Towards Sustainable and Circular Practices with Plastics: Exploring the Potential of Law and Governance Tools Based on Holistic and Harmonized Life Cycle Assessment

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Abstract: *Low recycling rates, varying recycling possibilities, and accumulation in nature are issues commonly associated with plastics. Promoting sustainable and circular practices with plastics requires the awareness and engagement of all the stakeholders from public to private actors operating in the plastics value chain. Notwithstanding the existence of several public laws and policies aiming to regulate plastic production and use in order to make the whole value chain more circular, most of these instruments target only specific stakeholder groups (e.g. plastics producers) and affect only certain types of plastics. Even if some private law and governance instruments, such as certifications (including intellectual property rights) and eco-labelling schemes, have great potential to affect a broader range of actors, among them consumers and other end-users, they suffer from several shortcomings, particularly when it comes to transparency and accountability. In addition, both public and private law instruments are challenged by the immaturity and complexity of the methodologies currently employed, such as life cycle assessment (LCA). This is apt to lead these legal tools to have a limited ability to establish the actual environmental impacts of different types of plastics, and thus properly contribute to sustainable and circular practices. We argue that to be effective in guiding stakeholder behaviour towards sustainability, these legal tools should be accountable, transparent, and backed up by adequate scientific evidence on the environmental impacts of plastics throughout their life cycle. We propose that such evidence could be obtained through holistic LCA that is based on harmonized international standards.*

Keywords: *plastics, biodegradability, recyclability, plastics regulation and policies, private law and governance, certifications, eco-labels, IPR, life cycle assessment (LCA)*

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1. Introduction

Plastics are central to contemporary life and have many useful properties that advance sustainability. However, they have recently received considerable attention due to several shortcomings related to plastic waste and the inadequate management of end-of-life of plastics. Indeed, it is not plastics as such that is the problem. In many ways, plastics are superior materials in terms of performance: they are lightweight (Shrivastava 2018), durable (Satti and Shah 2020), cheap to manufacture (Shrivastava 2018), and easy to process (Lagaron et al. 2004). Moreover, due to their excellent gas and vapor barrier properties, some plastics are well suited for storing food and therefore preventing food spoilage (Lagaron et al. 2004). Instead, it is how plastics are used and ultimately disposed of or recycled that have possibly the most significant negative environmental impact.

Indeed, the practices of multiple stakeholders[1] in relation to promoting the circularity of plastics need to be improved. To this end, several legislative and policy efforts have been implemented in the European Union (EU) to efficiently drive stakeholder behaviour towards both increasing knowledge and transparency about the actual environmental effects of different types of plastics and fostering the circularity of plastics. For instance, as far as public legislation is concerned, the EU has adopted several tools to drive the behaviour of especially plastics producers, such as via the European Strategy for Plastics in a Circular Economy and the EU Plastic Strategy (European Commission 2018), the Single-Use Plastics Directive (EU) 2019/904, as well as the Packaging and Packaging Waste Directive 94/62/EC. Moreover, key private law and governance regimes, such as some forms of intellectual property rights (IPR), certifications and labelling, are thought to hold considerable potential for private environmental governance (see e.g. Adelman and Austin 2017). These instruments could also potentially foster circularity of plastics as a specific area, while targeting the behaviour and choices of diverse stakeholders broadly and directly, and in a less categorical and strict manner than public laws.

Notwithstanding all these major efforts, several deficiencies in the regulatory system remain. On the one hand, the problem is that environmental evaluations based on LCA encompassing the entire plastics value chain are often not considered in legislation as an essential part of the process. This holds particularly true of the above-mentioned private law and governance tools, especially voluntary ones. On the other hand, even in cases where LCA is included in legislation (as with some of the already well-regulated private regulatory tools, like most mandatory certification schemes), the challenge remains that, under current rules, it is difficult to provide reliable data on the actual environmental impacts of different types of plastics by using existing methodologies such as LCA. For example, in order to improve sustainable and circular practices to reduce, reuse, and recycle plastics, considerable efforts have been put towards developing alternatives for fossil-based plastics (for instance, bio-based plastics[2]). The claim has been that the broader

1. In this article 'stakeholder' is used to refer to the various actors in the plastics value chain from the producers of raw materials and plastics to the consumer brand owners and retailers, all the way to the consumers, other end-users, and ultimately recycling operators (Siltaloppi and Jähi 2021).

2. To note is that the terms 'bio-based plastics' and 'bioplastics', although often confused or misunderstood, have separate meanings. 'Bio-based plastics' stands for biodegradable or non-biodegradable plastics (fully or partially) made from renewable resources, while 'bioplastics' refers to plastics which are either bio-based or biodegradable, or share both features simultaneously (European Bioplastics 2018; Rujnić-Sokele and Pilipović 2017). In this article, we prefer to talk about bio-based plastics

renewable origin of bio-based plastics could help solve the problem of depletion of fossil resources (Shogren et al. 2019), while also offering some extra benefits with their possible biodegradability (Narancic and O'Connor 2019; Thakur et al. 2018). But then again, when considering the whole life cycle of new types of bio-based plastics, it is not always self-evident that these new materials are any better for circularity and for the environment in comparison to conventional fossil-based plastics (Walker and Rothman 2020). Such claims could stand only if backed up, for instance, by holistic and thorough LCA. Simultaneously, when selecting the materials, a reasonable balance between direct (caused by, e.g. production stage) and indirect (caused by, e.g. use stage) environmental impacts of plastics should be maintained. Unfortunately, though, given the inherent complexities of measuring the actual environmental impacts of plastics, such as the amount of greenhouse gases emitted, the water and energy used, as well as the eutrophication and acidification impacts of the many different types of plastics (especially the new bio-based plastics), it is very difficult to conduct a reliable LCA. This is also partly due to the current immaturity and the consequent shortcomings of LCA as a methodology, which clearly has direct repercussions on the legal and policy frameworks, creating challenges for both public and private regulators in terms of their ability to properly promote circular and sustainable stakeholder practices with plastics.

