



Circular bioeconomy: Actors and dynamics of knowledge co-production in Finland

D. D'Amato^{a,b,c,*}, K. Korhonen-Kurki^{a,b,c}, V. Lyytikäinen^d, B.D. Matthies^d,
A-I. Horcea-Milcu^{b,e}

^a Department of Forest Sciences, Faculty of Agriculture and Forestry, University of Helsinki, Finland

^b Helsinki Institute of Sustainability Science, University of Helsinki, Finland

^c Finnish Environment Institute, Environmental Policy Centre (Suomen ympäristökeskus – SYKE), Finland

^d Alumni, University of Helsinki, Finland

^e Institute for Advanced Sustainability Studies (IASS), Potsdam, Germany

ARTICLE INFO

Keywords:

Bioeconomy
Circular economy
Forest
Science-policy
Sustainability transformations
Sustainability transitions

ABSTRACT

The circular bioeconomy is a highly scrutinized concept in Finland and internationally, with a high degree of polarization regarding forest utilization rates and distrust between certain actors. This offers an interesting case for an exploratory analysis of issues associated with knowledge co-production. Knowledge co-production entails the integration of different knowledge types and collaboration across multiple societal actors with potentially conflicting viewpoints and agendas. We interviewed key organizations operating at the nexus of science and policy in the processes of knowledge co-production regarding the circular bioeconomy in Finland, including representatives from ministries, universities, research institutes, innovation promoters, and interest organizations. Using qualitative content analysis, we assessed the actors' tacit knowledge and perceptions regarding 1) their role in knowledge co-production across knowledge types; 2) elements enabling knowledge co-production; and 3) tensions and needs/opportunities of knowledge co-production. To frame our data collection and analysis, we particularly draw from recent sustainability science literature on knowledge types in co-production. The findings reveal that the three main knowledge types – lay, expert, and scientific – are acknowledged by all actors, but are dealt with, to different extents, according to the roles played by different actors in the process of knowledge generation. Collaboration was reported to be largely project-oriented, enabled by funding, similar mindsets, and organizational/individual networks. Tensions included conflicting ideological positions held by various actors in the circular bioeconomy, mainly hampering the co-production of normative/target knowledge; funding-induced gaps and risks in inter-actor cooperation, mainly affecting process/system knowledge of the circular bioeconomy; and gaps and difficulties in cross-sectoral and cross-discipline engagement, mainly affecting predictive/transformational knowledge. Knowledge synthesis, policy-supporting knowledge, and transformational knowledge were perceived by several interviewees to be important avenues towards improving the sustainability potential of the Finnish forest sector.

1. Introduction

The circular bioeconomy is a globally relevant sustainability concept that combines and refines the individual concepts of circular and bioeconomy (Carus and Dammer, 2018; European Environmental Agency, 2018; Hetemäki et al., 2017; Stegmann et al., 2020). In its more general definition, the circular bioeconomy promotes economic development and industrial renewal through the substitution of fossil resources in a number of sectors (e.g. forest, agri-food, construction, packaging,

textile, chemical, energy) through the development of bio-based products and services. Innovation at the product, process, and organizational levels fosters such a shift, which is also coupled with an efficient and circular use of material and energy. However, several scholars have raised concerns about the concrete contribution of the circular bioeconomy to pursuing ecological and social sustainability goals (El-Chichakli et al., 2016; Kröger and Raitio, 2017; Pfau et al., 2014). The potential for such a contribution is dependent on ensuring the sustainable sourcing and use of biomass and on the regional and global

* Corresponding author at: Department of Forest Sciences, Faculty of Agriculture and Forestry, University of Helsinki, Finland.

E-mail address: dalia.damato@helsinki.fi (D. D'Amato).

<https://doi.org/10.1016/j.forpol.2022.102820>

Received 24 June 2021; Received in revised form 16 May 2022; Accepted 15 August 2022

Available online 1 September 2022

1389-9341/© 2022 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

distribution of resources and prosperity (Issa et al., 2019).

Sustainable biomass sourcing means addressing the expected trade-offs between increased biomass requirements and biodiversity conservation (which underpins the delivery of key regulating and cultural ecosystem services). The sustainable use of biomass pertains to the competition between biomass uses such as food, feed, biomaterial, and bioenergy. Technical avenues for solving these problems include improvement of land-use practices, prioritizing food and higher value fibre-based products, cascading of material and energy, and deployment of residues and biowaste along with alternative biomass sources (e.g. algae, fungi) with a lower land-use footprint (European Environment Agency, 2018).

Value redistribution in the bioeconomy includes a domestic and international dimension. The circular bioeconomy is expected to create 'modern jobs in rural areas, thus counteracting both the limited geographical distribution of accessible fossil resources and the current concentration of job and income opportunities in urban areas' (Lewandowski et al., 2017, p. 14). However, concerns remain regarding the circular bioeconomy replicating power structures and creating new forms of extractivism, nature commodification, and inequality (Ramci-ovic-Suominen and Püzl, 2018). In the context of European forest systems, for example, the political arena is characterized by interest coalitions, such as those leveraging the bioeconomy to frame economically profitable forestry (with forest-rich northern countries playing an important role) against those advocating for a 'gentler' version of the circular bioeconomy, inclusive of environmental intangible values (Wolfslehner et al., 2020).

The circular bioeconomy has also been criticized as an insufficiently radical and transformative solution against complex sustainability challenges. Some scholars have pointed out the technocratic and market-driven nature of the circular bioeconomy, which places excessive responsibility on governments and industries (with agro-food and pulp and paper incumbents as key players) against the role of smaller actors and citizens (Befort, 2020; Holmgren et al., 2020; Leopold et al., 2019; Mustalahti, 2018). The circular bioeconomy – as currently mainstreamed – embraces the growth paradigm, although scholars have attempted to advocate compatibility with degrowth and post-growth ideas (Giampietro, 2019; Vivien et al., 2019).

While national (circular) bioeconomy policies are being implemented in several countries worldwide (Dietz et al., 2018), the concept has gained particular significance in Finland, both in public and private decision-making, and in academia. This emphasis is reflected, for example, in the critical mass of scientific research produced in Finland, especially in the context of a forest-based (circular) bioeconomy (D'Amato et al., 2020; Holmgren et al., 2020; Lovrić et al., 2020). The Finnish bioeconomy comprised approximately 13% of the total value added to the economy in 2019, with a contribution of 26 billion euros and over 300,000 people employed. The forest sector represents nearly 40% of the total output of and value added to the Finnish bioeconomy (LUKE, 2019). Bioeconomy policy and strategies in Finland are closely related to industrial long-term competitiveness and renewal, especially for the forest industry (Holmgren et al., 2020; Näyhä, 2019). Product diversification, high value added, and customer sustainability awareness are the expected leverages and opportunities of change for the pulp and paper industry in the bioeconomy (Toppinen et al., 2017). Government institutions, such as ministries, have a catalyst role in implementing the bioeconomy in Finland (Korhonen et al., 2018a), and large and smaller firms are increasingly aligning with the concept (Antikainen et al., 2017; Näyhä, 2019; Toppinen et al., 2020).

The development of the Finnish circular bioeconomy, however, implies several unresolved issues that persist in the public discourse and affect how knowledge in the field is generated, collated, and synthesized collaboratively by multiple actors. These particularly regard the use of harvested wood in bio-based value chains (including use in energy production, which is another currently debated issue) versus the maintenance of Finnish forest resources for climate regulation. Forest

utilization levels are an ongoing debate in Finland, and a growing divide exists among forest policy actors as to the desirable and appropriate pathway towards sustainability (Kröger and Raitio, 2017). Existing policies favour increasing timber production and forest bioenergy (Makkonen et al., 2015). However, forest management is also viewed as having multiple objectives such as carbon storage (Makkonen et al., 2015) and biodiversity conservation (Eyvindson et al., 2018). The need to reconcile diverse objectives in Finnish forest management highlights policy conflicts between the circular bioeconomy and conservation interests (Eyvindson et al., 2018; Kröger and Raitio, 2017; Makkonen et al., 2015; Norton et al., 2019). In addition to competing and conflicting agendas and objectives, a lack of trust among actors has been identified as a main characteristic of forest policy in Finland (Rantala and Primmer, 2003).

