



# Implementation of the European Union's packaging and packaging waste regulation: A decision support framework combining quantitative environmental sustainability assessment methods and socio-technical approaches

Monia Niero

Sant'Anna School of Advanced Studies, Sustainability and Climate Interdisciplinary Centre, Piazza Martiri della Libertà 33, Pisa 56127, Italy

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## ABSTRACT

The recent proposal for a European Union Regulation on packaging and packaging waste has a two-fold aims: i) to reduce the negative environmental impacts of packaging and packaging waste and ii) to improve the functioning of the internal market. Life Cycle Assessment (LCA) has historically been able to address the specific objectives of the proposal and is recognized as a key decision support tool in the circular economy context. In this short communication, it is argued that the new EU regulation calls for systemic changes, i.e. changes that are not simply just technological changes, but changes that might give rise to conflicts among actors and that are reliant on the active involvement of end-users. Therefore, to tackle the challenges in the implementation of the requirements of the new regulation a multi-disciplinary research approach able to address both technical aspects and social relations is needed. Accordingly, a conceptual framework combining quantitative environmental sustainability assessment tools (i.e. LCA and Material Flow Analysis) and qualitative socio-technical approaches (i.e. Actor-Network mapping and Practice Theory) is presented. The added value of such combination is illustrated in relation to two cases relevant for packaging, i.e. take-away food and food waste sorting. To exploit the full potential of LCA as a support to the decision-making process, the need to move beyond a product-centric analysis and instead adopt a socio-material perspective is outlined and the packaging sector has the potential to be a frontrunner in this context.

Packaging waste represents a key societal issue which needs to be urgently tackled. Within the European Union, packaging accounts for 36 % of municipal solid waste, as it is indeed one of the main users of virgin materials in Europe, where 40 % of plastics and 50 % of paper used is destined for packaging (Coelho et al., 2020). The recent publication on 30 November 2022 of the “Proposal for a Regulation of the European Parliament and of the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive (EU) 2019/904, and repealing Directive 94/62/EC” (EC, 2022) provides food for thought on how the packaging waste challenge can be addressed from a systemic point of view and the need to include a broader perspective when implementing the policy goals. As reported in the proposal, “Members States shall implement measures aiming to prevent the generation of packaging waste and to minimise the environmental impact of packaging” and its specific objectives are: (i) to reduce the generation of packaging waste; (ii) to promote a circular economy (CE) for packaging in a cost-effective

manner; and (iii) to promote the use of recycled content in packaging.

A powerful tool that can support fulfilling these objectives is Life Cycle Assessment (LCA), which can be used to assess different options for (packaging) waste treatment and management from an environmental point of view (Christensen et al., 2020; Laurent et al., 2014). LCA has already been used to assess waste prevention activities (Gentil et al., 2011; Nessi et al., 2013) including packaging waste, e.g. Casson et al. (2022); Nessi et al. (2014); Tua et al. (2017). Second, LCA is a prominent decision support tool in the implementation of CE for the packaging sector (Jagoda et al., 2023; Niero and Manzardo, 2021; Vadoudi et al., 2022). As an example, LCA is used to identify when and under which conditions reusable packaging alternatives are best from an environmental point of view compared to single use packaging (Gallego-Schmid et al., 2019, 2018). Third, LCA helps in detecting the benefits of increasing the recycled content in packaging and consumer products, e.g. Niero et al. (2016); van der Harst et al. (2016), although challenges

E-mail address: [monia.niero@santannapisa.it](mailto:monia.niero@santannapisa.it).

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still exist on how multiple loops of beverage packaging should be modelled (Niero and Olsen, 2016; Sazdovski et al., 2021).

LCA is applied in the context of CE, but when it comes to the implementation of CE strategies, studies have shown that the role of consumers is key (Camacho-Otero et al., 2018; Shevchenko et al., 2023). Therefore, it has been suggested to combine LCA with other disciplines addressing consumers' behaviour, such as behavioral science (Polizzi di Sorrentino et al., 2016). In the case of packaging, it is particularly important to consider how consumer behaviour is influenced by packaging attributes, such as easiness to be emptied or cleaned (Wikstrom et al. 2016). Moreover, there is a gap between consumers' perception of the environmental sustainability of packaging solutions and the actual LCA results, e.g. Boesen et al. (2019); Steenis et al. (2017). The legislative proposal on packaging and packaging waste states that "producers should also inform that end users have an important role in ensuring an environmentally optimal management of packaging waste". This highlights the importance of providing consumers with harmonized instructions on how to sort packaging waste, suggesting the inclusion of a label containing information on its material composition, as well as on its reusability. However, consumers should be given relevant information in order to guide their consumption choices towards more circular practices, e.g. Testa et al. (2021, 2020). Moreover, there are studies showing that consumers' knowledge of packaging labels is limited, e.g. Boesen et al. (2019); Nemat et al. (2019), so different ways of looking at the role of consumer in a CE context should be explored.

