



Research paper

Managing innovation in the bioeconomy: An open innovation perspective

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ABSTRACT

The transition towards a bioeconomy is increasingly viewed by both policy makers and scholars as one of the primary ways to reduce our dependency on fossil resources. However, socio-economic research on the transition towards the bioeconomy at the firm-level remains scarce. Specifically, studies approaching the bioeconomy from the technology and innovation management (TIM) concepts are particularly uncommon, although the importance of knowledge generation and innovation is considered crucial to make the transition towards a greener economy. In this study, we take a first step in addressing this issue by developing a set of guiding principles for the management of innovation processes in the bioeconomy comprised in three key issues: the relevant stakeholder groups and their importance in innovation development within the bioeconomy, the innovation network strategy and management, and organizational features considered prerequisites for collaborative innovation. This called for an identification of influencing factors specific to the bioeconomy context and the establishment of basic characteristics of innovation processes in the bioeconomy. The five identified influencing factors, the basic innovation process characteristics, and the guidelines and recommendations presented in this paper are based on insights derived from a four-staged literature research of the bioeconomy and TIM literature. In particular, we focused on the Open Innovation approach because of the evident fit between this approach and the requirements for innovation in the bioeconomy.

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1. Introduction

Increasing population, scarcity of resources and materials, environmental pressures, and climate change are issues that challenge our current fossil-based economy [1,2]. To help address these issues, Europe, the United States and countries such as Japan, India, Brazil, and China are investing heavily into the transition to a more sustainable economy: the bioeconomy [3,4]. Since the increase in attention in the early to mid 2000's [3,5,6], the bioeconomy concept has been given various definitions and its conceptualization is still evolving [7–9]. However, two aspects are shared by the majority of the different conceptualizations and definitions. One, the bioeconomy will rely on renewable biomass instead of finite fossil inputs for the production of a wide range of value-added products

such as food, feed, bio-based products and bio-energy [e.g. Refs. [6,7,10,11]]. Second, these products will be produced in bio-refineries following a cascade principle in order to maximally valorize the available biomass [e.g. Refs. [3,11,12]]. This entails that biomass is initially processed into high value products (e.g. pharmaceutical materials, chemicals) and the residues are then used for lower value applications until a minimum of waste remains at the end of the process [13–15]. The bioeconomy can thus be considered a collection of sectors and subsectors (e.g. food, feed, chemistry, energy, fuel, and pharmaceutical sector), working in conjunction to derive products from renewable biological resources originating from agriculture, fisheries and forestry [3,12].

Bünger (2010) [16] posits that over 90% of oil-based products could be replaced by biobased alternatives and projections show that by 2030 one third of chemicals and materials and 50% of the pharma market will be biobased [17]. Yet, few biobased alternatives to the current fossil-based products are already available [18], as illustrated by estimates in 2010 indicating that today's economy still relies heavily on fossil fuels with only 5% biobased economy in

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the European Union and 12% (excluding energy use) in the USA [9]. Moreover, the majority of the currently operational biorefineries are based on a single conversion technology and not on a cascading combination of technologies [3,15].

Realizing the bioeconomy, with biobased applications produced in biorefineries combining multiple conversion technologies, requires knowledge creation, research & development and innovation as its major cornerstones [2,3,19,20]. Despite the recognition of the importance of knowledge creation, R&D and innovation [e.g. Refs. [2,3,14]], managerial and economic work on how to develop the necessary (radical) innovations at the organizational or value chain level is scarce [18]. Existing publications on bioeconomy and biobased topics mainly originate from governmental institutions [e.g. Refs. [2,11,21,22]], often describing policy and strategic agendas [18]. The current bioeconomy related scientific literature primarily focuses on technical aspects (e.g., processing techniques) or consequences (e.g., environmental or social impacts) [7]. And although a number studies in literature on e.g. sustainable socio–technical transitions [e.g. Ref. [23]], sustainable business models [e.g. Ref. [24]] or sustainable business management [e.g. Ref. [25]] also approach bioeconomy issues from a socio-economic point of view, what is presently lacking is technology and innovation management (TIM) research guiding R&D and innovation efforts capable of realizing the future bioeconomy [18]. Yet, a large body of literature exists on technology and innovation management in sectors such as food and nutrition [e.g. Refs. [26–28]], biotechnology [e.g. Refs. [29–31]], and information and communication technology (ICT) [e.g. Refs. [32–34]], containing insights and knowledge relevant to guide the development of innovations in the bioeconomy context.