In summary, developing and implementing knowledge concerning the circular bioeconomy requires high interdisciplinarity and cross-sectoral collaboration (Knierim et al., 2018; Winkel, 2017), and – given its highly controversial nature related to economic growth and sustainability – also requires multiple actors to cohere from conflicting viewpoints towards a shared understanding. The aim of our study is to explore the emerging phenomenon of the Finnish circular bioeconomy and its implementation by focusing on inter-actor dynamics in knowledge co-production at the nexus of science and policy. Knowledge co-production refers to the collaboration of academic and non-academic actors (Mauser et al., 2013) to achieve scientific and social impacts (Moser, 2016). 'Co-production is an inherently political act' and requires individuals and organizations to 'acknowledge their role in motivating social and political change and attend to the tensions and tradeoffs therein' (Wyborn et al., 2019, p. 339).

To our knowledge, little to no empirical studies exist exploring such dynamics in the circular bioeconomy. Our research questions for this study are as follows.

1. How do actors perceive their role in knowledge co-production, and what types of knowledge (i.e. lay, expert, scientific) are co-produced and dealt with?
2. What elements enable knowledge co-production and thus influence outcomes?
3. What are the tensions and needs/opportunities of knowledge co-production among actors?

2. Conceptual background

Research on co-production has emerged at the intersection between public administration, science and technology studies, and sustainability science, and the issue of power has been a central element in understanding co-production from all three scientific perspectives (Miller and Wyborn, 2020). In the context of public administration, co-production referred to the contribution and collaboration of citizens with governmental agencies to deliver public goods and services, including the co-production of environmental policies and outcomes related to the management of common pool resources (e.g. Ostrom and Ostrom, 1977; Parks et al., 1981). Power manifests for instance in the relations between governmental agencies and multiple societal actors. Key authors in science and technology studies, such as Jasanoff (2004) and Latour (1990), have further suggested that knowledge is inseparable from the context where it is produced, and that there is interdependence between knowledge and action. Science is thus seen as the product of research as well as politics. In sustainability science, the focus of co-production is on adaptive socio-ecological system research, where co-production is a means to engage scholars and stakeholders in defining problems and exploring solutions. Questions of power and legitimacy are central to stakeholder engagement for knowledge co-production (Cash et al., 2003; Turnhout et al., 2020), a process during which different kinds of tensions can emerge (Ojanen et al., 2021).

In this manuscript we particularly refer to the literature rooted in

sustainability science. According to Forsyth (2003, p. 104), co-production is 'the processes by which knowledge, including scientific knowledge, is framed, collated, and disseminated through social interaction and change, and how such knowledge also impacts upon such change'. He continues: 'the important principle of co-production is that it is a dynamic process, in which knowledge and society continually shape each other'. Miller and Wyborn (2020, p. 320), suggest that 'co-production encompasses many ambitions, namely to involve multiple participants (scientists, policymakers, civil society, etc.) to produce multiple outcomes, including new knowledge, new ways of integrating knowledge into decision-making and action, and, most importantly, new outcomes in the world'.

Co-production of knowledge entails the integration of various knowledge types (Stepanova et al., 2020). Strategies for successful integration include, inter alia, creating a shared understanding of the problem, setting common research objectives, collaborative knowledge production processes, and joint synthesis, implementation, and communication of results (Lang et al., 2012; Polk, 2015). The requirement of commitment and trust between actors, both individual and institutional, is central to creating productive integration processes and going beyond the cognitive dimension towards including diverse ways of acting and building a group identity (Chapman and Schott, 2020; Pohl et al., 2021; Stepanova et al., 2020). Integration, intended as collating and synthesizing 'various knowledge pieces into something new' also implies the recognition of power relations between various groups of actors (Apetrei et al., 2021, p.12).

To frame the data collection and analysis in this study, we refer to the conceptualization proposed by Stepanova et al. (2020). The authors propose a typology of knowledge based on three analytical levels: context (informal/experiential, formal), actors (e.g. individuals, professionals, decision makers, academics with lay, expert, or scientific knowledge), and practice (normative/target, process/system, predictive/transformational). Formal knowledge, in opposition to informal/experiential knowledge, is deposited in written documents, norms, and procedures. Along the informal–formal spectrum, lay knowledge is based on observation, practice, or experience; expert (including administrative, managerial, indigenous) knowledge is used in formalized decision-making; scientific knowledge is formalized by scientific methods. Normative/target knowledge regards appropriate goals for planning, process/system knowledge concerns current states and processes, and predictive/transformational knowledge involves the investigation of future trends.

3. Method

Our findings are drawn from the content analysis of interview data with representatives of key organizations involved in knowledge generation concerning the circular bioeconomy in Finland, with a focus on the science–policy interface. The sampling process was based on a social network analysis by Korhonen et al., (2018a). According to that study, the Finnish forest sector or wood-based bioeconomy network is characterized by high density, with 57 key actors. A 'brokerage triangle' of three organizations forms the central nodes consisting of the Natural Resources Institute Finland (LUKE), the Ministry of Economic Affairs and Employment of Finland, and the Chemical Industry Federation of Finland. All actors within the network are predominantly from the research, government, and industry categories. Periphery actors include researchers, non-governmental organizations, and consultancies. Based on Leventon et al. (2016), we considered the following recommendations to identify relevant stakeholders for our qualitative study: opening up pre-existing networks, considering the role stakeholders play in the specific context, and considering the sector, composition, interests, and ownership of each stakeholder.

We selected seventeen organizations to narrow the focus on actors operating at the science–policy interface in the context of forest management. Interviews were conducted with representatives from fifteen

of the seventeen key actors identified (Tables 1 and 2). At least one key representative for each organization was interviewed between November 2019 and January 2020. All interviews were conducted by one of the authors, lasted approximately 45 min, and were audio-recorded and transcribed by a professional service. The limitations of the data collection method used in the study are related to the elicitation of self-reported information and other opinions and perspectives from the interviewed actors. Typically, information that is familiar and desirable or less sensitive is more likely to be actively disclosed in interviews (Grimm, 2010), even though this is mitigated by the confidentiality guaranteed during the interviews.

At the beginning of the interview, a brief definition of the circular bioeconomy was provided. The circular bioeconomy was defined as having value chains (1) where input materials are predominantly biological and renewable; (2) where the material lifecycle is closed loop or cradle-to-cradle, i.e. material flows are circular; (3) at local and/or global scales with a single actor or multiple actors; and (4) with the key aim of creating or co-creating value-added propositions. This definition was purposefully broadly framed, in line with current understandings of the circular bioeconomy (Carus and Dammer, 2018; D'Amato et al., 2018), and it created a contextual background for the interviewees to discuss their personal and their organizations' perspectives on the circular bioeconomy.