All these uncertainties have not only led to an opaque – or even unreliable – system, but they have also left many stakeholders frustrated and confused because it is difficult for them to understand the effects of their choices in terms of their actual environmental impacts and to compare the qualities and features of different types of plastics (Mehta et al. 2020). Indeed, the role and actual impact of consumer choices may be undermined due to the law or current doctrines not providing for clear frameworks for embedding accountability and reliability in terms of the relevant information-related aspects (Adelman and Austin 2017). It is indicative that, to similar ends, a bill was recently passed in California to combat misleading use of labelling, that is, addressing the validity of claims concerning environmental friendliness, biodegradability and recyclability in the field of plastics (Senate Bill 2021/343:507). According to the Legislative Counsel's Digest:

> It is the public policy of the state that environmental marketing claims, whether explicit or implied, should be substantiated by competent and reliable evidence to prevent deceiving or misleading consumers about the environmental impact of plastic products and that, for consumers to have accurate and useful information about the environmental impact of plastic products, environmental marketing claims should adhere to uniform and recognized standards. (Ibid).

Against this background, we ask: How can we develop proper law and governance tools as well as policy mechanisms that better employ their potential to drive stakeholder behaviour towards more sustainable and circular practices with plastics through using reliable environmental impact assessment methodologies such as LCA? Deception as such is not discussed.

To address this question, there is a need to holistically and critically assess both the technical advances related to developing renewable and circular plastics, and those concerning the legislative and policy tools to promote sustainability and circularity of plastics. With that in mind, this article will start by briefly introducing the concept of plastics developed from renewable raw materials, such as bio-based plastics, and by

only, due to their less confusing nature among stakeholders in comparison to the term 'bioplastics'.

highlighting both their potential and their challenges in terms of fostering resource efficiency and circularity. The particular focus here will be on their biodegradability and recyclability as 'stopping end-of-life' (SEOL) options[3]. After this, we briefly present the EU public law and policy framework related to regulation of the SEOL stages of plastics. However, the primary focus is on identification, analysis, and elaboration of some prominent forms of private law and governance regimes, namely eco-labelling, certifications, and technical standards, as well as one form of IPR, namely the recently created EU certification marks (EUCM). The reason for this focus relates first and foremost to the fact that, although environmental considerations are already – albeit with shortcomings – being considered in relevant fields of public law, this discussion is still at its initial stages in the selected fields of private law and governance. Yet as mentioned above, these legislative tools can be very effective to drive stakeholder behaviour, thus complementing and reinforcing the efforts coming from the public law side.

A critical assessment, stemming from both polymer science and legal analyses, on the ability of these selected private regulatory tools to promote sustainability and circularity of plastics is then conducted. We conclude that to be able to drive stakeholder behaviour towards sustainable and circular practices with plastics, the selected private law and governance tools should be solidly regulated in terms of their *processual* elements and thereby acknowledging the regulatory role of the private actors in question. In this way, transparency and accountability of the information delivered should be prioritized (see also Vallejo 2020). To this end, these tools should carefully consider LCA holistically, while delivering the information it wishes to convey. To overcome the challenges related to the reliability of the environmental impact assessment of different types of plastics, LCA should be *inter alia* holistic and based on harmonized international technical standards. Indeed, these same principles and approaches should be followed and affect public regulation as well.

3. In this article we choose SEOL as a preferred term to the often used 'end-of-life' expression, as SEOL is more indicative of stages such as biodegradability and recyclability that aim at reviving nutrients, materials, or products, putting them back into the 'circle', instead of making them 'die' or 'end'.

2. Stopping End-of-Life of Plastics: Recyclable, Renewable, and Biodegradable

As previously mentioned, circularity is often claimed to be an important phenomenon in the promotion of SEOL of plastics (Karayılan et al. 2021). At the same time, however, there seems to be a general lack of information as to which types of plastics are 'better' from the standpoint of recyclability and/or biodegradability and, in general, from the environmental perspective. This ultimately leads to the challenge related to the provision of reliable LCA considerations. Before going into this last point, though, it is important to shed light on the nature of this problematic.

2.1 Plastics and Biodegradability

When opening up the concept of *biodegradability of plastics*, both bio-based and fossil-based biodegradable plastics have to be considered. As a general remark, it is important to note that synthetic, fossil-based plastics can also be biodegradable (Rujnić-Sokele and Pilipović 2017), even though many conventional, fossil-based plastics do not biodegrade, but only slowly degrade (Joo et al. 2018). Overall, though, biodegradation is a complex phenomenon and even if fossil-based or bio-based plastics were claimed as biodegradable, it does not automatically follow that they will completely biodegrade in the wild.

In the context of circularity of plastics, biodegradability as a feature becomes particularly significant in the following cases: 1) when mechanical or chemical recycling is impractical or not economic (organic recycling being an alternative) (Bastioli and Capuzzi 2011); 2) when plastics present a real risk of dispersion in the environment (i.e. mulch films) (Bastioli and Capuzzi 2011); and 3) when conventional plastics may contaminate bio-waste streams (for example, in the form of carrier bags) (European Environment Agency 2020a).

However, it should not be forgotten that biodegradation might also cause challenges for sustainability. For instance, accumulation of plastic waste in nature may ensue if plastics designed to biodegrade in the environment fail to do so. Degradation and inadequate biodegradation of plastics can also result in generation of secondary microplastics, which pose hazards not only to the environment but also to living organisms and human health (SAPEA 2020). Moreover, unsubstantiated claims about the ability of plastics to safely biodegrade in the environment are apt to mislead stakeholders, especially consumers, generating a false sense of assurance regarding the environmentally friendly nature of certain plastics (Bhagwat et al. 2020). Ultimately, this could even promote unsustainable practices, such as disposing of such plastics straight into nature.

To prevent the consequences related to (intentional or unintentional) green-washing and misleading information, the extent and time of biodegradation need to be measured separately for each type of plastic in the receiving environment in which the plastics are to be biodegraded (SAPEA 2020). For this purpose, information about biodegradation of plastics should not be based, as often claimed, on factors such as visual observations, mass loss of plastics, or microbial growth (Kliem et al. 2020; Krueger et al. 2015; Zumstein et al. 2019). Instead, they should be based on respirometric measurements, where tracking the carbon conversion of plastics into CO_2 or CH_4, and additionally tracing the biomass contents by using ^{13}C analysis, is central (SAPEA 2020; Zumstein et al. 2019).

