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Toppinen, Anne

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Forest-based circular bioeconomy: matching sustainability challenges and novel business opportunities?

Toppinen, A.^a, D'Amato, D.^a, Stern, T.^b

a Helsinki Institute of Sustainability Science - Department of Forest Sciences, Faculty of Agriculture and Forestry, University of Helsinki, Finland.

b Institute of Systems Sciences, Innovation and Sustainability Research, University of Graz, Merangasse 18/I, 8010 Graz, Austria

Keywords: biorefinery; circular economy; consumer acceptance; corporate responsibility; innovation; sustainable business models.

1. The need for a social sciences perspective to forward the circular bioeconomy

This special issue addresses the current need to enhance the conceptual and empirical understanding of economic, societal and environmental challenges along with opportunities related to transitioning to a forest-based circular bioeconomy (Sanz-Hernández et al., 2019). Hosting a high degree of internal diversity, circular economy and bioeconomy are distinct concepts globally proposed at political, industrial and academic levels (D'Amato et al., 2017; Dietz et al., 2018). Different, yet somehow compatible recipes are suggested for changing consumption-production systems with the aim of forwarding a sustainability transformation (Schanz et al., 2019) while reconciling socio-ecological and economic goals.

The circular economy has its roots in industrial ecology and metabolism, and contemplates a rethinking of industrial processes and product life cycles towards a minimization of input and waste by promoting, inter alia, efficiency, recycling and reuse, while also hinting at ideas such as sufficiency and a sharing economy (Kirchherr et al., 2017; Korhonen et al., 2019). While the term bioeconomy maybe traced back to the “bioeconomics” introduced by Georgescu-Roegen, its current connotation is driven by policymakers (Vivien et al., 2019). The bioeconomy advocates industrial inputs (e.g. materials, chemicals, energy) to be substituted by or complemented with renewable biological resources, which are deemed to cause lower environmental impacts than non-renewables (Bugge et al., 2016). The primary productive sectors (forestry, agriculture and fisheries) hence play a fundamental role in providing resources in the bioeconomy, with research and innovation expected to enable such transformation (Ollikainen, 2014; Roos and Stendahl, 2015).

A convergence of these concepts has occurred recently, with certain scientific, grey and policy literature advocating a circular bioeconomy, which in its simplest form implies a parsimonious use of bio-based resources (Carus and Dammer, 2018; Hetemäki, 2017). Given their

complementarity, several sources have suggested that connecting the two concepts would be more effective at addressing complex societal goals compared to advancing them separately. This new term holds the promise of addressing the current limitations of both the circular and bioeconomy concepts (Hetemäki, 2017), while spurring more discussion about their role in sustainability transformations.

The updated European bioeconomy strategy (EC, 2018) refers to both concepts, confirming that these are currently becoming more intertwined, also in policymaking. The circular bioeconomy may be described e.g., as inclusively considering the sustainable sourcing of biomass, sustainable design and production of bio-based products, the recycling and re-use of resources, and the sharing economy features. In the forest sector context, an example of the synergies between circular economy and bioeconomy includes the principle of a cascading use of biomass (e.g. Mair and Stern, 2017), which prioritizes and optimizes (whenever economically/ecologically desirable and technically feasible) wood use through the life cycle to maximize social, economic and environmental values, and to minimize inevitable trade-offs.

Various ways of interpreting and facilitating circular and bioeconomy solutions are discussed in the literature (Bosman and Rotmans, 2016; de Jesus and Mendonça, 2018). Innovation is considered to play a vital role by renewing and improving existing utilization paths towards resource efficiency or by creating new products and applications, which substitute fossil-based counterparts. Accordingly, research activities have been fostered by thematic research programmes such as the Knowledge-Based BioEconomy section within the 7th framework programme or the Bio-Based Industries Joint Undertaking (<https://www.bbi-europe.eu/>). Despite the increasing number of scientific articles jointly mentioning ‘circular’ and ‘bioeconomy’, the research field appears to be largely covered by technical disciplines (Figures 1 and 2); the scientific and political debate on the conceptual and business strategic meaning of ‘circular bioeconomy’ is still in its infancy.

