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The Sustainable Path to a Circular Bioeconomy

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Circular bioeconomy is gaining prominence in academic, policy, and industry contexts, linking circular economy and bioeconomy agendas in service of sustainability. However, it is at risk of developing in narrow, unsustainable ways. A sustainable path to circular bioeconomies must embrace diverse expert and stakeholder input, multiple solutions, and non-economic value.

Two Paths to a Circular Bioeconomy

'Circular bioeconomy' signifies the convergence of circular economy and bioeconomy agendas, with varying degrees of emphasis on biotechnology. Its recent delineation in research papers, policy documents and industry practices has resulted in the marginalisation of several important social, ethical, and ecological dimensions, and risks setting circular bioeconomy on an unsustainable trajectory [1,2,3].

Drawing on recent policy analysis [1,4], research papers [2,3], and a transdisciplinary workshop convened in 2019 (https://sbrc-nottingham.ac.uk/rri/circular-bioeconomy/circling-sustainability-and-responsibility.aspx), we identify two potential trajectories for circular bioeconomies: a delimiting path, where a limited range of actors define problems and solutions narrowly, prioritising economic value; and a sustainable path, incorporating diverse stakeholder and expert input, accommodating multiple solutions, and delivering social, environmental and economic value. We outline these trajectories and argue the sustainable path will lead to more equitable, resilient and socially robust circular bioeconomies.

The Delineation of Circular Bioeconomy

Circular economy and bioeconomy have gained traction independently in policy and academic literature since their popularisation in the 1990s and 2000s [5]. Both concepts have been explored extensively in theory and practice, but they remain ambiguous and contested [5–7]. A circular economy attempts to realign the linear take–make–use–dispose model of production and consumption with a circular model where resources can be reused or (bio)degraded and reincorporated back into the system, minimising detrimental externalities and encouraging restoration and regeneration [1,5]. Bioeconomy broadly means the production and use of biological resources, products, and processes to replace fossil resources and/or sustainably provide goods and services [1,6]. Since publication in 2015 of the EU Circular Economy Action Plan, many European (and American) bioeconomy strategies have made links with circular economy approaches [8], and a new term, circular bioeconomy, has emerged in policy and scientific literature [2].

Stegmann and colleagues found that circular bioeconomy has been defined diversely as: a part of the circular economy; the intersection of circular economy and bioeconomy; and more than circular economy and bioeconomy alone [2]. Although explicit definitions are rare, one example is 'more efficient resource management of bio-based renewable resources by integrating circular economy principles into the bioeconomy' (p. 1) [3]. Since its emergence in the mid-2010s, the term has become embedded into policy via (among others) the European Commission's 2018 Updated Bioeconomy Strategy, and the 2019 European Circular Bioeconomy Fund, which aims to mobilise €250 million for circular bioeconomy development [2,8] (https://circulareconomy.europa.eu/platform/en/news-and-events/all-news/european-fund-support-circular-bioeconomy). Policy reports suggest the circular bioeconomy is necessary for achieving the UN Sustainable Development Goals, the Paris Climate Agreement [1], and post-COVID-19 economic transformation (https://efi.int/articles/circular-bioeconomy-offers-game-changing-solutions).

Academia and industry are now harnessing the potential of biotechnology to play a key role in circular bioeconomy, through waste valorisation, greenhouse gas utilisation, and production of biobased or biosynthesised materials, chemicals, and fuels [9]. However, current debate in the circular bioeconomy literature is often oriented towards natural resource management and extractive bioindustries (e.g., forestry) rather than biotechnology more broadly [1–3], echoing earlier tensions between biotechnology-driven and biomass-centric interpretations of bioeconomy [6,10].

This is a decisive moment in the evolution of circular bioeconomy, and its nascent delineation provides an opportunity for critical interrogation [2]. There is a risk that interpretive flexibility could be closed down in favour of trajectories that seek public support for a science-led circular bioeconomy delivering economic value [1,2]. This delimiting path potentially excludes more sustainable trajectories, hampering opportunities for biotechnology to tackle complex environmental challenges and create social value.