The interviews were conducted using a semi-structured questionnaire, organized in three parts, and largely based on the notion of co-production by Stepanova et al. (2020) described in Section 2. Accordingly, interviewees were also provided with definitions for knowledge co-production and knowledge types. In the first part of the questionnaire, actors were asked to self-identify their organization on a continuum ranging from knowledge producer to knowledge user. The term 'user' was explained to each actor as inclusive of knowledge brokerage and integration. Interviewees were also asked to self-identify their organization's independence in both the production and utilization of knowledge. Actors were also requested to identify how their organization produced and utilized formal and informal knowledge, including scientific and expert knowledge, and lay knowledge (definitions in Section 2.1). Data in the first section were collected on a 7-point Likert scale. In the second part of the questionnaire, interviewees were asked to identify other key actors with whom their organization had collaborated with concerning the circular bioeconomy. This bound the time period to be within the year range when this concept was pertinent, including the last two national Government Programmes (2015–2019; 2019–2023). For each actor, the interviewees were asked to discuss the reasons, nature, and implications of collaboration. The third part of the questionnaire was future-oriented, focusing on gaps, barriers, and opportunities for collaboration on the circular bioeconomy. Despite the three-part structure of the questionnaire, respondents often answered freely, without prompting from the interviewer. Probing and follow-up questions were asked at all stages of the interview to explore certain topics or actor-to-actor relationships in greater detail.

Table 1

Categorization of interviewed actors based on their societal role. At least one key representative was interviewed for each organization.

Actor category	Interviewed organizations included in the sample
Ministries	Ministry of Agriculture and Forestry, Ministry of Economic Affairs and Employment, Ministry of the Environment.
Universities	Aalto University, University of Eastern Finland, University of Helsinki.
Research organizations	European Forest Institute (EFI), Finnish Environment Institute (SYKE), Natural Resources Institute Finland (LUKE), Technical Research Centre of Finland (VTT).
Innovation promoters	Business Finland, The Finnish Innovation Fund (Sitra).
Interest organizations	Central Union of Agricultural Producers and Forest Owners, Forest Industry Association, Forest Stewardship Council (FSC).

Table 2
Categorization of interviewed actors based on their attitudes towards the bioeconomy.

Pro-bioeconomy attitude	Interviewed organizations included in the sample
Cautiously interested	Aalto University, Forest Stewardship Council (FSC), Ministry of the Environment, University of Eastern Finland, University of Helsinki.
Cautiously supportive Highly supportive	European Forest Institute (EFI), Natural Resources Institute Finland (LUKE), Technical Research Centre of Finland (VTT), Business Finland, Central Union of Agricultural Producers and Forest Owners, Forest Industry Association, Ministry of Agriculture and Forestry, Ministry of Economic Affairs and Employment, The Finnish Innovation Fund (Sitra).

The qualitative analysis was supported by the software ATLAS.ti v. 9. To improve reliability, each author read and coded a sub-sample of the interview material, and the codebook was developed iteratively with inputs from three authors. The whole material was eventually read through thoroughly and coded by a researcher with previous experience of content analysis (Lyytikäinen et al., 2021). The analysis was abductive and largely based on the knowledge typology described in Section 2, which was used to code part of the data (i.e. findings in Sections 3.1 and 3.3).

4. Findings

4.1. Actors' roles and knowledge types in co-production

Ministerial representatives were coherent in interpreting the role of ministers as knowledge 'users' (i.e. more oriented towards the integration and brokerage of existing knowledge), while universities and governmental research institutes self-reported themselves to be concerned with the production of new knowledge. Innovation promoters

and interest organizations fell in between. All representatives suggested their respective institute to be more collaborative than independent concerning knowledge production, except for the two industry/owners/producers/associations. Opinions were divergent regarding the level of collaboration in knowledge integration and brokerage for ministries, universities, and research institutes, while innovation promoters and interest organizations saw themselves as more collaborative in that regard.

Across all actors, lay knowledge was the least produced or used, while expert knowledge was the most produced, and scientific and expert knowledge were the most used (Fig. 1). Research institutes and interest organizations dealt more with lay knowledge compared to the other actors. Universities and research institutes dealt more with scientific knowledge, while ministries were self-reportedly the actors that produced and used less scientific knowledge compared to the others but relied more on expert knowledge. One ministerial representative noted that 'we are users of [knowledge] because we need all the best information and scientific knowledge to make good decisions or prepare good decisions for politicians. That is our role.' Innovation promoters and interest organizations were more involved in the production and use of expert knowledge. Some ministerial representatives and representatives of governmental institutes, for example, mentioned interest organizations as important knowledge producers delivering statistical information.

Based on our analysis, the role of research institutes in co-producing knowledge about the circular bioeconomy differed slightly from the role of universities. University representatives perceived themselves to have fewer opportunities to collaborate with the ministries compared to research institutes. Innovation promoters saw themselves as brokers of knowledge, particularly helping the forest industry to innovate and increase its value. One interviewee explained that forerunner small and medium enterprises (SMEs) follow what larger companies do in the context of the energy sector and circular bioeconomy metasector, but a large part of SMEs is currently unaware of this concept (i.e. the circular

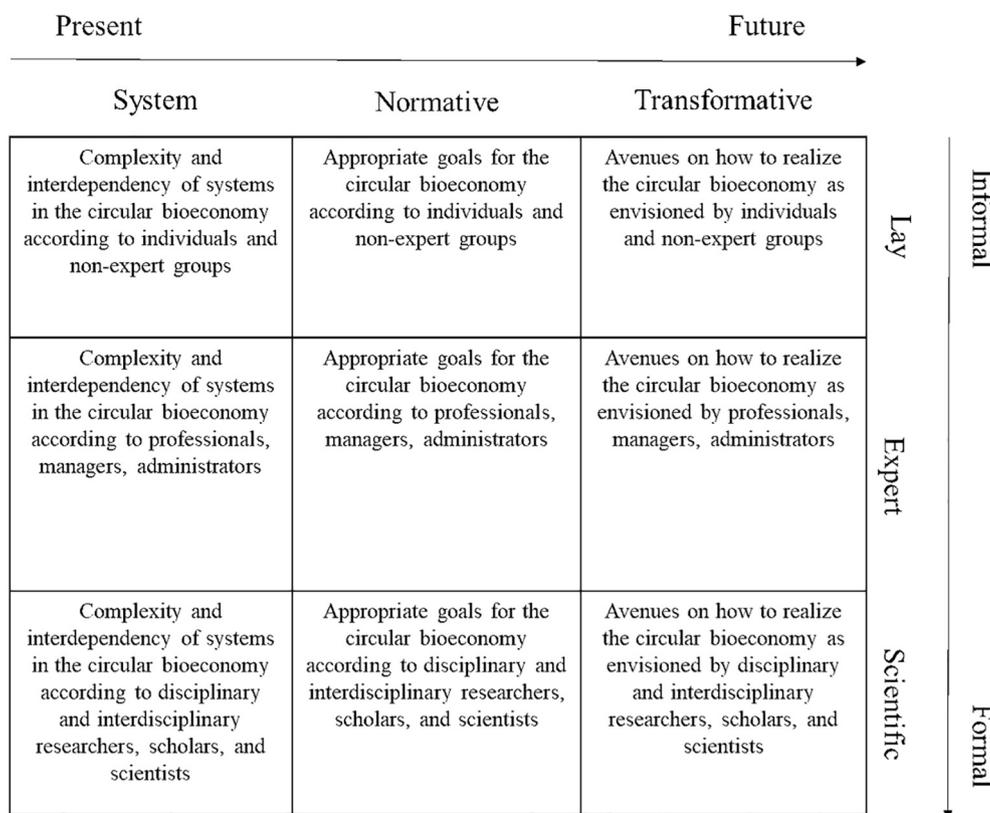


Fig. 1. Conceptual framework used for data collection and analysis (own representation adapted from Stepanova et al., 2020).

bioeconomy), which emphasizes the need for the brokering role of innovation promoters.

4.2. Elements enabling knowledge co-production among actors

The interviews revealed a multifaceted situation regarding elements enabling knowledge co-production, which is fundamentally interlinked with the nature and strength of relations among actors. Enabling elements that emerged from the interviews were related to financial resources (i.e. project-oriented joint funding), similar agendas, and mindsets, and official institutional relations or individual professional networks.

