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EDITORIAL

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1 | INTRODUCTION

The field of industrial ecology draws inspiration from the similarities between natural systems and economic systems. Since its inception, it has worked to develop a set of robust and scientifically rigorous methodologies, tools, and approaches to understand how production, consumption, and disposal of material goods impact the environment. This knowledge can thus be used to inform and devise the most effective means to minimize these impacts, just as natural ecosystems manage resources in flows and cycles.

Together with other fields, industrial ecology serves as the theoretical foundation for the circular economy, and its tools including material flow analysis (MFA), environmentally extended input–output (EEIO) models, life cycle assessment (LCA), among others, provide the scientific foundation to assess and develop effective and impactful circular strategies. One of the key issues studied in industrial ecology is material efficiency and how it can be optimized to minimize environmental impacts associated with the delivery of a certain amount of functionality.

With regard to consumer goods, product lifetime is one of the most important parameters to consider in developing a richer understanding of how society metabolizes the goods that are produced, along with the materials extracted to make them and the waste resulting when their useful lifetime is over (Cooper, 2005). Extending product lifetimes is argued to be one the most effective ways to preserve resources and contribute to a circular economy (Hollander et al., 2017). But for such an important topic, product lifetimes and their interplay with environmental impacts are very complex and still understudied.

Product lifetimes can be difficult to define in practice, as product lifetimes can be dependent not only on technical attributes such as the product design and the quality of materials, but also economic and practical factors such as the price and convenience of repairs (Russell et al., 2023b), as well as user behaviors and perceptions (van den Berge, 2023) and even less tangible factors such as brand names (Makov et al., 2019) and social norms influencing (fast) fashion trends (Manieson & Ferrero-Regis, 2023). Therefore, product lifetimes must also be considered in the context of obsolescence (Hollander et al., 2017). Developing such a deep understanding of product lifetimes then requires more than disciplinary approaches, with inputs required from across the academic spectrum.

The general assumption is that longer product lifetimes are desirable and lead to reductions in environmental impacts. This should be especially true for products such as electronics and textiles amongst others where the majority of environmental impacts are associated with extracting materials and production (Cooper & Gutowski, 2017). For other products where the use stage dominates impacts, optimal product lifetimes need to be considered, balancing energy efficiency improvements with longevity, and including factors such as the evolution of energy systems and user behaviors (Bakker et al., 2014; Richter et al., 2019).

It is also important to consider how longer lifetimes are enabled. They may be achieved through a single user or cascaded through multiple users, the latter often involving transboundary movements. The distribution of benefits, risks, and impacts between different actors also needs to be considered with longer product lifetimes. Validation of key assumptions through empirical studies is still needed as well as more exploration of the complexities.

This special issue of the *Journal of Industrial Ecology* addresses product lifetimes and their assumed environmental benefits, with a focus on empirical validation. The special issue includes a selection of papers that were first presented at the 2021 event, which was hosted online by the University of Limerick due to the COVID pandemic. The Product Lifetimes and the Environment (PLATE)[1] consortium was formed in 2015 to develop and share understanding of the effect that product longevity has on environmental, economic, and social sustainability. The articles in this special issue have been published in a virtual special issue, and they are available on the journal website at https://bit.ly/JIE-product-lifetimes.

2 | SPECIAL ISSUE CONTRIBUTIONS

Product repair and reuse for electrical and electronic equipment (EEE) features heavily as a topic in this special issue. This reflects not only the increasing complexity of these products but also the barriers that emerge through increasing complexity in product innovation and changing consumer expectations and behavior. These trends were apparent at the PLATE conference, where there were many contributions focused on products other than EEE, including textiles, furniture, and buildings that highlight that there are also common barriers and issues common for many different products. That issues cut across product groups is also evident from the issue of transboundary movement of secondhand goods, often focused on electronics in the literature but with the flows of used garments and textiles increasingly coming into focus, including in this special issue.

Four contributions focus on repairability of products as a means to extend their lifetime and counter premature obsolescence. It is evident from the contributions that a narrow focus on the technical side of repairability will not bring about the needed change. Instead, the authors propose a system perspective to comprehensively address the complex technical, business, infrastructural, social, and regulatory aspects of repair. The frameworks proposed take a more systemic approach or add new elements to assessments of repairability.

Russell et al. (2023b) propose to consider a more holistic "system of repairability" to be addressed by a policy mix. Using a system framework, they demonstrate that non-technical aspects of repairability such as warranty duration, after-sale service provision, and access to necessities are affected by the passage of time and how these affect the ability to repair, and thus the likelihood of repair in practice.

Parajuly et al. (2023) apply a systems framework in their survey of barriers. The authors conducted a survey of almost 1000 public repair volunteers across 14 countries to gain an understanding of this fascinating social phenomenon from a systems perspective. They conclude that influencing repair behavior must be primarily supported through more repairable products.

Van den Berge et al. (2023) conducted an interview study for a more in-depth look at barriers in the Netherlands. They perform interview analysis to deliver an insight into Dutch consumers' considerations about the lifetimes of electronic products. They find that lifetime extending practices are very much hindered by consumers' limited knowledge and inability to estimate how long a product could or should actually last. They also discuss the potential role of product lifetime labeling to address this. They suggest solutions such as repairability indexes and information.

