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# The socio-environmental challenges in the transition to sustainable bioeconomy: a review

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## Abstract
The bioeconomy has been proposed worldwide as a way to combat global environmental and socio-economic challenges, from climate change to income diversification and food security. Consequently, the term "bioeconomy" has gained considerable attention in the economic field over the last 15 years. Interestingly, an alleged global sustainable development model has become the subject of intense sustainability debate among researchers in recent years. The sustainability of the bioeconomy itself remains unanswered today. Most of the previous studies on sustainable bioeconomy focused on the analysis of the impacts on technology related to environmental issues while overlooking the socio-environmental implications and excluding society. Meanwhile, various studies highlight potential socio-environmental negative impacts associated with the new economic model. It is possible that the increased use of biological resources could further compromise ecosystems and create increasing social and ethical issues. Furthermore, this economic model could bring new environmental challenges related to the excessive use of soil and water. Therefore, the purpose of this paper is to examine and identify potential socio-environmental sustainability challenges and pitfalls that need to be addressed in order to ensure a successful transition to a sustainable bioeconomy. Following a systematic literature review, scientific studies and field reports were selected for this review after searching Google Scholar, Web of Science and Scopus databases. The results identified a number of potential key socio-environmental concerns related to the transition to the bioeconomy.

## Keywords
bioeconomy, sustainable bioeconomy, sustainability risks, bioeconomy risks, conceptual framework

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## 1. Introduction

It was the discovery of the steam engine and internal combustion engine followed by the use of fossil fuels which became the root of exponential population growth, widespread consumerism, and rapid social, economic, and technological development (Oláh et al., 2021; Wohlgemuth et al., 2021). Unfortunately, our global ecosystem and human health have been paying the price of this unprecedented period of socio-economic growth in the last century (Giampietro, 2019; Aguilar & Patermann, 2020; Mustafa & Lengyel, 2022). Moreover, rapid population growth and its pressures on the environment and natural resources have already exceeded ecological sustainability (Fitzpatrick, 2020). In the course of environmental and social concerns becoming increasingly pressing, countries around the globe, international organizations, and non-governmental organizations propose alternative economic approaches to creating an ethical and sustainable economy (Pfau et al., 2014; Gawel et al., 2019; Fitzpatrick, 2020; Kardung et al., 2021).

Consequently, the term "bioeconomy" has gained considerable attention in the economic field in a relatively short period of time (Lakner et al., 2021). According to scientists, using bio-based materials might be the key to creating a sustainable future. (Giampietro, 2019; Böcher et al., 2020; Wozniak et al., 2021). Scholars argue that by switching from a fossil-fuel-based economy to a bioeconomy that uses bio-materials, we can make current production and consumption patterns more sustainable. The successful adoption of this new economic paradigm is expected to make a significant contribution to securing livelihoods for future generations and the social development of humankind (Ronzon & M'Barek, 2018; Wozniak et al., 2021).

Interestingly, an alleged global sustainable development model has become the subject of intense sustainability debate and critique in recent years. The sustainability of the bioeconomy itself, which is promised to lead the world to sustainable development, has been the subject of heated debate among researchers, and it remains unanswered today (Wohlfahrt et al., 2019). Although there is a broad consensus on the goals of the bioeconomy, such as mitigating climate change, reducing fossil fuel consumption, enhancing the use of bioresources for industries, and ensuring food security (Gawel et al., 2019; Pfau et al., 2020; Stegmann et al., 2020; Wozniak et al., 2021), various paths for achieving these objectives have been subject to fierce controversy (Wellisch et al., 2010; Landeweerd et al., 2011; Böcher et al., 2020). Recent studies indicate many direct and indirect challenges and risks associated with this alternative economic model. In other words, it can be concluded that the bioeconomy itself cannot be considered sustainable (Landeweerd et al., 2011; Pfau et al., 2014; Böcher et al., 2020).

There are a number of controversies in scientific debates that raise questions about the impact of such a transition on humans and the environment. On the other hand, an opposing perspective is more critical of the development and use of the bioeconomy, and it tends to focus more on the potential negative consequences. While the bioeconomy is based on renewable bio-resources, several studies concluded that this does not mean it is automatically sustainable or solves sustainability issues. Others even argue that this economic model could bring more new environmental challenges associated with the excessive use of soil and water (Pfau et al., 2014; Unmüßig, 2014; Pannicke et al., 2015). Additionally, there are potential sustainability risks associated not only with the cultivation of biomass but also with the uncertainties associated with biotechnology developments, such as quality, the life cycle of biomass, costs and the effects of bio-based production methods.

As part of the scientific bioeconomy debate, special attention is paid to sustainability and a number of socio-environmental problems and risks that should be considered and avoided. Many of the potential negative impacts of the bioeconomy discussed in their public debates relate to land-use change and competition among fuel and food (Landeweerd, 2011; Pfau et al., 2014; Böcher et al., 2020).

Although research papers on bioeconomy have recently focused on the effects of sustainability, in most cases, there is a tendency to deal with specific elements of the bioeconomy, such as the biorefinery industry (Wellisch et al., 2010; Bugge et al., 2016; Gabrielle et al., 2018; Wohlfahrt et al., 2019). Others discussed policy development for the bioeconomy and how sustainability can be integrated (Staffas et al., 2013). Overall, the authors note the importance of taking sustainability into consideration when discussing the bioeconomy (Pfau et al., 2014; Golembiewski et al., 2015; Wohlfahrt et al., 2021).

How does sustainability fit into the bioeconomy? Researchers are now attempting to understand *how* bioeconomy relates to sustainability and its possible social, economic and environmental impacts. Studies show a wide range of relationships identified between bioeconomy and sustainability in scientific publications, from inherent sustainability to direct adverse effects.

Several papers have been published in identifying uncertainties and risks in transitioning to the bioeconomy.