Collaboration was in most cases based on research projects with joint funding, particularly cooperation among universities and between universities and research institutes. However, the importance of similar formae mentis also emerged as a prevalent element in the interviews, as co-production, at least at the organizational level, appeared to be more consistent between actors with similar agendas. One interviewee representing a research institute explained: 'it's not just that you decide that we are now partners. A few projects must be completed together and, of course, by sharing a [common] target.' Similarly, a representative of a university shared that '[m]aybe often the collaboration is based on getting money. And that is, of course, a good reason to collaborate, but I have found that it's even better if you first have the willingness to do something together, and that is not so much based on money.'

Organizational relations were also mentioned as key channels of collaboration. Knowledge co-production between ministries and organizations with whom they have institutional relations (e.g. governmental research institutes, innovation promoters) appeared to be more continuous, while co-production between universities, innovation promoters, and interest organizations was more based on ad hoc working groups and research projects. The representative of the Ministry of Agriculture and Forestry highlighted the close ties with LUKE, which is a part of their administrative branch. Similarly, the representative of the Ministry of Environment emphasized SYKE as a partner in co-production: 'they are experts, and you can call them and they give you an answer quickly, or then they put together some summary of what is known at the moment or they then do actual research'. The representative of the Ministry of Economic Affairs and Employment reported collaborations with several actors, including interest organizations and the forest industry. Ministries and interest groups collaborated with universities, for example, as members of steering groups or guest lecturers in university teaching.

Individual professional networks emerged as straightforward means for information seeking and as a motivator for cooperation. For example, the representative of one of the innovation promoter organizations mentioned collaborations with SYKE and LUKE, 'due to the fact that I have very good networks in these institutes, because of my background so [...] for example I can ask for their expertise in some kind of collaboration projects'. Personal networks flagged by the ministries included researchers in governmental research institutes and representatives of interest groups, although universities were also mentioned.

4.3. Tensions, needs and opportunities in co-production

A variety of tensions, needs and opportunities emerged from the interviews in relation to knowledge co-production. We organized these around the three types of knowledge proposed by Stepanova et al. (2020): system, normative and transformative (Table 3).

4.3.1. Tensions in co-production

Three main types of tensions in knowledge co-production emerged from the interviews: limitations in funding opportunities for cooperation beyond specific areas of study; lack of shared understandings and ideological positions regarding the circular bioeconomy; and difficulties in cross-sectoral and cross-discipline engagement (including differences

Table 3

Summary of tensions and needs/opportunities in co-production, as highlighted by the interviewees.

Knowledge types (analytic level of practice)	Tensions in co-production	Needs and opportunities in co-production
System	System knowledge suffers from funding scarcity-driven competition between and within organizations, with risks to the temporal continuity of cooperation, along with knowledge gaps outside of narrow project-level objectives.	Further knowledge exchange and synthesis beyond project-by-project considerations.
Normative	Conflicting visions and expert opinions and agendas result in an unclear definition of the circular bioeconomy and its potential and realm of action, including a gap in circularity ambitions between industry and other actors.	Clarifying (as far as possible) the definition of circular bioeconomy and aligning it to the sustainability targets for the forest sector.
Transformative	Knowledge concerning future trends and developments is affected by difficulties and gaps in cross-sectoral and cross-discipline engagement, such as differences in personal and organizational modes of operation and institutional frameworks, knowledge gaps between science and industry, and mismatching timescales between science and policy cycles. ^a	Collaboration on policy-supporting and transformative knowledge, leveraging the political momentum of the circular bioeconomy.

^a Based on the interview material, cooperation across organizations relies on personal networks. While this was presented as a generally neutral phenomenon by the interviewees, excessive parochialism may be detrimental to long-term co-production of knowledge.

in personal and organizational modes of operation, a gap between science and industry and academia and ministries, and mismatching time horizons).

As funding was among the main motivations for collaboration (Section 3.2), limitations related to funding were perceived as a major barrier for co-production. According to the interviewees, funding instruments favour projects with narrow objectives. Competition for the same funding among actors, with international competition considered toughest, was perceived as a barrier to knowledge exchange, not only between various organizations, but also within the same organizations. Some interviewees suggested that cooperation often focuses on planning rather than implementation, while some representatives of research institutes and ministries felt that the limited timeframe of the funding could also be problematic for the continuity of cooperation.

One ministry representative also highlighted the need to coordinate national and European funding processes to foster partnership and cooperation: 'I think we should have some kind of [national] plan for the next framework programme, Horizon Europe, because the commission is driving really strongly this kind of partnership type of ideas and missions and all. The idea is that the European countries should align their resources together for solving these big problems.'

The lack of a shared understanding of the circular bioeconomy was perceived as problematic, as multiple ideological positions were recognized to affect knowledge co-production and collaboration. Difficulties in reconciling various visions and ambition levels was thus a recognized tension in collaboration. A representative of a research institute explained that '[i]n general, circular economy is currently accepted by

almost all. Mainly because it's so widely framed. Everyone can understand it in their own way and it's easy to accept [...]. Then if you go for more concrete actions and try to analyse them then there is of course more potential for conflict because the aims of the circular economy are conflicting.' Overall, the interviewees were aware that the field is contested, and actors have different ideological or conceptual positions. Some interviewees discussed the difficulties of managing information from multiple sources and stakeholders, and recognized that navigating this is important. A representative of an interest organization explained: 'we are actually making a lot of effort to try to base our work on scientific knowledge, rather than going along with these different, opposing [sides]'. However, there are challenges in discerning what is considered to be scientific knowledge and who counts as an expert: 'who is the expert is also contested because different companies have their own experts'. One ministerial representative explained: 'the Forest Industry Association. I call them and ask to tell me the statistics behind this fact. Collaborate with them quite much because they have the industry data [...] I trust the numbers that they create [...] but again the numbers always come with the text [i.e. a storyline, a message]'

Related to the abstract conceptualization of the circular bioeconomy, the circularity of the bioeconomy in Finland was perceived by some interviewees (e.g. representatives of universities and ministries) to lag behind, and the industry has been suggested to lack the means and incentives to advance the transformation of its practices. Some interviewees criticized the promotion of Finland as a forerunner in the circular bioeconomy by innovation promoters. One ministry representative explained: 'They [innovation promoters] have created quite a nice blue sky with the circular economy and giving that Finnish brand that we are the leader as in circular economy. Now that we are the ones that tried to make it happen in practice and it doesn't work. The companies are not there yet'.

All interviewed actors recognized tensions with respect to cross-sectoral engagement, as described by one university representative: 'there is a lot of development going on under the circular bioeconomy, but somehow it does not reach across these sectoral boundaries so easily'. Some interviewees often described knowledge co-production as project-oriented, striving to find answers to specific research questions, funding being one of the main enabling elements. Some interviewees also suggested the need for more transformative knowledge, for example, regarding more circularity-oriented practices. Interviewees pointed out how differences in the *forma mentis* across organization types hindered cooperation between organizations as well as internally, especially regarding the gap between science and industry. Some interviewees representing research institutes explained how tensions in the cooperation with industry actors often relate to how the industry's improvements are only marginal and small in scale. On the other hand, an innovation promoter organization representative explained: 'on the innovation side [...] I feel that Finns are far too modest, and we tend to research some topics, till the end of the world, without understanding that this would be, making great added value to companies'. One university representative explained that 'it might be so that the universities don't understand the business world well enough, and then the business world is too much looking at the business and not thinking [...] forwards like maybe it would be good to have more this kind of financial support for something that in future could benefit them.'

