



Tying Up Loose Ends. Integrating Consumers' Psychology into a Broad Interdisciplinary Perspective on a Circular Sustainable Bioeconomy

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Abstract

A shift towards a bioeconomy is not sustainable per se. In order to contribute to sustainable development, a bioeconomy must meet certain conditions. These conditions have been discussed with respect to technology and also to the importance of ethical aspects. Consumers' behavior has also been acknowledged. However, consumers still have to choose sustainable consumption options, and this choice depends on their psychological makeup, which can be related to two factors: behavioral costs and individual sustainability motivation. Behavioral costs determine how difficult the consumption of a bio-based product is, relative to other less sustainable consumption options. Sustainability motivation determines how much effort a person is willing to expend for a more sustainable consumption option, for the sustainable use and recycling of a product, or even to refrain from engaging in consumption. In addition, in a complex bioeconomic system, the sustainability of a bio-based consumption option is not always clear cut. After providing an introduction to the systemic and technological background of bio-based products, we present how consumers' sustainability motivation is an essential and decisive pull factor for a circular sustainable bioeconomy. We also present the drivers of consumers' sustainability motivation as necessary components of a sustainable bioeconomic system.

Keywords Sustainable bioeconomy · Consumer psychology · Individual motivation · Consumer behavior · Biobasedproducts · Interdisciplinary · Ethics

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Introduction

In the twenty-first century, the world community faces the challenge of providing food security, energy security, and the security of having a supply of raw materials for a growing world population. At the same time, we are facing global environmental problems such as climate change, biodiversity loss, soil degradation, and deforestation, all of which are caused by an economic system that is based primarily on unlimited growth and the use of fossil fuels. The effects of this economic system on resources and the environment threaten people's health, livelihoods, and lives and raise ethical issues (UNEP, 2019) which have been addressed by sustainable development goals (UN, 2019). Hence, one main challenge in the twenty-first century is to create a new economic system that will allow the world population to meet its needs while remaining within our planet's boundary conditions (Haberl et al., 2014; Steffen et al., 2015). In order to master this challenge and integrate it into our economic system, several concepts have been developed. Two such popular and promising concepts are (a) a green economy, which includes ecological modernization and a Green New Deal, and (b) a circular economy, which stresses the circularity of production systems as an alternative to linear production systems (D'Amato et al., 2019). A sustainable bioeconomy can be an important means for manifesting these concepts, especially for a circular economy (EC, 2018; Viaggi, 2018; Zwier et al., 2015). However, in order to become sustainable, a bioeconomy must meet sustainability criteria on the sides of both supply and demand. This systemic view also includes consumers who, for example, are necessary for an optimal use of bio-based products because consumers have to help keep resources within the cycle by practicing the correct ways of disposing of waste (Zeug et al., 2019). After all, consumer behavior and its ethical implications (Sandin & Röcklinsberg, 2016) are decisive elements with respect to the sustainable development of any economic system because it drives the consumption, production, and use of products (Kallhoff, 2016). On the same level as corporate social responsibility, consumers' responsibility involves (a) product choice, (b) product use and recycling, and (c) an influence on market-economy conditions (Heidbrink & Schmidt, 2011; Jacobsen & Dulsrud, 2007; Schmidt, 2016).

Due to the many interdependencies that exist within a sustainable bioeconomy, a holistic perspective is essential for developing sustainable production systems that go hand in hand with sustainable consumer behavior. Furthermore, not only are people a crucial factor for the sustainability of an economic system, but they are also affected by the economy—even a bio-based circular economy (Murray et al., 2017). For instance, the ethics of biofuel on its own are a highly complex issue even without taking a closer look at related individual behavior (Thompson, 2008). Especially in food production and consumption, ethical aspects of consumer decisions are important (Beekman, 2000; De Tavernier, 2012). However, we could not identify any study that linked individual behavior and its psychological background – naturally also including the ethical and sustainability aspects of consumption – with the economy and production of bio-based products. We

will fill this gap and argue that this overall perspective is essential for a sustainable bioeconomy because consumers and citizens also influence market-economic conditions and decisions with regard to more or less sustainable options.

In order to draw the necessary links between individual consumption and its interdependencies with the complex production system, we introduce a model with push (regulatory, civil society, technology) and pull factors (regulatory, market, vision) in the following section. In the section on sustainable bio-based products, we derive typologies for the classification of bio-based products in the production process in order to show how to assess the sustainability of the products of the bioeconomy as a precondition for informed consumer decisions. In our main section on behavioral determinants, we focus on sustainable consumption (i.e., market pull) and how consumers' psychology affects this pull in combination with factors that reduce behavioral costs. We deepen our considerations of the factor of market pull with a focus on psychological drivers that determine consumers' choices for or against sustainable bio-based products.

Transforming the System Toward a Sustainable Bioeconomy

A transformation of our economic system toward sustainability cannot be achieved by simply changing the resource base and introducing innovative products. Even though a bioeconomy (i.e., biomass use and use of biotechnology) has the potential to reduce the use of natural resources, such a path is not granted and is also tied to ethical issues (Székács, 2017). On the production side, we need a fundamental redesigning of industrial carbon and material cycles for which a sustainable bioeconomy is an essential element (Lewandowski, 2018). Thus, in the following, we take a broad perspective on the bioeconomy and its constituting systems (D'Amato et al., 2017). Even though we are focusing on the production and consumption of bio-based products, it is important to consider that different elements of the economic system are interdependent. The production systems for a bio-based economy (a bioeconomy) and a renewable carbon economy are becoming increasingly more interwoven, and there are overlaps with circular and green economies. Because sustainable development in other sectors also relies on one or more of these four economic concepts, they are interlinked with the bioeconomy as well. For instance, sustainable development in the energy sector also relies on the renewable carbon economy (Carus & Dammer, 2018; Grim et al., 2020). In order to assess the sustainability of bio-based products, the principles of all these economy concepts need to be integrated, which makes the assessment of sustainability quite complex.