Most publications that studied bioeconomy concerning sustainability recommended that unless sustainability is placed at the heart of bioeconomy research agendas, negative impacts are certainly expected (Pfau et al., 2014). However, most of their focus centred on examining the impacts of technology while overlooking the socio-environmental implications and excluding society (Unmüßig, 2014; Peltomaa, 2018).

Hence, this study critically examines potential socio-environmental risks of the bioeconomy and identifies whether this economic model is the key to sustainable development or simply a "fig leaf" strategy, as some researchers have argued for the economy to remain quiet during a period in which sustainability including fossil fuel dependency and climate change discourses are becoming more prevalent.

The following is the outline of this paper: Section 1 addresses the challenges of sustainable bioeconomy development and current research areas on sustainable bioeconomy, the potential gaps, and the risks involved in the transition to a sustainable bioeconomy. Additionally, the authors discuss the significance of this study in this section. In Section 2, the authors describe in detail how the systematic literature review was conducted. There were 124 articles identified from three multi-disciplinary research databases, Google Scholar, Scopus and Web of Science. Further, articles were reviewed, and 34 articles were selected for further analysis based on their direct relevance to the research topic.

Section 3 describes the bioeconomy concept, its global significance, as well as different definitions and various directions of the bioeconomy concept. Moreover, an attempt has been made to determine how the bioeconomy works from a systems perspective and the driving forces affecting the bioeconomy. The results of the study are presented in Section 4, illustrating the negative environmental impacts that should be addressed in achieving a sustainable bioeconomy (Section 4.1) and the social challenges of the bioeconomy (Section 4.2). Section 5 addresses the discussion of sustainability implications in the bioeconomy based on the information presented in the earlier chapters. Finally, conclusions are presented.

## 2. Research Methodology

This study uses a systematic literature review to examine the links between the bioeconomy and sustainable development and describes socio-environmental negative impacts in relation to the bioeconomy.

Hence, in the literature review, the authors followed Stechemesser et al. (2012) four-step approach. The first step is to identify research questions, databases, and keywords. As the second step, a screening process will be used to select literature directly related to the research topic. Step three involves assessing the content of the literature selected in accordance with the research question. In the last step, selected scientific articles are reviewed and analyzed.

The subject of bioeconomy is multi-disciplinary and has been studied from many different perspectives. Therefore, authors have not restricted themself to a single scientific discipline. Multi-disciplinary research addresses a given issue from multiple perspectives, each pursuing different goals and contributing to their disciplinary knowledge. The aim of interdisciplinary research is to explore a particular topic with multiple disciplines, sharing knowledge and attempting joint knowledge production (Tress et al., 2005).

### 2.1. Literature search

For the purpose of creating a comprehensive view of socio-environmental negative impacts, a broad research question was selected: "What are the risks and negative impacts of the bioeconomy on sustainability?"

Based on this question, two primary topics have been identified for this review: bioeconomy and sustainability risks. For this study, we examined the literature about the bioeconomy from a sustainability point of view. Thus, the bioeconomy was regarded as a primary topic, while associated sustainability risks were viewed as a secondary issue. Because of the variety of ways in which the bioeconomy has been described and written, therefore, the most commonly used terms among the various written terms were used in the search: "bioeconomy", "biomass-based economy", "bio-economy", and "biomass economy". As a search term for "sustainability risks", three options have been examined: "sustainability risks", "negative sustainability impacts", and "socio-environmental impacts".

The authors conducted a thorough literature review on the current bioeconomy and the sustainability challenges and potential risks with it based predominantly on a survey of scientific articles. A review of research articles from Google Scholar, Scopus and Web of Science was used to identify directly linked publications, including research articles and reports relevant to the analysis of the research topic.

### 2.2 A systematic review steps

Figure 1 shows the logical steps of the systematic literature review process and literature results in a simplified way. As bioeconomy is a relatively new concept, there were no restrictions on publication dates. First, the analysis was reduced to academic journal articles with a focus on the different views and debates related to the bioeconomy. There were 124 articles identified based on abstracts that appeared to be potentially relevant, including conference proceedings and editorials. The next step was to identify and eliminate duplicates found in both databases. In the study, finally, 34 articles were selected for further analysis on the basis of their direct relevance to the research topic.

In the course of the inquiry, it quickly became evident that there are numerous related discourses in addition to the immediate debate on the bioeconomy. The implications of these discourses, such as sustainable land use and land-use change, technology advancement issues in agriculture, sustainable consumption, and a circular economy,

can be applied to the bioeconomy. Therefore, these topics were also covered in the literature review. From the previously selected scientific literature, 11 additional journals were identified as relevant to the research study and selected.

Based on the pillars of sustainability, two clusters, namely socio and environmental effects, were formed. In order to identify divergent positions and potential trade-offs of bioeconomy development, the relevant books and research materials were reviewed according to these pillars of sustainable development.