Notably, representatives on both the ministerial and university levels recognized that little cooperation was occurring between policymaking and academia. A university representative explained: 'We have been sharing the information yes but [...] I don't think that there has been so-called co-production of knowledge between ministries policymakers and the universities. Several actors recognized that the University of Eastern Finland and Aalto University were more involved in the circular bioeconomy compared to the University of Helsinki, especially given the broader strategic profile of Helsinki University. Ministry representatives noted difficulties in contacting university researchers: 'I don't believe for a moment that this third task for universities [i.e. providing

knowledge to ministries] would happen without any [...] incentives, and I don't think it would be right. None of us work for free. You can't get away from that unless you work with the small number of researchers who are really enthusiastic and do it for the good of society [...] which is nice, but we are 25 000 researchers here in Finland and that's just Finland'.

Interviewees also reported that the differences in timeframes across the actors hindered collaboration, as scientific processes are slower than policy cycles. One ministry representative explained: 'If we start off a research project, like I said, it can sometimes take a year from the conception of the idea or the need to the beginning of the project, which could [then] take a year or half a year. So, then the results are 18 months late from the moment [we began]'. From the university and research institute representatives' perspective, cooperation with ministries was also demanding because their knowledge needs were seen as rigid.

4.3.2. Needs and opportunities

Interviewees perceived knowledge co-production to be an important opportunity for knowledge exchange, and they recognized that cooperation is needed to enable a transformation towards more sustainable forest sector practices. For example, one university representative commented that despite tensions, cooperation was worth pursuing: 'even though we may have some troubles, we want to collaborate, because what we get is more valuable than these small troubles'. Across the network, actors suggested that co-production is very much needed in summarizing knowledge from isolated initiatives. Knowledge synthesis was also perceived to be important with respect to clarifying ideological stances, as one representative of a research institute argued: 'in the science field, messages are not clear because you can have exactly opposite views coming from high-level scientists'. The importance of basic research was, however, emphasized by one university representative: 'If you are working with for example, chemistry or you work with the health sciences, as some of our bioeconomy researchers do. I think that it's good that they concentrate. They work, and that should be respected as well. It's not that all of us need to do it in the co-production way'.

Interviewees recognized that ministerial knowledge needs differ from the knowledge needs of academia, as ministries rely on summarized policy-oriented knowledge. Therefore, interviewees saw opportunities for future collaboration towards policy-supporting knowledge, in the light of the increasing policy and societal interest taken in the circular bioeconomy. One representative of a research institute explained: 'I think there have been several reasons, mainly climate change. I think that has given more room for us to operate, and what is more, these issues are politically more in the top agenda than they were maybe 15–30 years ago.' In the same interview, a colleague added: 'That need for transformative type of knowledge is constantly increasing and the need for, not only producing knowledge, but knowledge that can really be fed into the policy system [...] and that would be rightly timed and able to nourish the policy cycle so that a transformation can happen. I think the pressure for that and the need for us to work on new manners are increasing constantly'. A third researcher, however, criticized that decisions in certain conditions are made at the ministerial level to promote certain policies, although research may point in another direction: 'the ministries were more willing to believe maybe those numbers that were more suitable for their own targets and aims related to how they would like to use forests in the upcoming years'. Representatives of innovation promoters and one interest organization also perceived the increasing political demand for the circular bioeconomy as an opportunity, one that particularly forestry companies would benefit from.

5. Discussion

While the results from this qualitative study cannot be generalized beyond the Finnish context, reflections can be advanced regarding the critical dynamics of knowledge co-production in the context of the

circular bioeconomy. In particular, this study explores the issue of knowledge co-production from the perspective of different knowledge types. As suggested by [Urmetzer et al. \(2019\)](#), the knowledge base a sustainable knowledge-based bioeconomy 'cannot be a purely techno-economic one', but must leverage system knowledge, normative knowledge, and transformative knowledge. The empirical analysis in the manuscript thus examines issues in the co-production of these three types of knowledge, as well in the co-production of lay, expert and scientific knowledge [Stepanova et al. \(2020\)](#). Although this framework does not address directly the issue of power, power and politics emerged indirectly from the interviews. Power manifests in particular in the relations between governmental agencies and multiple other societal actors, and these power dynamics were also visible in the knowledge process of co-production, for example manifested in tensions related to cross-sectoral engagement.

The findings reveal that all lay, expert, and scientific are recognized by the interviewed actors, but are dealt with in different ways according to their role in the process of knowledge co-production (Section 3.1). Knowledge co-production among various actors is enabled by project-driven funding, similar agendas and forma mentis, and organizational (e.g. dependencies between governmental research institutes and ministries) and individual professional networks (Section 3.2). Externally perceived authority and reputation were not directly mentioned in the interviews. They emerged, however, as an underlying issue in navigating ideological positions and the legitimacy of information sources on the circular economy (presented in Section 3.3).

In line with our findings, [Korhonen et al., 2018a](#) reported that the relationships between actors in the Finnish bioeconomy network are partially driven by formalized agreements and the proximity of central offices. Those authors also note that the tight network structure may be detrimental towards the aims of innovation and inclusive knowledge transfer. In our interviews, this phenomenon did not emerge as a challenge or threat to co-production, but it was presented by the interviewees as a neutral observation. The question thus remains whether tight networks and reliance on personal networks may restrict the transformative knowledge on co-production (e.g. entrant individuals or organizations cannot participate effectively). It should also be noted that during the past decade, key organizations in the Finnish circular bioeconomy network have been subject to deep changes and restructuring at the organizational level. This no doubt has an influence on intra- and inter-actor relationships and co-production dynamics.

Three main themes emerged regarding the tensions of co-production (Section 3.3): lack of shared understandings and ideological positions regarding the circular bioeconomy; limitations in funding opportunities for cooperation beyond specific areas of study; and difficulties in cross-sectoral and cross-discipline engagement. Such tensions affect process/system knowledge, normative/target knowledge, and predictive/transformative knowledge (i.e. the practice analytical level outlined by [Stepanova et al. \(2020\)](#)).

Funding emerged from the interviews as both a catalyst and a tension for collaboration, in particular in the context of process/system knowledge (i.e. knowledge regarding current states and processes), in that funding scarcity may cause competition between and within organizations, hamper the temporal continuity of cooperation, along with producing knowledge gaps beyond narrow project-level objectives. While funding competitiveness and scarcity is a physiological issue in any field, Finland, following Germany and France, is reportedly among the European countries with the highest levels of resources for research in the forest-based bioeconomy ([Lovrić et al., 2020](#)). This raises the question of whether space can be made for further refining of the overarching purposes of funding.

Conflicting visions and ideologies concerning the meaning and aim of the circular bioeconomy were perceived by the interviewees to be an obstacle to collaboration. In other words, this challenges the convergence of various actors on co-producing normative/target knowledge, i.e. knowledge about appropriate goals for the circular bioeconomy. The

same problem is reported by a number of articles examining the challenges of implementing the forest-based circular bioeconomy in Europe, published in a recent editorial by [Toppinen et al. \(2020\)](#). Literature on the (circular) bioeconomy widely acknowledges the diversity of ideological interpretations associated with the concept ([Giampietro, 2019](#); [Holmgren et al., 2020](#); [Stegmann et al., 2020](#)), which in fact has been suggested to be an umbrella concept, with various actors using it to frame and legitimize their work and agenda (in the Nordic countries, e.g. [Hodge et al., 2017](#); [Korhonen et al., 2018b](#)). While it is important to stress the need to reconcile these visions to the extent that is possible, the elastic nature of the concept likely allows for cooperation between actors with different or even conflicting interests. This raises the questions such as, to what extent is it possible and desirable to crystallize the 'true' ethos of the circular bioeconomy economy? who would be responsible for this process (i.e. legitimacy)? would it improve collaboration or further exacerbate tensions? In this regard, an important outcome in knowledge co-production is learning in and strengthening of institutional networks, where '[t]he assumption is that a diversity of perspectives provides a more complete picture of the whole system' ([Apetrei et al., 2021](#), p. 11). Moreover, a recent study by [Chambers et al. \(2021\)](#) suggested that in addition to researching solutions, co-production can also be leveraged to navigate differences between stakeholders and knowledge types, empower voices, broker and reframe power, and reframe agency.