Still today, it remains a mostly unresolved challenge to adapt the production and consumption of goods and services to the requirements and goals of sustainable development (UN, 2019). Resource extraction today exceeds the recovery of these resources, and strategies for consistently closing material cycles have yet to be sufficiently developed. In addition, a growing world population and the globalization of Western consumption patterns are leading to an ever increasing demand for resources, while at the same time, climate change and other environmental effects are leading to an additional decrease in resources. Hence, the pressure on natural

resources is growing massively (Jackson, 2014; Worldwatch Institute, 2014). One main idea that is entailed in the concept of the bioeconomy is that these challenges can be overcome by replacing non-renewable fossil resources with the use of renewable raw materials for producing bio-based consumer products, bio-based building materials, bio-based chemicals, and renewable energy. However, a transformation of the economy in this sense can only succeed if the necessary technical developments are adopted by society as a whole, for which changes in attitudes and behavior on an individual level are imperative (Besi & McCormick, 2015; Lewandowski, 2018; Otto et al., 2014; Viaggi, 2018).

Aspects that are particularly relevant in this context are the acceptance of new technologies, bioenergy with carbon capture and storage, more sustainable consumption behavior, and support for effective recycling and the broader reuse of materials. Especially a cascading use is essential for a sustainable bioeconomy because it is aimed at deriving the most utility from a resource through a sequential reusing of resources (e.g., wood, plastics, paper, textiles) for multiple applications as high-quality products before the final use for energy recovery (Sirkin & Houten, 1994). One central factor in this context is consumer psychology which explains the choices between sustainable bio-based products and conventional products. Another central factor comprises institutions which form the framework of society and the political arena in which democratic decisions – also based on individual preferences and the underlying psychology – take place. Building on the findings of environmental innovation research (e.g., Klemmer et al., 1999; Pyka, 2017), the external factors that shape the cost of individual behavior in a society (institutions) can be brought together in the multi-impulse model (see Fig. 1).

Regulatory push refers to interventions that exert pressure for change and include governmental and legal interventions in the form of bans, conditions, liability regulations, or labeling requirements. Pressure can also result from civil society through public debate, scandals, and boycotts. Technology can push through disruptive and incremental innovations and key technologies. Pull factors are incentives that promote decisions and courses of action by supporting them. Incentives are provided through policy measures such as subsidies, tax breaks, emissions trading, etc. (i.e., regulatory pull). On the market side, changes in demand and customer requirements create incentives for adaptation (i.e., market pull). Finally, cross-company or

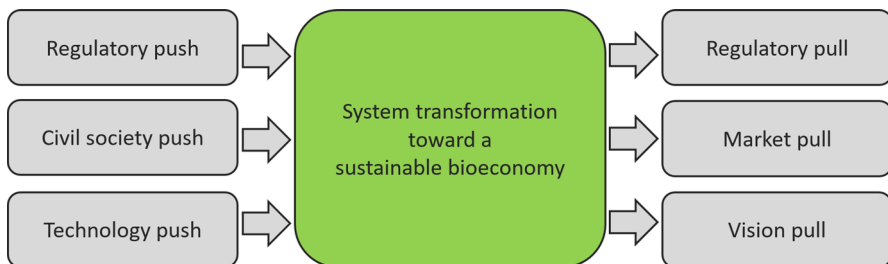


Fig. 1 Push and pull factors for the transformation of the system toward a sustainable bioeconomy (based on Fichter, 2005, p. 132)

individual visions, mission statements, and principles of action pull toward more sustainable consumption (i.e., vision pull). We focus on the pull factors and the ways in which they can have an impact on the transformation process, and we will show that especially the market pull is strongly related to consumers' psychology. Market pull refers to a perceived need for a new solution, technology, or product that stems from the market side (i.e., the customers). The expectation is that the producers and providers will increasingly offer more sustainable products out of self-interest and these products will ultimately become more sustainable in this way if sufficient market demand is present. For instance, a growing demand for more sustainable, climate-friendly, or cruelty-free products may induce innovation and new product development.

Sustainable Bio-Based Products

A bioeconomy encompasses several economic and industrial sectors and their products (Sillanpää & Ncibi, 2017). In particular, all the industrial sectors and branches that produce, process, or use biological resources in any form will be affected: agriculture and forestry, horticulture, fisheries and aquaculture, plant breeding, the food and beverage industry, as well as the wood, paper, leather, textile, chemical, and pharmaceutical industries (EC, 2018; McCormick & Kautto, 2013). Furthermore, a bioeconomy is also linked to a number of sustainability promises, such as ensuring food security, the sustainable management of natural resources, reducing the dependence on non-renewable resources, mitigating and adapting to climate change, creating jobs, and maintaining European competitiveness. Against this background, we now focus on the production of bio-based products. We leave food, energy, and services aside and provide an overview of product types in a bioeconomy in order to show points of reference for the assessment of the sustainability of bio-based products. A schematic representation of the stages of the life cycle and the psychological determinants that are discussed in the following sections is provided in Fig. 2.

Origin of Raw Material (Biomass)

The first stage of the life cycle of a bio-based product involves the production of biogenic carbon (e.g., biomass from livestock breeding, agriculture, and forestry) which is available in different forms and can be used as a substitute for fossil-based carbon. However, new technologies that can provide new non-fossil carbon sources (e.g., carbon capturing) have emerged (Carus & Dammer, 2018). The processing of biomass leads to environmental impacts that need to be considered when assessing sustainability. The impacts of industrial production processes that use bio-based carbon are in many ways similar to the environmental impacts of the industrial processing of conventional fossil-based products (Hermann et al., 2011).