One option could be to shift the focus from consumers' behavior to consumers' practices. Some recent studies have indeed outlined the key role that **Practice Theory (PT)** can play in research on sustainable consumption (Corsini et al., 2019; Suski et al., 2021), also in relation to circular consumer practices (Rabiu and Jaeger-Erben, 2022). According to PT, consumption does not happen as something intentional and meaningful in and of itself and is not just a result of economic incentive or rational reasoning. Rather, it is an outcome of several habitual and routinized practices (Shove, 2003). In PT, social practices constitute the basic unit of analysis (Røpke, 2009; Shove et al., 2012). PT directs attention to the interconnectedness of *materiality* (design of packaging), *meaning* (consuming what and why), and *skills* (for wise product use, waste sorting, etc) (Shove et al., 2012). The findings of Rabiu and Jaeger-Erben (2022) "unveil the need to examine circular consumer practices as interlocking networks of everyday practices that support and compete with each other in their appropriation and routinisation, taking into account socio-structural contexts, rebound effects, and trade-offs." LCA alone can address trade-offs, by ensuring net resource reduction and avoiding burden shifting between life cycle stages, but it is unable to deal with rebound effects mitigation (Kjaer et al., 2018). Thus, the combined use of LCA and PT has been advocated to address unintended side effects from CE strategies (Niero et al., 2021).

Another element emphasised in the legislative proposal is the key roles of Member States in providing reliable and updated data on packaging waste production and the need to establish a common base for calculations of recycling rates. The way recycling rates are calculated does indeed differ among Member States and this is problematic when dealing with policy interventions on packaging waste, given that mandatory recycling targets are set. The role of information and communication technology could help in this regard, not only for the calculation of recycling rates, but also to support traceability for reusable packaging (Ellsworth-Krebs et al., 2022). The importance of including all different collection and processing losses has been clearly outlined in literature, e.g. Haupt et al. (2017). Calculations based on **Material Flow Analysis (MFA)** are thus key to provide a realistic picture of the available material flows. The combination of MFA and LCA in the assessment of CE strategies for packaging in a CE context has been implemented in the case of packaging, e.g. Niero and Olsen (2016); Van Eygen et al., 2018, including the assessment of waste prevention activities (Wiprächtinger et al., 2022).

Chapter IV in the new packaging waste regulation (EC, 2022) is

devoted to the obligations of economic operators, i.e. manufacturers, suppliers of packaging and packaging materials, authorized representatives, importers, distributors. There is a huge network of stakeholders involved in different socio-technical systems using packaging, all with different interests that might not necessarily be aligned. The changes outlined in the legislative proposal, such as the establishment of mandatory deposit and return systems (DRS) in Member States, as well as the encouragement of reuse and refill solutions, demand new relations to be created among actors in the value chain. Some actors will benefit from the suggested changes, while others will not. Therefore, an assessment of the value creation potential of CE strategies requires special attention (Stewart et al., 2018). An **actor-network mapping** (Doganova, 2020; Latour, 1996) directs attention to the human and non-human actors in technological and economic settings. Value creation evolves from the networks of human and non-human actors, and which constitute their actions. As outlined by Niero et al. (2021), ANT can be combined with LCA to better understand the unintended side effects from CE initiatives, as it focuses on problematizations of the existing systems, how action is generated through interactions, representations, performance, and the enrolment of actors. The use of ANT in combination with LCA has been suggested to explore how actors and action networks shape material flows and thus form a basis for a relational analysis of governance, organization, and management of the flows in industrial ecologies (Baumann and Lindkvist, 2022). A socio-material analysis of the national context of bioplastics through ANT supported the scoping of LCA and interpretations of its results, when comparing single-use and reusable tableware systems (Walker, 2022).

The new EU regulation calls for systemic changes, i.e. changes that are not simply just technological changes, but changes that might give rise to conflicts (given the many stakeholders with divergent interests) and that are reliant on the active involvement of end-users. Therefore, in this short communication I argue that to tackle the challenges in the implementation of the requirements of such proposal there is a need for a **multi-disciplinary research approach** considering not only technical aspects, but also social relations. Both quantitative environmental sustainability assessment tools (such as MFA and LCA) and qualitative socio-technical approaches (such as actor-network mapping and PT) should be included when aiming at providing decision support to policy makers and operators in the packaging and packaging waste value chain. Thus, a proposal for a conceptual framework combining the above-mentioned methods and theories is represented in Fig. 1.

According to the proposed conceptual framework, the first step is the quantification of packaging and packaging waste production through MFA, which allows to quantitatively map material flows, thus providing an overview of the available resources to be recovered. As second step, there is the analysis of the stakeholders' involved in the system under investigation, which can be conducted by means of an Actor-Network mapping. Such tool is indeed capable of identifying the human (e.g. waste management operators) and non-human actors (e.g. packaging waste, waste bins) and their relations, i.e. how they are connected one with the other, how they influence each other and how they can be convinced to have an interest in recovered resources. A further step consists in the quantification of potential environmental impacts by means of LCA, which allows to identify the trade-offs between life cycle stages (i.e. production of the packaging vs the end-of-life management) and potential environmental impacts (such as between the climate change impacts and water use in the case of comparison of reusable options vs single-use packaging). The last step focuses on the understanding of consumers' practices by means of PT, i.e. in relation to the materials involved in the fulfillment of the need under investigation, the meanings that are given to such practice, as well as the skills needed to perform the practice. This kind of combined analysis helps gaining knowledge on the changes needed to implement CE strategies from a systemic point of view, including not only material aspects, i.e. flows of materials, but also including the social relations that are needed for

