim of the paper as literature reviews are essential to identify and synthesize what was written on a specific subject/topic, determine the extent, occurring patterns and trends, critically analyze the prior research, gather empirical findings to a research question, generate new frameworks and theories, but also to identify topics and question that need to be investigated (Paré et al., 2015). When deciding, which type of literature review to choose I was hesitating between a narrative and a scoping review. A scoping review is a relatively new approach for mapping broad topics that is increasingly popular for the synthesis of research evidence, yet the definition or procedure has not been established (Pham et al., 2014). The understanding of this type also differs as some perceive it as part of a procedure aiming to make a full systematic review, but others see its aim in identifying the gaps in existing evidence with no need to lead to a systematic review (Arksey and O'Malley, 2005). The narrative review is a traditional way to create a comprehensive background to understand current knowledge, but also to identify gaps in the knowledge, and often leads to determining research questions or hypotheses (Paré and Kitsiou, 2017). This approach is traditionally used at faculties and provides a broad perspective on a topic, yet can provoke thought and controversy and stimulate a scholarly dialog (Green, Johnson and Adams, 2006). However, some reviews also blurred the line between different types of reviews, such as narrative and scoping review, scoping and rapid review, or scoping and systematic reviews (Pham et al., 2014).

In the initial phase, I made a preliminary search of the literature to refine the topics of the overview. I decided to focus on what is known about environmentally thinking in economics before reviewing the bioeconomy and bioplastics as such, which was the next step. I identified several topics that I should address in my review, which I found essential for my work. I made a structure of the topics ranging from historical sources of environmental thinking, through various economic approaches based on environment and natural resources to bioeconomy and circular economy, biotechnology, plastics, and relevant subtopics where necessary. As for the sources of information, I used mainly electronic databases recognized by scientists including Web of Science, Science Direct, and Google Scholar. Apart from these sources I searched also for books and reports to gather valuable information.

3. Literature review

3.1. Environmental thinking in economics

3.1.1. Historical sources of environmental thinking in economics

Ideas concerning population growth, resource scarcity and environmental pollution have accompanied economics for more than 200 years, and even contemporary discourse often draws on the work of classical economists such as Malthus, Ricardo and Mill. Throughout history, the reckless use of resources and lack of foresight have led to environmental degradation. The first industrial revolution in the 18th century had the greatest impact on the diversification of economic activities combined with the ever-increasing pressure on resources to meet the needs of a growing population. One of the negative effects of industrial production was pollution. It is not surprising that economists began to pay more attention to the issue of natural resources and the environment at this time (Kula, 1998).

Smith (1776) assumed that the decisive sign of a country's prosperity was the increase in its population. He considered agriculture, production and free trade important to achieve growth. Production and trade were provided by the cities but they depended on primary agricultural production in the countryside. However, Malthus (1798) feared that as production and population increased, so would the pressure on land and its use for feeding the population, with the better soils being cultivated earlier. Over time, the less fertile soils would also be cultivated until all fertile soils were occupied. Harvest and yield would depend on maintaining and improving soil quality, which would gradually decline. As agricultural and industrial production increased, so would the population. The increasing possibilities of production in each country would depend on the prevailing industry, the knowledge and habits of the people, but also on some transitory factors, including the degree of equality and civil liberties. Although it appears that the occasional plague outbreaks led to a decline in population, birth records show that the number of births increased after the plague waves. While food production usually increases arithmetically, population growth, if left unchecked, increases geometrically. The availability of food plays an important role in regulating populations in nature and keeps them within certain limits. Partial depopulation can be caused not only by plague and famine, but also by times of war, disease and epidemic outbreaks.

Population growth has led to the need to increase the efficiency of agricultural production in order to avert the "Malthusian" catastrophe. The development of agricultural machinery and the introduction of horse-drawn combines have led to an increase in the amount of grain harvested. Despite the advancement of technology, new ways still need to be found to increase yields while preserving natural habitats and biodiversity in the face of a growing population. While the development of plant breeding and genetics achieved a stabilisation of crop production in the nineteenth century, a century later this process led to a dominance of monocultures with limited genetic variability and increased susceptibility to diseases (Trewavas, 2002).

Malthus' ideas relate not only to the field of economics or agriculture, but also to population biology. In modern population biology, however, human population growth is referred as exponential rather than geometric, because geometric growth occurs in populations that have a limited mating and reproductive season, whereas exponentially growing populations reproduce at any time of the year, as in the case with humans. However, in a world with limited resources, no form of population growth can continue indefinitely. Once resources are exhausted, population growth slows or even stops at a level commonly referred to as the carrying capacity of the environment. At a population size equal to the carrying capacity of the environment, the birth rate is equal to the death rate and population growth is zero (Edwards and Edwards, 2011). Interestingly, current growth, driven by stable growth in per capita income and technology levels, shows a negative relationship between output levels and population growth rates. This is reflected in the fact that the poorest countries have the highest population growth rates, while in many rich countries population growth rates are close to zero. In the Malthus period, technology and population growth can be said to be frozen and per capita income constant. The period between "Malthus" and modern growth is characterised by a feature of both: per capita income is growing, although not as fast as today, but the Malthusian relationship between per capita income and population growth is still valid (Galor and Weil, 2000).

Ricardo (1817) agreed with Malthus' idea of decreasing yields and pressure on land use when less and less can be produced on the same area of fertile land. This results in the need to acquire land of inferior quality to meet the need to food requirements of the population, even if the demand for crops remains constant over the years. In his opinion, Malhus succeeded in describing the principle of land rent decreasing or increasing according to its fertility or the location of its cultivation in relation to a comparative advantage. However, he did not share the view that the rent of quality land is a definite gain and is a new form of wealth creation. This is explained by the fact that in some countries where fertile land is already occupied, cultivation, even of low-quality land, benefits its owners, while in countries with higher-quality uncultivated land, where labour and capital are insufficient to use it, its price is negligible. The introduction of machines is seen positively from the point of view of saving human labour and shifting capital and labour from one sector to another. Successful introduction of new machines gives the inventors or first owners an additive competitive advantage that leads to temporarily high profits until these machines are introduced by other market players. Compared to agriculture, Ricardo predicted higher in the mining industry.

Mill (1885) states that industry is limited by capital, which indicates the amount of labour that can be put into the production process. He extends the idea that industrial production depends not only on the productive power of labour, but also on materials and food to be carried out. As capital grows, more people can be employed to provide labour, materials, but also bread and butter. Although industry is limited by capital, it does not always reach its limits, for example, because of the lack of labour to employ with that capital. The limits of wealth are the possibilities of production and the productive forces, because with capital one can either employ more people or pay the existing ones better. However, he does not see agricultural land as being too limited, but rather coal and metal deposits, which he believes are easily depleted and therefore tend to have diminishing returns in the long run with cumulative extraction. Furthermore, he notes that in cases where there is no effective demand for these deposits, their market value is close to zero. However, he believes that in the mining sector, compared to agriculture, technological progress can be better exploited, making it possible to reduce operating costs. Marx (1887) sees rising productivity in capitalist agriculture and industry in the context of the costs of increasing waste production. Moreover, he describes agricultural progress as the robbery of labour and land, because all progress in the growth of soil fertility in a given period leads to the destruction of this resource and its fertility in the future. The faster the state experiences progress through industrial development, the faster will be the process of destruction. In his view, capitalist production thus leads to the erosion of the original sources of wealth: land and labour.

The possibility of depletion of coal mines was also discussed by Jevons (1866). In his opinion, a direct exhaustion of all coal seams is not to be expected, but rather a situation in which a deepening of these mines in connection with increasing industrial use would lead to an increase in coal prices. Although he did not think of the end or downfall of any nation or civilisation, he did believe that the progressive state of growth would come to an end. Thanks to coal, trade, employment and wealth increased every year, which had to be maintained in order to satisfy the needs of the population, otherwise exodus would have been inevitable. He believed that while the industrial spirit can develop, material resources are limited, and the consumption of fuel/coal consumption will increase despite technological advances leading to greater resource efficiency. Nevertheless, he also predicted that in the future, instead of using pig iron or coal, companies would prefer to use the skills and talents of workers for production, which would radically change the whole industry and production. According to Spash (1999), the discovery of oil as a substitute for coal but also technological progress, were the reasons why the predicted catastrophe and decline in growth did not occur. These reasons subsequently led to a negative argumentation of mainstream economists against the issue and question of a possible exhaustion of resources. Keynes (1933) states that the world would be much wiser and richer if the economy of the 19th century was based on the ideas of Malthus instead of those of Ricardo.

After the death of these economists, there was a period when economists paid little or no attention to resource depletion or environmental problems (Spash, 1999). An exception was Hotelling (1931), who drew attention to the world's dwindling reserves of minerals, forests and other resources, whose low price allowed rapid extraction to the detriment of future generations. The waste of resources subsequently influenced the rise of the protectionist movement. One possible solution to this situation was to stop the destruction of non-renewable and renewable resources in the long term by banning production at certain times and in certain regions or by banning inefficient production methods. Another proposed solution was the introduction of a tax. Spash (1999) notes that in the first half of the 20th century, some economists emphasised the issue of resource conservation and wise use, especially in relation to agriculture and forestry, but also to the extraction of non-renewables, which then became the basis of natural resource economics. However, these observations did not become common knowledge or concern among economists, but only among specialists in the various sub-disciplines. At the same time, mainstream economics developed theories according to which the economy can function independently of natural resource limitations or assimilative capacity, which led to a further marginalisation of environmental problems.

3.1. Economic approaches based on environment and natural resources

3.1.1. Natural resources economics

In the 1950s, some economists began to call for a special approach to the environment and the natural resources it provides (Spash, 1999). The origins of natural resource economics as well as environmental economics are linked to the founding of the independent research organisation Resources for the Future (RFF), which developed and applied economics to a wide range of environmental issues. The main focus was on the issue of natural resources, estimating the future supply of mineral resources, but also agricultural crops (Pearce, 2002). While economics is concerned with the efficient allocation of limited resources in general, natural resource economics is concerned with the allocation of limited natural resources, such as fish stocks, trees, clean water, oil and other naturally occurring resources. These resources are usually divided into renewable and non-renewable. Sometimes a distinction is made between natural resource economics and environmental economics, which also deals with waste management or the resulting quality of air, water and soil after the source has become waste. In addition, environmental economics also deals with environmental protection and biodiversity issues (Conrad, 1999). Current natural resource economics focuses primarily on modelling efficient and optimal use of fisheries, forests or minerals, where natural resources are understood as capital, wealth reserves and factor of production (Spash, 1999; Conrad and Rondeau, 2020). Natural resource economics draws on neoclassical economics (Spash, 1999). A crucial issue in natural resource allocation is the amount that can be extracted over time. This is often referred to as a dynamic optimisation problem. The result would be a time path that specifies the amount of the resource that can be extracted at different points in time to maximise its economic value (Conrad, 1999). Nevertheless, some models are not directly focused on optimising resource allocation, but rather simulate possible scenarios for the use of these resources (Conrad and Rondeau, 2020).