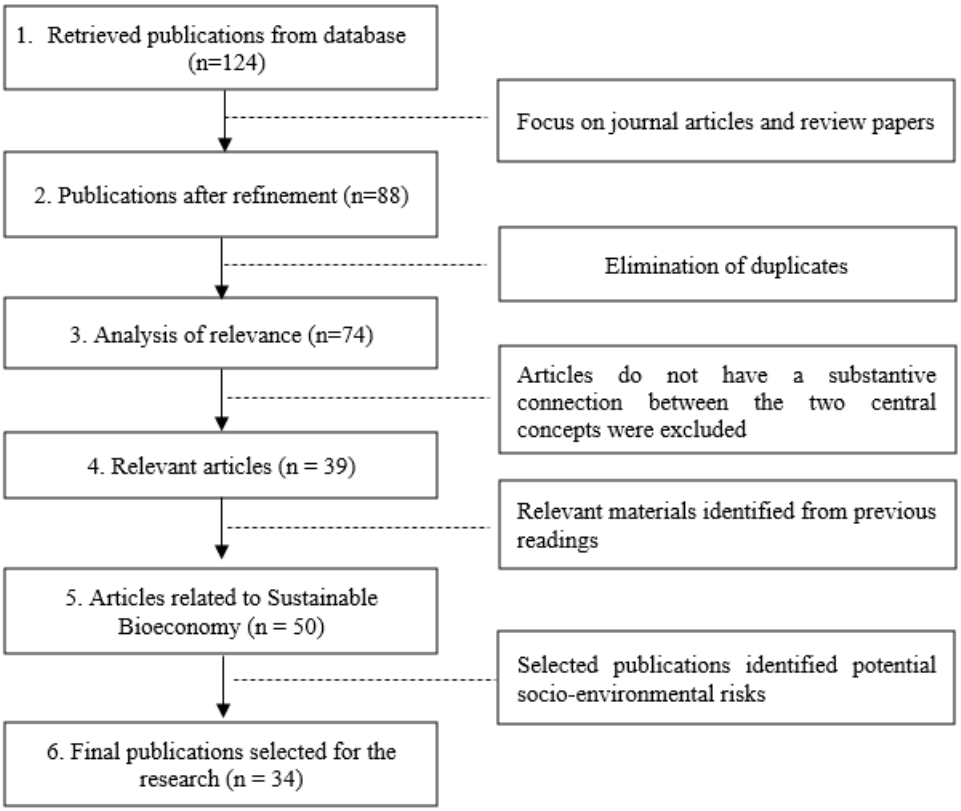


*Fig. 1: Results and methods of literature selection*
*Source: Pfau et al., 2014*

## 3. Literature Review: Defining, Framing Bioeconomy and Its Global Trend

Originally, the term "bioeconomy" was first used in the 1980s to promote sustainable development, and the concept was based on the use of solar energy, which is considered more environmentally friendly and does not require continual expansion (Gawel et al., 2019). In the 1990s, the bioeconomy emerged as a new business industry that uses the latest advances in biological science and biotechnology in a commercial and industrial context (von Braun, 2014).

However, a report entitled "Biotechnology for Sustainable Growth and Development" was published in 2004 by the Organization for Economic Cooperation and Development (OECD, 2004). This report marked a turning point in introducing the modern bioeconomy concept worldwide. Parallel to the OECD document, the European Commission organized a conference on "Knowledge-based Bioeconomy" (KBBE) in 2005, which focused on recent scientific studies and advances in biotechnology, which are the fundamentals in transforming biological resource-based production (European Commission, 2005). As a result, the KBBE concept was developed in 2005 (Levidow et al., 2013). The European Bioeconomy Strategy was later introduced under the title "Innovating for Sustainable Growth: A Bioeconomy for Europe" in 2012 (European Commission, 2012). The KBBE conference report (European Commission, 2005) defines a knowledge-based bioeconomy as "a sustainable economy based on renewable resources". The report underlines that this new economic paradigm is expected not only to contribute to sustainable production and the advancement and application of science in industries but also to ensure resource supply during a time when the oil supply is diminishing. Furthermore, new biobased products and services were predicted to increase Europe's competitiveness (European Commission, 2005).

Bioeconomy generally refers to all sectors and industries in which biomass resources are utilized to produce a variety of products ranging from energy to food. All the entities and industries that utilize biomass resources, such as animals, microorganisms, plants, and derived biomass, as well as their functions and principles, are considered part of the bioeconomy (Ronzon et al., 2017). The main concept is the production of food, feed,

different bio-materials and energy through the sustainable use of renewable biological resources. It is a multi-disciplinary subject and covers a broad spectrum of fields, including agriculture, fisheries, forestry, pulp and paper, biotechnology, the chemical industry, and bioenergy (Ronzon et al., 2017).

Interestingly, bioeconomy is ambiguous in its meaning, and every bioeconomy strategy uses its own definition. In fact, the bioeconomy has been defined differently in research studies, policy and strategy documents, and other sources (Hausknost et al., 2017; Lakner et al., 2021). Due to this, its definition remains unclear, and there is still a lack of consistency in understanding the concept.

Table 1 shows how countries and organizations, which play a critical role in developing the bioeconomy, define the bioeconomy.

*Tab 1: Different definitions of bioeconomy*
*Source: Barañano et al., 2021*

| Definition | Institutions |
|---|---|
| A world in which biotechnology contributes to a significant share of economic output. The emerging bioeconomy is likely to involve three elements: the use of advanced knowledge of genes and complex cell processes to develop new processes and products, the use of renewable biomass and efficient bioprocesses to support sustainable production, and the integration of biotechnology knowledge and applications across sectors. | (OECD, 2009) |
| The production of renewable biological resources and the conversion of these resources and waste streams into value-added products, such as food, feed, bio-based products and bioenergy | (European Commission, 2012) |
| The knowledge-based production and use of biological resources to provide products, processes and services in all economic sectors within the frame of a sustainable economic system. | (German Bioeconomy Council, 2021) |

However, the common consensus between these definitions is producing food, feed, biobased products, and bioenergy through sustainably harvesting biological resources and organic waste. Further, researchers (Hausknost et al., 2017; Biber-Freudenberger et al., 2018) distinguished three different development paths of the bioeconomy that emerged simultaneously: (1) A biotechnology vision that emphasizes the research, development, and commercialization of biotechnology innovations; (2) a bio-resources vision focused on maximizing raw material (biomass) efficiency and productivity; and (3) the bio-ecological concept of conserving ecosystems and preserving sustainability through increased efficiency (Vivien et al., 2019).