All in all, it is clear that when designing new policies for sustainability and circularity of plastics, the underlying challenges must be addressed on a multidisciplinary basis, as the factors to consider are complex and numerous.

2.2 Plastics and Recycling

Generally speaking, recycling of plastics includes three main categories (Sethi 2017; see also Figure 1):

1. Primary recycling: reuse of plastics-based products by maintaining their original structure (closed-loop mechanical recycling);
2. Secondary recycling: reprocessing of plastics by physical means (downgrading mechanical recycling);
3. Tertiary or feedstock recycling: depolymerization or mineralization (SAPEA 2020) of plastics into smaller compounds (chemical and organic recycling).

On a general level, when evaluating the performance of these recycling methods, the most important aspects to consider include: 1) *technical feasibility* in terms of contaminant tolerance and quality of the resulting recyclate (e.g. molecular weight, structure, purity, suitability for targeted application) (VTT 2020), 2) *economic feasibility* in terms of capital investment and operational costs, 3) the *required level of infrastructure and know-how* for running a recycling plant, 4) *environmental impacts* associated with certain recycling methods, and 5) existing *country-specific regulation*.

However, the performance of recycling methods is not flawless. Combining various incompatible plastics grades in the recycling processes may be problematic from the final materials property perspective. Chemical recycling can operate without serious problems with mixed waste and contaminated materials when compared to mechanical recycling (Alaerts et al. 2018; Briassoulis et al. 2019) and it also results in higher quality recyclates (Bucknall 2020).

Chemical recycling, especially pyrolysis, is a very potential large-scale option for recycling, being, nevertheless, a more capital- and knowhow-intensive method than mechanical recycling (Bucknall 2020).

Expanding the use of organic recycling could compensate mechanical recycling in terms of contaminant tolerance, as well as enhance recycling of nutrients (van der Wiel et al. 2020). However, industrial and home composting possibilities for bio-waste and, simultaneously, bio-based, biodegradable plastics are limited in comparison to mechanical and chemical recycling. Industrial composting is well-established in many European countries, but a reliable separate waste collection system needs to be established for this purpose. Instead, home composting can serve only as a small-scale complementary option for treatment of organic waste, especially in remote, sparsely populated areas (Briassoulis et al. 2019; European Environment Agency 2020b). Separately collected bio-waste rates currently vary from below 10% to over 80%, depending on the European country (European Environment Agency 2020b). Moreover, industrial composting is more readily available, simpler, requires lower capital investment, operational costs, and level of process control, and is better standardized in comparison to anaerobic digestion (Briassoulis et al. 2019). Additionally, even if some scholarly articles have compared the environmental impacts of recycling methods, it is well known that a comprehensive analysis is challenging, for instance due to the insufficient quantity of the LCA studies conducted (Spierling et al. 2020).

More research in this area is evidently needed. For example, some studies show that mechanical and chemical recycling result in lower environmental impacts in comparison to aerobic and anaerobic digestion (organic recycling) (Cosate de Andrade et al. 2016; Spierling et al. 2020). At the same time, however, there are different results about the status of chemical and mechanical recycling from an environmental point of view. This is due to different impact categories being utilized during LCA (Cosate de Andrade et al. 2016; Spierling et al. 2020). With an increased number of impact categories in addition to greenhouse gas emissions, chemical recycling seems to perform better in the LCA analysis (Spierling et al. 2020).

In sum – and in similar ways as with biodegradability – creating efficient legal tools to foster sustainable and circular practices with plastics is not an easy task given the inherent complexities related to, for example, performance and the challenges of understanding the actual environmental impacts of recycling methods from the perspective of the entire life cycle of different types of plastics.

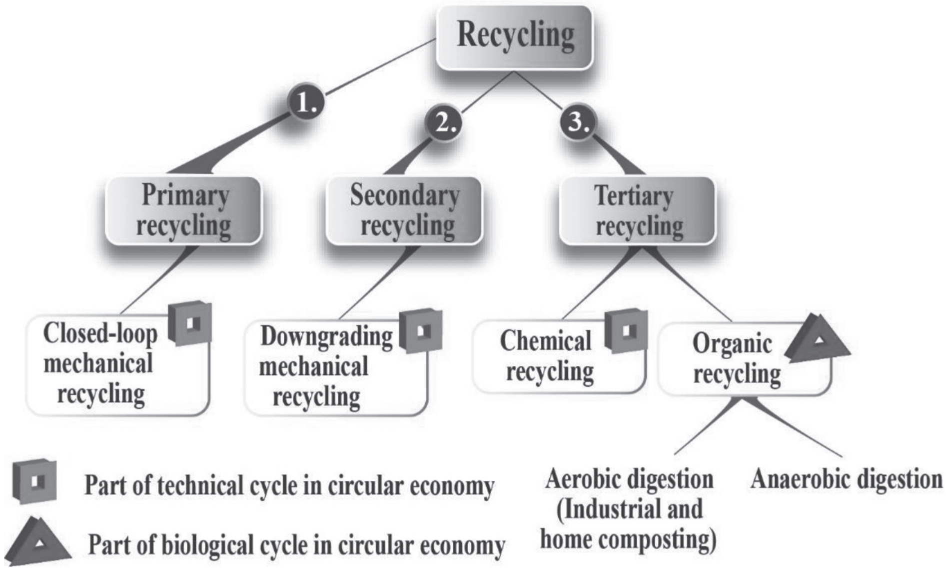

Figure 1. *'Stopping end-of-life' options for plastics under the umbrella term of recycling (excludes energy recovery, landfilling, and littering). The Figure is based on data compiled from the following sources: Alaerts et al. 2018; Briassoulis et al. 2019; Sethi 2017; Hopewell et al. 2009; Spierling et al. 2020; VTT 2020.*