A major driver of environmental impacts in terms of greenhouse gas emissions is the energy carrier that is used. On the one hand, substituting fossil-based materials with bio-based materials can result in environmental benefits. On the other hand,

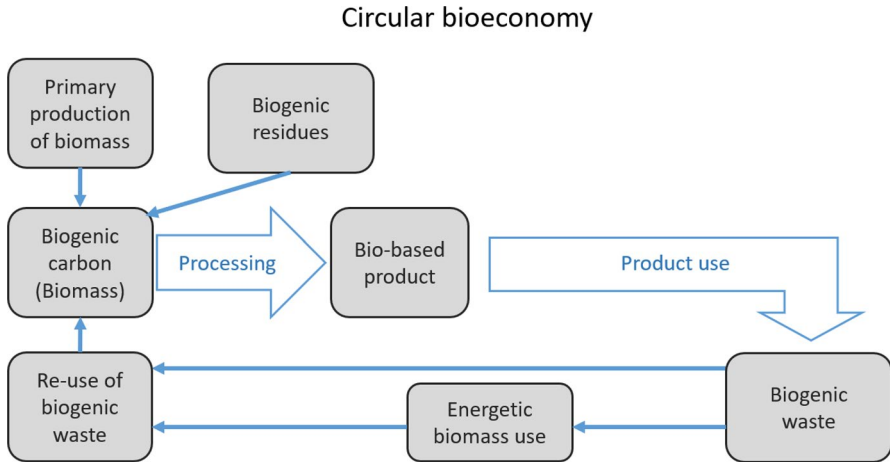


Fig. 2 Industrial production process of bio-based products in a circular bioeconomy

livestock breeding and the growing of biomass as a feedstock is connected to a number of direct and indirect environmental impacts (Nemecek & Kägi, 2007). Direct environmental effects result from agricultural inputs such as fertilizers or pesticides and from field emissions (e.g., emissions of ammonia into the air, nitrate leaching to groundwater, or phosphorous emissions to water). Biodiversity is impacted by land use change and agricultural processes. Finally, land availability and more precisely the availability of sustainably grown biomass is probably the most prominent concern and limiting factor for a sustainable bioeconomy (Alvarenga et al., 2013; Brehmer et al., 2008; Pfau, 2015).

A generally positive factor of bio-based products is the temporal binding of carbon dioxide and solar energy. During the growth phase, biomass binds CO_2 from the atmosphere. This carbon dioxide is released back into the atmosphere during (natural) decomposition, rotting, or combustion after use. It is important to understand that a CO_2 -storage effect only occurs for long-living biomass such as trees.

Processing and Products

In order to assess the sustainability of bio-based products, a distinction between the drop-in and the non-drop-in route in production processes is essential. Bio-based raw materials and feedstock that can be used in existing (petrochemical) processing infrastructures (i.e., “drop-ins”) can rely on competitive, efficient, and mature technologies. Hence, their immediate and intermediate environmental impacts are lower in comparison with innovative products (e.g., biofabrication, see Table 1) for which completely new infrastructures need to be built. In order to produce a broad diversity of bio-based products, biomass processing involves a variety of conversation processes (see Table 1) and technology routes. This variety along with technological complexity make it difficult to conduct a general appraisal of sustainability impacts. However, environmental benefits may occur when fossil-based materials or other

Table 1 Overview of bio-based technologies and products

Categories	Technologies and products
Traditional biomass production	Agriculture Forestry Aquaculture, fishery
Innovative biotechnology routes	Biorefinery: conversion and refining of biomass (e.g., sugar, starch, vegetable oil, algal lipids, biogas, lignocellulose) to intermediate products and platform chemicals/building blocks Biofabrication: production of complex living and non-living biological products (e.g., tissues, alternative leather) based on living cells, molecules, extracellular matrices, and biomaterials Synthetic biology: genetically modified microorganisms, bacteria, and yeast are utilized as cell factories for biomaterials, amino acids, enzymes, and antibiotics
Process technologies	Physical–mechanical processing (filtration, distillation, extraction, fragmentation, crystallization) Chemical processing (pulping, oxidation, esterification, hydrogenation, hydrolysis, etherification, isomerization, polymerization) Thermochemical processing (incineration, gasification, thermolysis, pyrolysis) Hydrothermal processing Biochemical processing (fermentation, aerobic conversion), anaerobic digestion (biogas)
Products	Conventional products (wood, pulp and paper, textile, plastics, food, animal feed and feed additives) Energy and fuels (biofuels, fuel additives) Chemicals (basic/platform such as organic acids and fine chemicals) Materials (polymers and bioplastics, biochars and activated carbons, wood-based materials, fibers, composites, insulation materials from cellulose, lubricants, surfactants)

products that are considered non-sustainable can be replaced and any environmental impacts that are related to them can be avoided.

Resource Use after the End-of-Life of a Product

Bio-based products will end up as consumer or construction material waste. Bio-based products, particularly bioplastics, are suitable for typical end-of-life treatment options such as mechanical recycling, composting (i.e., biodegradation, mineralization and/or recovery of organic fertilizers and humus substrates), and incineration power generation (i.e., heat or electricity). The goal from a sustainability perspective is to avoid waste and final incineration for “as long as possible” in order to allow efficient resource use. This aim is most likely realized through a cascading use or recycling: Biomass is used in a cascade when it is processed into a bio-based product, and this product (or the raw materials it consists of) is used at least one more time before final incineration. However, in the present conventional waste system

and most likely in the immediate future, bio-based materials will not be sorted out and will not be used in a cascade; instead, they will be incinerated.