Initially, the bioeconomy was promoted as an economic model aimed at reducing our dependence on fossil fuels. The aim of the new economic model was to revolutionize the economy from a fossil fuel-based economy to a biomass-based and recirculated economy that utilizes renewable energy sources (Baranano et al., 2021). Through the years, the original goal of the bioeconomy has expanded to include not just economic growth and employment but also taking steps towards solving global challenges such as food and energy security, reduction of fossil fuel dependency, climate change, and economic development of rural areas (Gawel et al., 2019; Böcher et al., 2020; Stegmann et al., 2020; Wozniak et al., 2021).

There has been a growing interest in the bioeconomy from national and regional governments because of its promising potential for addressing global challenges (Pfau et al., 2014; Gawel et al., 2019; Kardung et al., 2021). Many developed and developing countries and reputable organizations worldwide promote this new economic model. The OECD and the EU are leading the way in successfully implementing a sustainable bioeconomy (Pfau et al., 2014; Wozniak et al., 2021). The bioeconomy strategy has been adopted by 49 countries so far, which highlights its contribution to an environmentally friendly production system (Stegmann et al., 2020; German Bioeconomy Council, 2021; Popp et al., 2021) (Table 2).

*Tab 2: Countries with political bioeconomy strategies*

| Africa | America | Asia | Australia & Oceania | Europe |
|---|---|---|---|---|
| Kenya | Argentina | China | | Austria |
| Mali | Brazil | India | Australia | Belgium |
| Mauritania | Canada | Indonesia | New Zealand | Denmark |
| Mozambique | Colombia | Japan | | Estonia |
| Namibia | Mexico | Malaysia | | Finland |
| Nigeria | Paraguay | South Korea | | France |
| Senegal | Uruguay | Sri Lanka | | Germany |
| South Africa | USA | Thailand | | Iceland |
| Tanzania | | Vietnam | | Ireland |
| Uganda | | | | Italy |
| | | | | Latvia |
| | | | | Lithuania |
| | | | | Norway |

| | | | | |
|---|---|---|---|---|
| | | | | Poland<br>Portugal<br>Russia<br>Spain<br>Sweden<br>The Netherlands<br>The United Kingdom |

*Source:* https://biooekonomie.de/article-map, accessed on Feb 16, 2022, and https://biooekonomie.de/en/topics/in-depth-reports-worldwide

Figure 1 summarizes the bioeconomy conceptual framework as well as relevant drivers and challenges. The process should be viewed as dynamic rather than static (Gawel et al., 2019; Kardung et al., 2021). The key factors influencing demand and supply for bioeconomy development are shown in the top middle of the figure. The measures taken by governments to direct the development of this economic model are a combination of strategies, policies, and legislation shown on the top right side of the figure. We also recognize that different natural resources are available to produce biomass, including labour, land, organic wastes and water, all of which have an impact on the biomass cycle. Below the framework are the different biomass supplies, which are determined endogenously by the three categories of drivers.