The Delimiting Path

Current circular bioeconomy trajectories are at risk of being impeded by the limited range of actors shaping them, narrow problem and solution framings, and the foregrounding of economic value. Collectively, these factors threaten to create a

trajectory that no one actor is advocating (and to which there are notable exceptions [11]), but that nonetheless has the potential to propel circular bioeconomies along an unsustainable path.

First, despite recent calls for co-development of the circular bioeconomy [11], currently much circular bioeconomy literature, policy and practice emerges from and focuses on European academic, policy and industry contexts, meaning that a limited range of actors in higher-income countries dominate processes defining circular bioeconomy [1–3]. Sometimes, these actors seek public support for circular bioeconomy but do not consider citizens and other stakeholders as agenda-setting actors (Box 1). This may reduce the social robustness of biotechnology-based solutions [4], lead to failures in anticipating detrimental impacts of reconfiguring resource flows and the social conditions with which they are co-constituted, or raise social justice concerns (Box 1). For example, commercial structures for GMOs perpetuated inequalities between the multinational corporations that own intellectual property rights to modified seeds and the small-scale farmers required to buy licenses to use them [12].

Second, the problems that the circular bioeconomy is intended to solve are often framed in narrow ways, obfuscating alternative and/or broader problem diagnoses. One prevalent problem framing for the circular bioeconomy is resource depletion and excess waste [2,3,9]. However, there are plural ways of understanding and approaching highly complex sustainability problems, which have social, political, economic, and environmental dimensions. Neglecting these dimensions increases the chances of unanticipated impacts and missed opportunities. For example, circular bioeconomy strategies do not tend to address societal dynamics such as the drivers of consumption [3]. Predominantly, they assume the continuation of existing socioeconomic systems rather than engaging with more radical transitions such as degrowth [2,3]. Attention should be paid to potential unintended rebound effects of circular bioeconomy implementation, such as the legitimisation of – or even increase in – material demand, which may forestall rethinking carbon-intensive production and existing consumption patterns [2,3,7]. Similarly, biotechnology must be considered in conjunction with complementary means of achieving circular bioeconomies, such as surplus food redistribution, composting, and ecological agriculture. Limited problem framings invite a narrow range of solutions.

Third, current circular bioeconomy strategies tend to foreground economic value at the expense of other value [2,3]. This focus frequently coincides with constricted conceptualisations of environmental harm, and neglect of social aspects [2,3]. Such approaches consider the environment as a resource base and waste sink, but fail to acknowledge its amenity value (e.g., recreation and happiness) or life-support system function, missing the full range of cultural, regulating, and provisioning services offered by natural resources and ecosystems [1,7]. Following trends in circular economy and sustainability [7,13], social value – or social dimensions more widely – are rarely considered in academic and policy texts defining the circular bioeconomy [2]. When social aspects are included, they are circumscribed in narrow ways (Box 1).

The Sustainable Path

Despite the delineation of circular bioeconomy towards a trajectory with narrowly defined problems and solutions delivering economic value driven by an elite few, a more sustainable path is possible [11]. A sustainable trajectory requires the circular bioeconomy to embrace a broad range of knowledge and perspectives; multiple, multidimensional problem diagnoses and solution propositions; and noneconomic values.

The increasing political capital of circular bioeconomy is accompanied by a risk that potential benefits are overstated in order to prioritise technoeconomic aims without fully considering socioethical, ecological implications, or inclusive agenda setting. Questions about which goals are served by circular bioeconomy and how social and environmental value will be created cannot be decided solely by a narrow range of actors from higher-income countries when circular bioeconomy has wide-ranging, potentially global impacts [11]. These are value-based questions; therefore, policy-making and implementation must involve diverse stakeholders who can provide input on a range of values and knowledge about the problems circular bioeconomy is addressing.