Only when cascading uses or the recycling of specific plastics are established, as in the case of the now commonly familiar PE/PET plastics (Polyethylene/Polyethylene Terephthalate), can bio-based alternatives be recycled as well. Polylactide (PLA), for instance, is also potentially recyclable. But even though sorting technology is already available, no separate recycling avenue exists for PLA. Studies on PLA recycling have shown that mechanical and feedstock recycling is beneficial from an environmental point of view, and recycled bio-plastics can be substituted for virgin petrochemical plastics (Hermann et al., 2011). Thus, a shift toward the recycling of PLA instead of incineration could lead to an overall systemic improvement in the sustainability of the bioeconomy. But such a shift would need structural and customer support.

Biodegradation occurs under aerobic conditions and usually takes 6–12 weeks. However, biodegradability does not mean that products (e.g., organic waste products from supermarkets or homes) will degrade in the open environment. Instead, certain conditions have to be met and controlled (i.e., temperature between 50 and 70 °C, humidity, aeration, the presence of certain microbes such as bacteria, fungi, and their enzymes). Industrial composting facilities provide these requirements and convert compostable plastic products into CO₂, water, and biomass. Home composting is not an alternative to this kind of industrial composting because it does not provide the necessary conditions. The benefit of biodegradability is that microplastics will not be put into the environment. With regard to GHG emissions, biodegradation is favorable if the bio-based products cannot be collected or recycled by other means or if they are mixed with other organic waste (e.g., food waste) and cannot be separated. It seems that in all other cases (i.e., when collection, separation, recycling, or incineration with energy recovery is possible), biodegradation is the worst end-of-life option. This is, besides other factors, because methane is emitted for both composting and landfilling. The predominant environmental benefits of recycling and incineration are that the replacement of virgin materials and fuels can be achieved, and when waste is incinerated, CO₂ is emitted with a lower global warming potential.

Sustainability Assessment of Bio-Based Products

In order to support a sustainable bioeconomy, we need to ask how sustainable bio-based products are. The answer is not easy in many respects because of the complexity of the bioeconomy itself, its products and technologies, and the inherent complexity of sustainability assessment (Pfau et al., 2014). A bio-based product is not necessarily a sustainable product, and the bioeconomy therefore cannot be considered to be self-evidently sustainable (Pfau et al., 2014). Based on an integrative understanding of sustainability, in the sense of integrating the dimensions of sustainability (Kopfmüller et al., 2001), Table 2 suggests a set of criteria that may be used to get a comprehensive view (Schidler, 2005). This list is related to the technology

Table 2 Criteria for Sustainability Assessment in the Bioeconomy (Schidler, 2005, pp 234)

Category	Cluster	Criteria
Health and environmental impacts	Inputs	Total energy consumption and share of non-renewable energy Chemicals (toxic chemicals and petrochemicals)
	Outputs	Water use Emissions to water, air, and soil (from production plants and transportation)
Safety and quality of employment	Risks	Waste, hazardous waste, and its treatment Error tolerance of the system (technical issues)
	Agriculture and land use	Effects of the type of farming such as monocultures, field release of GHG, application of pesticides and fertilizers, soil compaction through (increased) machine use and emissions Share of extensively farmed areas (especially organic) and how they change over time
Knowledge	Technical plants and installations	Sealing through plant construction and transport routes
	Actors	Exposure of workers, workplace safety Quality of work
Regional development	Existing resources	Protection and creation of (qualified) jobs
	Resources to be built	Use/sharing of traditional knowledges and experience Need for additional qualifications to work in the plant or to work in raw material production
Actor interactions	Regional economy and supply	Research accompanying the operation of the plant Support for regional infrastructure
	Cultural and individual identity	Added values remain in the region Preservation of the cultural/anthropogenic landscape as an asset worth protecting
Economic aspects	Actor interactions	Consideration of tradition and self-image of the actors Shift in the self-image of the agricultural actors away from the subsidy recipient
	Profitability of the plant	Enabling the equal participation of actors, appropriate forms of cooperation Possibility of the participation of affected individuals during the approval procedure and operation
Economic aspects	Economic profitability from the perspective of the actors	Various economic indicators of the profitability of the plant Self-employed livelihood security instead of transfer payments Various indicators of the profitability of the plant

level (not the product level) and can serve as a starting point for introducing product categories in the bioeconomy.

Whether and in what ways a bio-based product is rated as sustainable in a sustainability assessment also depends on the normative definition of “sustainable” (Otto, 2010; Pfau et al., 2014) and how this is reflected in an innovative bioeconomy (Schlaile et al., 2017). Given the different perceptions and positions and their legitimacy, there is a need for an adequate sustainability assessment that is appropriate for supporting agenda-setting and decision-making beyond rhetoric and lip-service. However, the ambiguity of evaluations under conditions of uncertainty, the possibility of unintended and unexpected side effects make it difficult to draw a clear conclusion (Grunwald, 2007). Thus, assessment experts and decision makers are challenged to transform complexity in such a way that decision making can continue “in good conscience.” For consumers, understanding the uncertainty and ambiguity of scientific impact assessments is even more difficult and they may need to base their purchasing decisions on other overarching principles – where ethics and psychology come into play. To begin with, citizens and consumers have to spend some time and effort understanding at least some basics of the evaluation of the sustainability of bio-based products. In order to do so, people have to have a certain level of motivation to behave sustainably which is one psychological determinant we will present in the following.