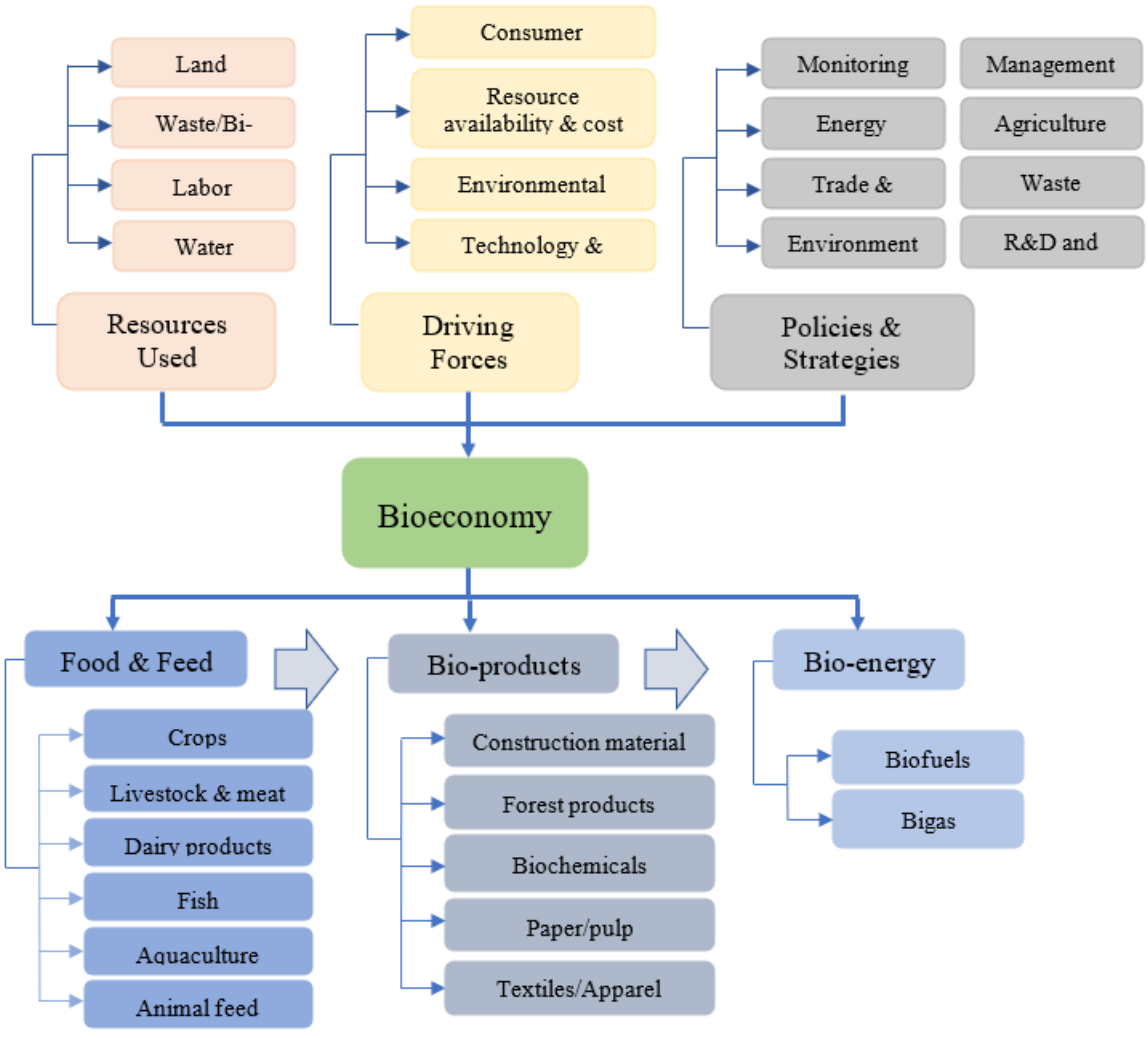


*Fig. 2. Overview of the relations within the bioeconomy*
*Source: Authors' own creation, 2022*

## 4. Results

Sustainable bioeconomy development is inevitably measured by the sustainability of the socio-environmental impacts of the bioeconomy since sustainable social and environmental development are two of the three pillars of

sustainable development. Although researchers continue to explain the positive effects that bioeconomy can have on sustainable development, the results of this study indicate that bioeconomy development may have some potential adverse social and environmental consequences.

A number of socio-environmental issues have been raised in relation to the bioeconomy, including land competition and direct and indirect impacts of land-use changes, scarcity and pollution of water, the price increase in food and energy, potential competition for bioresources for food and biomass production, loss of biodiversity, GHG emissions and loss of consumer trust. Figure 3 displays the bioeconomy model and its potential socio-environmental negative impacts.

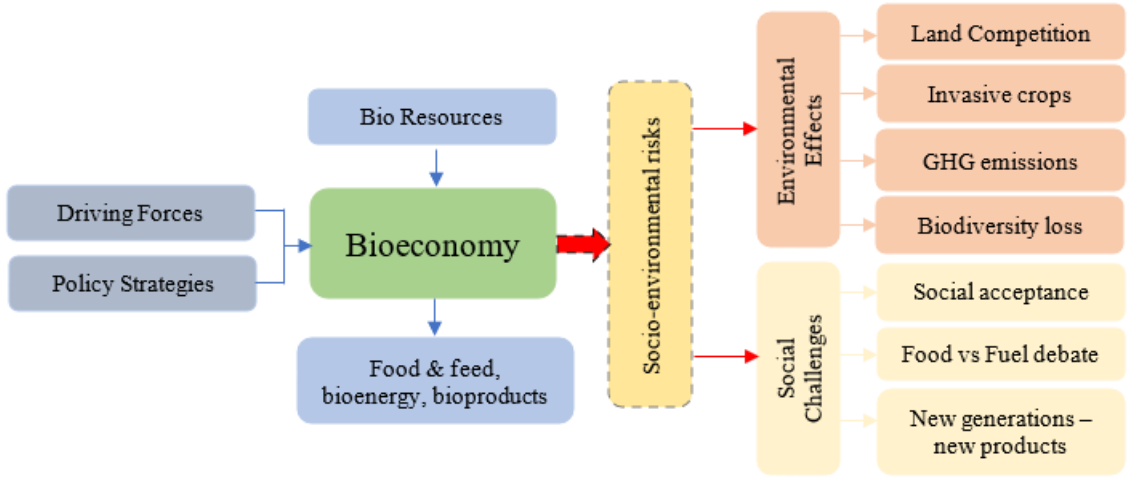


*Fig. 3: The bioeconomy model and its potential socio-environmental risks*
*Source: Authors' own creation, 2022*

One of the strongest criticisms of the bioeconomy is its insufficient supply of biomass and potentially unsustainable use of land, and direct and indirect impacts of changing land use. Another main environmental issue in promoting bioeconomy development is the challenge of supplying sustainably grown biomass. The result is that sustainability goals, such as food accessibility and supply, energy security, and land management, can become conflicted, resulting in economic, social, and environmental damage (Pfau et al., 2014; Gawel et al., 2019). These are the biggest obstacles to the development of the bioeconomy, according to most opposing researchers (Lewandowski, 2015; Gawel et al., 2019).

Furthermore, increasing the production of bio-based products will result in an increase in the demand for biomass, which will put strong pressure on water consumption and biodiversity (Templer & van der Wielen, 2011; Rosegrant et al., 2013; Lewandowski, 2015). This might lead to higher prices for biomass and other natural resources utilized, while on the other hand, more consumer concerns regarding the sustainable bio-based resource supply for the bioeconomy.

Studies have also indicated that this economic model may adversely affect social sustainability issues such as food security and consumers sustainability perspectives (see Figure 3). Besides the debate about food vs fuel, which has been at the centre of a sustainable bioeconomy for some time (Lewandowski, 2015; Gawel et al., 2019), discussions about social trust and acceptance issues raised concerns about social sustainability (Vivien et al., 2019). Although the bioeconomy is a new and green economic dimension designed to achieve sustainable development, this economic model uses traditional production approaches. Bio-products in the bioeconomy are developed and produced using a business-to-business model, meaning that end-users do not participate in the product development process. This uncertainty leads the public not possible to assess the risks and benefits of bio-products and creates social acceptance issues (Paula & Birrer, 2006; McCormick & Kautto, 2013; Lewandowski, 2015; Mustalahti, 2018). Moreover, the use of plants and animals to produce raw materials for products and biotechnology, which may absorb any biomass resources significantly, raises questions among the public as well (Arancibia, 2013). Ultimately, this may end up challenging not only environmental resilience but also social acceptance.

