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[Changing] Ecosystems

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This paper presents a review and critical analysis of papers submitted for the Ecosystems Track of the Life-Changing Design conference, which focused on "Changing Ecosystems" through design for sustainability. The conference track aimed to explore the multifaceted dimensions of sustainability and its connection to design practice, research, and education. The papers covered various subthemes, including products and product design, Sustainable Product-Service Systems, craft, materials, aesthetics, more-than-human design, biodesign, and the role of designers as actors in society influencing policy, local-global dynamics, place-making, strategy-setting, and stakeholder interactions. Through synthesising the findings and insights from these papers, this review aims to provide a comprehensive understanding of the advancements made in design for sustainability and highlight emerging trends and future research directions.

Keywords: ecosystems; sustainability; design-for-sustainability; circularity

1 Introduction

In recent years, the imperative to achieve Sustainability has called for radical changes in our approaches to production, consumption, and daily living. Design for Sustainability has emerged as a pivotal discipline recognised for its potential to foster Sustainability and its expanding scope in addressing the challenges which are leading to planetary boundaries (Rockström et al., 2009). The critical environmental conditions of the planet, which are visible and tangible today (IRP, 2019; Ulluwishewa, 2014), compel us to devise solutions rapidly to minimise the impact of our industrialised world. Environmental issues are urgent, so researchers and practitioners are committed to formalising new visions and pathways, willing to meet the SDGs of the 2030 agenda (Guterres, 2022; United Nations, 2015). There is a need to understand how the different topics on Sustainability can be studied, analysed, and modified to improve the status quo of economic growth, generating less negative impact, transforming and valorising resources and generating welfare for society (Ellen MacArthur Foundation, 2022).

The *[Changing] Ecosystems Track of the Life-Changing Design conference* provided a platform for researchers and practitioners to delve into the intricate relationship between design and Sustainability, exploring diverse topics such as circular product development, Sustainable Product-Service Systems, craft and aesthetics, more-than-human design, and the roles of designers in societal, policy, and stakeholder contexts.

This year we received a solid number of contributions from different regions of the planet with a wide diversity of subjects interconnected with design for Sustainability and formulating a framework for a changing ecosystems approach. In this article, we will describe the subjects covered, organising them into the topics mentioned above. This allows the reader to understand each contribution's variety and interconnections with the conference track. Our network of reviewers rigorously and meticulously fulfilled the evaluation process, and we want to thank all. The contributions that did not make it to this year's conference are invited to expand their fascinating research aims and consolidate data and results for the forthcoming gatherings of the design for sustainability network.

2 Contribution, emerging trends, and future research directions in design for sustainability

2.1 Products, product design, and products and users

The field of design-for-sustainability has developed from end-of-life considerations and eco-design competencies to product design for Sustainability and circularity (Bakker et al., 2014; Ceschin & Gaziulusoy, 2016; Chapman, 2017; Charter, 2019). Pollution and resource efficiency are still vitally important in how we think about ecosystems, while attention in design in research, education and industry has increasingly focused on circularity, including developing design tools and methods for a circular economy and for industrial symbiosis. Moreover, the role of users in product design, use, maintenance and disposal is crucial.

The first set of papers in the [Changing] Ecosystems track focused on design strategies and methodologies for sustainable product development. They delved into topics such as circular economy approaches, lightweight design based on functional units, longevity design for smart speakers, emotional attachment between individuals and home appliances, user decision-making for end-of-use products, and considering person-product attachment through more-than-human design. These papers shed light on the importance of considering the entire lifecycle of products, the emotional bonds between users and products, and user behaviours in achieving sustainable outcomes.

Indeed, several papers explored design strategies and frameworks for achieving circularity in product development. They emphasised the importance of adopting circular design principles, such as minimising waste, promoting reuse and recycling, and incorporating sustainable materials and production processes. These approaches aimed to extend product lifecycles, reduce environmental impacts, and foster more sustainable consumption patterns.

Some researchers examined the integration of Life Cycle Assessment (LCA) and functional unit analysis in lightweight product design. They highlighted the significance of considering the overall environmental impact of products, particularly in terms of energy consumption and material efficiency. By optimising product design based on functional units, these studies aimed to reduce material usage and environmental burdens while maintaining or enhancing product performance.