Therefore, the aim of this special issue is to build critical mass around the emerging understanding and operationalization of circular bioeconomy, especially from a social sciences perspectives and with a focus on forest systems.

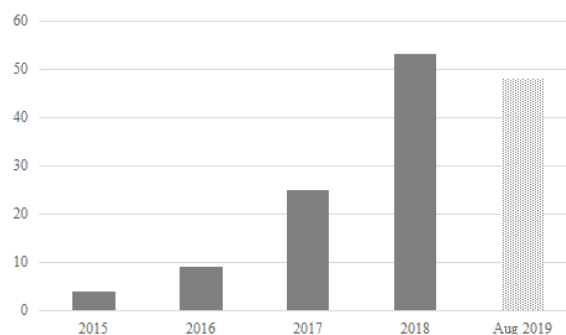


Figure 1. Number of scientific articles mentioning ‘circular bioeconomy’ in the title, abstract and keywords. Source: Scopus. (Note, the search was performed during August 2019, so the data do not include all the articles published in 2019.)

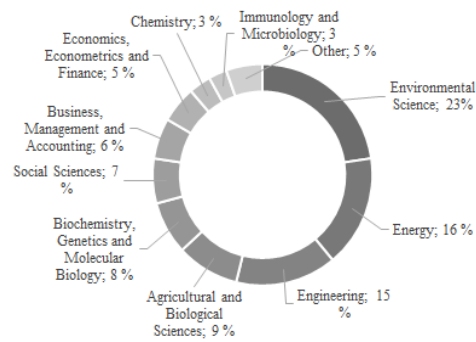


Figure 2. Breakdown of disciplinarity in the scientific articles mentioning 'circular bioeconomy' in the title, abstract and keywords. Source: Scopus. (Note, the search was performed during August 2019, so the data do not include all the articles published in 2019.)

2. Contribution of the special issue

This special issue is a collection of fourteen articles. The investigated topics range from scientific research networks to policy processes and business models, along with the integration of sustainability principles and social expectations in the practical implementation of the circular bioeconomy. We grouped the articles into three macro-categories: *discourse and governance*; *industry and business*; *biorefineries as an innovation platform*.

Discourse and governance

By combining quantitative network analysis and discourse analysis, Giurca (2019) unravelled emerging discourses within the forest-based circular bioeconomy in Germany. Results showed that this discourse was broad enough for multiple stakeholders to identify and legitimize their actions by it. According to Giurca (2019), this openness and diversity of organizational strategies and interests highlighted a series of internal conflicting and consenting storylines, which may ultimately affect the success of the bioeconomy project.

Lovric et al. (2019) mapped the structure of the European forest-based bioeconomy research network. Their results showed that the diversity of expertise explains the research collaboration structure. The network was concurrently centralized towards northwestern Europe and must be considered a relatively closed club of interlinked organizations. Furthermore, Lovric et al. (2019) stated that actors from primary and secondary processing are not involved in research topics more closely related to forestry.

As circular forest-based bioeconomy is predominantly a policy-driven concept, Ladu et al. (2019) investigated effective policy mixes to support the European forest-based circular bioeconomy by performing a fuzzy inference simulation. According to their analysis, a combination of 'climate mitigation policies' with 'sustainable forest management policies', 'R&D policies' and 'awareness raising policies' was most promising.

Falcone et al. (2019) combined a multi-level perspective and a SWOT analysis to identify weaknesses, opportunities and threats in the Italian forest sector. Strengths included a diffuse culture for woodwork and high-value products, compliance with certification, high mechanization, intra-sectoral networks in the processing phase and participation in the Italian National Forest Programme. Weaknesses included, but were not limited to inconsistent political conditions, excessive bureaucracy, a decreasing number of enterprises and employees and lack of forestry culture in local communities. Opportunities ranged from, inter alia, the development of innovative wood-based products and services, including e.g. construction, the improvement of forest infrastructures and the promotion of rural development in conjunction with activities that enhance local ecosystem services. Threats included the effects of climate change, the low price of international timber, the delocalization of wood-processing industries, irregular work conditions and a lack of long-term planning and policy coordination. In light of the SWOT analysis, the authors outline possible sector-level strategies for enabling a transition to a sustainable circular bioeconomy.