This paper aims to present such a set of guiding principles and recommendations based on relevant insights from this technology and innovation management literature, aggregated into three topics (Section 4). In order to do so, in Section 3, we first describe the specificities of an innovation process in the bioeconomy, based on five identified bioeconomy contextual factors that will determine the nature of innovation development in this context. But first, the methodology, a four-staged literature research, for the identification of these bioeconomy contextual factors, guiding principles, and recommendations is elaborated in the next section. The paper ends with a discussion on the contributions of the study to theory and practice in section five and some concluding remarks in section six.

2. Research approach

The development of the guiding principles and recommendations to organize innovation processes within the bioeconomy is based on a four-staged literature research. In the first stage, we carefully examined the bioeconomy literature in order to identify which aspects specific to the bioeconomy will influence the innovation process. Besides a search in scientific literature using the Science Citation Index (SCI) search engine, we also examined the gray literature on bioeconomy because many important documents on the topic originate from governmental institutions [e.g. Refs. [2,11,21,22]] published between the year 2000 up until the end of 2015 when the search was conducted. The keywords used in this search were different spellings of bioeconomy as well as different search strings of biobased economy and knowledge based bioeconomy, as the definition of the bioeconomy is still evolving and many authors treat these similar concepts as interchangeable concepts or even synonyms [e.g. Refs. [3,12,18]]. We included articles from English peer-reviewed journals and English texts from international organizations [e.g. Refs. [2,11]] or nations [e.g. Refs. [21,22]] that approach the bioeconomy from a socio-economic

point of view. Work tackling a bioeconomy related topic from a purely techno-scientific perspective were excluded from the study. Based on the included texts, we identified five factors that influence the characteristics of innovation processes in the bioeconomy.

Based on these factors and insights provided by these texts, in stage two of the research, the aim was to identify the most relevant literature for the development of the recommendations and guidelines. The Open Innovation approach was selected as main vein of technology and innovation management literature for the development of the paper. A more elaborate discussion on the identified specificities of innovation processes in the bioeconomy as a result of stage one and the reasoning for selecting open innovation as the main theoretical backbone for the development of the guidelines and recommendations (i.e. stage two) can be found in Section 3.

In the third stage, an extensive literature review of the Open Innovation literature was conducted. A search for different variations on Open Innovation was entered into the Social Science Citation Index (SSCI) search engine for the years 2003 (when the term Open Innovation was first coined by Henry Chesbrough (2003) [37]) to the end of 2015. In a first selection round, all articles published in peer-reviewed English-language journals with open innovation in the title, keywords or abstracts were withheld. In a second selection round, papers were selected for further analysis based on the title and abstract. Only papers on open innovation topics at the organizational level were included. In addition, we conducted backward citation searching of the reference lists of the included publications in order to identify further relevant publications in topics such as Innovation Adoption [e.g. Refs. [38,39]], Business Model Innovation [e.g. Refs. [40–42]], Innovation Systems and related Transition Management [e.g. Refs. [43–45]]. The same backward citation searching was applied in stage 1 on the bioeconomy texts in order to identify further relevant publications. During these three stages, over 200 publications were analyzed. In the fourth research stage, the recommendations and guidelines were synthesized into a model (Fig. 1) and discussed at length in individual interviews with eight innovation experts, to improve the validity of our analysis. The group of experts consisted of two innovation management researchers, one innovation consultant, three innovation managers, and one director of an innovation broker. Overall, these experts agreed with the majority of the findings and only provided a limited amount of additional information and suggestions (e.g. specific wording of certain results or comments on the presentation of the findings in the model).

3. Innovation development in the bioeconomy

The study of Golembiewski et al., 2015 [18] uses an approach similar to the one applied in this work. They identify three challenges the bioeconomy faces; a complex knowledge base, converging technologies, and issues concerning commercialization and market diffusion. They then analyze how the limited TIM research on topics related to the bioeconomy provides answers to these challenges. Building on this work and other publications on the bioeconomy, we identified five important factors that will impact the implementation and management of innovation development processes in the context of the bioeconomy. First, although some existing products and processes may only need some incremental, gradual innovations [2,40], the transition will mainly require diverse, **radically new and disruptive innovations** [1,2,18,19], such as redesigned business models [8,46], reconfigured supply chains [1], and the setup of entirely new supply chains between organizations from sectors currently un- or only remotely related [47,48]. Second, these innovations will be based on a **complex knowledge base**, from a variety of sciences and

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