### 4.1 Negative environmental effects

There is strong criticism of the concept of bioeconomy due to its insufficient availability of biomass and potentially unsustainable use of land. According to most opposing researchers, these are the major constraints to the development of bioeconomy (Lewandowski, 2015; Philp, 2018; Gawel et al., 2019). The lack of sustainably

grown biomass is one of the biggest obstacles to achieving a sustainable bioeconomy (Giampietro, 2019; Lakner et al., 2021; Popp et al., 2021).

*Tab 3: Negative impacts of bioeconomy on the environment*

| Environment Impacts | Cause & Effects | References |
|---|---|---|
| Land | - Increase bio-based products<br>- Biomass demand increases<br>- Strong pressure on limited land | Scarlat et al., 2015; Aguilar et al., 2018; Bell et al., 2018; Liobikiene et al., 2019; |
| Water | - Intensified agriculture;<br>- More water usage<br>- Scarcity of water | Golembiewski et al., 2015; Böcher et al., 2020; Ladu et al., 2020 |
| Biodiversity | - pasture, savannah, species-rich grassland, wetland and forest conversion for crop production<br>- Negative impact on biodiversity | Ferdinands et al., 2011; Sheppard et al., 2011, Barney et al., 2012 |
| Invasive crops | - New crops that can become invasive;<br>- Endanger traditional ecosystems; | Ferdinands et al., 2011; Sheppard et al., 2011; Barney et al., 2012; Barney 2014 |
| GHG emissions | - No direct positive impact as a result of biomass cultivation and production requirements and associated potential adverse effects | Pfeiffer & Thran, 2018; Gawel et al., 2019 |

*Source: Authors' own creation, 2022*

*Pressure on land and biodiversity loss:* Due to the rising production of biomass-based materials and products, the need for biomass will increase and lead to significant pressure on the land and biomass resources (Templer & van der Wielen, 2011; Lewandowski, 2015). As a consequence, it will create pressure to cultivate more and more arable land to meet this growing demand. The intense extraction and use of biomass-based resources could compromise the bioeconomy's sustainability (Scarlat et al., 2015). For example, by 2050, global biomass consumption is expected to double, and in the European Union, it will rise by 50% (Bell et al., 2018; Liobikiene et al., 2019). In addition, not all regions of the world can supply sufficient biomass, particularly in the EU, where the local supply of biomass is limited (Aguilar et al., 2018; Liobikiene et al., 2019).

The authors expect that there will be greater competition for biomass between food and non-food use in the future. The land is a limited resource, and increased competition for cropland means that pastures, savannahs, species-rich grassland, wetlands and forests will be converted into agricultural land. Researchers believe that this process is particularly likely to occur in tropical countries and could negatively affect global biodiversity (Haberl, 2015; IISAS, 2015; Böcher et al., 2020). In addition, the competition for land, conversion of these areas as well as intensification of agriculture may result in a scarcity of other essential resources, such as water and phosphorus and lead to negative impacts (Golembiewski et al., 2015; Böcher et al., 2020; Ladu et al., 2020).

*Risk of introducing invasive crops:* Furthermore, introducing new crops that can become invasive and endanger traditional ecosystems and agricultural production is another environmental sustainability concern scientists raise today. It is possible for invasive species to spread along with pests if invasion issues aren't addressed and properly managed (Ferdinands et al., 2011; Sheppard et al., 2011; Barney, 2014). According to Barney et al. (2012), the crops selected for biomass production will be highly invasive. A key feature of such crops is their high productivity and, thus, attract pests and compete with other plant species. Such characteristics have been seen in invasive species. Moreover, frequent harvesting and transportation of such invasive species may cause such species to spread to other regions and ecosystems.

*Sceptical on GHG reduction:* Scholars also debate whether biomass conversion into bioenergy production can lead to the reduction of the greenhouse effect and environmental protection. Considering the biomass cultivation and production conditions and requirements and associated potential adverse effects such as certain climatic conditions, a greater use of nitrogen fertilizer, increased energy consumption in intensive agriculture, converting species-rich grassland, wetlands, forests and protected areas into intensive farming, it is doubtful that the bioeconomy will have a positive effect on climate protection (Pfeiffer & Thrän, 2018; Gawel et al., 2019).

### 4.2 Social Challenges

Dozens of studies have indicated that the new economic model may adversely affect social sustainability issues such as food security and consumers sustainability perspectives. Ultimately, this may end up challenging not only environmental resilience but also social sustainability issues.

*Tab 4: Potential social challenges associated with the bioeconomy*

| Social Challenges | Effects Flow | References |
|---|---|---|
| Social Acceptance Issues | - consumers are not directly and visibly benefited<br>- ethical issues<br>- trust issues associated with biotechnology | Marris, 2001; Paula & Birrer, 2006; Arancibia 2013; Goven & Pavone, 2014; Pahl-Wostl, 2017; Gawel et al., 2019 |
| Food vs Fuel issue | - biomass production for non-food use;<br>- biomass products for non-food use compete with biomass for food and feed use | WFP, 2015; Sillanpää & Ncibi, 2017, p. 80; Gawel et al., 2019 |
| New generations – new products | - prefer new products;<br>- bio-based products differ only in the source of their resources;<br>- less attracted to bio-based products | Darby & Karni, 1973; Ranacher et al., 2018; Gawel et al., 2019 |

*Source: Authors' own creation, 2022*

*Problems with social acceptance:* Although multiple governments, international agencies, and other stakeholders see the bioeconomy model as a vital tool to create a more sustainable economy, it does not necessarily mean it will be accepted by society as a whole. Experience and previous studies have shown that there are three key factors that should be considered regarding the social acceptance of biomass-based economy: (i) consumers benefit, with acceptable risks; (ii) following key moral values related to the treatment of humans and non-humans, and (iii) the technology is governed with trust (Marris, 2001; Paula & Birrer, 2006; Daher, 2018; Wohlfahrt et al., 2021).