3. Public Policy Framework for Plastics in the EU – Some Remarks

The current public law and policy framework in relation to regulation of plastics in the EU has a strong focus on promoting recyclability (and, lately to some extent, reusability), but with a strong emphasis on regulating producer activities. The newly developed rules in e.g. the EU Circular Economy Action Plan (European Commission 2020), the EU Plastic Strategy (European Commission 2018), as well as the Green Deal announced by the European Commission (European Commission 2019), heavily focus on increasing targets related to fostering recyclability and resource efficiency in production (see Directives 96/62/EC, 1999/31/EC and (EU) 2018/851). Moreover, such public laws are sectorial rather than holistic, banning or regulating only certain pre-determined categories of materials or products, thus leaving e.g. several plastics unregulated. Moreover, these mechanisms do not necessarily consider the environmental impacts of the plastics at stake based on for instance a (reliable) LCA. For example, the recently passed Single-Use Plastics Directive (EU) 2019/904 defines what is to be considered as plastics in the sense of the Directive and actually only restricts the marketing and use of certain selected categories of 'single-use plastic products', entirely or partially made of plastics as defined in the Directive. The categories have not been established on the basis of research-based knowledge of the environmental impacts of those products, but simply by virtue of their being (partly) 'plastics'. Indeed, as was mentioned previously, the challenge is not only that LCA is not always considered in legislation, but also that under current rules, it is difficult to conduct a reliable LCA for plastics – even when such methodologies are included in the legal provisions.

All in all, it is clear that EU policy is heavily focused on fostering SEOL stages for certain plastics. However, most of these instruments are sectorial (that is, they apply to certain types of plastics and applications thereof) instead of being holistic. They thus possibly leave outside the domain of regulation several other plastics, likely without this being based on any thorough evaluation of their environmental impacts. Moreover, such an approach, in turn, makes it possible to develop problematically strict, often politically driven, definitions as to what should or should not be caught by the legal provisions. For instance, important decisions that directly or indirectly affect SEOL of plastics, such as definitions of 'plastics' in terms of 'single-use plastic products'[4] or for taxation purposes, are not often based on reliable scientific proof or reliable methods for assessing the actual environmental impacts of the materials at stake.

It is also worth mentioning that the emphasis of EU policy on plastics seems to be largely on regulating the practices of certain specific stakeholders, such as public entities operating in the value chain, especially municipalities, or some categories of producers, often omitting the role of hybrid type of actors, such as consumers and other end-users. Instead, to promote circularity of plastics, a holistic regulatory approach based on a comprehensive LCA that aims at driving the behaviour of all the stakeholders operating in the plastics value chain would be highly beneficial.

4. Private Law and Governance Regimes

What is the role of private law and governance in this context then?

In terms of private law regimes, several scholars (e.g. Adelman and Austin 2017; Pihlajarinne and Ballardini 2020) have pointed out that some areas of intellectual property law, traditionally seen as a rather objective area, could indeed play an important role in driving stakeholder behaviour towards more sustainable and circular practices. Moreover, according to e.g. Chon (2009), private standard-setting has gained ground as an alternative to public regulation especially since the start of the World Trade Organization. In fact, private regulation and governance tools (e.g. in the form of standards) have increased in diverse areas of the economy since the late 1990s as ways of creating sustainability industry criteria and driving stakeholder behaviour towards that direction (Chon 2009). In addition, in the field of plastics, there currently are various certification and eco-labelling schemes developed by private actors instead of the legislator, into which technical standards are integrated. As such, all these types of private regulatory tools could be effective ways of complementing and integrating the efforts pushed through public law regimes, as argued above.

However, the more these private governance and law systems influence stakeholder behaviour, the more crucial the need for acknowledging the regulatory dimensions of these instruments and the private actors involved becomes (Chon 2009[5]; Vallejo 2020). Private regulators are indeed increasingly being subjected to legal requirements (similar to those of public officials) related to transparency and participation, among others (Vallejo 2020). Here, it has been emphasized that private involvement, although adding to expertise and efficiency in a world of rapidly evolving (technical) requirements, would, if left to private hands only, be problematic from the point of view of accountability and the public interest, as well as the quality of the goals to be achieved (Vallejo 2020).

New types of models for legal oversight of private regulators have recently been proposed and examined in relation to private regulatory

4. See Article 3 of the Single-Use Plastics Directive (EU) 2019/904.

5. According to Chon (2009, 1010), 'a tighter and more transparent connection between standards and marks' was needed a decade ago.

regimes – to the point of discussing the possibility of private administrative law when it comes to the EU approach to such transnational private regulation (Vallejo 2020). Models such as those presented by van Gestel and van Lochem (2020), where stakeholder participation is subject to *procedural rules* and a door to judicial review is opened, should also be considered in relation to labelling and even certification schemes in fostering sustainable and circular practices with plastics in the field of e.g. IPR. At the moment, a long way remains to go in establishing a system where private regulatory tools would be systematically integrated with science-based requirements in order to foster transparency and accountability of the information (e.g. on environmental impacts) delivered. As will be explained below, all this is particularly evident in the field of plastics and especially bio-based plastics. Before going into the detail of the challenges related to the use of private regulatory tools in driving stakeholder behaviour towards more sustainable practices with plastics (4.3.), there is a need to shed light on how some of these key tools are built and the ways in which they function (4.1. and 4.2.).

4.1 Private Governance: Eco-Labelling, Certifications, and Standards

'Eco-label' is a voluntary or mandatory communicative instrument to nudge decision-making by consumers and other stakeholders towards purchasing more environmentally friendly products or services (Chon 2009) – which may include or make use of various materials, such as plastics. While mandatory labels (information that must be disclosed by law) are generally well regulated, voluntary ones (information that the producers can include on a voluntary basis as they feel it may be useful for the consumer) often are not. As pointed out above, they are however – in principle – bound to fulfil similar regulatory functions (see also van Gestel and van Lochem 2020). For this reason, in this article we primarily focus on voluntary eco-labels related to plastics for which some processual oversight is especially needed.