Psychological Determinants of Sustainable Consumption in the Bioeconomy

From a psychological perspective, two main factors determine individual consumption decisions: the behavioral costs that make a specific consumption behavior more or less difficult on the one hand (e.g., price, effort, uncertainty, social disapproval) and individual motivation and interests or preferences (i.e., person-intrinsic factors) on the other. We refer to sustainability motivation as the specific motivation that is driven intrinsically, for example, by the desire to contribute to sustainability (Deci & Ryan, 2000; Masson & Otto, 2021). In the following, we build on environmental psychology and consumer psychology to derive the most central psychological aspects for sustainable behavior related to the bioeconomy. We have learned from the previous sections that neither bio-based products nor the bioeconomy are sustainable per se and that judgments about the sustainability of certain bio-based products are often not clear cut even on the expert level. Thus, in the following, we refer to consumers’ choices where a sustainable decision is possible from a consumer’s perspective and we discuss the idea that such decisions also depend on the extent to which the consumer seeks information on the basis of their sustainability motivation. Furthermore, the sustainability motivation of consumers translates into the market pull described above because the market pull is the readiness to consume sustainable bio-based products. Thus, in Fig. 3 we describe the “Product use” arrow from Fig. 2 in more detail by including the consumers’ purchase decision, product use, and recycling as well as the psychological determinants thereof. But also indirectly, on a societal level, sustainability motivation (e.g., expressed through political

activism or a sustainable prosumer activity) can affect regulatory push, civil society push, technology push, as well as regulatory pull and vision pull. From the perspective of the consumer, however, regulatory push, civil society push, technology push, and regulatory pull affect behavioral costs: Any of these processes that make sustainable behaviors easier or more likely to occur mean a reduction in behavioral costs.

Behavioral costs are determined by external conditions that facilitate or aggravate specific behaviors and thus make them more or less demanding. These costs are the same for everyone (in a given context), but the individual motivation is different – therefore, some people will overcome only very low behavioral costs, whereas others will easily perform sustainable behaviors because they are highly motivated to move toward the sustainability goal. Conceptually speaking, individual motivation and the externally determined behavioral costs are independent, separate factors of influence for sustainable behaviors.

Behavioral Costs: What Makes Sustainable Consumption Easy or Difficult?

Infrastructure

Consumer behavior in a bioeconomy is, on a very general level, constrained by a more or less supportive infrastructure which is an expression of the overall effect of the push and pull factors described above. This applies to the availability of bio-based sustainable products in the first place but also during the use and disposal phases of consumption. If someone buys a car that runs on natural gas, the most effective use in the sense of a sustainable bioeconomy will depend on infrastructure (e.g., gas stations that offer bio-methane). The presence of a tight network of such gas stations will increase the likelihood that car owners will run their cars on bio-based fuel, whereas if bio-based methane is only scarcely available, few car owners will expend the effort to do research on where to best fuel up their cars and will just fuel up on fossil fuels instead. The sustainability of a bio-based product, including its life cycle or cascading use, depends not only on technologies and the competing use of raw material (e.g., whether the production of a bio-based product prevents the cultivation of food crops; Meyer & Priefer, 2015) but also on the consistency of its resource cycle. In order to achieve a closed resource cycle, including an optimized cascading use as an important element of a sustainable bioeconomy, consumers' participation is necessary at this end as well. Consumers, by recycling and, if necessary, by engaging in other beneficial use behavior, contribute to ensuring that no resources are lost. Also to this end, the costs of the related sustainable behavior (e.g., correct disposal of bio-based products) play a decisive role. It has been shown for recycling in general that the barriers consumers have to overcome are directly reflected in the recycling rate. Recycling is much easier and more people engage in it when the distances from recycling centers are short, for example, when there is a curbside collection system in place or when there are depot containers in one's neighborhood. Through structural facilitation, recycling rates can be dramatically increased as has been shown for the disposal of electronic appliances (Otto et al.,

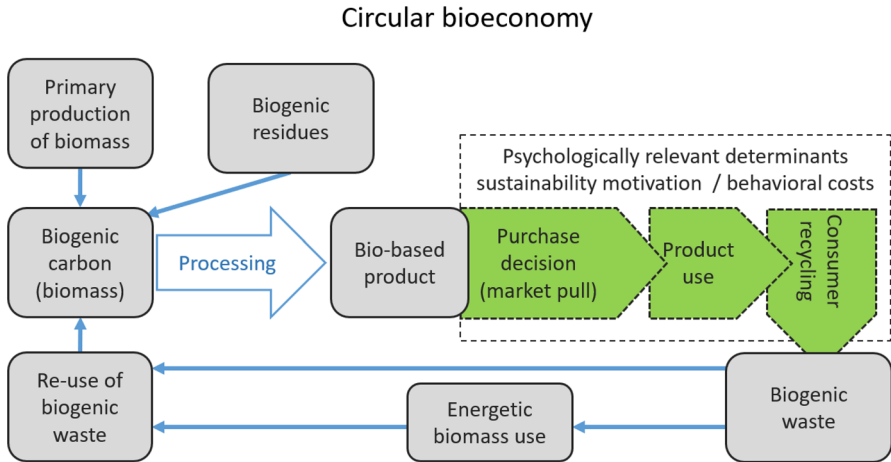


Fig. 3 The industrial production process of bio-based products in a circular bioeconomy, including consumers' behavior and its psychological determinants

2018). If bio-based products need to be treated separately from other kinds of waste after their disposal, and if consumers have to engage in correct recycling, it is important to provide infrastructure that reduces the behavioral costs that are involved (e.g., a pick-up scheme). Last but not least, recycling can lead to rebound, that is, even more consumption and more waste through more efficient recycling (Bortoletto & Otto, 2015). However, for a bio-based resource cycle, rebound is also likely but with a much lower environmental impact due to the bio-based renewable origin of the resources (e.g., carbon neutrality) in contrast to fossil fuels.