The division of resources into renewable and non-renewable is crucial for management. Renewable resources have a significant physical inflow or endogenous biological growth over a time horizon suitable for economic planning and management. Non-renewable resources, on the other hand, do not increase over a reasonable time horizon, apart from the discovery of new deposits that increase overall supply but do not increase supply at existing sites. It is also important to evaluate renewable resources from an economic point of view. If the source under consideration is a slow-growing tree that takes 200-300 years to grow, it can also be considered a non-renewable resource, even though it grows every year. In the classification of resources into renewable and non-renewable, therefore, it is not only biophysical growth that plays a role, but rather an economically relevant growth rate. Like non-renewable resources, renewable resources can also become exhausted. Individual organisms can become extinct and their genetic information can disappear. In this context, the possibilities of genetic engineering for the potential conservation and restoration of species should be mentioned, even if this raises other ethical questions (Conrad and Rondeau, 2020).

3.1.2. Environmental economics

Like natural resource economics mentioned above, environmental economics is based on neoclassical economics and its origins can be traced back to the 1950s (Spash, 1999; Tietenberg and Lewis, 2020). Environmental economics, and later ecological economics, are not only sub-disciplines of economics but also part of a broad spectrum of environmental sciences. Originally, environmental economics was strongly influenced by agricultural economics and the rapidly growing field of natural resource economics, which was concerned with the theoretical analysis of the optimal extraction and use of resources (van den Bergh, 2007). Over time, however, the concept of capital in the form of natural resources has moved away from its understanding as a factor of production and a source of wealth, particularly through the recognition of other intangible services provided by nature through ecosystem services. Ecosystem services have later become the main conceptual framework for environmental economics (Morrissey, 2020).

In the 1960s, environmental economics in the USA also began to address the problem of increasing pollution, which by then was already being registered by the general public (Spash, 1999). The far-reaching negative effects of economic growth on the environment were already highlighted by Kapp (1950), who defined the problem behind these negative effects as so-called societal costs, which include all direct and indirect burdens that economic agents impose on third parties through production processes in the form of air and water pollution, which not only affect human health but also lead to a reduction in agricultural yields, accelerate the corrosion of materials and even the endanger aquatic life, flora and fauna. The growing public awareness of environmental problems related to economic activities was soon awakened by publications such as the book "Silent Spring" (Carson, 1962) and "Limits to Growth" (Meadows et al., 1972), which presented catastrophic scenarios if economic activities continued unchanged.

Environmental economics is based on the central idea that environmental problems have their roots in the failure of economic systems to seek to maximise human well-being, as the quality of the environment is important not only for nature itself but also for human well-being and economic growth (Pearce, 2002). These market failures include externalities (Söderholm and Sundqvist, 2003; Bird, 1987), public goods (Gordon, 1954; Reinhardt, 1999), information asymmetries (Weitzman, 1974; D'Amato and Dijkstra, 2015) or imperfect competition (Dean and McMullen, 2007; Fowlie, 2009). Since there is no economic decision that does not affect nature and the environment, just as there is no environmental change that does not have an economic impact, environmental economics attempts to address the problems in a series of logical steps. It first tries to assess the economic significance of environmental degradation, looks for the causes of that degradation, and then proposes economic incentives to slow, stop and avert that degradation (Turner, Pearce and Bateman, 1993). Environmental economics not only perceives the existence of market failures, but also seeks to measure the surpluses lost due to these failures. Various techniques have been developed for this purpose, such as the travel cost method, the hedonic price method, the dual profit function, the household production function, mathematical programming or the contingent valuation method. All techniques are based on the existence and specification of a complementary or substitutive relationship between a market good and a non-traded environmental good of interest (Crocker, 1999).

3.1.3. Ecological economics

The ecological and later green economy is based on the failure of the mainstream economy in relation to nature (Johanisová, 2014). Dissatisfaction with mainstream neoclassical theory was an important reason for the emergence of ecological economics, which engages with a range of perspectives from other disciplines such as geography, ecology and hydrology, in addition to a dominant economic view of issues and problems. In addition to multidisciplinary research efforts, ecological economics has sought to counter various critics and offer viable alternatives (van den Bergh, 2007; van den Bergh, 2001). Although the basic ideas of ecological economics emerged as early as 1970, when there were numerous meetings between proponents and actors essential to the emergence of formal ecological economics, the new economic direction was not formally established until around 1980 (Røpke, 2004). However, it is not an ideologically and methodologically uniform field (Johanisová, 2014).

The basic premise of ecological economics is the recognition that economics is rooted in nature and that economic processes are also natural processes, as they can be seen as biological, physical and chemical processes or transformations. The inspiration of thermodynamics had a great impact, thanks to which people started to perceive economic processes from a biophysical point of view, especially in relation to energy and mass flows (Røpke, 2004). The economy is connected to the planet's ecosystems through energy and mass flows (Johanisová, 2014). An important milestone was the founding of the International Society for Ecological Economics (ISEE), whose main impetus was the growing concern about neoclassical economics and its incomplex approach to the use of natural resources, their depletion and degradation, as well as its unreliability as an appropriate compass for future development of society and economy. Another valuable sources for ecological economics were empirical analyses of energy and material flows between the economy and ecosystems, carried out, for example, in the search for sustainable development indicators or in land use modelling (Cleveland, Stern and Constanza, 2001).

Ecological economics has chosen sustainable development as its central concept, emphasising the issue of locality vs. globality, the rich North vs. the poor South, but also the limits to growth, often referring to the maximum size of the economy or the carrying capacity of the environment (van den Berg, 2001; Sagoff, 1995). This approach often uses (co-)evolutionary thinking, which, in contrast to environmental economics, views whole systems, including markets as adaptive and coincidental rather than optimal. In such systems, the market does not always give the right signal, for example, to select optimal technologies. Ecological economics is also based on a longer time horizon. The focus is among others on the equitable distribution of resources or issues related to biodiversity loss. Ecological economics attempts to integrate various elements from different fields of natural and social sciences such as economics, ecology, ethics, thermodynamics and many more to provide a comprehensive biophysical view of the interactions between the environment and the economy to contribute to structural solutions to environmental problems (van den Bergh, 2001). Although ecological economics also contains elements and problems of neoclassical environmental economics and natural resource economics, it goes much further than these economic directions by incorporating the biophysical aspect of the environmental impact of the economy. Ecological economics seeks to study and evaluate (un)sustainability, often using the neoclassical toolkit. However, unlike mainstream economics, it rejects the paradigm of comparability of values and assumes their incommensurability, which manifests itself mainly in multi-criteria valuation, as there are often conflicts between competing values, interests, stakeholders and communities when it comes to the environment. In some cases, the cost-benefit analysis method can be used to obtain similar values for selected projects that can be considered weakly to strongly comparable. In addition to the cost-benefit method, other approaches such as contingent valuation, energy analysis and ecological footprint are also commonly used. Multicriteria analysis is appropriate because of the inclusion of various conflicting, multidimensional, non-combinable and uncertain impacts of decisions (Martinez-Allier, Munda and O'Neill, 2001; Martinez-Allier, Munda and O'Neill, 1998).

3.1.4. Green economy

The Green New Deal, the green economy and green growth present themselves as possible solutions to major global problems such as the financial crisis, environmental degradation, climate change and poverty in the context of sustainable development (Cudlínová, 2014). Like ecological economics, green economics also refers to its basis in ecology. Nevertheless, green economy accuses ecological economics of focusing too much on mainstream economic concepts, techniques and methods of valuation and measurement. Much of the work of green economics is based on the insights and approaches of ecological economics or alternative directions, which may include ecofeminist and eco-socialist economics. The green economy differs from the mainstream economic paradigm in three ways: it focuses on social justice; it has grown from the bottom up as eco-activists and green politicians seek a practical solution for a sustainable economy instead of abstract theories; it rejects the current globalised economic system, which is a source of social inequalities (Cato, 2009).

A fundamental problem that green economy is facing is the re-evaluation of the idea that the economic system should fulfil the unlimited desires of *Homo oeconomicus*, who weighs costs and benefits and then acts to maximise his utility and satisfy his own needs. This concept does not take into account the fact that people often act out of selfless interests and may be motivated by selfless interests or fears. The green economy tends to lead to a change that will result in less greed, more sustainability and that will separate the rate of change of economic output from the environmental goods used in the process. Two of the most important questions are: the extent of change in the economy and how the change can be achieved. In that given extent, economic growth would be possible (Pearce, 1992). The green economy offers a low-carbon, resource-efficient economic model that brings useful improvements to the status quo and opportunities for poorer countries (Mathai and Parayil, 2013).

The trend for the green economy is green or low-carbon growth through green investments in green renewable energy technologies such as capital-intensive hydro, wind or photovoltaic power plants (Eyraud, Clements and Wane, 2013; Johnson and Lybecker, 2009; Mathai and Parayil, 2013). Green programmes were supposed to provide a significant fiscal stimulus during the global financial crisis in 2008 and 2009 (Eyraud, Clements and Wane, 2013). Nevertheless, environmental crises currently seem intractable without abandoning the idea of miraculous 'green growth' that can reduce environmental impacts while increasing the scale of the economy (Read, 2015). Occasionally, it is suggested that the absolute level of economic scale should not decrease, but also not increase, referring to a thought of zero economic growth and zero population growth or even degrowth to achieve sustainability (Pearce, 1992; Read, 2015, Spangenberg, 2010; Mathai and Parayil, 2013). Interestingly, the economic crisis of 2008 and 2009 contributed to the focus on economic growth and further neglect of the environment, despite the rhetoric of green or low-carbon growth and the call to decouple economic growth from environmental degradation by promoting and implementing green investments. Ultimately, most financial and bailout programmes were not geared towards investing in green infrastructure or cleaning up the environment. However, China, the United States, South Korea and Germany top the list of countries using green incentives (Spangenberg, 2010). This does not have to be a bad result considering that China and the United States are the biggest polluters in the world (Torres-González, 2015). Currently, there are many different theories, concepts and approaches related to the green economy. These include the concepts of clean production, bioeconomy, industrial ecology and circular economy, among others (Louiseau et al., 2016).