Eco-labels can be granted or 'self-declared' by producers or service providers based on the environmental friendliness of attributes based on e.g. standards, life cycle assessment or other methods of environmental impact assessment, like Production and Process Methods (PPMs) (Thøgersen 2000). Every year, hundreds of voluntary eco-labels are registered (e.g. as trademarks or certification marks – including EU certification marks presented below in 4.2.) or affixed to various products and services as a medium to balance the information asymmetry between consumers' environmental desires and, furthermore, to incentivize producers to meet the consumers demand by providing more innovative solutions in terms of environmental sustainability (Chon 2009). In the EU, the approach followed with voluntary labelling focuses on minimum standards and introduces economic incentives for companies and organizations to pursue a certain desired policy. In the case of eco-labels, the policy at stake is the protection of the environment (see e.g. Regulation (EC) No 66/2010 on the EU Ecolabel).

Ownership of eco-labels and control over their use may be vested in governmental, non-governmental, or private entities. Producers and retailers wishing to use eco-labels can use either their own label, or the label of another party, under a license or similar authorization. The label can be of the type awarded by a third-party certifier, a third-party-validated claim, or a producer's self-certification (Belson 2012).

Various national governments around the world have become active in regulating eco-labelling, and national eco-label schemes are nowadays often part of the Global Ecolabelling Network (GEN), an international association of eco-labelling bodies. Moreover, due to the fact that public confidence in eco-labels is increasingly premised on consumer expectations that certified goods or services meet certain environmental standards, considerable efforts have also been made by the standards organizations themselves (van Amstel et al. 2008). For instance, the International Organization for Standardization (ISO) has attempted to standardize the principles, practices, and key characteristics of voluntary eco-labelling in the ISO 14000 standards, which is a family of standards related to environmental management: type I, type II and type III of eco-labels classifications.

Yet, these private governance tools suffer from shortcomings. On the one hand, some of them (such as voluntary labels) are lacking oversight with regard to their regulatory dimensions and, as a consequence, they might not meet the needs of accountability and transparency. In other words, they are restricted to conveying reliable information on the actual environmental impacts the label indicates, and they are unable to contribute at a global level due to fragmentation in their origin. This is apt to ultimately drive stakeholders towards unsustainable practices. On the other hand, in areas such as plastics, even when these tools are used in combination with methodologies such as LCA to show the environmental impacts of specific types of plastics (e.g. in the case of technical standards), the complexity of the variables to be considered for such an LCA, coupled with the immaturity of the methodology when applied to plastics, might end up compromising the message delivered. This will be further elaborated in the context of plastics in section 4.3 below.

4.2 Private Law Regimes: EU Certification Marks as a Prominent IPR Tool

One or more intellectual property rights may attach to an eco-label, affording protection against infringement under the relevant intellectual property laws. For instance, alongside trademark protection, which affords protection to a sign or symbol in the eco-label, also copyright is normally relevant (e.g. copyright in the picture of the label). However, for the purpose of this article, the EU's IPR regulatory framework offers an interesting and more specific type of eco-label, which is linked to – yet slightly different from – the general umbrella framework of trademarks: the so-called EU certification mark (EUCM).

The EUCM has been recently harmonized by the EU trademark reform and the renewed EU Trademark Regulation (EU) 2017/1001 (EUTMR). EUCM is a well-regulated and high-level certification that aims to certify that a good or a service that contains or makes use of plastics complies with specific quality standards (such as those related to materials, production methods, and service performance) irrespective of their origin (Engels and Grubler 2017). According to Article 83(1), in order to be granted, an EUCM must be 'capable of distinguishing goods or services which are certified by the proprietor of the mark…from goods and services which are not so certified'.

EUCM are owned and governed by an independent organization competent to certify a good or a service. Like other certification schemes, EUCM is tailored to function as a 'guarantee' for goods and services labelled with the mark. In this case, the EUCM indicates that they comply with the standard set in the specific regulations of use (RoUs). The mark is controlled by or under the supervision of the CM owner, irrespective of the identity of the undertaking that actually uses the CM and is responsible for the production.

EUCM may be applied for by any natural or judicial person, including institutions, authorities, and bodies governed by public law (Article 83(2) EUTMR). The applicant must also submit RoUs that cover, for example, issues related to authorized users, the characteristics to be certified and how these are tested, conditions of use of the mark, sanctions, and methods of supervising EUCM (Article 84(1)-(2) EUTMR). The information to be included in RoUs is specified in Article 17 of the Commission Implementing Regulation (EU) 2018/826: the characteristics to be certified must be described together with testing methods.

Obviously, the CM user's conformity with the owner's regulations must be ensured alongside defining liability for nonconformity. This is also reflected in the structure of the CM regime and relevant liability: According to Article 90(1) EUTMR, only the EUCM owner alongside persons authorized by the owner, is entitled to bring an action for CM infringement. The EUCM holder may also end up losing the mark afterwards, for example if they themselves become involved in an activity covered by the certification, or they fail to take action where the use of the mark contradicts the RoUs, or if the CM is granted and governed so as to render it misleading to the public in terms of its character or significance (Article 91 EUTMR).

In sum, EUCM is based on strict, well-regulated requirements including reliance on methodologies such as LCA to show the environmental impacts behind the certification. However, as discussed above, the methodological challenges of applying LCA to the field of plastics may influence the reliability and comprehensiveness of the LCA results. Moreover, it should be noted that the strict requirements to gain an EUCM have also led to a quite low number of EUCM being granted yearly when compared e.g. with the vast volume of (voluntary) ecolabels awarded.

4.3 Private Law and Governance – Challenges with Plastics

This section presents some examples of certifications, labels, and standards granted in the field of plastics with the objective of concretizing the above discourse related to private law and governance tools in the context of promoting environmentally conscious decisions with plastics, as well as introduces the main points in need of improvement. The compilation of the examples used in the analysis presented in this section is also provided in Tables 1 and 2.

As pointed out above, some voluntary certification and eco-labelling schemes in the field of plastics to date are developed by regulators other than the legislator (e.g. by the label provider), which poses the first challenge to our analysis. In fact, this setting might carry certain risks, such as lack of standardization, reduced transparency, or inadequate reflection of public interests, for instance those related to sustainability. While some EU certification and eco-labelling schemes in the field of plastics are currently robustly underpinned by sound criteria such as technical standards, others are either unsubstantiated or insufficiently substantiated.