Box 1. Circumscriptions of Social Aspects in the Circular Bioeconomy

Academic and policy texts defining circular bioeconomy often conflate social and environmental issues. For example, Hetemäki and colleagues note national bioeconomy strategies address the 'social goal' of replacing fossil resources with biomass alternatives (p. 18) [1]. This (albeit laudable) intention overlooks wider social challenges which may arise from disrupting complex fossil-based systems. Society is positioned as an actor that should be enrolled to support – rather than to shape – circular bioeconomy: 'An evidence-based circular bioeconomy narrative is essential to engage society […] to support policies needed for circular bioeconomy strategy and policy implementation.' (p. 14) [1]. Social inclusiveness is taken to mean inclusive growth [1], and an OECD paper suggests 'social issues are addressed through job creation in the engine of the CBE – the biorefinery or bioproduction plant' (p. 12) [14]. However, inclusive growth and job creation do not redress all social inequalities: even in a more distributed growth model, issues of private ownership remain; and new, specialised jobs do not counter livelihood losses, for example, if biosynthetic products displace farmed crops [15]. Further, as the OECD paper notes, bioeconomy sustainability assessment tools (e.g., life cycle analysis or indexes placing monetary values on socioethical costs and benefits) do not adequately capture social aspects [14].

To begin to consider some of these questions, we convened a transdisciplinary, international workshop in April 2019, inviting social scientists and humanities researchers, bioscientists, policy-makers, and representatives from industry, as well as the Ellen McArthur Foundation, to reflect on the circular bioeconomy (https://sbrc-nottingham.ac.uk/rri/circular-bioeconomy/circling-sustainability-and-responsibility.aspx). Participants argued that the rise of the circular bioeconomy offers a valuable opportunity to contemplate collective visions of what 'circular living' or 'the good life' might entail. There is a need for collaborative, systems-oriented thinking and action, as well as renewed considerations of how responsibility can be distributed throughout the complex networks and ecologies through which resources flow, in which they are embedded, and that they constitute.

Participants further proposed that it is more productive to envisage many circular bioeconomies, rather than thinking in singular terms. These could be locally or regionally situated efforts towards developing contextually appropriate circular bioeconomy approaches, incorporating social innovations and nonmarket solutions (in addition to technoeconomic pathways), and involving a plurality of actors in multilevel, multistakeholder governance. Responsible innovation is one means to pursue this more sustainable path towards circular bioeconomies (Box 2), alongside other approaches to inclusive, collaborative governance such as transdisciplinarity, co-creation, public–private partnerships, and alternative business models (e.g., cooperatives, foundations, and community interest companies) [3,10,11].

Circular bioeconomies offer the potential to support transitions to more sustainable, low carbon societies, but their success could be jeopardised by a narrowing of actors involved, of problem/solution framings, and of types of value prioritised [4]. Diversifying expertise and stakeholder input, encouraging multiple visions and implementations, and pluralising the values that shape and are derived from biotechnology are imperative for more equitable, resilient, socially robust circular bioeconomies that meet shared social, environmental and economic sustainability goals.

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Box 2. Responsible Innovation and Circular Bioeconomies

Responsible innovation is an approach to the governance and practice of research and innovation that aims to align innovation with societal values, needs, and priorities [4]. This will be key to exploring and establishing the role and contribution of biotechnology in circular bioeconomies. The goals of responsible innovation include anticipating socioethical and environmental implications of sociotechnical developments, contextualising them within wider systemic shifts, and considering motivations for and impacts of innovation on an ongoing basis [4,7]. Responsible innovation processes foster collective responsibility across sociotechnical systems and extend agenda-setting, knowledge-producing, and decision-making capacities to a broader range of actors, such as societal stakeholders, multiple publics and a full range of disciplines including social and environmental sciences, and humanities [4,7]. In the UK, emerging technologies, particularly synthetic biology, have been closely connected with responsible innovation approaches. While this has encompassed much meaningful work, a consistent commitment to operationalising responsible innovation is not always evident in synthetic biology and broader biotechnology contexts [4]. Despite lags and challenges in uptake, studies of responsible innovation highlight the importance of paying attention to the complex social, ethical, political, economic and environmental dimensions of circular bioeconomies, rather than allowing hype and profit to supercede these aspects [4,15].

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