Bio-based Materials Within the Circular Economy: Opportunities and Challenges

Birgit Brunklaus and Ellen Riise

Abstract In a circular society, material consumption should be a circular process where renewable resources and waste streams are used for new bio-based materials. In such a society, bio-based materials are also reused, repaired, recycled, and remanufactured. Not only choices on resources, but also other life cycle choices pertaining to circularity must be done based on technological, environmental and economic basis. For this session, presentations and discussions regarding life cycle management of bio-based materials were suggested. The session had five oral presentations and six poster presentations that gave a general picture of a broader environmental and a positive economic result on a life cycle basis when renewable raw materials are used, while further exploration of the technical aspects within circularity and end-of-life challenges are needed in the future.

1 Introduction

The linear economy is based on the notion "Take, make and dispose", which is not in line with resource restriction posed on society today. Instead, there is a need for an economy that aims for circularity based on the notion "Restore, rebuilt and regenerate". In a circular society, material consumption should be a circular process where both renewable resources as well as finite resources are reused, recovered or recycled, inducing not only choices on resources, but also other life cycle choices pertaining to circularity that must be done based on technological, environmental and economic basis. This turns the linear life cycle "upside-down" to some extent

B. Brunklaus (✉)
RISE Research Institutes of Sweden, Energy and Circular Economy, Sustainable Society, Energy and Environmental Systems Analysis, 41296 Göteborg, Sweden
e-mail: birgit.brunklaus@ri.se

E. Riise
Essity, SCA Hygiene Products AB Group Function Sustainability, 40503 Göteborg, Sweden

E. Benetto et al. (eds.), *Designing Sustainable Technologies, Products and Policies*, https://doi.org/10.1007/978-3-319-66981-6_5

since it also puts another value of resources that earlier was only regarded as waste and as a burden to be minimised. This is one of the differences to be considered in the life cycles of the two material streams, linear and circular. In circular material streams, there are also some differences to be done when considering renewable resources or finite resources cycles. Therefore, the session was focusing on circularity opportunities and challenges for bio-based materials.

2 Session Contributions

For this session, both theoretical and practical examples, relating to a variety of industrial sectors and bio-based materials were welcomed, and the submission of abstracts resulted in five oral presentations and six posters. The session ended with a brief panel discussion where the presenters were invited to share their view on the variety of challenges and opportunities for their product or sector.

2.1 Oral Presentations

The first presentation on "Wood products circularity and the biodiversity challenge" was given by Christian Bauer, SIG [1]. Wood is a major input for many circular products, including half of all packaging material. Within the assessment methods to quantify the circularity potential, such as Life Cycle Assessment, there are limitations regarding the evaluation of impacts on biodiversity, for instance due to the complexity of the characterization of land use and land use change, and to the lack of consideration of forest management on landscape level and labelling, as done through certified forestry management. Therefore, practitioners and decision-makers prefer to look at other impact categories, such as climate change and water use. Starting from the existing work of UNEP SETAC and other significant existing methods, a new methodology relying on landscape management system was proposed in order to establish characterization factors aiming at integrating forest management practices and biodiversity.

The second presentation by Serenella Sala, European Commissions had the title "Bioeconomy contribution to Circular Economy" [2]. Focusing on food waste, the presentation demonstrated the potential for circularity from the bio-economy and highlighted the added-value and shortcomings of Life Cycle Thinking based approaches applied as supporting tools. Based on the quantification of food losses and waste at the EU scale, and the valorisation options, LCT and LCA approaches were applied in order to support the identification of the best options. The main challenges in order to improve LCT methods are related to the characterization of biotic resources in LCIA, and to the integration of eco-system, water, food, land and energy into LCA, considering all these issues as correlated.

"Assessing the availability of bio-based materials in product design" was presented by Vanessa Bach from TU Berlin [3]. The use of bio-based materials can be considered as a key strategy in eco-design approach, also contributing to circular economy at some points. However, several socio-economic factors induced by market conditions or disrupting political structures within society can constrain their availability. The presented work proposed a method for assessing bio-based materials availability constraints, aiming at supporting eco-design strategies. The method considers five main sources of constrains (environmental, socio-economic and physical constraints to plants growth), over the materials supply chain, and results in a set of availability indicators. For this study, the indicators were applied to energy-related products, such as production of biodiesel from rapeseed and soy beans, and showed that the indicators seem appropriate and that interpretation leads to meaningful conclusions while methodological robustness of some indicators could be refined.