Information and Knowledge

For consumers, it is at times difficult to assess the sustainability of products. Especially for complex (i.e., highly manufactured) products, the types of materials and processes involved in the production process are often not evident to consumers (Gjerris et al., 2016). For example, consumers could assume that the origin from renewable resources guarantees good biodegradability and that bio-based products are disposed of as organic waste. This is problematic in two respects: First, not all bio-based products are readily biodegradable. In fact, only a few of them are. Second, for a sustainable bioeconomy which, among other things, is heavily dependent on a functioning cascading use, it is necessary to take various bio-based products to the next stage of use. Thus, for the purchase, use, and disposal of bio-based products, consumers will usually have to rely on information provided along with the product to perceive it as (potentially) sustainable. As shown above, a bioeconomy encompasses a complex system with a broad range of technologies, products, materials, and dependencies on policy decisions that foster specific economic concepts (e.g., green or circular economies). For consumers to be responsible and active stakeholders in the process of a transformation, knowledge and information play

significant roles (Abrahamse et al., 2005; Voget-Kleschin, 2015). The acquisition of information and knowledge represents behavioral costs: A fair amount of intellectual effort has to be invested in understanding, for example, why biodegradable plastic should nonetheless not be put with organic waste, why certain genetic or synthetic-biological technologies are not risk-free, or how an apparently leather-like material can be made from pineapple. Therefore, just as for fair trade and organic agricultural production, for the dissemination of bio-based products, the informative labeling of bio-based products will be necessary to support consumers' decisions. The easier this information is for consumers to perceive and understand, the lower the behavioral costs will be to identify and perform bio-based consumption as a contribution to a sustainable lifestyle. In addition, new learning approaches such as deeper learning can provide the necessary fascination and motivation to invest the necessary resources to overcome behavioral costs of knowledge acquisition (Otto et al., 2020).

Material or Financial Incentives

Material incentives or financial costs can play important roles in promoting sustainable behavior (e.g., Abrahamse et al., 2005; Maki et al., 2016). Material and financial incentives come in many forms, such as subsidies, taxes, tax reductions, and free giveaways. These strategies can be deployed to support the establishment of a bioeconomy as well because they determine the behavioral costs for sustainable bio-based consumption on the consumer side, relative to non-sustainable consumption practices. Thus, despite the limited usefulness of incentivization for changing specific behaviors one by one (see e.g., Kaiser et al., 2020) it is a very important lever on a societal level to define the relative costs of more and less sustainable behavior by design. This is not least because the prominence of certain behavior options (e.g., the default in a decision situation, the availability, the tax structure) also has a communicative function by conveying the message of "what is the usual, normal thing to do" in a situation. However, material incentives come with the drawbacks that they are only effective when in place and the behavior change is not long-lasting (see, e.g., Kaiser et al., 2020). This is because people's intrinsic motivation remains more or less unchanged by the use of incentives. If there is a financial advantage when purchasing a certain product, people's motivation to engage in the subsidized behavior is a financial one, and as such, it is by and large independent from their sustainability motivation.

Norms and Social Influence

People have a need for social affiliation (Hill, 1987) and thus endeavor not to fall into social disgrace but instead conform with what most people do. Norms are people's perceptions of "the right thing to do," and they can have a powerful influence on people's behavior in public (Cialdini et al., 2006). Importantly, people are often not aware of the influence of norms on their behavior. Even though someone might claim to engage in a certain action for environmental reasons or because it is beneficial for society (i.e., claiming to have selfless reasons), the behavior can be substantially influenced by the behavior of others (e.g., Nolan et al., 2008). Because social

norms based on the behavior of other people usually help to foster such behavior, establishing consumption decisions in favor of bio-based products as the norm is an important step. As an example, people in leadership positions (e.g., CEOs of companies, group leaders) or public figures (e.g., politicians, celebrities) can inspire norm shifts when they engage in certain behaviors. But direct social contacts such as friends, family members, or colleagues can also exert social influence and this can be a promising way to spread information and thus to change norms and ultimately behaviors (Abrahamse & Steg, 2013). Social influence appears with two faces: On the one hand, adhering to the norm can manifest in social status or reputation; on the other hand, social pressure can exert a motivational force when a behavior is frowned upon (e.g., when people are excluded, blamed, or laughed at). In any form, social influence is closely related to gaining or maintaining social status (Griskevicius et al. 2010). In particular, this kind of influence can be expected to affect the types of behavior that are very visible or observable and are also relevant for an energy transition (Korcaj, Hahnel, & Spada 2015). The latest research results show that the willingness to act sustainably can increase if the corresponding action is perceived as a collective (rather than a purely personal) project—even beyond personal cost–benefit balances (Fritsche et al., 2017). This can be relevant for collective behaviors in a bioeconomy such as meeting resource recycling goals or the collective investment in infrastructure similar to the citizen-owned renewable power plants that have raised the acceptance of and identification with the transformation of the energy system in Germany (Langer et al., 2017).

Sustainability Motivation – the Market Pull: What Drives People to Consume Sustainably?

If sustainability is a highly valued goal for a person, this person's actions are likely to be in line with (or to work toward reaching) this goal and, accordingly, this person will implement more sustainability-oriented behaviors than a person with a lower level of sustainability motivation. If bio-based products are perceived as supportive of sustainability, a person's attitude toward sustainability should determine this person's probability of consuming bio-based products.

Attitude toward Personal Sustainability

In our understanding, because the dominant criterion for identifying bio-based products is their potential contribution to sustainable development, the most important motivational driver to be analyzed on the consumer side is the consumer's attitude toward personal sustainability. Attitude and motivation are closely related empirically and conceptually (Peak, 1955) such that attitudes commonly account for the persistence and intensity of motivated behavior. Thus, in situations with free choices, attitudes are individual drivers of motivated behavior. For instance, in ethically highly relevant food politics, consumer choice is even seen as an expression of a political ideology (Kjærnes, 2012). Choosing a more vegetarian diet is certainly such a consumer choice that is empirically well in line with many other individual

sustainable choices and behaviors (Kaiser et al., 2020). Furthermore, an attitude toward personal sustainability will most likely be reflected in any of the domains of consumers' social responsibility (Heidbrink & Schmidt, 2011).