Repair indexes are further examined by Barros and Dimla (2023). The availability of useful information about repairability at the point of sale is often suggested as playing a part in shifting producer and consumer behavior toward longer product lifetimes. The authors have examined smartphone repairability indexes, specifically the Index of Repairability in France and the repairability scoring system from iFixit, and find that incorporating both product design features and high quality and affordable service into a single index can lead to misperceptions among consumers.

A more complex understanding of value, including dimensions of space and time, is another major theme in this special issue. Spatial issues come into play when exporting obsolete products (e.g., garments) from high-income to low-income countries, with both positive and negative side effects. Peoples' needs change over time, which influences their relationships with products and how they value them.

Manieson and Ferrero-Regis (2023) explore multiple values and their flows across boundaries in addressing the vexed issue of the flow of used goods from high-income to low-income countries with the case study of secondhand clothing imports in West Africa. The paper exposes a duality where on the one hand the symbolic value loss in the global north is reconstituted through exchange and labor creation in the global south but on the other hand it reinforces colonialist relations between the global north and the global south as items produced for consumers in high-income countries will ultimately end up in African landfills.

Values are also personal and change over time. The relationships that people have with their products and how that impact product lifetime is addressed by Madon (2023) through the analysis of interviews with 60 individuals. Using this social scientific approach, the author uncovers biographical factors as a means to explain peoples' propensity to make certain objects last.

Many of the contributions focus on expanding and applying more complex value frameworks to particular cases. For example, Richter et al. (2023) consider economic, environmental, and social values in exploring spare part harvesting from used and end-of-life household appliances and consumer goods. Through case studies from Norway, Sweden, and California the authors identified the key stakeholders and mapped the values captured, missed, and destroyed to identify opportunities for increased value retention.

Lepawsky et al. (2023) explore political industrial ecology in their paper on the impacts of a cluster of third party electronics repair businesses in Lima, Peru. In their work on quantifying the CO_2e and water savings of repair they also discuss interesting questions on the attribution of the conservation value and whether that should be local to the country of repair or in the country of manufacture.

Evaluating the cascading use of wood furniture is the subject of analysis by Russell et al. (2023a) where value retention processes (VRP) such as reuse, repair, and refurbishment are assessed using the UN International Resource Panel VRP model to quantify the potential environmental benefits. This is especially welcome as the contemporary circular economy literature focuses on used wood as a consumable material within the bio-cycle.

Early identification of reusable products in the waste stream before the reuse value is destroyed through mishandling is vitally important for product life extension. Sterkens et al. (2023) have demonstrated the potential of automated product label identification using optical character recognition on large household appliances and discuss how it could play a part in product triage for reuse at recycling centers.

Overcoming some barriers, however, requires more significant changes to both consumer behavior and larger systems. Meshulam et al. (2023) explore sharing economy platforms and, through a quantitative analysis, put the research on micro-level improvements in perspective in showing that there is a larger level rebound effect working to undermine the first-order environmental benefits that lifetime extension strategies aim to achieve. Addressing this rebound to fully realize the benefits of lifetime extensions will ultimately rely on the support of macro ecological economic policies.

3 | PRODUCT LIFETIMES IN FUTURE INDUSTRIAL ECOLOGY RESEARCH

Many of the contributions reflect different perspectives of better understanding challenges and barriers but also focus on ways of better addressing complexity through frameworks and practical solutions. The contributions add new perspectives that can be incorporated into existing approaches used in industrial ecology research. For example, LCA almost never include primary data on product lifetimes and often make highly simplistic and uniform assumptions about user behavior. This extends to analysis of reuse and refurbishment where environmental burdens are mitigated only if and when they actually displace the production and ultimately disposal of new products. While this is taken as the base assumption in many LCAs and sustainability assessments, and policy plans, empirical evidence suggests that one-to-one displacement is extremely rare and environmental benefits are overestimated (Zink & Geyer, 2017). LCAs need to account for the complexity of lifetimes as well as considering lifetime extension strategies carefully (Proske & Finkbeiner, 2020). Future research needs to ensure realistic assumptions about displacement in environmental assessment methods and build on incorporating these.

Likewise, in policy discourses surrounding premature obsolescence there is a tendency to place a lot of emphasis on technical durability and to ignore the complex psychological relations between people and their products and how that influences their decision making around product replacement (Shevchenko et al., 2023). Further, how different products interact to dictate product lifetimes, for example, hardware platforms and application software, is also complex and oftentimes non-deterministic. This special issue makes a strong case for the incorporation of the social and psychological factors that influence product replacement. It is clear that more research is needed to ensure that policy recommendations are evidence based, and to prevent wishful thinking.

Product lifetime extension is also central to the captivating "right to repair" movements seen emerging in countries and regions around the world (Parajuly et al., 2023). These movements have not only been supported from a policy perspective, but have also emerged independently as a grassroots social response in the desire to lengthen product lifetimes. The degree to which grassroots activities such as community repair cafes prolong product lifetimes in practice is another area for further research. Again, the contribution of such movements requires going beyond technical understandings of product lifetimes.

In short, future research by the industrial ecology community can engage more in the complexities of product lifetime extension as part of a circular economy. We are pleased to initiate the debate through this special issue.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

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Note

[1] https://www.plateconference.org/about-plate/

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