The fourth presentation dealt with "Integrated market orientation in technical R&D processes—opportunities and challenges for environmentally friendly bio-based resins" by Miriam Lettner from K Plus, Austria [4]. The use of lignin, an under-utilized by-product from the pulp and paper industry, has the potential to be used as a valuable source for sustainable bio-based products. The market assessment of emerging lignin products aims at support R&D process by providing information on challenges and opportunities for such products at early design stage. Based on the Smartli H2020 project outcomes and a case study performed with Delphi, it was shown that the life cycle thinking integrated technical R&D processes based on the involvement of stakeholders and on a multi-perspective assessment (economic, environmental and technological) of newly developed products are highly valuable to face the barriers and incentives for the product market diffusion.

Sebastian Sperling, Institute for Bioplastics and Bio-composites, University of Hannover, gave the presentation "The sustainability of bio-based plastics—quantifying environmental and socio-economic aspects of a computer mouse for a circular economy" [5]. Through the presentation of the environmental and socio-economic impacts of a bio-based plastic housing of a computer mouse, the importance of sourcing bio-based plastics and the associated social aspects in different countries was revealed, despite the fact that these socio-economic aspects are often neglected and the availability of such information is limited. An important conclusion is that a joint guideline for bio-based plastic and fossil-based plastics is needed to reduce the methodological gaps existing for the assessment for such materials.

3 Messages and Outcomes of the Session

The messages and outcomes of the session are manifold. Among the bio-based processes there are both the well-proven processes (e.g. corn-based) and new processes (e.g. waste-based), which span a large technical variety of technological opportunities for the future to match with the objectives of circular economy.

However, the session demonstrated that to ensure the sustainability of these processes and materials, it is required to develop further the characterization of the related environmental impacts, and to integrate the systematic assessment of socio-economic aspects along the bio-based products value chain. Also the waste-based processes will turn the waste into economic value and so would reverse the value chain from end-of-life to new resource, leading to adapt consideration in Life Cycle modelling approaches. Indeed, taking the example of wood-based lignin or coconut fibre as waste-based (by-product) bio-materials, they become more valuable than the main product (timber, coconut), which leads to rethink the allocation system from mass to economic allocation.

At the end of the session, every presenter got the chance to give their view on the variety of challenges: the technical, the environmental or the economic challenge, as well as future implications. The discussion addressed many new aspects, such as the variety of related environmental and socio-economic challenges (impacts on biodiversity [1], resource availability and market of bio-based materials [3–5]), while the technical challenges were addressed in a lower extent.

4 Future Perspectives Based on the Session

The opportunity of bio-based materials to contribute to circular economy goes hand in hand with challenges mentioned for the business society, such as the challenge of reverse logistics and infrastructure, the new resource management and value creation from no cost waste to high profit products, the business opportunity to create new services, placing the consumer at the centre of the value chain.

Bio-based materials within the circular economy are one of the emerging areas where life cycle management can connect bio-based resources supply chain management with waste management systems. One of the next practical challenge for bio-based materials will be the management of their End of Life (EoL). Indeed, these resources and products they are part of will be sooner or later subject to European waste legislation or directives, as it is already the case for many sectors in Europe. For instance EoL directives exist for the automotive and electronic products, setting high targets for products and materials recycling and/or reuse rates. At the time these objectives are not achievable for bio-based materials and products, due to the lack of technological solutions. However, the biodegradability of some of these resources could present an advantage.

To our knowledge there are several other technical challenges based on ongoing and recent research projects the Research Institute of Sweden RISE have been involved in with the area of: food waste and bio-refinery, eco-cycle in building construction, forest-based plastics, recycling of green plastics and industrial waste. Within the construction sector, companies recycle and apply their products, but rarely sell further or even buy recycled products! Within bio-based plastics the durability and quality requirements for industrial products are important, while the

health aspects are important for consumer products. Within bio-based waste and bio-refineries the upgrading process is essential and the downcycling of poorer quality products occurs.

References

1. Vionnet S, Bauer C, Cockburn D, Brunberg B, Stevenson M, Wood products circularity and the biodiversity. challenge, LCM 2017 Conference, Luxembourg, 2017.
2. Sala S, Bioeconomy contribution to Circular Economy, International Conference on Life Cycle Management, 3–6 September, Luxemburg, 2017.
3. Bach V, Berger M, Finogenova N, Finkbeiner M, Assessing the availability of bio-based materials in product design, LCM 2017 Conference, Luxembourg, 2017.
4. Lettner M, Greiner D, Stern T, Hesser F, Integrated Market Orientation in Technical R&D Processes—Opportunities and Challenges for environmentally Friendly Bio-Based Resins, LCM 2017 Conference, Luxembourg, 2017.
5. Spierling S, Knüpffer E, Venkatachalam V, Mudersbach M, Behnsen H, Krieg H, Albrecht S, Endres H-J, The sustainability of bio-based plastics—quantifying environmental and socio-economic aspects of a computer mouse for a circular economy, LCM 2017 Conference, Luxembourg, 2017.