Our study recorded that collaboration is normatively accepted by all interviewed actors as one of the means of achieving the sustainability goals of the circular bioeconomy. In particular, knowledge synthesis, policy-oriented knowledge, and transformative knowledge were valued by several interviewees. This places high stakes on the prerequisites, quality, and effectiveness of collaboration. However, gaps and difficulties in cross-sectoral and cross-discipline engagement emerged as problematic in the context of knowledge co-production for the circular bioeconomy. These included differences in organizational modes of operation and institutional frameworks, the knowledge gap between science and industry, and mismatching timescales between science and policy cycles. We interpreted such tensions to mainly affect predictive/transformative knowledge (i.e. future trends and developments) because collaboration is inherent to, and almost a sine qua non condition for, realizing the circular bioeconomy, as reflected by its very ethos ([Knierim et al., 2018](#); [Winkel, 2017](#)).

Knowledge co-production is a notion in its infancy, and this typically affects other sustainability domains such as energy transitions and climate change ([Binder et al., 2015](#); [Cvitanić et al., 2019](#); [Muccione et al., 2019](#)). The development of interpersonal and communicative capacities, and collaborative competencies at large, is thus highly relevant, as is also acknowledged in other domains, starting first with the interdisciplinary field of sustainability education ([Caniglia et al., 2016](#); [Schank and Rieckmann, 2019](#); [Wiek et al., 2011](#)). These meta-competencies are all the more useful for attaining a transdisciplinary integration beyond the mere cognitive dimension towards a balance of styles of thinking, acting, and ultimately being ([Pohl et al., 2021](#)).

6. Conclusions

The circular bioeconomy presents a set of solutions deemed pivotal at the policy, industry, and academic levels, from the implementation of the European Green Deal, and more generally, to fostering global sustainability transformations ([Marchetti and Palahí, 2020](#)). The conceptual development and concrete operationalization of the circular bioeconomy, however, relies deeply on knowledge co-production, which requires the coordination and collaboration of various societal actors. This study performed an exploratory analysis of issues associated with co-production in the context of the Finnish circular bioeconomy by eliciting tacit knowledge from representatives of organizations in between science and policy.

Knowledge co-production was acknowledged and deemed important

to support policymaking and transformative processes towards improving sustainability in the forest sector. Three areas of improvement were identified, and accordingly, recommendations are provided to actors and organizations co-producing knowledge or fostering knowledge regarding the circular bioeconomy. The first area is acknowledging and reconciling (to the extent possible) different visions and meanings of the circular bioeconomy, including ones that are more sustainability-oriented. The second is improving the effectiveness of funding in reference to the specific issues raised by the interviews. This includes targeting gap areas in interdisciplinary research; fostering organizational intra- and inter-collaboration; guaranteeing the continuity of cooperation beyond project-specific goals (especially between academia, innovation promoters and interest organizations, which appear to collaborate more on ad hoc projects); and further aligning national funding plans with European-level ones. The third area is supporting the development of collaborative skills across actors, thus providing the necessary resources (in addition to the financial ones) for knowledge co-production concerning the circular bioeconomy.

CRedit authorship contribution statement

D. D'Amato: Funding acquisition, Conceptualization, Methodology, Data curation, Formal analysis, Visualization, Writing – original draft, Writing – review & editing, Project administration, Supervision. **K. Korhonen-Kurki:** Funding acquisition, Conceptualization, Methodology, Data curation, Formal analysis, Writing – original draft, Writing – review & editing, Project administration. **V. Lyttikainen:** Data curation, Formal analysis, Validation, Writing – original draft. **B.D. Matthies:** Conceptualization, Methodology, Investigation, Data curation, Writing – original draft. **A. Horcea-Milku:** Data curation, Formal analysis, Writing – original draft.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Dalia D'Amato and Kaisa Korhonen-Kurki report financial support was provided by University of Helsinki, Faculty of Agriculture and Forestry. Dalia D'Amato reports financial support was provided by Academy of Finland, NordForsk, Formas and Nordic Forest Research (SNS). Brent Matthies reports financial support was provided by Ella and Georg Ehrnrooth Foundation. Andra Horcea-Milku reports financial support was provided by European Commission (Marie Skłodowska-Curie). Dalia D'Amato reports a relationship with the University of Helsinki that includes employment and funding grants, and also a consulting or advisory relationship for the Italian Ministry of the Environment during the year 2020.

Acknowledgements

Funding to develop this study was received from the Faculty of Agriculture and Forestry at the University of Helsinki. Other funding agencies which supported the authors include: the Academy of Finland (Operationalising Ecosystem services in business Sustainability: drawing from green and circular bioeconomy – OPES, Grant no. 315912); NordForsk and Formas, which are respectively an organization under the Nordic Council of Ministers that funds Nordic research cooperation, and the Swedish Research Council for Sustainable Development (Green forests policies: a comparative assessment of outcomes and trade-offs across Fenno-Scandinavia – GreenPole, decision no. 103443); Nordic Forest Research SNS (Transdisciplinary co-production in forest policy research – ForPol, decision no. SNS-128); the Ella and Georg Ehrnrooth Foundation (Grant no. 190046); EU funding through the Marie Skłodowska-Curie (Grant no. 840207).