3.2. Bioeconomy and circular economy

The green economy has reached the peak of political attention. In the long term, politicians and business are willing to replace the fossil economy with a bio-based economy, the so-called bioeconomy (Gottwald, 2016). The green economy, the bioeconomy and the circular economy are considered the global mainstreams of the concept of sustainability. While the green economy emphasises the role of ecological processes, the bioeconomy and the circular economy focus mainly on the importance and role of natural resources. The green economy also focuses more on social and environmental inclusion than the bioeconomy, although there is increasing pressure on rural policy and development within the bioeconomy (D'Amato et al., 2017). The bioeconomy is sometimes understood as a superset (Socaciu, 2014), sometimes as a subset of the green economy (Hautakangas, 2017), or the green economy is perceived as an umbrella concept that includes elements of the circular economy, the bioeconomy and some other ideas (D'Amato et al., 2017). The bioeconomy is a presented as a promising solution for key global problems and challenges. Its implementation should lead to sustainable development and economic growth while solving various problems, including climate change, the efficient use of natural resources and the conservation of biodiversity (European Commission, 2012b). The circular economy in the European sense also promises similar results in terms of sustainable growth with less impact on natural resources and biodiversity, more efficient use of natural resources, creation of new jobs, new business opportunities and new sustainable products. Furthermore, it promises new patterns of consumption. However, with regard to renewable natural resources and products made from them, it is also dependent on compliance with the bioeconomy strategy and action plan (European Commission, 2020). According to Carrez and van Leeuwen (2015), the bioeconomy is circular by nature and thus a renewable component of the circular economy that will continue to grow in importance in the future.

The term bioeconomy was first used in 1970 when Georgescu-Roegen wanted to name his own idea of an emerging ecological economy, but the non-use of this name is sometimes attributed to Clark's use of the term bioeconomy in 1976 to describe an economy that uses renewable resources (Røpke, 2004). The modern bioeconomy was first outlined by Healy (1994), who assumed that the development of the natural sciences will permeate the fields of medicine, agriculture, chemical production, environmental science and microelectronics, with biotechnology creating new, sophisticated and well-paid intellectually satisfying jobs, new industries that will be a growing source of economic power and leadership, and that there are already signs that the 21st century will be based on the bioeconomy. Enríquez (1998) took a similar view, foreseeing the restructuring of society, industry and entire economies through the creation of a new economic sector that will use the discoveries of genomics, molecular technologies and other natural sciences and biotechnologies for production. He predicted the impact of the combination of economics and natural sciences on the traditional chemical industry, the pharmaceutical industry and agriculture.

As in the case of the green economy, the reason for the current focus on the bioeconomy is the economic crisis. This led to the recognition of the potential of the use of renewable resources for economic development, resulting in a renaissance of the economy and the flourishing of the bioeconomy (Romano, 2013), in which the development of the biotechnologies plays an important role (Birch and Tyfield, 2012). The initiative to develop the bioeconomy came from policy makers rather than the private sector. Successful implementation of the bioeconomy requires research, but also investment in new processes and technologies or subsidies based on national and transnational strategies (Lauri et al., 2014). The bioeconomy itself should not be seen as a new economic phenomenon or discipline, but rather as a complex system theory, a new dimension within the existing system. We can conceive of it as a concept that uses natural resources through innovative cross-sectoral approaches that form the basis for a circular economy that will contribute to more sustainable growth with positive environmental and social impacts (Maciejczak, 2015). However, the bioeconomy is not a uniformly accepted concept. It often differs in its actual name, in the accepted definitions and in the actual application and implementation. The terms bioeconomy, bioeconomics, biocapitalism, bio-based economy, or knowledge bioeconomy are often used as synonyms. The definitions differ mainly in the set of inputs and outputs of biotechnological processes (Maciejczak and Hofreiter, 2013; Staffas, Gustavsson and McCormick, 2013).

The OECD (2009) sees the bioeconomy as a world in which biotechnology makes a significant contribution to economic output, with the expectation that the bioeconomy will be global, guided by the principles of sustainable development and environmental sustainability, and will use biotechnology knowledge, renewable biomass and cross-application integration. A recent OECD document (2018) considers the bioeconomy as a set of activities in which biotechnology plays a central role in primary production and industry, recognising the role of advanced life sciences in converting biomass into materials, chemicals and fuels, but also the need to develop strategies that go beyond the scope of biotechnology. At EU level, many different „conceptualizations" and definitions of the bioeconomy have emerged over time. The so-called Cologne Paper sees it as the translation of life science knowledge into new, sustainable, eco-efficient and competitive products (German EU Presidency of the Council of the European Union, 2007). In the background paper for the public consultation, the bioeconomy was described as an economy based as a low-waste chain based on land and sea use, transformation and the production of bioproducts tailored to the needs of end consumers. In doing so, the bioeconomy integrates a wide range of natural and renewable biological terrestrial and marine resources, conserves biodiversity and encompasses agriculture, forestry, fisheries, food, biotechnology, industry, as well as a range of technological solutions for growth and sustainable development even for future generations. In addition, the document mentions that some organisations have proposed other definitions or even a change in focus of the European bioeconomy. Some proposed definitions are included in the document (European Commission, 2011). The newsletter on the adoption of the EU bioeconomy strategy presents the bioeconomy as an economy that uses biological resources of the lands and seas, but also waste, including food waste, as an input for industrial and energy production. It also includes the use of biological processes in green industries (European Commission, 2012a). According to the strategy itself, the bioeconomy consists of the production of renewable natural resources and their conversion into food, feed, bioproducts and bioenergy (European Commission, 2012b). The updated version of the EU bioeconomy strategy refines the definition to focus more on ecological aspects, links to ecosystems and an emphasis on sustainability and circular economy, as well as positive environmental and social impacts. According to the updated strategy, the bioeconomy encompasses all sectors and systems that depend on biological resources (animals, plants, microorganisms and derived biomass, including organic waste), their functions and principles. It encompasses and links: terrestrial and marine ecosystems and the services they provide; all primary production industries that use and produce biological resources (agriculture, forestry, fisheries and aquaculture); and all industrial sectors that use biological resources and processes to produce food, feed, biological products, energy and services. A sustainable circular bioeconomy should lead to the regeneration of industries, the modernisation of primary production systems, the protection of the environment and the enhancement of biodiversity (European Commission, 2018). According to the US, the bioeconomy is based on the use of research and innovation in the life sciences to generate economic activity and public benefits (White House, 2012). The OECD (2009) focuses on the technological approach and biotechnological applications that will be key to the development of the bioeconomy, as well as new innovations and products that will help companies benefit from improved population health, higher productivity and environmental sustainability; the EU aims for sustainability through sustainable biological resources that will reignite economic growth in Europe but also lead to a renaissance of industry, the primary sector and rural development (European Commission, 2012b), and the US sees the unique potential of developing a technology-driven bioeconomy that will bring not only economic growth but also various societal benefits (The White House, 2012). Befort (2020) and Dieken et al. (2021) discuss the problem of different understandings of bioeconomy as such, especially in policy documents, and they identify two main approaches to the bioeconomy. While the first focuses on biotechnology, the second is resource-oriented. Different approaches can thus lead to different outcomes, whether in the development of biotechnology, green growth or sustainable development. The concept of circular economy could be a similar case, as it could be seen as a new growth paradigm, although there are already methods and systems in place to quantify and communicate the impacts and benefits of circular systems that can lead to a more sustainable and healthier society (Benetto, Gericke and Guiton, 2018).

From today's perspective, dealing with waste is an important part of the bioeconomy, even though it is still underdeveloped in many countries, although the importance of waste as a resource is increasing. The emphasis on the circular bioeconomy, which aims to combine the concepts of the bioeconomy and the circular economy and which should lead to synergies between the two concepts (D'Amato et al., 2017), is set mainly by the EU and individual European countries. Waste management systems that take into account the potential of waste from agriculture, forestry and municipal biowaste will be essential for achieving the circular economy (Carrez and van Leeuwen, 2015). The European Commission has issued an Action Plan for the Circular Economy, which should be one of the key building blocks for Europe's green deal and a new agenda for sustainable growth. A fully functioning regenerative growth model should lead to resource use within planetary boundaries, reducing the ecological footprint while strengthening the EU's industrial base. The EU aims to be a global leader in the circular economy, using its influence, knowledge and financial resources to achieve the Sustainable Development Goals (European Commission, 2020).

There are two key factors in shaping future bioeconomy: the quality of governance (defined as a system of regulations and policies that influence the development of the bioeconomy) and the economic competitiveness of biotechnological innovations. In addition, sustainable economic growth and increasing incomes appear to be key factors for bioeconomy development. Higher global incomes, especially in developing countries, will create additional demand for quality healthcare, food, consumer durables, education and travel (OECD, 2009).

3.2.1. Criticism of bioeconomy production

At first glance, both the green economy and the bioeconomy seem harmless and even environmentally friendly. On closer inspection and reflection, both concepts speak for themselves when it comes to the intention to commercially exploit the biosphere, even through the introduction of genetically modified organisms that we do not know exactly how they will interact with the environment and native organisms (Gottwald, 2016). A clear prerequisite for the development of the bioeconomy, in addition to political and financial support, research and implementation of biotechnology and plant innovation, is the availability of a sufficient quantity of biomass of appropriate quality. This should be achieved through sustainable production (van Dam et al., 2005). However, ensuring sustainable biomass production is not included in most national strategies (Staffas, Gustavsson and McCormick, 2013). The lack of a strategy to ensure sustainable biomass production can lead to the intended advantage of the bioeconomy, the possibility to produce renewable resources in terrestrial and aquatic ecosystems, turning into a disadvantage in the form of increased pressure on soils and aquatic ecosystems and their productivity, deforestation or competition with food and feed production. Thus, the bioeconomy may also come into conflict with the principles of sustainable development (Cudlínová and Sagapova, 2019).