For instance, the type and content of technical standards of biodegradable plastics vary globally from international ISO and ASTM to European and national standards (e.g. Australian AS and Chinese CNS), all the way to certification schemes developed by the label provider (IEA Bioenergy 2018; European Environment Agency 2020a; Open-BIO 2014). Despite this, however, not all the biodegradability tests for granting certifications or eco-labels for plastics are based on ISO standards, or any other standards (Bhagwat et al. 2020). On the contrary, most certification and eco-labelling schemes certifying plastics recyclability mainly contain ISO standards (Agriculture and Environment Research Unit 2010; Cradle to Cradle Products Innovation Institute 2016; EuCertPlast 2018; Global GreenTag n.d.a.; ISCC 2019).

On the other hand, the eco-labels with a focus on the controlled environment, such as industrial composting, in comparison to the less controlled ones found in nature or home composting, are often based on different standards rather than a certification scheme. For instance, as shown in Tables 1 and 2, the eco-label certifying industrial compostability by Jätelaitosyhdistys (Finland) is based on EN 13432, whereas the ones certifying home compostability and biodegradability in soil, fresh water, or marine water by TÜV Austria are all based on certification schemes developed by the label provider

(European Environment Agency 2020a; Open-BIO 2014). Moreover, the eco-labels 'biodegradable in soil' and 'biodegradable in marine water' utilize EN 17033 with two additional ecotoxicity tests and withdrawn ASTM D7081, respectively (European Environment Agency 2020a). This difference in standardization can be due to a lack of specific time definition for full biodegradation (SAPEA 2020), variable and uncontrolled conditions in nature (European Environment Agency 2020a), as well as variability of home composters in comparison to industrial facilities (Bhagwat et al. 2020).

The variable situation with standardization presents the second challenge: The regional fragmentation results in a high number of eco-labels, especially voluntary ones. Instead, certification and eco-labelling schemes which enable coordination even at a global level are needed to properly drive stakeholder behaviour and increase the effectiveness of these certifications and eco-labels in promoting sustainability with plastics. Again, as presented in Table 1, for example the eco-labels certifying industrial compostability by Cedar Grove (United States) and Environmentally Biodegradable Polymer Association (Taiwan) are based on ASTM D6400 and ASTM D6868 with additionally full-scale test as well as CNS 14433, CNS 14478, CNS 14432, and CNS 900332, respectively (Open-BIO 2014). Simultaneously, as listed in Table 2, despite the use of ISO standards, some of the eco-label and certification schemes certifying recyclability are local such as Global GreenTag$^{\mathrm{CertTM}}$ (Australia and USA) (Global GreenTag, n.d.a.), Earthsure (USA and Canada) (Ecolabel Index 2021), and EUCertPlast (Europe) (EuCertPlast 2018).

The third – and the most crucial – challenge in terms of reliability and accountability is that, although most systems of certifications and eco-labels for plastics rely on different methods to gain insight into the performance of plastics, such methods might not be able to provide scientifically adequate, reliable, and/or solid results. The use of adequate, reliable, and solid methods is important in measuring the full biodegradation of plastics in nature (section 2), for evaluating the environmental impacts of plastics, or in order to assure the circularity of plastics (recyclability). For the latter two, the most used methods in certification and eco-labelling schemes are LCA over a portion or the whole life cycle of a plastic and mass balance (Agriculture and Environment Research Unit 2010; EuCertPlast 2018; Global GreenTag n.d.b.; ISCC 2019). In addition, methodologies such as LCA are more often used in eco-labels certifying recyclability, whereas the ones certifying biodegradability are based on biodegradability tests. This variability in methods may cause differences in the results obtained about the environmental impacts of plastics, whereas the variable purpose of certifications and eco-labels can increase fragmentation, for instance.

Finally, it is important to note that, notwithstanding the several certifications and eco-labels currently used both for plastics biodegradability and recyclability, to our knowledge, to date no EUCM has been issued.

Table 1. *Examples of certification and eco-labelling schemes considering biodegradability of plastics.*

Scheme	Content	Owner	Standard	References
1	Home compostable	TÜV Austria (Belgium)	Certification scheme by TÜV Austria	(European Environment Agency 2020a)
2	Biodegradable in soil	TÜV Austria (Belgium)	Certification scheme by the label provider, and EN 17033 with two additional ecotoxicity tests	(European Environment Agency 2020a)
3	Biodegradable in fresh water	TÜV Austria (Belgium)	Certification scheme by the label provider	(European Environment Agency 2020a)
4	Biodegradable in marine water	TÜV Austria (Belgium)	Certification scheme by the label provider, and basis on ASTM D7081 (withdrawn)	(European Environment Agency 2020a)
5	Industrially compostable, digestible	DIN CERTCO (Germany)	EN 13432, ASTM D6400, EN 14995, ISO 17088, ISO 18606, and AS 4736	(IEA Bioenergy 2018; Open-BIO 2014)
6	Industrially compostable	Japanese Bioplastics Association (JBPA)	Green PLA certification scheme	(IEA Bioenergy 2018; Open-BIO 2014)
7	Industrially compostable	Environmentally Biodegradable Polymer Association (Taiwan)	CNS 14433, CNS 14478, CNS 14432, and CNS 900332	(Open-BIO 2014)
8	Industrially compostable	Jätelaitosyhdistys (Finland)	EN 13432	(IEA Bioenergy 2018; Open-BIO 2014)
9	Industrially compostable	Cedar Grove (United States)	ASTM D6400 and ASTM D6868 with additionally full-scale test	(IEA Bioenergy 2018; Open-BIO 2014)

Table 2. *Examples of existing certification and eco-labelling schemes considering recyclability of plastics.*