References

- Antikainen, R., Dalhammar, C., Hildén, M., Judl, J., Jääskeläinen, T., Kautto, P., Koskela, S., Kuisma, M., Lazarevic, D., Mäenpää, I., Ovaska, J.-K., Peck, P., Rodhe, H., Temmes, A., Thidell, Å., 2017. *Renewal of Forest Based Manufacturing Towards a Sustainable Circular Bioeconomy*. Reports of the Finnish Environment Institute 13/2017.
- Apetrei, C.I., Caniglia, G., von Wehrden, H., Lang, D.J., 2021. Just another buzzword? A systematic literature review of knowledge-related concepts in sustainability science. *Glob. Environ. Chang.* 68, 102222 <https://doi.org/10.1016/j.gloenvcha.2021.102222>.
- Beforet, N., 2020. Going beyond definitions to understand tensions within the bioeconomy: the contribution of sociotechnical regimes to contested fields. *Technol. Forecast. Soc. Change* 153, 119923. <https://doi.org/10.1016/j.techfore.2020.119923>.
- Binder, C.R., Absenger-Helmli, I., Schilling, T., 2015. The reality of transdisciplinarity: A framework-based self-reflection from science and practice leaders. *Sustain. Sci.* 10, 545–562. <https://doi.org/10.1007/s11625-015-0328-2>.
- Caniglia, G., John, B., Kohler, M., Bellina, L., Wiek, A., Rojas, C., Laubichler, M.D., Lang, D., 2016. An experience-based learning framework: activities for the initial development of sustainability competencies. *Int. J. Sustain. High. Educ.* 17, 827–852. <https://doi.org/10.1108/IJSHE-04-2015-0065>.
- Carus, M., Dammer, L., 2018. The circular bioeconomy—concepts, opportunities, and limitations. *Ind. Biotechnol.* 14, 83–91. <https://doi.org/10.1089/ind.2018.29121.mca>.
- Cash, D.W., Clark, W.C., Alcock, F., Mitchell, R.B., 2003. Knowledge systems for sustainable development. *PNAS* 100, 8086–8091. <https://doi.org/10.1073/pnas.1231332100>.
- Chambers, J.M., Wyborn, C., Ryan, M.E., Reid, R.S., Riechers, M., Serban, A., Bennett, N. J., Cvitanovic, C., Fernández-Giménez, M.E., Galvin, K.A., Goldstein, B.E., Klenk, N. L., Tengö, M., Brennan, R., Cockburn, J.J., Hill, R., Munera, C., Nel, J.L., Österblom, H., Pickering, T., 2021. 2021 Six modes of co-production for sustainability. *Nat. Sustain.* <https://doi.org/10.1038/s41893-021-00755-x>.
- Chapman, J.M., Schott, S., 2020. Knowledge coevolution: generating new understanding through bridging and strengthening distinct knowledge systems and empowering local knowledge holders. *Sustain. Sci.* 1 (5), 931–943. <https://doi.org/10.1007/s11625-020-00781-2>.
- Cvitanovic, C., Howden, M., Colvin, R.M., Norström, A., Meadow, A.M., Addison, P.F.E., 2019. Maximising the benefits of participatory climate adaptation research by understanding and managing the associated challenges and risks. *Environ. Sci. Pol.* 94, 20–31. <https://doi.org/10.1016/j.envsci.2018.12.028>.
- D'Amato, D., Veijonaho, S., Toppinen, A., 2018. Towards sustainability? Forest-based circular bioeconomy business models in Finnish SMEs. *For. Policy Econ.* 110, 101848 <https://doi.org/10.1016/j.forpol.2018.12.004>.
- D'Amato, D., Bartkowski, B., Droste, N., 2020. Reviewing the interface of bioeconomy and ecosystem service research. *Ambio* 49, 1878–1896. <https://doi.org/10.1007/s13280-020-01374-4>.
- Dietz, T., Börner, J., Förster, J.J., von Braun, J., 2018. Governance of the bioeconomy: A global comparative study of national bioeconomy strategies. *Sustain.* 10, 3190. <https://doi.org/10.3390/su10093190>.
- El-Chichakli, B., von Braun, J., Lang, C., Barben, D., Philp, J., 2016. Policy: five cornerstones of a global bioeconomy. *Nature* 535, 221–223. <https://doi.org/10.1038/535221a>.
- European Environment Agency, 2018. *The Circular Economy and the Bioeconomy - Partners in Sustainability*, EEA Report 8/2018 (ISSN 1977-8449).
- Eyvindson, K., Repo, A., Mönkkönen, M., 2018. Mitigating forest biodiversity and ecosystem service losses in the era of bio-based economy. *For. Policy Econ.* 92, 119–127. <https://doi.org/10.1016/j.forpol.2018.04.009>.
- Forsyth, T., 2003. *Critical Political Ecology: The Politics of Environmental Science*. Routledge, New York.
- Giampietro, M., 2019. On the circular bioeconomy and decoupling: implications for sustainable growth. *Ecol. Econ.* 162, 143–156. <https://doi.org/10.1016/j.ecolecon.2019.05.001>.
- Grimm, P., 2010. Social desirability bias. In: *Wiley International Encyclopedia of Marketing*. Wiley, Chichester. <https://doi.org/10.1002/9781444316568.wiem02057>.
- Hetemäki, L., Hanewinkel, M., Muys, B., Ollikainen, M., Palahí, M., Trasobares, A., 2017. Leading the way to a European circular bioeconomy strategy. In: *From Science to Policy 5*. European Forest Institute.
- Hodge, D., Brukas, V., Giurca, A., 2017. Forests in a bioeconomy: bridge, boundary or divide? *Scand. J. For. Res.* 32, 582–587. <https://doi.org/10.1080/02827581.2017.1315833>.
- Holmgren, S., D'Amato, D., Giurca, A., 2020. Bioeconomy imaginaries: A review of forest-related social science literature. *Ambio* 49, 1860–1877. <https://doi.org/10.1007/s13280-020-01398-6>.
- Issa, I., Delbrück, S., Hamm, U., 2019. Bioeconomy from experts' perspectives – results of a global expert survey. *PLoS One* 14, e0215917. <https://doi.org/10.1371/journal.pone.0215917>.
- Jasanoff, S., 2004. *States of Knowledge. The Co-Production of Science and Social Order*. Routledge, Lond.
- Knierim, A., Laschewski, L., Boyarintseva, O., 2018. Inter- and transdisciplinarity in bioeconomy. In: *Lewandowski, I. (Ed.), Bioeconomy*. Springer, Cham. https://doi.org/10.1007/978-3-319-68152-8_4.
- Korhonen, J., Giurca, A., Brockhaus, M., Toppinen, A., 2018a. Actors and politics in Finland's forest-based bioeconomy network. *Sustain.* 10, 3785. <https://doi.org/10.3390/su10103785>.