Bioeconomy uses various plants and resources that can be used to produce bioenergy, bioproducts or food and feed. The individual uses are in a competitive situation. This situation is often referred to as the food-feed-biofuel trilemma (e.g. Das, 2017) or, with regard to the biophysical dimension and environmental impacts, also as the food-energy-environment trilemma (e.g. Steinbuks and Hertel, 2016). Biofuel production was the first area of the bioeconomy that the European Union supported through the Renewable Energy Directive, which states that 10% of all transport fuels should come from renewable sources by 2020. The transition to biofuels is intended in order to achieve a reduction in carbon emissions, increased energy security, but also rural development. The problem is that the EU cannot achieve this ambitious target with its own biomass resources. Therefore, there is a risk of increased use of renewable resources from the Global South, where land grabbing can occur, food prices might rise and natural resources might degrade or be exploited (Levidow, 2013). An increase in food prices was recorded in Mexico during the so-called Mexican tortilla crisis, when speculation in the maize market due to the use of maize as biofuel, but also due to farmers switching to growing energy crops instead of food, drove up maize prices and worsened the situation of the poor (Sinn, 2012). Even the reduction of carbon emissions is not a clear result of the transition to biofuels, as emissions are associated with land use changes, including deforestation to establish plantations (Melillo et al., 2009) or conversion to agricultural land for crops (Searchinger et al., 2008). Many biodiversity hotspots also suffer from these land use changes due to habitat loss (Melillo et al., 2009). The implementation of a bioeconomy strategy in the EU raises the question of whether further land grabbing will also be necessary within Europe (O'Brien, Schütz and Bringez, 2015). Otherwise, the EU seems to be dependent on the global biomass market, with the main source regions being Africa, Asia and South America. These regions are known for their low food security, but also for their largely unsustainable agricultural production. This scenario is highly controversial in terms of sustainable development (Pavanan et al., 2013).

A major problem of the bioeconomy is also that while the biomass resources are renewable, the land on which terrestrial production largely takes place is not renewable in the human time scale and horizon. Soil is limited and, moreover, vulnerable to degradation due to complex interactions between different processes, factors and relationships operating at different spatial and temporal scales. The main processes of soil degradation include erosion, organic carbon depletion, biodiversity loss, elemental imbalance, acidification, salinisation (Lal, 2015) or phosphorus deficiency (Alewell et al., 2020), which could limit agricultural production not only of food and feed in the future. Fertile soil is an essential factor for the transition to a sustainable bioeconomy, and society depends on its conservation and management in the long term (Juerges and Hansjürgens, 2018). Soil management that maintains its functions and prevents degradation helps to maintain ecosystem services and resource efficiency while respecting the goals enshrined in bioeconomy strategies and the Sustainable Development Goals. While the concept of resource efficiency has a long tradition, the role of soils in assessing the efficiency of agricultural management is often overlooked (Helming et al., 2018).

A crucial prerequisite for a sustainable bioeconomy is its scale, with the regional dimension being a more sustainable form of application (Cudlínová, Lapka and Vávra, 2017). The original European policy framework for the bioeconomy could be accused of emphasising an industrial perspective with a dream of the global competitiveness of the European economy, which shall be primarily based on capital-intensive industries and higher value-added products. At the same time, a bioeconomy that can be labelled as sustainable and which takes into account the provision of public goods should emphasise, among others, agro-ecological practises, organic and low-input farming, ecosystem services, social innovation in collective multi-actor approaches and the co-production of knowledge or the use of local knowledge (Schmid, Padel, and Levidow, 2012).

Biomass, which enters production as a primary raw material, contains different amounts and structures of simple sugars, polymeric carbohydrates, lignin, vegetable oils and proteins. Green chemistry should always make the best use of these different structures to maximise the incorporation of all atoms into the final product while minimising the waste produced. It has been proven that vegetable oils can serve as a perfect substitute for fossil resources. However, the majority of biomass is made up of sugars, which are found in first generation biomass, i.e. food crops, in the form of simple sugars or polymeric starch, but also in second generation biomass in the form of cellulose and hemicellulose polymers in lignocellulose. There is now a general consensus in the scientific community that the only valuable source of carbohydrates for non-food purposes, including the production of various chemicals and materials, is second-generation biomass. However, in industrial practise, fermentation of sugars derived from first-generation biomass still predominates. The advantage of first-generation biomass is its ease of use due to the elimination of pre-treatment methods and higher land efficiency compared to second-generation biomass (Deneyer, Ennaert and Sels, 2018). In addition to first generation biomass, which includes food crops, or second generation biomass, which includes lignocellulosic sources as well as municipal waste, the use of third generation biomass, i.e. algae or CO2, is also being considered for production. Increasing the scale of second- and third-generation biomass-based production processes requires optimising carbon use, which depends on the ability to economically produce high-value products and by-products (Lee and Lavoie, 2013). Financial incentives, whether through payments or fines, would motivate producers to switch from first-generation biomass to second-generation biomass. Although less efficient than first-generation biomass, the use of first-generation biomass raises debates about the use of these crops, as bioeconomic production directly competes with their traditional use as feed and food (Esmaeili et al., 2020). It is clear from the above that the economic interests of many companies that rely on renewable raw materials are currently in collision not only with social and ecological interests, but also with the declared mission of the bioeconomy. The whole situation is exacerbated by the complexity of the problem.

3.2.2. Biotechnology

Biotechnology has accompanied mankind since the beginnings of brewing beer and baking bread, as well as other forms of using microbial cultures to produce a variety of foods and beverages. Today, biotechnology is defined as the application of living organisms or bioprocesses to produce new products. As knowledge evolves, especially in the fields of genetics, molecular biology, microbiology and biochemistry, so do the applications of biotechnology (Clark and Pazdernik, 2016). Biological systems can convert renewable resources, including lignocellulosic biomass, starch crops or even carbon dioxide, into fuels, chemicals and materials. Although starch plants such as corn are still the most widely used, enzyme technologies have long been developed to convert lignocellulosic biomass such as wood, grass, agricultural and municipal waste, as well as productive strains of microalgae, into a wide range of chemicals and materials (Wyman and Goodman, 1993).

Given the growing demand for energy and materials, but also the volatile and uncertain oil resources as well as the growing concern about global climate change, biomass is seen as an important renewable resource to secure future energy supply, fuel, chemical and material production, but also sustainable development. Successful conversion of biomass into end products requires knowledge in biotechnology, microbiology, green chemistry, materials science and engineering (Baskar, Baskar and Dhillon, 2012). In the biotechnology industry, there is a strong demand for resources and speed in product development, leading to patent races and commercialisation (Powell, Koput and Smith-Doerr, 1996). A prerequisite for the development of the entire bioeconomy is the development of biotechnology (Tang, 2002). Biotechnologies cover a wide range of industries, including medicine, agriculture, but also the aforementioned energy, chemical and material production. The products are derived from living organisms or parts of living organisms, which can also be cells, proteins or genes. This results in new products, some of which help save lives, some of which increase the resistance of crops to disease and other harmful influences, and many others environmentally friendly products. The expansion of the biotechnology industry is driven by three global demographic trends: a growing population, increasing life expectancy and a growing proportion of older people in the overall population. However, the development and production of biotechnology products is a very complex and extremely costly process, and in order to finance the extraordinary opportunities in this industry, the companies need to use modern financing options (Minnesota Department of Employment and Economic Developmet et Lindquist & Vennum, 2005).

Potential success in the biotechnology industry can be extremely lucrative. Individual products can increase the value of companies by tens of millions dollars. High growth in the market value of companies is the result of high marginal sales that last for a decade or even longer (Tang, 2002). The biotechnology sector is dependent on knowledge, which is often complex and multidisciplinary, but also on science and research. In many science- and research-dependent sectors, potential innovations originate from small research firms that typically do not have the skills and assets needed to subsequently commercialise these innovations. Established firms may have these competencies, which forms the basis for the division of labour in innovation, where there is a systematic exchange of technological information, resources and knowledge between firms (Arora and Gambardella, 1994).

3.3. Plastics

One of the important issues on the way to a "post-oil" society is the production of plastic products and composites. These are traditionally made from fossil fuels. Ducháček (2006) states that, as some important periods of human development were named after the most widely used materials at the time, such as the Stone Age or the Bronze Age, the current epoch could be called the Polymer Age. Polymers are substances of extraordinary breadth of properties, which most often contain carbon, oxygen and hydrogen atoms in their macromolecules. The distinction of polymers is into elastomers (rubbers) and plastics (thermoplastics and reactosets, formerly thermosets). It was the term thermoplastic that began to be shortened to "plastic", creating the widely used name today (UNEP, 2015). Avio, Gorbi and Regoli (2017) call the current epoch Age of Plastics.

The beginnings of plastic production and use date back to 1839, when Charles Goodyear and later Thomas Hancock discovered that heating natural rubber with a few percent sulphur could withstand high temperatures and solvents, while adding more sulphur produced ebonite or vulcanite. Ebonite was the first plastic made by chemically modifying a natural polymer and it was used to make buttons, jewellery and matchboxes. The first fully synthetic plastic was bakelite, discovered in 1907. Bakelite was used in the manufacture of electrical insulation, radios, telephones, cookware and laminate. In the mid-1930s, melamine was developer. Melamine was more resistant to higher temperatures and was an attractive material for making cups, saucers and plates with a porcelain look. Later, materials such as PVC, polyethylene, polyester, polypropylene, polycarbonate and other plastics were developed (Shashoua, 2012).

Plastics penetrated on the world market mainly because they are easy to produce and offer the possibility of creating low-cost products of very high quality and wide application, from shopping bags, packaging, personal care products to the manufacture of sports equipment, toys, furniture, etc. (Špajcar, Horvat and Kržan, 2012). The society has benefited greatly from the development and use of synthetic polymers and plastics. One of the most important properties of these materials was their durability, but this, combined with poor management of plastic waste, led to the ubiquity of plastics in nature and the oceans (UNEP, 2015). Awareness of the problems associated with plastics, such as the lack of degradability, increasing pollution of soils and water bodies, and the demand for landfilling and better recyclability, is behind the development of biodegradable plastics. Understanding the interactions between materials, microorganisms and biochemical processes is essential to ensure that these materials do not harm the environment (Shah et al., 2008). These intentions are exacerbated by the problem of microplastic particles contaminating the marine environment and freshwater, which allows them to enter the food chain and accumulate at higher trophic levels (Lots et al., 2017; Ivleva, Wiesheu and Niessner, 2016). In addition, microplastics can adsorb toxic chemicals and transmit pathogenic microorganisms (Liu et al., 2021; Boni et al., 2021), which can easily enter the food chain (Athey et al., 2020; Mercogliano et al., 2020). The plastic pollution therefore needs to be addressed from the perspective of life-cycle and at its source, and the efforts must be integrated within the framework of international environmental law, global economic, financial, industial and trade policies and cooperation to enable the transformation of the industry (Barrowclough and Birkbeck, 2022).