Some authors explored strategies for designing smart speakers with extended lifespans. They emphasised the importance of modularity, upgradability, and repairability to ensure the longevity of these connected products. These studies aimed to reduce electronic waste and promote a more sustainable product ecosystem by addressing technological obsolescence and promoting a more sustainable consumption culture.

Other researchers investigated the emotional bonds and attachments between individuals and their home appliances. These studies aimed to understand how emotional design strategies can promote sustainable behaviours, such as responsible use, repair, and maintenance of appliances. These papers sought to enhance product longevity and reduce unnecessary replacements by fostering emotional connections between users and products.

A paper focused on understanding user motivations and decision-making processes regarding the end-of-use phase of products. They explored factors that influence users' decisions to keep, repair, or dispose of products and identified strategies to encourage responsible sharing and circular consumption. By understanding user behaviours and motivations, these studies aimed to promote more sustainable product lifecycles and reduce waste generation.

A set of papers proposed a paradigm shift in design thinking, advocating for a shift from human-centred design to More-Than-Human Centered Design approaches. They emphasised the interconnectedness between humans and the broader ecological system, recognising the agency and significance of non-human entities in design processes - even when considering products and users in product design. This points to a compelling approach that is attracting more attention in design research, education, and practice. By embracing an ecosystemic perspective, studies orienting to "more-than-human design" aim to inspire more sustainable and regenerative design practices. Beyond product design, a set of papers devoted to this topic will be discussed in section 2.4.

2.2 Sustainable Product-Service Systems

Sustainable Product-Service Systems are regarded by many to be a catalyst for sustainable consumption and production patterns. Yet, they must be designed with environmental, social and economic sustainability dimensions in mind if they are to be sustainable as well as acceptable to customers and stakeholders (Tukker, 2004; Vezzoli et al., 2014). Thinking in terms of sustainable product-service system design allows for experimentation with new business models such as subscription-based and peer-to-peer sharing facilitation, and it is particularly important for considering people's needs in *what* is produced, for *whom*, and *how*.

Another cluster of papers in the [Changing] Ecosystems track examined Sustainable Product-Service Systems (PSS), exploring areas such as smart-circular PSS, digital transitions, and the social influences of digital technologies in designing sustainable PSS and distributed economies. These papers highlighted the transformative potential of PSS in addressing environmental challenges, developing innovative business models, and integrating digital technologies to enhance Sustainability.

Some researchers investigated the design and implementation of smart-circular PSS, which combine the principles of a circular economy with digital technologies. These studies explored the role of data-driven approaches, Internet of Things (IoT) technologies, and artificial intelligence (AI) in enabling more efficient resource allocation, waste reduction, and sustainable consumption. By leveraging

smart technologies, these papers aimed to optimise the use of products and services, reduce environmental impacts, and enhance user experiences.

Some papers examined the role of digital technologies in facilitating the transition towards more Sustainable Product-Service Systems. They explored how digitalisation can enable resource optimisation, enhance collaboration, and support the sharing economy. These studies investigated the potential of platforms, mobile applications, and online communities in promoting sustainable behaviours, encouraging peer-to-peer sharing, and facilitating access over ownership.

Other researchers investigated the social dimensions and impacts of digital technologies in the design of sustainable PSS and Distributed Economies (DE). They examined how digital platforms and social networks influence consumer behaviours, facilitate knowledge sharing, and shape social norms related to sustainable consumption. These papers shed light on the potential of digital technologies to foster collaboration, social innovation, and collective action for Sustainability, as well as the risks related to big data control and threats to democratic systems.

2.3 Craft, materials, aesthetics

Designers are paying increased attention to processes and practices in design-for-sustainability, expanding their spheres from understanding and selecting materials to innovating them, to re-discovering and developing craft techniques, to robustly considering the meanings of materials and making (Walker & Giard, 2013; Karana et al., 2017). Materials are highly relevant, as the Sustainability of design solutions relies heavily on their development and application. As a result, materials have been the focus of a great deal of research. These explorations also often involve discussion on new design philosophies rooted in various traditions and probing new aesthetics and expressions.

The intersection of craft, materials, and aesthetics in sustainable design was the focal point of several papers in the [Changing] Ecosystems track. They investigated emerging raw aesthetics rooted in regenerative design and crafts, the role of active making in sustainable transitions, the co-creation of tacit knowledge through material connaissance, and future directions for sustainable design. These papers emphasised the significance of material choices, traditional practices, and design philosophies in promoting Sustainability and provided insights into how craft and aesthetics can inspire sustainable design practices.