Scheme	Description	Name	Type	Standard	LCA	Region	References
1	Eco-label based on, e.g. continuous reclamation and reuse of safe materials, such as plastics	Cradle to Cradle Certified™	Eco-label	ISO 16000 series, ISO 17025	Does not utilize LCA; is based on a certain reused content within a plastic	Global	(Cradle to Cradle Products Innovation Institute 2016)
2	LCA-based eco-label which analyses the environmental impacts of products, such as plastics, at every life stage	Global GreenTag CertTM (LCARate™)	Eco-label	Based on ISO 9001:2015, ISO 14024, ISO 17065, ISO 14040, ISO 14067, ISO 219030, and EN 15804	Utilizes LCA; includes 'cradle-to-grave' LCA of a plastic	Australia, USA	(Global GreenTag n.d.a.; Global GreenTag n.d.b.)
3	LCA-based eco-label which analyses the environmental impacts of products, such as plastics, at every life stage if necessary	Earthsure	Eco-label	Fully in compliance with ISO 14025	Utilizes LCA; can focus on a portion or a whole life cycle of a plastic	USA, Canada	(Agriculture and Environment Research Unit 2010; Ecolabel Index 2021)
4	Certification with a focus on recyclability, e.g. traceability of plastics waste and recycled content within the product, such as plastic	EUCertPlast	European Certification	ISO 15343:2007	Does not utilize LCA; is based on mass balance calculations	Europe	(EuCertPlast, 2018)
5	Certification focusing on sustainable and traceable supply chain of bio-based and recycled materials, such as plastics	ISCC PLUS	Certification	ISO 14021:2016, ISO 14040/44, ISO 14064	Does not utilize LCA; is based on a mass balance method	Global	(ISCC 2019; SCS Global Services n.d.)

5. Fostering Sustainable and Circular Practices with Plastics in Law Through Reliable LCA

5.1 Embedding Sustainability into Private Law and Governance Mechanisms

As the above analysis shows, even if both public and private areas of law have shortcomings when it comes to driving stakeholder behaviour towards sustainable and circular practices with plastics, it is especially private regulation that is currently lagging behind.

The first challenge identified in previous sections discussing private law and governance tools in the context of plastics is related to the need to increase transparency and to better reflect public interest such as sustainability. In fact, even though the regulatory role and importance of private regulators (like label providers) must be acknowledged (Vallejo 2020), in the context of eco-labelling, their activities should primarily be linked to values connected with the public good, such as sustainability or circularity, considering the global environmental challenges we are facing. This challenge affects especially those unregulated or less regulated private regulatory mechanisms, for instance voluntary certifications.

At the same time, the examples presented in section 4.3 show that very rigidly regulated schemes, such as the EUCM, have a tendency to become unused – especially, one could argue, when other more 'loose' mechanisms are in place. This could affect the quality of the goals to be achieved (see also Vallejo 2020). For instance, although allegedly highly reliable and able to provide clear and transparent indications of the qualities of plastics, the EUCM system has been criticized for being very difficult to access, unless clear, defined, and harmonized standards are in place. A case in point is that, in the field of plastics, not a single EUCM was found neither in relation to recyclability nor to biodegradability, while several voluntary certifications do already exist. Thus, one could question whether this system is actually fostering development towards more sustainable practices – which could be seen as one of the key policy goals for having passed the rigid system of EUCM in the first place. At the same time, however, when many 'soft' and not well-regulated certification and eco-labelling systems exist, the ultimate result is often fragmented and overly complex, with problems related to the absence of transparency, which is likely to increase confusion and result in lack of coordination. Indeed, this cannot properly contribute to driving stakeholder behaviour towards actual sustainable and circular practices. How, then, can we achieve a proper balance between private governance, regulation through law, and sustainability, in a way that it is accountable, yet accessible and efficient in driving stakeholder behaviour towards sustainability?

When reflecting on this in the broad sense, it could be argued that if sustainability is (to become) a primary value driving innovation and practices, for instance in the context of plastics, and if tools such as labelling and certifications are considered as powerful drivers of stakeholder behaviour, then perhaps only 'solid' (or 'rigid') eco-label and certification schemes should be promoted. This is not to imply that all eco-labels and certifications should become mandatory, but rather, it means that oversight should be employed in the process. As previously mentioned, the key difference between mandatory and voluntary labels in terms of accountability and effectiveness is that the former includes information that producers *must* provide, while the latter rests on information that the producer *can* provide voluntarily. As also presented above, it is these (little regulated) voluntary labels that are particularly problematic from the perspective of transparency and conveying reliable information.

This being said, in the context of plastics, this failure also partly affects well-regulated schemes such as the EUCM due to the current difficulties in being able to produce reliable data on the actual environmental impacts in the first place. To increase transparency and accountability, thus, it might be helpful to regulate also voluntary schemes in such a way that if producers wish to provide further information on a voluntary basis, they can do so only if such information is backed up by solid scientific data based on LCA. In other words, this would mean to regulate by law also voluntary certification and labelling schemes, via embedding obligations in terms of reliability, accountability, and transparency much similar to establishing some essential 'procedural rules' as discussed above (van Gestel and van Lochem 2020).

One could argue that this move might actually lead to the increase of e.g. 'eco-type' marketing strategies ('green-washing'). However, if sustainability as well as values linked to care and respect for the environment are to truly become a primary objective of, for example, EU policy and legal decision-making (European Commission 2018, 2019), they need to be valued by legislators and businesses as part of their core activity. Marketing strategies that promote unsustainable activities could be regulated and banned via legal instruments other than certifications and eco-labels. Also, the counter-argument that this move could ultimately lead to fewer incentives for developing potentially more sustainable innovations fades away if sustainability is prioritized.

Especially in areas of law such as IPR, all this means channelling sustainability values into the doctrines and core justifications of such exclusive rights (Pihlajarinne and Ballardini 2020). For instance, in connection to trademark law, Chon (2009) speaks of regulation that is 'decentralized' and 'privatized', aptly noting the 'newer regulatory functions' of marks, while Adelman and Austin (2017) note the poorly assigned role of trademarks in terms of supporting 'information-based forms of private governance'. According to Chon (2009), trademark law, as part of intellectual property law, could 'function to mediate between extremely different local conditions within a global market system' and go beyond the traditional doctrine to signalling '*socially responsible practices* [emphasis added] within a global administrative framework'. All in all, this view, if extended to intellectual property law tools like EUCM, but also to labels of various sorts, would be compatible with scholarly ideas of including private regulators as 'crucial nodes in the regulatory process' (Vallejo 2020). This would enable legal recognition of their 'discretionary regulatory authority and coregulatory capabilities', as formulated by Vallejo, as well as the accompanying critique (Vallejo 2020).