World consumption of plastics is estimated to increase from the current level of around 350 million metric tonnes per year to 1 billion metric tonnes per year in 2050, with monomer and polymer production accounting for more than 80% of total chemical production (Valderrama, van Putten and Gruter, 2019). Like production and consumption, the amount of plastic waste that is not properly disposed of and enters the environment is also increasing (Lebreton and Andrady, 2019). Given the assumption of growth in plastics production, in the context of the mentioned problems, more sustainable production pathways are considered, as well as subsequent waste management. There is a requirement for greater collection and recycling of plastic materials for re-use in new production, which is a solution in terms of reducing the consumption of virgin plastic, improving the efficiency of fossil resources, but also waste prevention. In addition, this requirement is in line with the principle of a circular economy (Rhodes, 2018). On the other hand, the countries of the developed world face problems with recycling. Some of these are due to the different properties and composition of plastic materials, with some materials not being recyclable at all, and then the composition of the waste, which includes unidentifiable and undesirable materials (Egun and Evbayiro, 2020; Roosen et al., 2020; Lahtela, Hyvärinen and Kärki, 2019). However, some non-recyclable materials may at least undergo a downcycling process, which allows them to become part of materials for products, such as carpets, fillings for sleeping bags, waste bags, or toys (Egun and Evbayiro, 2020). Other materials, such as foils, bags and sacks, clog recycling devices (Sharuddin et al., 2017; Hou et al., 2018). Polystyrene is often not recycled due to the lightness and bulk of the material, which leads to the problem of easy blowing during collection and, on the other hand, to higher transport costs. Polystyrene is also perceived as a material that can become harmful to health after contact with food. Therefore, its recycling is often not profitable. Pyrolysis of non-recyclable plastics is a potentially suitable option (Sharuddin et al., 2017). Further waste management problems arose after China, which was much further ahead than Western countries in recycling and reuse infrastructure, introduced a ban on importing plastic waste from abroad. China has shipped 45% of the world's cumulative plastic waste since 1992, breaking a major role in the global circular economy with the import ban (Brooks, Wang and Jambeck, 2018). The recycling industry in developed countries thus faces a challenge in the short term, but also opportunities in the long term, due to their own limited capacity and past dependence on exports. Unfortunately, developing countries that do not currently have strict environmental regulations are likely to become new destination countries for waste from both developed and developing countries (Qu et al., 2019). In 2016, Asia imported 74% of all plastic waste. Following the Chinese ban, some Asian countries such as Vietnam and Malaysia have seen a rapid increase in plastic waste imports, and many countries are considering restricting waste imports from abroad (Liang et al., 2021). The disposal of plastics remains a problem in many countries. In India, for example, the most common methods for dealing with plastics are landfilling, incineration or simple disposal in nature and on the streets (Nkwachukwu et al., 2013). In South Asian countries, burning of waste on streets is still very common, increasing the amount of harmful emissions that threaten both human health and ecosystems (Saikawa et al., 2020). The burning of plastics releases not only CO2 emissions but also toxic chemicals into the air (Verma et al., 2016).

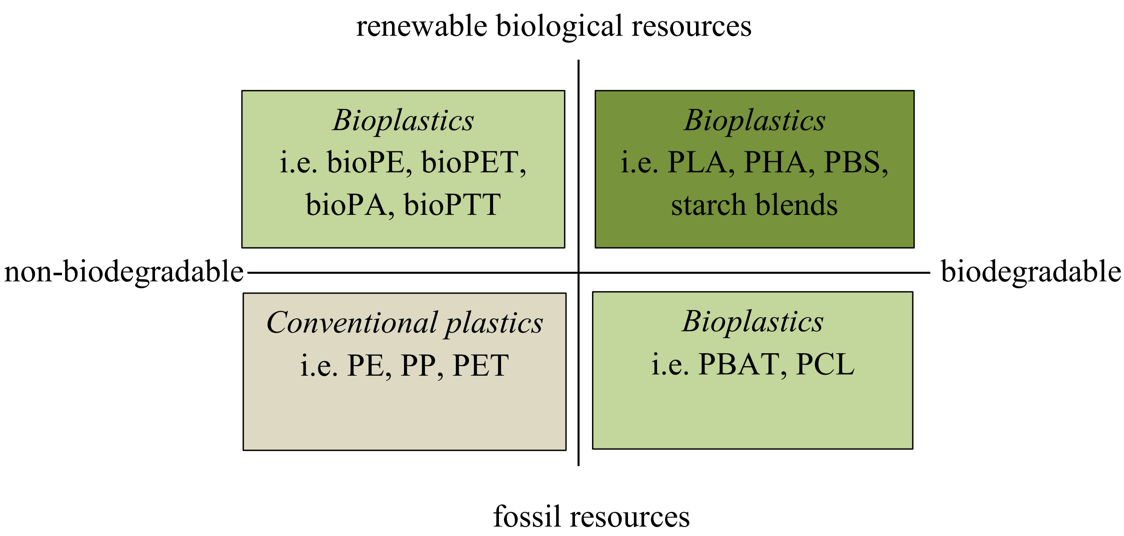
Another demand concerns limiting the use of plastic packaging and single-use plastics. Various countries and cities around the world are beginning to take this into account, introducing bans on the sale of plastic bags or single-use plastics in general (Herberz, Barlow and Finkbeiner, 2020; Walker and Xanthos, 2018). Individuals and households have long been committed to reducing the use of single-use plastics (Biswas et al., 2000; Barr, 2004). The zero plastic waste agenda is gaining support at various levels from households, communities, industry and cities (Zaman and Newman, 2021). In the United States, for example, 271 municipal ordinances banning single-use plastic bags were already passed in September 2017, and more than half of them also introduced a mandatory fee for paper or reusable bags (Wagner, 2017). The EU has adopted Directive (EU) 2019/904 on reducing the environmental impact of certain plastic products, which bans the use of selected single-use products. Plastic bags have also been banned by many African countries such as Benin, Burkina Faso, Kamrun, Cape Verde, Côte d'Ivoire, Gambia, Guinea-Bissau, Mauritania, Mauritius, Mozambique, Niger, Senegal, Kenya, Zambia and Tunisia (Turpie et al., 2019). Some states, such as Kenya, combine the ban with enforceable sanctions (Nielsen, Holmberg and Stripple, 2019). Herberz, Barlow and Finkbeiner (2020) note that the use of disposables (one-use items) is environmentally harmful regardless of the material and therefore suggest the introduction of bans or surcharges on disposables as the most effective measure to reduce consumption and thus pollution. However, the whole situation has been significantly affected by the Covid 19 pandemic, which has increased our dependence on plastics mainly for safety and hygiene reasons. It has also exacerbated problems related to waste management and raised concerns that the temporary lifting of the ban on single-use plastics could change consumer behaviour (Vanapalli et al., 2021). It is estimated that 129 billion masks and 65 billion gloves were used globally per month. This leads to widespread environmental pollution and far-reaching impacts on ecosystems and organisms. In addition, protective equipment made of plastic poses a public health risk as waste can carry the SARS-CoV-2 virus. Concern about the role of reusable plastics in potential virus transmission has contributed to the lifting of the ban on single-use plastics, which has been welcomed by the plastics industry (Prata et al., 2020). The pandemic has also led to increased online shopping, especially for food. Delivery services increased by 12-36%, increasing the volume of packaging waste in households. The pandemic led to the increase of non-biodegradable food packaging waste by 15 %, but on the other hand showed the need for single-use bioplastics for food packaging (de Oliveira, 2021).

The pressure to replace conventional plastics, which are a product of the petrochemical industry, with bioplastics was already present before the pandemic, despite the controversy over their biodegradability in the nature, the competition between food and feed crops versus their use in bioplastics, but also the ability to meet the demand for plastics through bioplastic solutions (Rhodes, 2018).

3.3.1. Bioplastics

According to Stevens (2002), the first mention of a fibre-reinforced composite bioplastic is in the Bible, in the Book of Exodus, where it is said that Moses' mother wore a cane cloth, which she wiped out with tar and pitch and placed a child in it. Today, bioplastics are plastics that are made from renewable biological resources or are biodegradable, or have both properties (Imre and Pukánszky, 2013). Although natural biopolymers are inherently biodegradable, materials made from them can no longer serve as a substrate for the same enzyme system that degrades the biopolymer. For a bioplastic to be biodegradable, microorganisms for which it is a substrate must be present in the environment (Stevens, 2002). The different types of plastics according to the sources of the initial raw materials and subsequently biodegradability are shown in Figure 1.

Fig. 1: Different types of plastics according to resources and biodegradability



Source: European Bioplastics (2018), own processing

In nature, biopolymers are plasticised with components from their immediate environment. In commercial extraction and purification processes, native plasticisers can be removed or reintroduced to form the desired plastic material. Other additives can improve the properties of plastics. One or more biopolymers can be used in combination with one or more plasticisers and other additives. Each ingredient affects the properties of the resulting material. Some biopolymers are thermoplastic and can be processed using the same methods used for synthetic polymers (Stevens, 2002). Biodegradable plastics and their subgroup compostable biodegradable plastics are considered the main alternatives to conventional plastics (Song et al., 2009). Switching plastic production from fossil resources, which today account for 99% of current polymer production, to renewable resources in the future is necessary, among other things, to achieve the goals of the Paris Agreement (Valderrama, van Putten and Gruter, 2019). The use of biomass rich in starch, cellulose and other sugars to replace fossil resources in plastics production is now a widely accepted strategy. Bioplastics based on plant esters, cellulose, starch derivatives, polyhydroxybutyrate and polylactic acid are commonly produced (Gironi and Piemonte, 2011). However, the whole value chain needs to focus not only on the raw materials, or plastics, but also their application, and waste management to cover all possible environmental problems, even though the existing regulations and systems are often an obstacle (Kawashima, Yagi and Kojima, 2019). Many of the bioeconomy strategies in various countries and regions cover biofuels, biobased chemicals, and biobased plastics, yet in the reality, the policy background supports mainly biofuels and bioenergies with low support of biomaterials, even though biobased chemicals and plastics are a better opportunity as they have longer value chains and may create more jobs. Moreover, the high demand for biomass triggered by biofuels and bioenergies also threatens the biochemicals and bioplastics production as they may be not able to compete for biomass on price without governmental support due to smaller production volume (Philp, 2014).