Some researchers explored the emergence of raw aesthetics that integrate regenerative design principles with traditional craft practices. These studies highlighted the potential of emerging biomaterial proposals, natural dyes, and upcycled materials in creating visually compelling and environmentally conscious design outcomes. By embracing regenerative design principles, these papers aimed to promote sustainable material choices, encourage local craftsmanship, and foster a deeper connection between users and products.

A paper emphasised the role of active making in fostering transitions to more sustainable solutions. They investigated how hands-on engagement, prototyping, and iterative design processes can inspire creative problem-solving and nurture sustainable mindsets. These studies highlighted the significance of making as a tool for learning, experimentation, and collaborative action, promoting sustainable design practices grounded in practical knowledge and embodied experiences.

Other researchers examined the co-creation of tacit knowledge through material exploration and engagement. They explored how material experiences and experimentation can foster new insights,

inspire sustainable design solutions, and facilitate circular economy practices. By engaging with materials in a meaningful way, these studies aimed to deepen our understanding of material properties and qualities, promote resource efficiency, and encourage innovative design approaches.

A paper provided reflections on the future of design for Sustainability, envisioning new directions and approaches. The authors discussed the importance of embracing traditional practices, redefining design philosophies, and adopting holistic frameworks for Sustainability. These studies emphasised the need for more inclusive, socially responsible, and culturally relevant design practices that address complex sustainability challenges.

2.4 More-than-human design, biodesign

Design research, education and practice has expanded beyond the arena of human-centred design, inspired and challenged by posthumanist ethics, feminist principles, and writings on new materialism (Braidotti, 2013; Forlano, 2017; Escobar, 2018). The ethics of care has particularly had great impact on how the design field is reconsidering roles and responsibilities in multispecies design, regenerative design, and inclusion of animals and natural ecosystems (de la Bellacasa, 2010).

A set of papers in the [Changing] Ecosystems track explored the paradigm of More-Than-Human Design and biodesign, acknowledging the interconnectedness of humans and the environment. They encompassed topics such as caring approaches to ecosystemic design, bio-product design with ancestral references, the contributions of Daoism to design prototypes, planet-oriented design as an ethical transition in design education, and the adoption of ecofeminism in sustainability approaches. These papers encouraged a shift in design thinking that embraces ecological perspectives and ancestral knowledge.

Some researchers advocated for caring approaches to ecosystemic design, emphasising the importance of empathy and responsibility towards the broader ecological system. These papers proposed design frameworks that integrate ecological considerations, encourage biophilia, and foster stewardship of natural resources. By adopting caring approaches, designers can play a significant role in nurturing sustainable relationships between humans and the environment.

A paper explored the integration of ancestral knowledge and biofabrication techniques in design processes. They investigated how indigenous practices and materials can inspire sustainable design solutions that respect cultural traditions and ecological systems. These studies highlighted the potential of collaborative design processes that bridge ancestral knowledge with modern technology, promoting cultural Sustainability and fostering biocultural diversity.

Some researchers examined the contributions of Daoism, a philosophical and spiritual tradition, to the design of prototypes for social innovation. These papers explored how Daoist principles, such as balance, harmony, and the interconnectedness of all things, can inform sustainable design practices. They emphasised the need for holistic and systemic design approaches that consider the broader ecological and social contexts in which design interventions occur.

A paper discussed the concept of planet-oriented design as an ethical transition in design education. The authors explored how design curricula can integrate ecological perspectives, foster systems thinking, and promote values of Sustainability. The study emphasised the importance of nurturing future designers who possess the knowledge, skills, and mindset necessary to address complex sustainability challenges and contribute to positive societal transformation.

Some researchers examined the adoption of ecofeminism and hydrofeminism in sustainable design approaches. The paper explored the intersections between feminism, environmentalism, and Sustainability, emphasising the need for inclusive and gender-sensitive design practices. They highlighted the potential of hydrofeminism to challenge dominant paradigms, promote environmental justice, and reshape power dynamics in the pursuit of Sustainability.