A person's attitude toward an object or goal (e.g., sustainability) is defined as the propensity for that person's actions to be in line with the goal (Kaiser et al., 2010). In this respect, our definition is rather straight forward and practical because it is defined by everything a person does or could do to personally foster sustainable development. While the specifics of how to best support sustainability through individual behavior might differ between people (e.g., whether it is more sustainable to buy a plastic-wrapped organically produced cucumber or an unpackaged regionally but conventionally produced cucumber), there is generally speaking a large common understanding of more and less sustainable behaviors that the majority of people share. This class of sustainable behaviors that is commonly acknowledged by most people in the same context (e.g., a nation) entails behaviors such as recycling, riding a bicycle instead of driving a car, or protesting against environmental pollution. In terms of ecological sustainability, these behaviors are what most people would consider behavior that helps, for instance, to mitigate climate change, which is after all related to the theoretical conception of sustainable development in the Agenda 21 (UN, 1992). In this conceptualization, an individual's attitude as the main driver of motivation (Peak, 1955) is not revealed by an introspective evaluation of the attitude object's valence (e.g., "I regard sustainability as very important") but rather by the extent to which the individual behavior is directed to serve that goal. Thus, from this perspective, the ubiquitous discussion of the so-called attitude-behavior gap (Vermeir & Verbeke, 2006) turns out to be a methodological issue or artifact (Kaiser & Schultz, 2009) rather than a challenge for behavior management.

In terms of social sustainability and related ethical issues, these behaviors are commonly defined by altruistic behavior as in the measure by Rushton et al. (1981). In our own research, we even found that more specific attitudes toward the social and ecological dimensions are very well-related (Neaman et al., 2018) and thus can be called attitudes toward sustainability on a practical personal level. Furthermore, an attitude toward sustainability is essential if one wants to promote sustainable development overall because it develops in early childhood (Otto et al., 2019), is rather stable over the course of life (Otto & Kaiser, 2014), and spills over to all sustainable behaviors that occur on a personal level (Henn et al., 2020).

The higher a person's attitude level, the more behavioral costs he or she is willing to accept for the consumption of bio-based products. As described above, there are different sources of behavioral costs. A bio-based product might come with higher financial costs, greater effort to process information about the product, its use, and its disposal, less functionality compared with a conventional product, or social disregard when deviating from the conventional norm. A person with a high level of attitude toward sustainability will probably see more advantages in a bio-based product than any disadvantages that the obstacles entail (i.e., the behavioral costs).

Appreciation for Nature

A related source of sustainability motivation for individuals might be their appreciation for nature (Evans et al., 2018). A person with a high level of appreciation of nature will likely also prefer nature-based products. A bio-based product with beneficial effects on nature compared with conventional alternatives will probably be preferred by such a person, whereas potentially harmful yet bio-based products (e.g., genetically modified organisms) will most likely not be preferred by someone with a great deal of appreciation for nature. We hypothesize that the more apparent the “naturalness” (i.e., the bio-base) of a product is, the more predictive a person’s appreciation for nature will be for choosing the product. A connection with nature has also been found to be positively related to sustainability motivation and has been shown to be a potential lever for its promotion (Otto & Pensini, 2017; Roczen et al., 2014). This is precisely where a unique opportunity for the bioeconomy and related product marketing might lie: If it is possible to address people’s connection with nature with bio-based products, sustainability motivation could be promoted through honest marketing. This will be in stark contrast to the prevailing but ethically questionable marketing practices used to sell animal products with concepts of naturalness that are far from of the actual reality behind these products (Borkfelt et al., 2015).

We have shown how attitude toward personal sustainability and appreciation for nature drive sustainability motivation which fosters sustainable consumption. However, this motivation is similarly important for product use, recycling, and sufficiently low consumption lifestyles. If bio-based products come with specific demands with regard to their use and disposal in order to exploit their potential for a sustainable bioeconomy, consumer motivation matters beyond the purchase decision. For example, in the case of bags for disposing of organic waste that are made of biodegradable plastic, consumers might conclude that these bags go into the organic waste stream and will optimally be composted. However, whereas the product is biodegradable under certain conditions, the retention times of kitchen and garden waste in industrial composting facilities with forced aeration are much shorter than the degradation time required to breakdown these bags. Thus, the optimal way to dispose of them is through household waste. In order to learn about the optimal use and correct disposal of bio-based products (i.e., the return of resources into the material cycle), a person’s motivation for sustainability is once again the key ingredient. Thus, if there is extra effort involved in correctly recycling bio-based products, sustainability motivation on the consumer side will also be important.

Bio-based products are not sustainable per se, and a sustainable bioeconomy depends on individual consumers to show sustainable consumption patterns. Despite being based on renewable raw materials, resources for the bioeconomy are limited, for example, by the availability of agricultural land. This means that in the bioeconomy, different bio-based products compete with each other for the same resource: biomass. Thus, the bioeconomy is not compatible with the current paradigm of unlimited growth of resource extraction and consumption. A reduction in the consumption of resources by consumers (as promoted by proponents of a sufficiency strategy; see, e.g., Princen, 2003) can help reduce this competition. Sustainable

behavior on the consumer side can be realized through sustainability motivation and external factors or costs that control relevant behavior and favor a sustainable lifestyle (Otto & Wittenberg, 2018; Verfuërth et al., 2019). Overall, sustainability motivation, which guides the preference for bio-based products, is an important factor of influence for determining people's engagement in the respective consumption behaviors (Otto et al., 2014). The motivation to engage in a sustainable lifestyle along with the behavioral costs of bio-based consumption should be the focus of investigations and programs that foster a sustainable bioeconomy.