Based on their literature review of 41 peer-reviewed publications, Jarre et al. (2019) identified major influencing factors for wood cascading. The study detected over 50 interdependent factors affecting the implementation of wood cascading in terms of barriers and enablers. These included factors related to policy, market, technical implementation, environmental effects and stakeholder involvement. Factors influencing the realization of wood cascading are similar to the barriers and enablers identified by the literature on circular economy.

The analysis of Lazarevic et al. (2019) regarding wooden multi-storey construction (WMC) innovation system functions highlighted the importance of creative destruction and the science and technology push as a motor for promoting innovation. Using data from Finland, they assessed the innovation system around WMC to be in its early, formative stage. The niche WMC technologies were competing against the incumbent concrete frame construction system, while the materialized diffusion of WMC as an innovation has been rather slow.

Industry and business

The forest-based circular bioeconomy and its sustainability targets may foster the renewal of conventional business models. D'Amato et al. (2019) contributed to this research area from the perspective of small and medium enterprises, by identifying the business model archetypes and the key characteristics that enable value capture and delivery for various stakeholders. They concluded that the concept of forest-based circular bioeconomy was still weakly recognized and that business profitability was dependent on R & D support and subsidies.

Through a review of nearly 200 scientific articles published in international journals between 2010 and 2016, DeBoer et al. (2019) shed light on the firm-level link between the circular bioeconomy initiatives level and competitiveness. Environmental sustainability initiatives adopted by firms towards a circular bioeconomy were characterized as either regulatory or voluntary, while competitiveness was assessed in terms of market, reputational, operational and innovation performance. They found that the relation between such initiatives and competitiveness is not univocal, but complex and dependent on contextual factors. They thus

warned against the accepted notion of circular bioeconomy as a mechanism to foster company performance, and provided insight for future research on the issue.

Korhonen et al. (2019), instead, focused on the fibre-based packaging sector as part of a forest-based circular bioeconomy. Based on an assessment of stakeholder perceptions concerning the definition of bioeconomy and its future pathways, the results indicated that opinions differ broadly even within a rather narrow subsector; opinions ranged from seeing the concept as a ‘Trojan Horse’ (i.e. a new term for driving old political agendas) to a totally new way of organizing a sustainable future. Also based on the qualitative assessment of perceptions, Näyhä (2019) used the dynamic capabilities approach to analyze firm-level development in the era of circular bioeconomy. Finnish firms perceived themselves as forerunners of circular bioeconomy, based on the strong traditions in the pulp and paper industry. Bioeconomy was seen among industry managers as a response to the climate challenge, involving the substitution of fossil materials with bio-based and renewable materials. Firm capabilities associated with customer orientation and foresight thinking were seen as areas that have not fully developed among the analysed companies; this would open up opportunities for managerial development, as well as a line of inquiry for future research.

Using the scenario approach from Argument Delphi-based futures research, Kunttu et al. (2019) emphasized various industry structures in defining sustainability priorities and the profitability of by-product uses. Their findings also highlight substantial possibilities in cross sectoral cooperation instead of competition for raw materials, due to a clearly lower market value and more limited side stream usage possibilities than of virgin fibre. They also voiced that circular and bioeconomy policies should more explicitly consider by-product-related targets.

Biorefineries as an innovation platform

Temmes and Peck (2019) investigated whether forest biorefinery projects explicitly integrate social or political expectations linked to a reflexive conceptualization of the circular bioeconomy. Their findings identified, in both the literature and in practice, a clear lack of formulation or application of the circular bioeconomy conceptual base to biorefinery projects, which results in what they call a ‘conceptual blurring’. Hence, they concluded that clearer framing was needed to avoid undermining trust and perceptions.

Based on a pan-European survey, Hedeler et al. (2019) map the current pilot and demonstration projects of forest-based biorefineries. They found that the knowledge created and diffused at lower stages of technological maturity was technologically oriented. Instead, higher stages of technological maturity were characterized by activities related to non-technological knowledge and system build-up. Recommendations highlighted by the authors included enhancing accessibility of the projects and collaboration of various actor types.