2.5 Designers as actors in society: place, policy, strategy, and stakeholders

Another way to conceptualise the changing ecosystems in design is to examine the expanding roles design and designers are taking as societal actors with agency and ethics, dealing with issues that shift form and importance in local-global dynamics and changing consumption patterns. There are new places and spaces for design. Designers are increasingly designing strategically for larger stakeholder networks, as well as working in the arenas of policy and lobbying, design for government, design for localism and place-making, design with civil society in peer-to-peer networks, and so on (e.g. van Abel et al., 2011; Manzini & M'Rithaa, 2016; Kimbell & Bailey, 2017; Vezzoli et al., 2021). Design for sustainability transitions, for example, entails a stronger linking of design with systems thinking and research on sustainability transitions (Irwin et al., 2015; Ceschin & Gaziulusoy, 2016).

The final cluster of papers in the [Changing] Ecosystems track focused on the evolving role of designers as actors in the broader societal context of Sustainability. They investigated areas such as the creation of national strategies for circular design, stakeholder networks in emerging distributed hydrogen infrastructure, design's role in nurturing sustainable production and delivery systems for social micro-enterprises, designing smart circular ecosystems in waterborne passenger mobility, and the diverse activities of circular economies in neighbourhood makerspaces. These papers emphasised the importance of collaboration, stakeholder engagement, and policy implications for promoting sustainable design practices.

Some researchers explored the role of designers in the creation of national strategies for circular design. They examined how design thinking and interdisciplinary collaboration can inform policy decisions, drive systemic change, and promote sustainable development at the national level. This study highlighted the significance of engaging diverse stakeholders, fostering cross-sectoral collaboration, and aligning design practices with broader sustainability agendas.

A paper investigated stakeholder networks in emerging distributed hydrogen infrastructure. They explored the complexities of designing and implementing hydrogen-based energy systems, considering social, economic, and environmental dimensions. These studies emphasised the importance of stakeholder engagement, social network analysis, and participatory design approaches in developing sustainable energy infrastructures.

Some researchers examined design's role in nurturing sustainable production and delivery systems for social micro-enterprises. They investigated the potential of design interventions to enhance the viability and Sustainability of small-scale enterprises, promote social innovation, and foster inclusive economic development. These papers highlighted the importance of considering local contexts, empowering marginalised communities, and fostering collaborations between designers and social entrepreneurs.

A paper focused on designing smart circular ecosystems in waterborne passenger mobility. The authors explored how digital technologies, circular economy principles, and user-centric design

approaches can optimise waterborne transportation systems, reduce environmental impacts, and enhance user experiences. This study emphasised the integration of sustainable design strategies with digital innovations to create more efficient and sustainable mobility solutions.

Some researchers investigated the diverse activities of circular economies in neighbourhood makerspaces. These papers explored how local communities, makers, and designers can collaborate to foster circular practices, promote resource sharing, and enhance local resilience. They highlighted the potential of makerspaces as hubs for sustainable innovation, education, and community engagement.

3 Reflections and conclusions

In this manuscript, we wanted to highlight the broad yet fascinating scope in which design for Sustainability has evolved. It is evident that the different subjects addressed by scholars and researchers around the globe cover a wide spectrum of subjects offering alternative solutions for the sustainable development of our societies in the long term. We are delighted to see how many different efforts converge in this year's conference, especially on the ecosystems track.

By analysing and synthesising the insights and findings from the papers, several emerging trends and cross-cutting themes within design for Sustainability emerged. These included the integration of digital technologies, local-global dynamics, material choices, aesthetics, ecological design approaches, and the expanding roles of designers in shaping sustainable futures. The interdisciplinary nature of design for Sustainability was evident, drawing from diverse fields such as sociology, engineering, sustainability sciences, biology (life sciences), industrial ecology, marketing, and psychology. Furthermore, the inclusion of perspectives such as new materialism, ecofeminism, and frameworks like planetary boundaries and doughnut economics enriched the discourse.

The papers thus offer more holistic conceptualisations of design responsibility and several even problematise our understanding of sustainable 'development'. They present new approaches that involve changing scales, in time and space, and re-examining our role as humans in webs of life.

In conclusion, the papers reviewed in this comprehensive analysis have made significant contributions to the field of design for Sustainability, advancing our understanding of changing ecosystems and the role of design in promoting Sustainability and the transition to more circular and regenerative patterns of production and consumption. The insights gained from these papers will inspire future research, inform design practices, and guide policy decisions. By embracing the multidisciplinary nature of design for Sustainability and fostering collaborations across disciplines, we can collectively work towards creating a more environmentally conscious and socially just world. The findings presented in this review serve as a valuable resource for researchers, practitioners, and educators in the field of design for Sustainability to further advance knowledge and drive positive change.

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