The main source of bioplastics are polysaccharides from cereals, legumes and tubers in the form of starch, although plant-based polyesters also have potential. By-products of agricultural production can also be used for bioplastics based on polylactic acid obtained by fermentation of starch-rich agricultural products such as maize and wheat (Jabeen, Majid and Nayik, 2015). Sugar cane (Santos et al., 2019), sugar beet and potatoes (Hann et al., 2020) are also used. In addition to the classical use of starch and cellulosic plants, proteins such as gelatin, casein, silk, marine prokaryotic organisms or the aforementioned polylactic acid (PLA) or various substances derived from microorganisms and genetically modified bacteria such as polyhydroxyalkanoate (PHA), polyhydroxybutyrate (PHB), polyhydroxyvalerate (PHV), bacterial cellulose, xanthan gum and pullulan can be used to produce biopolymers (Jamshidian et al., 2010). In some countries, the production of bioplastics based on palm oil, rapeseed oil, soybean and sunflower seeds is being considered, and these oils can even come from waste oils (Możejko and Ciesielski, 2013; Możejko and Ciesielski, 2014; Tsang et al., 2019). Considered are also palm oil effluents, lignocellulosic wastes from empty fertility of oil palms and palm kernels (Tsang et al., 2019), straw (Cesário et al., 2014), wastes from fruits, vegetables and root crops, i.e. peels and moulded parts (Moro et al., 2017; Sultan and Johari, 2017; Simonutti et al, 2020; Arıkan and Bilgen, 2019; Maulida, Siagian and Tarigan, 2016), whey (Pais et al, 2014) or animal by-products in the form of blood, fat and gut residues (Lin et al, 2013) or the organic component of municipal waste (Ebrahimian, Karimi and Kumar, 2020). Attention is also paid to cyanobacteria, algae and seaweed (Abdul-Latif et al., 2020).

Although it is now common to use first-generation biomass for the production of bioplastics, the gradually improving biotechnology industry is expected to switch to biowaste-based production, which also seems to be beneficial given the growing amount of waste or third-generation biomass (Lee and Lavoie, 2013; Morone, Tartiu and Falcone, 2015). The use of waste, including agricultural waste, seems to be an acceptable solution (Emadian, Onay and

Demirel, 2017). In addition to municipal biowaste or waste from agriculture, waste from forestry and wood industries, including sawdust, and even waste from industrial production can be used (Mendieta et al., 2020; Yu, 2007). Waste paper can also be a good source, and its conversion into bioplastic is not only suitable from the point of view of an environmental approach to waste management, but also contributes to the valorisation of this type of waste (Al-Battashi et al., 2019). Microalgal biomass is also currently being considered, as some strains have the ability to produce starch (Mathiot et al., 2019). Valderrama, van Putten and Gruter (2019) consider biomass, CO_2 and existing plastics and their recycling as the only truly sustainable sources suitable to replace fossil feedstocks, with CO_2, which can be electrochemically reduced to formic acid derivatives, being the truly circular source from which useful monomers such as glycolic acid and oxalic acid can subsequently be obtained.

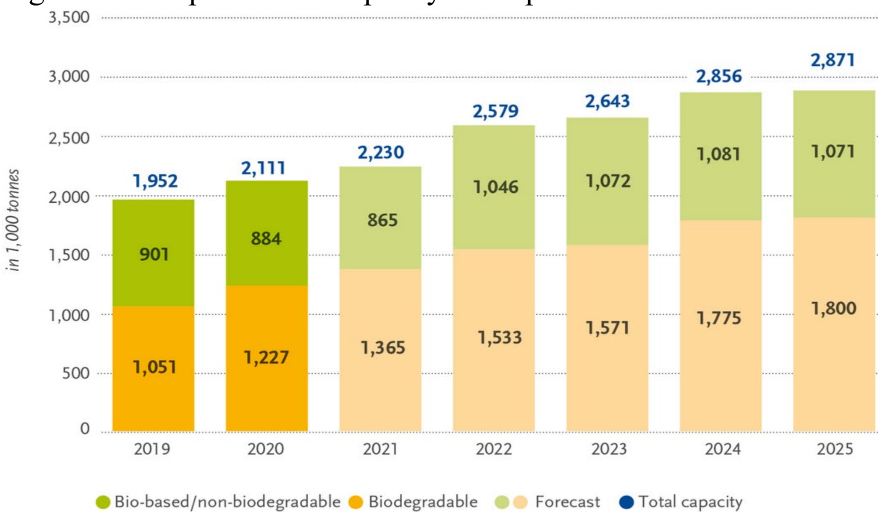
3.3.2. Market structure of bioplastics production

In the theories of dynamic stochastic aggregate equilibrium models as well as in more recent models of economic growth, a distinction is made between two types of firms, namely firms that produce final product and firms that produce intermediate product. Final product firms are assumed to operate in a competitive environment, while intermediate product firms have a differentiated product and operate in an imperfectly competitive environment (Kodera and Van Quang, 2013; Barro and Tenreyro, 2000). Products can be differentiated vertically (quality) and horizontally (variety). Thus, there is a possibility that each product actually exists in different qualities or different varieties of the same quality, even if it is not only an intermediate product but also a final product (Cheng and Chang, 2017; Helpman and Krugman, 1985). An expansion of competition encourages the use of intermediate goods and thus leads to an expansion of production, a growth in labour productivity, but also in consumption. An increase in the marginal product of labour means an increase in the real wage rate, which should have a positive effect on employment. The increase in competition would have similar effects even if some or even all specialised products were final goods. In open economies, domestic production is stimulated by a reduction in the relative price of foreign intermediate goods due to unexpected inflation abroad (Barro and Tenreyro, 2000).

The market structure in the bioplastics sector include producers of renewable feedstock, machinery and equipment, researcher institutes, manufacturers of bioplastics and auxiliaries, plastic converters, distributors, brand owners as industrial end users, but also the subsequent waste disposal, i.e. the entire value chain. The market for bioplastics is growing rapidly, and resource efficiency is increasing. This allows applying the principles of the circular economy from sustainable resources to product design to ensure that plastics do not become waste, but can be returned to the economy as valuable technical material or biological nutrients or energy. Bioplastics are being used in more and more markets and are found in the form of packaging materials, hospitality products, consumer electronics, automotive products and components, agriculture, horticulture, toys or textiles, etc. The developing bioplastics industry has the potential to develop both the economy and rural areas in the coming decades. The European bioplastics industry is expected to provide around 300,000 highly skilled jobs by 2030, but an integrated European policy, legislative and economic framework is needed to develop the full potential of the market (European Bioplastics, 2020a).

Although bioplastics account for only 1% of all plastics produced annually, demand for them is increasing. More sophisticated applications and products are emerging, so the market for bioplastics is constantly growing and diversifying, including an increase in global production capacity (European Bioplastics, 2020b). The rapid growth of the bioplastics market is faster than the policymaking. In such a case, it is difficult to adequately support the emerging industry. There is a need for showing policymakers the range of bioplastics being under development and the types of policies they can set (Philp, 2014). The bioplastics production and market creation and its growth can be stimulated directly by the purchases of government and related bodies as in the case of the Federal government and Federal agencies of the United States of America which should generally prioritize biobased products by both purchases and innovation promotion (The White House, 2012). The global production capacity of bioplastics is shown in Figure 2.

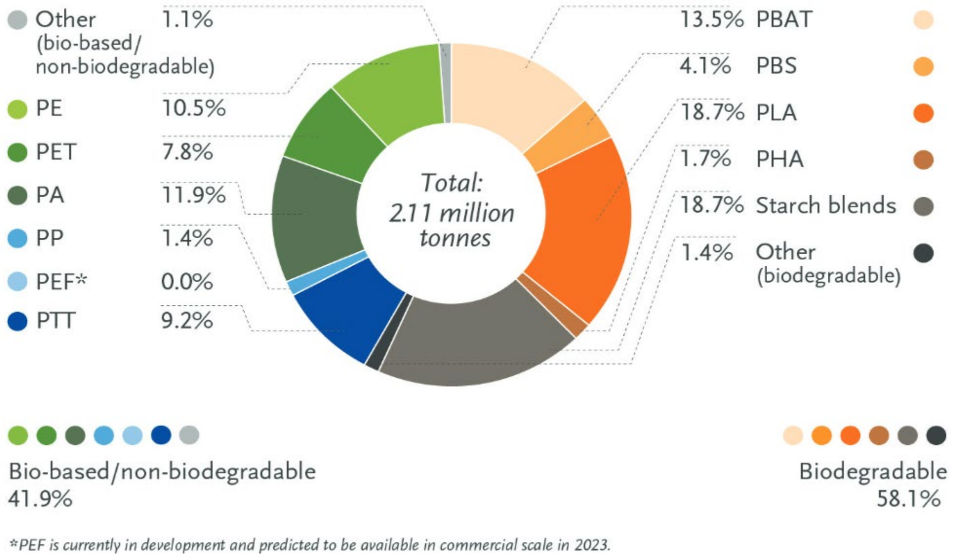
Fig. 2: Global production capacity of bioplastics



Source: European Bioplastics (2020b)

Alternatives made from bioplastics already exist for almost all traditional plastics and their applications. As more bioplastics are commercialised and the production of those that are on the market today is expanded, there will be an increase in production capacity (European Bioplastics, 2020b). The global production capacity of bioplastics by material type for 2020 is shown in Figure 3.

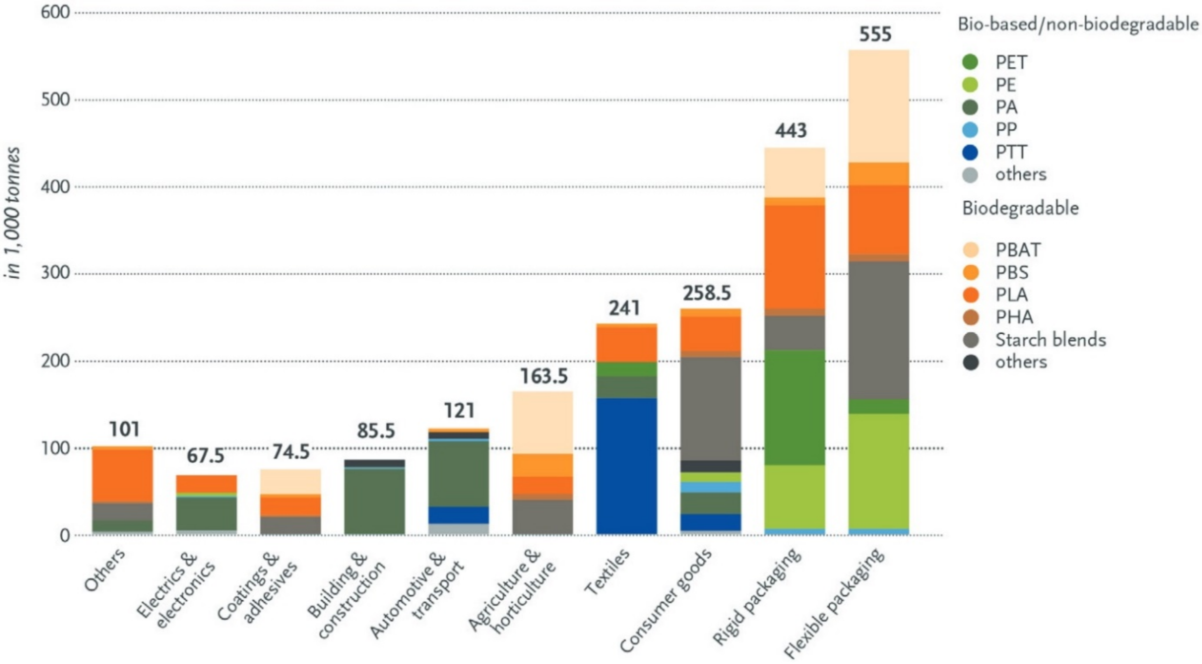
Fig. 3: The global production capacity of bioplastics by material type for 2020



Source: European Bioplastics (2020b)

Bioplastics are available on the market in various application variants and are used in the automotive and textile industries, in construction, agriculture, electronics, consumer goods and packaging materials. The largest market segment for bioplastics, accounting for 47% of current production capacity is packaging materials (European Bioplastics, 2020b). The global production capacity of bioplastics by market segment for 2020 is shown in Figure 4.