3. The way forward

The fourteen articles included in the special issues mainly focused on the European context, which is naturally a limitation for building an evidence base for a global phenomenon such as the circular bioeconomy (Dietz et al., 2018; D’Amato et al., 2017).

Nonetheless, a series of barriers and recommendations for the forest-based circular bioeconomy emerged from the articles, at various levels of the analysis (Table 1). Barriers regarded the lack of shared understanding and acceptance of the circular bioeconomy, the poor levels of capacity and cooperation/transfer across companies and industries, the fragmented and precarious policy environment along with the embryonic stage of markets. Recurrent issues across the studies were related to more efficient utilization of side streams, to the interplay between industry renewal strategies and competitiveness, and to the circular bioeconomy in relation to overall sustainability challenges.

Consequently, recurring recommendations were oriented towards further development and improvement: (i) the circular bioeconomy conceptualization and its link to sustainability; (ii) the functioning of innovation systems, including technological and information sharing across actors; (iii) the effective circularity in current processes; (iv) the financial support (especially addressing the ‘valley of death’) and (v) the market momentum.

Table 1. Barriers and recommendations for the forest-based circular bioeconomy as identified by the articles in the special issues.

Paper	Identified barriers	Suggested recommendations
Brunnhofer et al. (2019)	Investment risks and price competition were identified as problematic for the biorefinery transition in the European pulp and paper industry.	Highlighted suggestions included the need to address the question of appropriate investment costs and product price differences for biorefinery development.
D’Amato et al. (2019)	The concept of circular bioeconomy was still weakly recognized among small and medium enterprises (SMEs). The profitability of circular bioeconomy business was perceived as dependent on subsidies.	The following steps were recommended for moving forward: further conceptualization of the circular bioeconomy economy; evaluation of strategies to respond to ‘valley of death’ situations; incentives and support towards technological compatibility and partnerships across traditional and circular bioeconomy activities; evaluation of necessary conditions for more ‘radical’ circular bioeconomy activities, e.g. those promoting reduced user consumption or explicitly tackling sustainability challenges.
Falcone et al. (2019)	Weaknesses of the Italian forest sector were identified e.g. in reliance on imported biomass, inconsistent political conditions, excessive bureaucracy, abandonment of silvicultural practices, a decreasing number of enterprises and employees, and lack of forestry culture in local communities. Climate change, low timber prices, industry delocalization, irregular work conditions and lack of long-term planning and policy coordination were the identified threats.	Potential sector-level strategies were identified: promoting and improving environmental and forest planning tools; investment in forest infrastructure; entrepreneurship programmes for forest professionals; innovative forest-based value chains for rural income.