- Korhonen, J., Koskivaara, A., Toppinen, A., 2018b. Riding a Trojan horse? Future pathways of the fiber-based packaging industry in the bioeconomy. *For. Policy Econ.* 110, 101799. <https://doi.org/10.1016/j.forpol.2018.08.010>.
- Kröger, M., Raitio, K., 2017. Finnish forest policy in the era of bioeconomy: A pathway to sustainability? *For. Policy Econ.* 77, 6–15. <https://doi.org/10.1016/j.forpol.2016.12.003>.
- Lang, D.J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., Swilling, M., Thomas, C.J., 2012. Transdisciplinary research in sustainability science: practice, principles, and challenges. *Sustain. Sci.* 7, 25–43. <https://doi.org/10.1007/s11625-011-0149-x>.
- Latour, B., 1990. Postmodern? No, simply amodern! Steps towards an anthropology of science. *Stud. Hist. Philos. Sci. Part A* 21, 145–171. [https://doi.org/10.1016/0039-3681\(90\)90018-4](https://doi.org/10.1016/0039-3681(90)90018-4).
- Leipold, S., Feindt, P.H., Winkel, G., Keller, R., 2019. Discourse analysis of environmental policy revisited: traditions, trends, perspectives. *J. Environ. Policy Plan.* 21, 445–463. <https://doi.org/10.1080/1523908X.2019.1660462>.
- Leventon, J., Fleskens, L., Claringbould, H., Schwilch, G., Hessel, R., 2016. An applied methodology for stakeholder identification in transdisciplinary research. *Sustain. Sci.* 11, 763–775. <https://doi.org/10.1007/s11625-016-0385-1>.
- Lewandowski, I., Gaudet, N., Lask, J., Maier, J., Tchouga, B., Vargas-Carpintero, R., 2017. Context. In: Lewandowski, I. (Ed.), *Bioeconomy: Shaping the Transition to a Sustainable, Biobased Economy*. Springer. https://doi.org/10.1007/978-3-319-68152-8_2.
- Lovrić, M., Lovrić, N., Mavsar, R., 2020. Mapping forest-based bioeconomy research in Europe. *For. Policy Econ.* 110, 101874. <https://doi.org/10.1016/j.forpol.2019.01.019>.
- LUKE, 2019. Finnish Bioeconomy in Numbers. <https://www.luke.fi/en/natural-resources/finnish-bioeconomy-in-numbers/>.
- Lyytikäinen, V., Korhonen-Kurki, K., Pietikäinen, J., Sandström, V., Kalliokoski, T., Mattila, O., Vesala, T., Holopainen, J., 2021. Institutionalised positions steer perceptions of a virtual-reality science communication: The case of Finnish forest and climate policy. In: *Manuscript Under Development*.
- Makkonen, M., Huttunen, S., Primmer, E., Repo, A., Hildén, M., 2015. Policy coherence in climate change mitigation: an ecosystem service approach to forests as carbon sinks and bioenergy sources. *For. Policy Econ.* 50, 153–162. <https://doi.org/10.1016/j.forpol.2014.09.003>.
- Marchetti, M., Palahí, M., 2020. Perspectives in bioeconomy: strategies, Green Deal and Covid19. *Forest@ - J. Silvicult. Forest Ecol.* 17, 52–55. <https://doi.org/10.3832/efor0059-017>.
- Mausser, W., Klepper, G., Rice, M., Schmalzbauer, B.S., Hackmann, H., Leemans, R., Moore, H., 2013. Transdisciplinary global change research: the co-creation of knowledge for sustainability. *Curr. Opin. Environ. Sustain.* 5, 420–431. <https://doi.org/10.1016/j.cosust.2013.07.001>.
- Miller, C.A., Wyborn, C., 2020. Co-production in global sustainability: histories and theories. *Environ. Sci. Pol.* 113, 88–95. <https://doi.org/10.1016/j.envsci.2018.01.016>.
- Moser, S.C., 2016. Can science on transformation transform science? Lessons from co-design. *Curr. Opin. Environ. Sustain.* 20, 106–115. <https://doi.org/10.1016/j.cosust.2016.10.007>.
- Muccione, V., Huggel, C., Bresch, D.N., Jurt, C., Wallimann-Helmer, I., Mehra, M.K., Pabón Caicedo, J.D., 2019. Joint knowledge production in climate change adaptation networks. *Curr. Opin. Environ. Sustain.* 39, 147–152. <https://doi.org/10.1016/j.cosust.2019.09.011>.
- Mustalhti, I., 2018. The responsive bioeconomy: the need for inclusion of citizens and environmental capability in the forest based bioeconomy. *J. Clean. Prod.* 172, 3781–3790. <https://doi.org/10.1016/j.jclepro.2017.06.132>.
- Näyhä, A., 2019. Transition in the Finnish forest-based sector: company perspectives on the bioeconomy, circular economy and sustainability. *J. Clean. Prod.* 209, 1294–1306. <https://doi.org/10.1016/j.jclepro.2018.10.260>.
- Norton, M., Baldi, A., Buda, V., Carli, B., Cudlin, P., Jones, M.B., Korhola, A., Michalski, R., Novo, F., Oszlányi, J., Santos, F.D., Schink, B., Shepherd, J., Vet, L., Walloe, L., Wijkman, A., 2019. Serious mismatches continue between science and policy in forest bioenergy. *GCB Bioenergy* 11, 1256–1263. <https://doi.org/10.1111/gcb.12643>.
- Ojanen, M., Brockhaus, M., Korhonen-Kurki, K., Petrokofski, G., 2021. Navigating the science-policy interface: Forest researcher perspectives. *Environ. Sci. Pol.* 118, 10–17. <https://doi.org/10.1016/j.envsci.2021.01.002>.
- Ostrom, E., Ostrom, V., 1977. *Public Economy Organization and Service Delivery*. Workshop in Political Theory and Policy Analysis. Indiana University, Bloomington. <https://hdl.handle.net/10535/732>.
- Parks, R.B., Baker, P.C., Kiser, L., Oakerson, R., Ostrom, E., Ostrom, V., Percy, S., Vandivort, M., Whitaker, G., Wilson, R., 1981. Consumers as coproducers of public services: some economic and institutional considerations. *Policy Stud. J.* 9, 1001–1011. <https://doi.org/10.1111/j.1541-0072.1981.tb01208.x>.
- Pfau, S.F., Hagens, J.E., Dankbaar, B., Smits, A.J.M., 2014. Visions of sustainability in bioeconomy research. *Sustain.* 6, 1222–1249. <https://doi.org/10.3390/su6031222>.
- Pohl, C., Klein, J.T., Hoffmann, S., Mitchell, C., Fam, D., 2021. Conceptualising transdisciplinary integration as a multidimensional interactive process. *Environ. Sci. Pol.* 118, 18–26. <https://doi.org/10.1016/j.envsci.2020.12.005>.
- Polk, M., 2015. Transdisciplinary co-production: designing and testing a transdisciplinary research framework for societal problem solving. *Futures* 65, 110–122. <https://doi.org/10.1016/j.futures.2014.11.001>.
- Ramcilovic-Suominen, S., Pülzl, H., 2018. Sustainable development – A ‘selling point’ of the emerging EU bioeconomy policy framework? *J. Clean. Prod.* 172, 4170–4180. <https://doi.org/10.1016/j.jclepro.2016.12.157>.
- Rantala, T., Primmer, E., 2003. Value positions based on forest policy stakeholders’ rhetoric in Finland. *Environ. Sci. Pol.* 6, 205–216. [https://doi.org/10.1016/S1462-9011\(03\)00040-6](https://doi.org/10.1016/S1462-9011(03)00040-6).
- Schank, C., Rieckmann, M., 2019. Socio-economically substantiated education for sustainable development: development of competencies and value orientations between individual responsibility and structural transformation. *J. Educ. Sustain. Dev.* 13, 67–91. <https://doi.org/10.1177/0973408219844849>.
- Stegmann, P., Londo, M., Junginger, M., 2020. The circular bioeconomy: its elements and role in European bioeconomy clusters. *Resour. Conserv. Recycl. X* 6, 100029. <https://doi.org/10.1016/j.rcrx.2019.100029>.
- Stepanova, O., Polk, M., Saldert, H., 2020. Understanding mechanisms of conflict resolution beyond collaboration: an interdisciplinary typology of knowledge types and their integration in practice. *Sustain. Sci.* 15, 263–279. <https://doi.org/10.1007/s11625-019-00690-z>.
- Toppinen, A., D’Amato, D., Stern, T., 2020. Forest-based circular bioeconomy: matching sustainability challenges and novel business opportunities? *For. Policy Econ.* 110, 102041. <https://doi.org/10.1016/j.forpol.2019.102041>.
- Toppinen, A., Pätäri, S., Tuppur, A., Jantunen, A., 2017. The European pulp and paper industry in transition to a bio-economy: A Delphi study. *Futures* 88, 1–14. <https://doi.org/10.1016/j.futures.2017.02.002>.
- Turnhout, E., Metz, T., Wyborn, C., Klenk, N., Louderl, E., 2020. The politics of co-production: participation, power, and transformation. *Curr. Opin. Environ. Sustain.* 42, 15–21. <https://doi.org/10.1016/j.cosust.2019.11.009>.
- Urmeter, S., Schlaile, M.P., Bogner, K.B., Mueller, M., Pyka, A., 2019. Exploring the dedicated knowledge base of a transformation towards a sustainable bioeconomy. *Sustain.* 11, 16943. <https://doi.org/10.3390/su10061694>.
- Vivien, F.D., Nieddu, M., Befort, N., Debref, R., Giampietro, M., 2019. The hijacking of the bioeconomy. *Ecol. Econ.* 159, 189–197. <https://doi.org/10.1016/j.ecolecon.2019.01.027>.
- Wiek, A., Withycombe, L., Redman, C.L., 2011. Key competencies in sustainability: A reference framework for academic program development. *Sustain. Sci.* 6, 203–218. <https://doi.org/10.1007/s11625-011-0132-6>.
- Winkel, G., 2017. *Towards a sustainable European forest-based bioeconomy – assessment and the way forward*. In: *What Science Can Tell Us no. 8*. European Forest Institute, Joensuu.
- Wolfslehner, B., Pülzl, H., Kleinschmit, D., Aggestam, F., Winkel, G., Candel, J., Eckerberg, K., Feindt, P., McDermott, C., Secco, L., Sotirov, M., Lackner, M., Lazya Roux, J., 2020. European Forest Governance Post-2020 from Science to Policy 10. European Forest Institute, Joensuu, Finland. <https://doi.org/10.36333/fs10>.
- Wyborn, C., Datta, A., Montana, J., Ryan, M., Leith, P., Chaffin, B., Miller, C., Van Kerkhoff, L., 2019. Co-producing sustainability: reordering the governance of science, policy, and practice. *Annu. Rev. Environ. Resour.* 44, 319–346. <https://doi.org/10.1146/annurev-environ-101718-033103>.