Fig. 4: The global production capacity of bioplastics by market segment for 2020



Source: European Bioplastics (2020b), own editing

In addition to the focus on expanding production capacity and diversifying or reducing production costs, emphasis is currently being placed on creating suitable products and applications for the pharmaceutical and medical industries (Gill, 2014) as well as the cosmetics industry (Cinelli et al., 2019; Cinar et al. al., 2020). Biopolymer surgical and disposable medical materials, drug delivery system components, sutures, staples, patches, dressings, matrices for cell and tissue engineering, implants, various replacements, internal fixation devices, elements for transplantology, and many other modern biocompatible materials have been produced (Zinn, Witholt and Egli, 2001; Tan and Desai, 2003; Nemets et al., 2019).

3.3.3. Prerequisites of bioplastics production

Although many biomaterials can be produced without the use of modern biotechnology, the growth and development of others, including bioplastics, depend on technical progress in biotechnology. The market for biopolymers also depends to a large extent on the relative prices of biomass commodities compared to oil, a traditional raw material for plastics production. The increase in the price of oil increases the interest in the production of bioplastics, but this is often dampened by the corresponding increase in the prices of corn, which is an important source for the production of bioplastics. However, concerns about sustainable agricultural and oil commodity prices should stimulate research and development of biopolymers, especially those for which waste biomass or non-food crops will be the source. The development of advanced fermentation processes will be very important, and should lead to an increase in the scope of bioplastic production (OECD, 2009). Policy, research and development of the market will play a role in long-term production trends. The upper limit for the substitution of petroleum-based plastics by biomass is estimated at 33% (Williamson, 2010). However, another study reports the potential for technical substitution as high as 90% (Shen, Worrell and Patel, 2010). With the growing number of materials, applications and products, the number of producers, converters and end users of bioplastics is also expanding. This development is accompanied by significant financial investments not only in bioplastics production but also in marketing. Factors influencing market development are both internal and external, and bioplastics appear to enjoy a high level of consumer acceptance. Widely promoted issues such as climate change, rising fossil resource prices and growing dependence on fossil resources contribute to a favorable view of bioplastics (European Bioplastics, 2021).

There are several basic conditions and prerequisities for the successful production of bioplastics, which often act as driving forces for the entire industry. International demand for bioplastics is an important prerequisite that stimulates market development. Global demand for bioplastics as an alternative to petrochemical plastics has increased in recent decades and their popularity continues to grow (Al-Battashi et al., 2019; Cinar et al., 2020). Between 2014 and 2020, there were many activities evidenced in the realization of bioplastics production, which was due to rising demand. On the other hand there were a lot of deferred plans for the construction of new commercial plants, even cancellation of strategic plans and a turn back to oil-based products due to low oil prices. However, there is a fundamental shift in the behavior of consumers who demand the development of environmentally friendly packaging, packaging applications for antimicrobial purposes and food packaging for direct consumption, which presents opportunities in the field of bioplastics (Jaconis et al., 2019). As the human population grows, the demand for bioplastics can be expected to increase over time, and with it, the demand on businesses and their ability to produce bioplastics in bulk will increase (Singh and Verma, 2020). At the same time, demand is behind the requirement for the production of bioplastics with excellent properties that include renewable base or full biodegradability, and desirable functional, mechanical, thermal and optical properties of materials (Karan et al., 2019; Balaguer, 2011). The precondition for the expansion and development of bioplastics is environmentally conscious consumers who are willing to buy more and pay a higher price for them (Rx3, 2011; Klein et al., 2019). According to European Bioplastics (2021), not only consumers with higher purchasing power will be crucial, but there is the a for very advanced economies with an educated society. On the supply side, the world's leading companies in the chemical and plastics industries should be the driving force, as well as industrial users who are committed to the concept of sustainability. However, many companies make false claims about their products being environmentally friendly, biodegradable, or compostable to persuade consumers to make a good environmentally-friendly choice by buying these products and to gain an image of a responsible firm. As the regulations around bioplastics are not strict and enforceable, companies are allowed to use these terms with no fear. The reform of legislation and standards aiming at classifying the bioplastics are necessary to regulate the market and to support customer trust based on law, science, and technology (Bhagwat et al., 2020). The legislation and standards should lead to improvements in the design process and sustainable development of bioplastics (Karan et al., 2019). Legislation may require labeling based on raw materials used, energy consumption, emissions, or life cycle assessment analysis (Arıkan and Ozsoy, 2015).

The resource base itself in the form of renewable natural resources, its availability, quality and sustainability in the long term, is a necessary prerequisite for the production of bioplastic materials. This raises the question of whether this is not the time have when it would be possible and common to derive basic substances for the production of bioplastics from agricultural waste, algae and seaweed instead of food crops used today, which are easily available such as palm oil, maize, sugar cane and some other crops (Abdul-Latif et al., 2020). So far, the most used are starchy plants, which appear to be quite cheap, inexhaustible and renewable raw material (Krishnamurthy and Amritkumar, 2019).

Technological development is also related to the requirements for materials and their properties. In addition to properties, the development of technologies is desirable from economic and environmental point of view to increase cost efficiency and production possibilities (Garcia et al., 2021; Umerah et al., 2020) and with regard to waste management through recycling and composting possibilities as well as efficiency of these processes (Stachowiak and Łukasik, 2021), but also to solve the problem of macro and microplastics and their eventual removal from rivers and coastal waters (Barcelo and Pico, 2020). From a technological point of view, both petroleum and biodegradable plastics can undergo reprocessing. The products of regranulation are characterized by satisfactory parameters. Biodegradable plastics require the lowest energy costs associated with processing, mainly due to the temperature required for the process, but their composition and chemical structure are also important. The finding that even bioplastics can be reprocessed, moreover with low energy costs, contributes to the possibility of implementing a zero waste policy, which is being introduced by the EU and other developed countries. Modification and reprocessing of biodegradable plastics before their composting is justified from an ecological perspective (Stachowiak and Łukasik, 2021). Technological developments, especially the development of nanotechnologies, are leading to the expansion of many applications of bioplastic materials, which are expected to be technically and economically competitive, accompanied by reduced energy consumption and possible toxicological and environmental impacts (Lagaron and Lopez-Rubio, 2011). The continuous growth trend of bioplastics seems to be not only a response to a call for reduction in dependence on fossil resources or due to low greenhouse gas emissions throughout their life cycle, but also because they offer much wider options of applications than petrochemical plastics, are based on innovative technologies and provide a high potential for job creation (Cosma, 2018).

Strict environmental legislation aimed at sustainable development and related innovations can stimulate the use of bioplastics, thus becoming an important driving force that could positively influence the hitherto often low political support and constraints imposed mainly by security and economic concerns. With the tightening of environmental legislation, there should be increased government interest and incentives for public and private investment in the bioplastics market and the applications in agriculture, medicine, pharmaceuticals, construction, automotive etc. (Jaconis et al., 2019). The bioplastics market will depend on changing framework conditions and political support, as well as on oil prices. Without a change in the framework conditions, without rising oil prices, or without political incentives in the form of tax exemptions and subsidies for new technologies, the European bioplastic sector is unlikely to achieve cost competitiveness in the next 15 years (Horvat and Wydra, 2017).

Human resources are also a crucial prerequisite for the development of the whole bioeconomy, particularly bioplastics, as both is dependent on knowledge (McCormick and Kautto, 2013). Education, training and research are becoming increasingly important. Many applications are the result of the work of educated individuals who contribute to the better specialization of human capital (Bejinaru et al., 2018). In this respect, the role of universities is significant. Some universities offer courses, study programs and subjects focused on bioeconomy (Beluhova-Uzunova, Shishkova and Ivanova, 2019). In the Czech Republic, the education and research in bioeconomy is connected to the Czech University of Life Sciences Prague, the Mendel University in Brno, University of South Bohemia in České Budějovice, the Centre of the Region

Haná for Biotechnological and Agricultural Research, the Biology Center of the CAS, the Institute of Microbiology of the CAS and the Institute of Experimental Botany of the CAS (Hájek et al., 2021). When it comes to bioplastics and other advanced materials, including nanomaterials, one might perceive, e.g. Centre of Polymer Systems, Technical University of Liberec, Technical University of Ostrava, Brno University of Technology, University of Chemistry and Technology Prague, as important institutions.

Another key challenge for the development of a sustainable bioeconomy itself is political support. The policy can implement various mechanisms to provide a base for the development of bioeconomy and eventually the launch of bioplastics. Among these, we may include creation of bioeconomy R&D strategies, launch of a holistic or a focused national bioeconomy strategies and similar policies, the support of bioproducts through subsidies, or campaigning and raising awareness to involve society in the transition to responsible and sustainable consumption (Dietz et al., 2018). Similarly, governments can fund researchers, set up laboratories, set up support programs and business incubators, or set up specific funds to fund various bioeconomic activities (Salter, Cooper and Dickins, 2006).