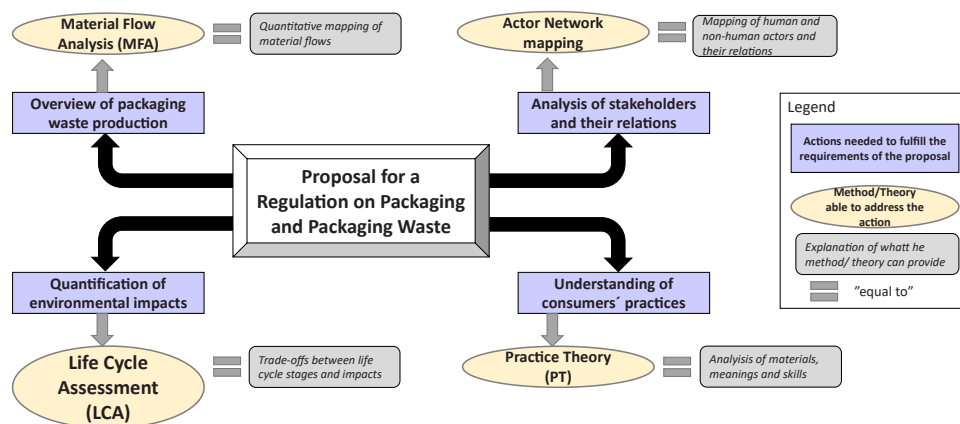


Fig. 1. Conceptual framework combining Life Cycle Assessment (LCA) with both a quantitative environmental sustainability assessment tool, i.e. Material Flow Analysis (MFA) and qualitative socio-technical approaches, based on Actor-Network mapping and Practice Theory (PT), to support decision making in the context of the proposal for a regulation on packaging and packaging waste.

establishing CE-oriented production and consumption systems. These insights are indeed relevant for all the actors affected by the proposal, i. e. from packaging material producers to retailers, from distributors to waste management operators.

Truong and Nicot (2022) provide an example of a combined use of LCA and PT in take-away food packaging, namely a comparison between single use plastic containers vs reusable sushi trays in a Danish context. Their study shows that to effectively make sure that the introduction of a CE strategy such as reuse will lead to a reduction of potential environmental impacts, it is first needed to understand which are the dynamics behind take-away consumption. PT helped to investigate the meanings that consumers give to take away food (e.g. a reward or practical solution after a busy day), the competences needed to perform such practice (grocery shopping, cooking skills, cleaning) and finally the materials involved in the practice (i.e. smartphone for ordering, waste bin, food itself). Such analysis provides an understanding of why practitioners might or might not keep the tray after use and that the primary factor stimulating users' to go for take-away food is convenience. This means that a reusable solution which does not require too many further efforts for the end-users should be preferred and a system inspired by the Danish DRS was suggested. This is an aspect that should be considered, since the legislative proposal requires the establishment of DRS, but this might be problematic in countries where other effective recycling systems are already in place, as it would disrupt already established routines.

A second example of joint application of LCA and PT is given by the case of food waste sorting on the Danish island of Bornholm, where a new system based on a separated collection of the food waste fraction was investigated (Langstrup Hagerstrand et al., 2022). The aim was to understand the dynamics behind consumers' practices and their influence on the overall environmental impacts of the food waste management system. The PT analysis showed that a relevant material is the waste bin and the space required in the kitchen. Examples of meanings are to fulfill a requirement from the municipality or to reduce personal environmental footprint. Finally, the competence needed is the knowledge on how to sort the different waste fractions. The latter is an essential aspect, given the prominent role that the new legislative proposal has attributed to end-users who should contribute to the separate collection of packaging waste and to the appropriate waste management for compostable packaging. Therefore, a thorough understanding of what can facilitate or hinder the actions of end-users is necessary, which means going beyond a mere comparison of technical solutions, as also recently concluded by Angouria-Tsorochidou et al. (2023).

In the implementation of the EU's new legislative proposal on packaging and packaging waste, LCA will still be essential in supporting decision makers in the packaging sector to identify the best solution

from an environmental point of view when it comes to waste prevention activities, encouraging re-use and refill solutions, as well as guiding end-users to how to best sort their waste. However, to exploit its full potential as a support to the decision-making process, it is important to move beyond a product-centric analysis and instead adopt a socio-material perspective, which considers not only the influence of technological solutions, but the role that different types of actors have in realizing CE strategies. A multidisciplinary research approach is suggested, which combines LCA with MFA and socio-technical approaches such as actor-mapping and PT, in order to provide a systemic perspective when the requirements of the new legislative proposal should be implemented. LCA is an established decision support tool in policy making (Sala et al., 2021), but there are still margins of improvement when it comes to its use for life cycle management in a circular economy and the packaging sector is encouraged to be a frontrunner in this context.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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