Producers and regulators are very confident about the positive social impact of this developing new economic model; however, consumers are not directly and visibly benefited. As a typical manufacturing process, products are developed using a business-to-business model with little or no input from end-users during the product development and production stages. Consequently, this can lead to self-delusion on the part of experts when it comes to the public's perception of the subject (Arancibia, 2013; Pahl-Wostl, 2017).

Regarding moral values, some ethical issues regarding bioeconomy and biomass production stages need to be addressed. The use of plants and animals to produce raw materials for products beyond those currently seen in the food sector may raise questions among the public. For example, producing valuable non-food proteins with animals, such as fibres that can be used in bullet-proof vests, raises serious concerns about respecting their intrinsic value. Moreover, society may see biotechnology as one of the clear examples of how a high-tech industry poses risks to global sustainable development (Arancibia, 2013). In particular, biotechnological processes may consume any biomass resources as if they were a vacuum cleaner when scaled up to industrial levels (Arancibia, 2013; Gawel et al., 2019). There is no doubt that biorefineries at a large scale will require a substantial and constant amount of biomass. Consequently, biomass resources will require large-scale exporting and importing in countries and may face social challenges (Goven & Pavone, 2014; Lewandowski, 2015; Gawel et al., 2019).

It is also important to note another issue that has played a significant role in the discussion about biomass. It is a serious issue that could affect the social acceptability of biomass production and associated biotechnology. The trust that the public has in the professionals who are producing the innovations is the issue. According to many scholars, when it is not possible for the public to assess clearly the risks and benefits of a product, trust in the producer and regulator is essential for positive judgment of that product and subsequently for social acceptance (Paula & Birrer, 2006; McCormick & Kautto, 2013; Lewandowski, 2015; Mustalahti, 2018). Trust alone, however, is not sufficient. Establishing mutual trust among stakeholders is crucial, in reality, for further collaborative actions (Vainio et al., 2019). In the absence of mutual trust, any attempt to engage in social dialogue about complex issues will fail.

*Well-known "food or fuel?" debate:* The discussion about the direct and indirect impacts of land change on the biomass industry as well as the food vs fuel debate, raised concerns about social sustainability (Vivien et al., 2020). Consequently, the debate about food vs fuel has become at the centre of a sustainable bioeconomy debate for some time (Lewandowski, 2015; Gawel et al., 2019). The primary source of food is and will remain agriculture. Even more hunger and malnutrition can be expected if food production will not keep pace with demand. Therefore,

production will have to outpace exponential population growth and make food, including meat and dairy products, more affordable and accessible for people in developing countries. Because a significant portion of hungry people around the world lives in developing countries. The major argument is that agricultural biomass production for non-food purposes could compete with feed and food production (Sillanpää & Ncibi, 2017, p. 42). Countries will adjust and adopt the bioeconomy and new agricultural practices to feed their populations and livestock. As a result, developed countries will achieve food security quite easily and will eventually have a production boom that will be sold on the world market or used for converting into biofuel and chemicals (Aguilar & Patermann, 2020). Developing countries, however, will experience a different situation than wealthy countries. These countries may face challenges in securing food and feed for their populations if reserving and converting lands for biomass energy production and other non-food bio-materials (McCormick & Kautto, 2013; Sillanpää & Ncibi 2017, p. 42).

*Expectations of new generations:* The new generations of the new century prefer new products, whether they are innovative in terms of product features, designs or functions and performance or together. Successful product improvements, innovations or new products are the ones that have undergone significant changes, improvements, or gaps that have been addressed (Gawel et al., 2019). Even though bio-based products aim to replace existing products, they often retain the same properties but differ only in the source of their resources (Gawel et al., 2019). Although such "new" products are a step toward sustainable production by replacing the resource base with fossil fuels and turning it into a bio-based product, the only change consumers can notice is just a "green" label on the outside of the product. Because "Bio" labelled products have lost their true meaning among the public. As trust becomes more critical, it becomes increasingly important to explain to the public how bio-based products are environmentally friendly (Ranacher et al., 2018).

## 5. Discussions: The Road to sustainable bioeconomy

**Sustainability perspectives for bioeconomy**

Different viewpoints are held about whether the bioeconomy is sustainable or not. Based on the different perspectives presented in the literature, different arguments were identified, which covered both positive and negative viewpoints: the bioeconomy is inherently sustainable; under certain requirements, the expectation of benefits; and effects of the bioeconomy on the environment. According to the findings of this review, it is evident that considerable attention has been given to sustainability in the scientific debate on bioeconomy. A number of publications highlighted that sustainability should be a focus of bioeconomy research or even the primary objective of bioeconomic development. It is possible for the bioeconomy to play an important part in creating a more sustainable future; however, positive impacts are not obvious; rather serious socio-environmental risks and pitfalls have been identified.

There are several factors and circumstances that indicate that the bio-economy does not necessarily thrive towards sustainable development. On the basis of the findings of this study, it is evident that sustainability is receiving considerable attention in the scientific discussion surrounding the bioeconomy.

However, it may be possible to achieve positive societal and environmental outcomes when sustainability is regarded as a goal of the bioeconomy while promoting economic growth and keeping traditional industries. In addition, it is important to take into account the interrelationships between the different sectors included in the bioeconomy.

**Concerns and challenges for sustainable bioeconomy**

The transition to a bioeconomy would require increased supply and consumption of natural resources from sea and land, resulting in a surge in biomass demand. Thus, the sustainability of the bioeconomy becomes questionable. Sustainability is critical for a variety of uses of biomass.