3.3.4. Barriers to bioplastics production

Bioplastics are still not competitive with conventional plastics, not only because of their higher cost but also because of their poorer mechanical properties (Jiménez-Rosado et al., 2020; Coppola et al., 2021). The current challenge is to create bioplastics that are a sustainable and cost-effective alternative, while achieving comparable mechanical properties to conventional plastics, yet making them more biodegradable and safer for the environment (Krishnamurthy and Amritkumar, 2019). According to Kalambur and Rizvi (2006), widely used starch, which can be obtained relatively cheaply, is not entirely suitable for bioplastic production due to disadvantageous properties such as brittleness in the absence of suitable plasticizers, hydrophilicity and poor water resistance, softness and material weakness when using plasticizers and thermodynamic immiscibility. These properties are being impaired by exposure to the environment. To overcome these disadvantages, it is necessary to mix starch with other synthetic polymers, but most such polymers are hydrophobic and thermodynamically immiscible with hydrophilic starch, i.e. simple mixing leads to incompatibility of materials and poor mechanical properties. Plasticizers such as sugars, glycerol, glycol, xylitol, sorbitol and amides, including urea, formamide and ethylene-bis-formamide, form hydrogen bonds with starch and improve material processing properties and flexibility (Yang, Yu and Ma, 2006; Dai et al., 2009). Suitable sources, additives, and plasticizers are still being sought to improve the properties of bioplastics. In the last two decades, the use of nanoparticle additives to improve the properties of bioplastic materials has enjoyed considerable interest and investment. Layered silicates are preferred, including clay, which occurs in nature, can be obtained at low cost and, in addition, has favorable properties for the resulting material and the environment (Mose and Maranga, 2011). However, research of bioplastic admixtures goes much further and it seems that it is possible not only to address the properties of these materials, but also to improve fertilization in horticulture, avoid excessive contamination and reduce product market prices by combining nanoscience, nanofertilization with bioplastics with controlled release of particles. These can be, for example, ZnO nanoparticles (Jimenez-Rosado et al., 2021).

This can be linked to another required property of bioplastics, biodegradability. Based on degradability experiments of bioplastics and conventional petroleum-based plastics some even question the organic origin of bioplastics and label biodegradability of bioplastics as a marketing myth (Harding, Gounden and Pretorius, 2017). However, bioplastics also include those that are based on renewable resources but are not biodegradable, or, conversely, those that are based on fossil fuels but are biodegradable. Approximately half of today's bioplastics are not biodegradable and waste management is becoming more problematic as production grows. Bioplastics therefore brings new challenges for waste management and policy makers, who should address both. On the other hand, non-degradable plastic waste can be considered a source for the circular economy if the waste is managed correctly, as fuels and chemicals can be derived, for example, by pyrolysis or gasification of bioplastic waste (Rahman and Bhoi, 2021). The current problem is the contamination of the conventional recycling process when bioplastics are not separated from conventional plastics (Arıkan and Ozsoy, 2015). Low consumer awareness and information about bioplastics when they become waste, including the existence of various disposal guidelines, seems to be an obstacle to their acceptance. There are cases of illegal dumping, disposal, burial and burning of bioplastics by consumers, as well as the aforementioned contamination of recycled plastic waste streams. The lack of an efficient and intuitive bioplastic recycling system leads to consumer frustration (Rx3, 2011; Selvamurugan and Sivakumar, 2019). However, biodegradability should lead to a reduction in the production of plastic waste, especially when used in agricultural mulch films, where this property is crucial. Nevertheless, the breakdown of plastics releases various substances into the soil, some of which affect plant growth and development, such as reducing germination, root development, growth of aboveground parts or increasing stress. In the case of mulch, it is necessary not only to monitor biodegradability itself, but also ecotoxicity, environmental safety and effects on the soil environment, in order to design and implement safe bioplastics (Serrano-Ruíz, Martín-Closas and Pelacho, 2018). One of the few researched areas of bioplastics is the potential impacts of microplastics, which should be a priority. It is necessary to understand the time frame of bioplastic disintegration and degradation, to ensure their degradability and less persistence, to support toxicity and effects tests on a wide range of organisms, to support experiments to assess impacts on whole ecosystems and to evaluate interactions between microorganisms and microplastics. Last but not least, to identify and publicly proclaim new ways of disposing of and collecting bioplastic waste in order to facilitate recycling and degradation processes (Shruti and Kutralam-Muniasamy, 2019). Similarly, compostable plastics need to be addressed, as some of them are destined for disposal on domestic compost, while others should end up in industrial composting plants (Ciriminna and Pagliaro, 2020). The advantage of compostable plastics is not only that they are biodegradable by naturally occurring microorganisms as in case of biodegradable plastics, but they must also meet the conditions of biodegradation to CO_2, water, inorganic compounds and biomass at a rate consistent with other known compostable materials and leave no visually distinguishable and toxic residues (Kale et al., 2007).

Countries with low financial resources have limited access to bioplastics (Cosma, 2018). In terms of costs, bioplastics cost two to three times more than conventional plastics. As production volumes increase, costs are expected to decrease (Arıkan and Ozsoy, 2015; Liu, Li and Zhang, 2019). Costs range from 1.3 - 4 €/kg (Shivam, 2016). Production costs are a significant limiting factor (Selvamurugan and Sivakumar, 2019). Production costs remain high with low production volumes and the lack of competition in the sector. The high cost of raw materials alone discourages many producers from switching to bioplastics (Lagaron and Lopez-Rubio, 2011). On the other hand, there is strong competition from other sectors, namely biofuels, which benefit from preferential support schemes (Cosma, 2018). One way to reduce costs is to use agricultural, food and forestry waste and other by-products as feedstock for bioplastics. Apart from the cost problem it would help to address the waste problem (Saharan, Ankita and Sharma, 2012; Jõgi and Bhat, 2020). Similarly, sludge is intended to be used to produce PHA and thereby obtain products with high added value. Again, this would reduce costs and address waste treatment and recycling, with economic assessments showing that production costs would be reduced by more than 50% using low-cost substrates, such as activated sludge (Liu, Li and Zhang, 2019; Meesters, 1998). Another approach is to utilize algae and microalgae, from which starch and triacylglycerol can be used to produce bioplastics, and by extracting high-quality compounds, the manufacturer could achieve two independent profits. The compounds profit could offset raw plastic production costs and make it competitive (Kato, 2019).

In addition to the obstacles mentioned above, today's market environment is turbulent (Branska, Patak and Pecinova, 2020). In this dynamic, complex and turbulent environment, which has developed around topics related to sustainable development and the use of renewable resources, a large number of different stakehoders is present including the chemical and petrochemical industries, agro-industry, oil and gas companies, brand owners, end users, biotechnology startups, governments, universities and society as a whole. The demand for technological forecasting, which would serve as an important tool for managerial decision-making, is increasing. Major bioplastic companies and brand holders, such as Corbion, BASF, DUPont, P&G, CocaCola, NatureWorks, are developing ways to create value and present that value, clearly label their products for better identification by consumers, expand the use of life cycle analysis, communicate product performance benefits, communicate the benefits of green products to end consumers and tools to improve bioplastics to reduce adverse effects, increase environmental and social benefits, improve biomass supply, product processing and marketing (Jaconis et al., 2019). The evident phenomenon of communication chaos in the field of environmental protection and sustainable development in turbulent environments gives organizations the opportunity to pretend environmental actions and practice greenwashing. Biodegradable plastics become the target of greenwashing practices, often using inconclusive or even false assertions and misinformation (Tkaczyk, Kuzincow and Ganczewski, 2014).

Another obstacle to the transition to bioplastics is changing legislation on plastics in general, including environmental policies to eliminate disposable plastics or ban oxo-degradable plastics (Thomas et al., 2019; Abdelmoez et al., 2021), the lack of standardization, and harmonization of standards as well as definitions of bioplastics at the international level. These constraints can be remedied by a number of targeted actions in the form of policies that can potentially affect the bioplastic sector, including agricultural policy, R&D support, trade and industrial policy, taxation, regulatory measures, etc. (Cosma, 2018). Last, but not least, there are also powerful lobbies of active major multinational companies and also state-owned enterprises in the fossil and petrochemical industries, continuing subsidizing of fossil fuels, while some countries try to reduce plastic pollution and carbon footprint of plastics, and promote circular plastic economies (Barrowclough and Birkbeck, 2022).

4. Conclusions

Environmental thinking in economics and concerns about resources, pollution, population, sustainable production, and consumption, accompany the society for a long period of time, yet the urgency to address these challenges is increasing. Bioeconomy stands for a new economic concept based on biotechnology, that aims to reduce dependence on fossil fuels and their producers, reduce carbon dioxide emission, bring new job opportunities, technological development, and economic growth. Various products that are based on oil and other fossil sources can become bio-based. Nevertheless, even the bioeconomy has some risks as biomass may be renewable, but the soil is limited and can be considered as non-renewable in a human time scale. Problems such as land-grabbing, deforestration, potential environmental hazards, pressure on soil, ecosystems and biodiversity, competition with food, feed and environment and its price effects may occur if bioeconomy is not applicated wisely.

Plastics are key materials of modern societies, and they surround us everywhere. However, their wide use and durability presents a threat when they become waste. Bioplastics are presented as an alternative to conventional plastics, and they might be bio-based, biodegradable or both. However, this alternative raises many concerns, some of which question its possible viability and sustainability. There are currently several prerequisities and barriers to the production. Prerequisities include reduced oil prices, available sustainable biomass of a good quality, developed economies, educated society, qualified human resources, as well as biotechnology and technology development, innovations, market development, demand for bioplastics which may be driven by conscious consumers or governments, supporting environmental legislation and other policies, financial support and investment. Barriers consist of low financial resources, high production costs, poor mechanical properties, concerns about biodegradability of bioplastics, their effective waste management or use in accordance with the principles of circular economy, contemporary communication chaos and greenwashing practices, turbulent market conditions and changing legislation that affects production. To evaluate the potential of the production of bioplastics the decision-makers within a given company and geographical location need to take these matters into consideration. Based on the conducted literature review I perceive several research gaps ranging from evaluating the potential for bioplastics production as such, lack of assessment on regulation and policy of various types of plastics and their applications together with lack of assessment of the impact of these materials, but also lack of information covering the financial issues related to the production, important factors playing the key role when deciding to join this alternative plastics production sector from a business point of view, or just a general consensus on what types of bioplastics to support, and further recommendations on how to precisely support their viable production growth. Based on a literature search, I decided to set the following research questions for my dissertation thesis:

RQ1: In which regions of the Czech Republic can we find biomass reserves for the production of bioplastics?

RQ2: What factors and conditions affect the willingness of petrochemical companies to engage in the bioplastic industry?

RQ3: Would the existence of a Czech bioeconomic strategy and the introduction of subsidies be a sufficient impetus for the transition to bioplastic production?

Therefore, I perceive the aim of this paper to be achieved.

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