Giurca (2019)	Conflicting and consenting storylines emerged from the wood-based bioeconomy discourse in Germany, but these were limited in capturing the complexity of the bioeconomy concept and that of sustainability issues.	Two options were recommended for the way forward: (i) to maintain the openness of the bioeconomy concept to allow integration of various actors, risking opposing visions and potential conflicts, or (ii) to strengthen the focus the network towards a shared vision and stronger target focus, even though compromising network diversity.
Hedeler et al. (2019)	Insufficient knowledge diffusion (compared to technological development) was identified as an issue in pilot and demonstration projects of forest-based biorefineries.	Suggestions to address 'valley of death' situations when transitioning to a circular forest bioeconomy included improving accessibility of pilot and demonstration projects, and collaboration of various actor types. Research-wise, a need was identified to further explore strategic decisions, actor motivations and contextual factors influencing pilot and demonstration projects.
Jarre et al. (2019)	Problem issues identified by the cascading literature identified included a lack of both policies and a market mechanism for cascading wood use.	Identified lines for future research included better understanding of causal relationships between the influencing factors, system dynamics and path-dependencies, actor coalitions and policy formation.
Korhonen et al. (2019)	Views concerning the bioeconomy differed broadly even within a narrow subsector, such as packaging. This also includes negative perceptions.	Future research lines were suggested pertaining to the investigation of how user values and behavioural patterns translate into the most sustainable packaging solutions.
Kunttu et al. (2019)	In regard to the utilization patterns of by-products in wood-based industries in Finland, the unstable political environment emerged as an issue hindering commercial piloting of new systems technologies other than pulp and bioenergy.	Communication between industry, research and policymakers was identified as an important factor in enabling the development of regulations and funding opportunities for pilot projects. Policy needs were identified in terms of a more explicit target setting for the utilization of side streams.
Ladu et al. (2019)	Policies related to climate change mitigation and to sustainable forest management were deemed to strongly influence the supply side. However, the competitiveness of high value-added products was strongly found to depend on sustainability and innovation capacity.	Suggestions for a policy mix towards a circular and innovative forest-based economy included leveraging climate mitigation with sustainable forest management policies, R&D policies and awareness raising.
Lazarevic et al. (2019)	Innovation systems in Finnish wooden multi-storey construction (WMC) were identified to still be at a formative phase.	Creative destruction in science and technology was highlighted as a push motor for WMC innovation.
Lovrić et al. (2019)	The European forest-based bioeconomy research network is characterized by high centralization of capacities in northwestern Europe; it is also not well integrated, with primary and secondary processing networks found to be separate research fields of their own.	Policy recommendations were articulated in terms of future support for research projects with stronger organizational involvement from eastern Europe, and with a better coverage of multiple supply chain categories.
Näyhä (2019)	Lacking firm capabilities in both customer orientation and foresight thinking were identified as the main issues in the transition of Finnish forest-based companies to the circular bioeconomy.	Identified avenues forward included an innovative and flexible organizational culture, communication and marketing skills, future-oriented strategic thinking and a stronger stakeholder and sustainability orientation.

DeBoer et al. (2019)	Hindering elements were identified as: a lack of shared conceptualization of circular bioeconomy; methodological challenges in assessing willingness to pay for environmentally sustainable products and services; lack of firm and stakeholder cooperation; need to evaluate concrete contribution of circular bioeconomy to firm competitiveness and overall global net sustainability.	Improvement areas for research were outlined in terms of more nuanced, specific and clear analyses of the circular bioeconomy discourse and of its potential links with competitiveness.
Temmes and Peck (2019)	Emerging problematic issues were identified in terms of a lack of formulation or application of the circular bioeconomy conceptual base to biorefinery projects.	Solutions outlined included a clearer framing to avoid undermining trust and perceptions.

Questions of trade-offs within and between sustainability dimensions remained underemphasized in the articles. For example, the link to strong sustainability and the United Nations Sustainable Development Goals towards realizing the circular bioeconomy is touched upon, but implementation at the practical level clearly deserves further research attention (as also recently pointed out by D'Amato et al., 2019; Liobikiene et al., 2019).

Biorefineries are considered a central technical platform of a circular bioeconomy (Clark and Deswarte, 2015). Lignocellulosic biomass, such as wood, is the principal feedstock in the development of biorefineries (Wenger and Stern, 2019). In the future, forest-based industrial transformation towards more ambitious circularity is to be expected, giving impetus to further analysis of the innovative use of side streams, for example. Nevertheless, research on circular bioeconomy business models and business model innovations is clearly at a very initial stage (see also Rauter et al. 2017). Business model development to better account for circularity essentially calls for stronger cross-sector collaboration (see also Guerrero and Hansen 2018), and related communication and information challenges also merit stronger emphasis in future research.

Developing policies and strategies, and increased funding in research and innovation programmes alone will most likely not be enough to realize the visions of a forest-based circular bioeconomy, which successfully contributes to sustainability (Ladu et al., 2019). A lack of recognition and common understanding of the concept remain major barriers identified in this special issue (e.g. D'Amato et al., 2018; Giurca, 2019). This is true even within specific subsectors (Korhonen et al., 2019). Moreover, investment risks mainly reflecting over-demand in the relevant side product markets (Brunnhofner et al., 2019) should be addressed from an industry perspective. Further research is needed to identify leverage points for system transformation within the forest-based circular bioeconomy (e.g. Schanz et al., 2019). Strengthening environmental policies, such as efficient carbon taxing (Aldieri et al., 2019), is a likely precondition for a more effective circular bioeconomy policy mix (Ladu et al., 2019).

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