Conclusion and Outlook

Several authors have outlined the interdependencies between society and the behavior of consumers and citizens within the economy (Schlaile, Klein, & Böck, 2018, 2020) or even sustainable development more specifically (Heidbrink & Schmidt, 2011). Herein, we went one step further by explaining the psychological mechanisms that drive choices and behavior in relation to the bioeconomy. With this paper, we provided an overview of the central factors that determine whether and under which circumstances an expansion of a bio-based economy can contribute to sustainable development. We introduced three push factors (regulatory push, civil society push, technology push) and three pull factors (regulatory pull, market pull, vision pull) that influence the transformation of the system toward a sustainable bioeconomy. We developed a typology of bio-based products that is oriented along the steps of the production process in order to show the ways in which and under which circumstances products of the bioeconomy can be assessed and labeled as sustainable products. Such a typology which is related to the underlying provision and production systems, is necessary to link such complex information to sustainable consumer decisions and behavior. In particular, two determinants of consumer behavior (i.e., behavioral costs and sustainability motivation) can be meaningfully linked to our typology of bio-based products. In addition, the acceptance and diffusion of novel technologies within the bioeconomy depend on societal and individual decisions that are guided by social norms and sustainability motivation. On the basis of our interdisciplinary review of the factors that influence the transformation of our economic system toward a sustainable bioeconomy, we draw the following conclusions:

- Both the bioeconomy (as a system that is based on biomass use) and bio-based products are not sustainable per se.
- In order to contribute to sustainable development, the purely technological foundations of a bioeconomy need to be combined with other concepts that focus on a sustainable economy (i.e., circular economy, green economy, and renewable carbon economy).
- There is a broad range of bio-based products with different characteristics concerning the raw materials that are used, the industrial processes that are applied, the time span of the period of use, and the options for disposal. Thus, sustain-

ability assessments of bio-based products are complex and outcomes can change substantially with changes in the overall system.

- In order to make sure that sustainable bio-based products and other sustainable consumption options are accepted in a society, risk assessment and transparent communication are key.
- Consumers' decisions are a decisive pull factor for a sustainable bioeconomy and are determined by two factors: behavioral costs and individual sustainability motivation.
- Lower behavioral costs increase the likelihood of sustainable consumer behavior. This can be achieved by improving infrastructure and by providing support for decisions (easily available information) and material or financial incentives.
- Sustainability motivation determines a society's level of sustainable consumption and also affects regulatory factors through democratic processes (e.g., political parties that are in favor of it with a sustainable bioeconomy on their agenda).

Two main issues need to be considered regarding the enhancement of the bioeconomy: First, the transformation of the economic system toward a bioeconomy is only ethically desirable if it contributes to the sustainable development goals that also include ethical aspects such as food security (Murray et al., 2017). In this context, direct and indirect effects of production processes and consumption behavior need to be taken into account. Second, the bioeconomy entails diverse innovative (bio-)technology options that are difficult to assess due to limited knowledge about possible effects. To decide today which technologies should be applied and which risks should be taken or not, studies in the field of ethics are necessary. Furthermore, research is needed in the field of bioeconomy, from both the natural and social sciences, in order to develop better and more comprehensive systems for assessments of sustainability and for the communication of the respective results.

Infrastructure, easily available information, material or financial incentives, and favorable social norms that influence behavioral costs and sustainability motivation are all crucial factors on the individual level for a sustainable bioeconomy as outlined above. In this final paragraph, we want to focus on information and its provision as support for consumers' and individuals' decisions because, at the present early stage of the bioeconomy, this is the first important step that also coincides with another unprecedented development, that is, digitalization and the development of intelligent decision support systems. Digitalization as a changing and much more efficient way to provide information has to be considered as an important means of informing people how to develop a sustainable bioeconomy (Uhle & Lange, 2017). Especially in reducing behavioral costs to inform oneself about the sustainability of a bio-based product, digital information and communication technology can help. Furthermore, to support other functions (e.g., cascading use), digitalization and the use of intelligent algorithms can fulfill a key function because it is necessary to organize and optimize a relatively complex system (Otto et al., 2021). Furthermore, to increase the sustainability of the bioeconomy, the life span of products should be extended by maintenance and repair; products should be reused by other consumers and finally recycled. On the production side, these processes are already being digitalized and optimized and will be even more so in the future. By integrating

users with the help of digital technology, the processes that are needed to create a sustainable bioeconomy can be further improved (e.g., on sharing platforms or through customer-to-customer services), thus raising the potential for sustainability. For example, the individualization and further development of products by consumers or prosumers—also with regard to sustainability aspects (Gähres et al., 2016)—will be fostered with the help of digital technologies which reduce behavioral costs to a level that is sufficient at least for some people. Thus, these new technologies that foster consumer involvement will also help so that the sustainability motivation of individuals can have much more impact on production and consumption directly.

In general, from the perspective of the dominant psychological paradigm of individual behavior, people choose the means that promise the highest personal benefit for achieving their goals (Ajzen & Fishbein, 2005). The realization of each individual goal and thus the consumption of resources by society as a whole is limited by the resources of time and money. Each person pursues multiple individual goals and only a few (if any) of them are in line with a sustainable bioeconomy. Only sustainability motivation is a direct driver of goals that can lead to more behavior in favor of a sustainable (bio)economy that is compatible with the limited resources on the planet. Over time, people seem to favor more individual sustainable behavior (Otto & Kaiser, 2014). Thus, it is our hope that more and more people will develop an integrative worldview that reconciles the rational pursuit of personal benefit and science with a sense of awe for nature, including other humans (Schramm, 2020).

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