Several factors affect biomass production, including water, land and nutrients. Conversion of land is the way to gain access to more cropland needed for increased biomass production. This means forest and grassland would be converted into arable land for biomass production, and significant amounts of $CO_2$ are released into the atmosphere. The land needed to produce biomass varies widely depending on the crop type and the land used for co-products such as materials, feed, etc. (Scarlat et al., 2013). Recently, bio-based materials are increasingly being used from agricultural and forest wastes; however, using such waste streams may negatively affect soil quality and productivity. Increasing fertilizer and pesticide usage is necessary to improve crop productivity, creating other negative environmental impacts on water and soil. Moreover, there will be a surge in water demand caused by a bio-based economy in many parts of the world which can exacerbate water scarcity. Monocultures and more pressure on biodiversity could result from the additional demand for agricultural land for biomass production.

From a social perspective, there have been a few studies that explored the issue of sustainability for biomass production processes. In fact, even though this vital observation has been made by scientists earlier, studies of sustainability are still analyzed primarily from environmental and economic angles (Stegmann et al., 2020). Specifically, it shows that the economic dimension has been the most studied due to obvious reasons. Over the

past 10 years, both the scientific and industrial communities have placed a strong emphasis on the environmental dimension. In recent years, the social dimension of sustainability has gained increasing attention. As a result, the sustainability of various bioeconomy products and production methods can be assessed in an enhanced and more accurate manner. If this new economic model is properly implemented, there are positive social effects that are promised by the bioeconomy (Lakner et al., 2021). One of these effects includes new job opportunities in a wide variety of industries, from biomass farming, harvesting and processing to organic waste recycling and from biotechnology and plants to technology development and scientific research (Ronzon & M'Barek, 2018; Vivien et al., 2019; D'Adamo at al., 2020).

However, there are social risks associated with competing for food security vs non-food biomass supply and social preference that may adversely affect the achievement of the promised benefits (Stegmann et al., 2020).

The global population may reach 10 billion people by 2050. Due to population growth, dietary changes, and improved living standards, an increase in food consumption will put more stress on the land. Food security is undermined by the increased use of biomass as a basis for biobased products, which has significant implications for the level of prices and volatility in the market. Food security is more concerned with food access than with food availability, even though crops other than food provide farmers with extra income. Moreover, the rise in food prices might have the greatest effect on poor people. Several options have been proposed to resolve the conflict between food production and non-food biomass use, such as converting unproductive and degraded lands into agriculture, improving biomass productivity, applying a cascading approach and expanding the biomass source (organic waste and residues, etc.). Nonetheless, it's unclear whether the increase in agricultural production will be able to meet the large increase in biomass demand (Pfau et al., 2014).

Another concern with regard to the bioeconomy is social acceptance related to ethical values regarding the bioeconomy and biomass production (Lakner et al., 2021). Using animals to produce non-food proteins raises serious concerns regarding preserving their intrinsic value. Additionally, there are societal criticisms regarding genetically modified organisms (GMOs) and gene editing (Arancibia, 2013). Agri-food biotechnology is receiving very little public support despite the fact that pharmaceutical and industrial biotechnologies are generally supported. Bioeconomy, therefore, raises a familiar question: is it acceptable to the public to compromise the ethical values of society and expose the environment and society to risks related to GMOs or gene editing? To protect the same environment and to maintain an affluent lifestyle?

Additionally, research indicates that the new generation prefers innovative products in exterior product designs or product performance and functions. Though bio-based products are intended to replace existing products of fossil origin, they often retain similar properties but differ only in their source. Consequently, these bioproducts may be less attractive to new generations, contributing to another aspect of social acceptance challenges of the bioeconomy.

## 6. Conclusions

Fossil resources have played a significant role in global development since industrialization. However, due to the adverse effects of the current traditional economy highly dependent on fossil fuels, many emerging environmental and social problems need to be addressed today, such as biodiversity loss, global warming, overpopulation, and food and energy security. These emerging environmental and social problems are forcing humanity to rethink how we live, produce and consume goods, and manage the natural resources on our planet in a sustainable way.

As a consequence, the bioeconomy theory has been developed over the last fifteen years. However, different countries define the new economic paradigm differently depending on their specifics, resources, and economic strategies.

Regardless of a different understanding of the new economic concept, it is becoming a regional development agenda in many countries as a political and economic project. With the growing interest of society and policymakers in bioeconomy, in recent years, scientific research and developments in bioeconomy have increased considerably over the past ten years.

Now, it is anticipated that the bioeconomy is the key to achieving sustainable economic growth and producing food, energy and materials for an ever-growing population while preserving the environment and improving the quality of life. A sustainable bioeconomy cannot be achieved unless socio-ecological sustainable development is taken into account, which is a key pillar of sustainable development, and synergies can be created between them. Therefore, the ultimate goal should not be the measure of the bioeconomy itself but its sustainability.

However, recent controversies have cast doubt on the validity of the direct link between sustainability and bioeconomy. A significant increase in biological resource usage will lead to a reduction in ecosystems' capacity to provide for human needs. Therefore, it is still unclear how countries can make the transition to a bioeconomy in a sustainable way. Studies indicate that bioeconomy is correlated with serious socio-environmental sustainability challenges: effects of direct and indirect land use changes, biodiversity loss, scarcity and pollution of water, social, and ethical value issues, the price increase in food and energy, bioresource competition for food, and biofuel

production, GHG emissions and loss of consumer trust. As a result, various sustainability goals, such as sustainable land management and food and energy security, are in conflict with each other, which can exacerbate environmental and social consequences.

To conclude, concerns regarding potential clashing between sustainability goals and transition barriers to a sustainable bioeconomy need to be addressed carefully. In order to create a sustainable bioeconomy, all socio-economic and environmental pillars of sustainability are considered from the beginning of the transition and synergies are made between these pillars. Typically, none of these pillars is maximized in this process, but rather, the most effective mixture of these elements is identified and implemented. Achieving economic sustainability is ultimately possible when acquiring and maintaining environmental and social sustainability.

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