In terms of sustainability in the field of plastics, such legal recognition and critique should be tied to scientific knowledge – to be linked to the public good.

5.2 Promoting Holistic and Harmonized Life Cycle Assessment

How, then, can we create a scientifically reliable system that objectively assesses the overall environmental impacts of plastics – especially in the context of new materials such as bio-based plastics? This refers especially to the second and third challenges that we identified in section 4.3, that is, regional fragmentation and unreliability or inconsistency of the methods currently used. Indeed, this is a challenge that affects all forms of public and private law and governance tools equally.

Currently, the most commonly used environmental LCA methodology suffers from various limitations, one major issue being the difficulty of obtaining a holistic and comparable overview (Cristóbal et al. 2016). In the field of plastics, this is due, for example, to varying methodological set-ups (Cristóbal et al. 2016; Dahiya et al. 2020), assumptions drawn (Cristóbal et al. 2016; Dahiya et al. 2020), as well as utilization or non-utilization of tools to interpret the results between LCA studies. Therefore, LCA as a methodology needs to be enhanced and harmonized, because its use in practice offers room for fallacious conclusions and possible variation in results even regarding the same plastic, ultimately negatively affecting decision-making. Obtaining a flawless and holistic LCA, however, can be challenging, because LCA methodology is still developing.

In this discourse, other general issues associated with LCA include its complexity as a methodology, requirements for adequate knowledge, and expertise for conducting LCA (Dahiya et al. 2020) (and, therefore, unequal competence of firms to perform an LCA), and issues with a sufficient level of transparency when reporting the results (Cristóbal et al. 2016; Dahiya et al. 2020). In terms of processes, problems can be caused by deficiency in yielding knowledge regarding the efficiency of process-level actions (Lokesh et al. 2020), and susceptibility to variation of results based on which inputs and outputs are included in the study (Dahiya et al. 2020; van den Oever et al 2017). In the case of data quality, in turn, difficulty in detecting and obtaining process-specific primary data in different environments, for instance, in terms of biodegradation as a SEOL option, is another factor that may hamper the effectiveness and reliability of LCA of plastics. In the end, use of secondary data is not flawless either due to lack of secondary data available in existing data banks and comprehensive LCA studies considering e.g. bio-based plastics.

Tools for making LCA more holistic and to supplement its shortcomings could include establishing more specific standards or modifying existing ones to give instructions for problematic areas of LCA prone to variability, such as collecting data (Dahiya et al. 2020), selecting the system boundaries (Dahiya et al. 2020), functional units (Dahiya et al. 2020), and impact categories (Dahiya et al. 2020), drawing assumptions in terms of allocation and substitution (Cristóbal et al. 2016; Dahiya et al. 2020; Moretti et al. 2020; Walker and Rothman 2020), as well as whether or not to utilize sensitivity analysis, normalization, and weighting (Moretti et al. 2020). Furthermore, simulation (Brunet et al. 2012), could be used more, for example in aiding general data collection and in compilation of inventory analysis. Alternative options to LCA (either instead of or in addition to LCA) in certification and eco-labelling schemes could also be considered. For instance, recently, some scholars coupled LCA with complementary indicators such as resource efficiency (Lokesh et al. 2020), and material circularity (Lokesh et al. 2020; Niero and Kalbar 2019), or even considered Life Cycle Sustainability Assessment (LCSA) (Dahiya et al. 2020; Spierling et al. 2018), which combines the three pillars of sustainability: environmental LCA, environmental life cycle costing (LCC), and social LCA (sLCA) (Spierling et al. 2018).

Moreover, one could ask whether and to what extent it is sensible, in order to foster more sustainable practices, to stick to certification and eco-labelling schemes that are indicative only of individual characteristics of the SEOL stages of e.g. products or services including plastics, such as recyclability and, especially, biodegradability. For instance, as presented in previous parts of this article, the fact that a plastic is biodegradable is not necessarily indicative of its sustainability. Even worse, if not well regulated, labels related to biodegradability could drive consumer behaviour towards highly unsustainable and linear practices, such as disposal in nature instead of recycling. Rather than concentrating on regulating and certifying separately or uniquely which plastics are recyclable, compostable, or digestible, would it not be better to use e.g. LCA to measure and analyse the overall life cycle and environmental impacts of a certain plastic, when possible? This holistic assessment could more sincerely certify the actual sustainability of plastics and be possibly less confusing to consumers and other stakeholders, consequently better fostering sustainable and circular practices.

Nonetheless, the use of LCA in this attempt in certification and eco-labelling schemes possesses limitations. On the one hand, the benefits of LCA include inter alia conveying knowledge about the environmental impacts of plastics over the whole plastics value chain, therefore preventing green-washing and helping the stakeholders to identify the more environmentally friendly plastics. On the other hand, however, LCA cannot yet be used alone to inhibit and gain knowledge about some environmental issues, such as mismanagement of plastics waste, e.g. littering, or microplastics pollution (Croxatto Vega et al. 2021). This is due to LCA's immaturity as a methodology, as in the case of the previously described limitations. To solve this problem, in addition to the methodological developments of LCA, certification and eco-labelling schemes could be required to include both LCA and substantiated biodegradability (in ensuring biodegradability characteristics) or mass balance (in ensuring recyclability characteristics) tests. This approach could be a step forward to promote sustainability through ensuring that plastics are not only claimed to be biodegradable or recyclable and potentially improving the occurrence of appropriate use and disposal practices of plastics among stakeholders, for instance towards reusing and recycling instead of littering.

Ultimately, any LCA framework aiming at fostering eco-innovation in production and consumption should keep in mind a holistic approach and consider the repercussions of the analysis and solutions not only in terms of some of the SEOL stages (like the recycling phase), but regarding their effects over the whole value chain. Ideally, here the role of economic and social sustainability should also be recognized.

Reliance on holistic LCA combined with harmonized and international standardization could lead to good environmental governance in both public and private legislative areas. As far as private law and governance is concerned, this approach – combined with the suggestion of having only 'solid' certification schemes – could also lead to coordination and 'generalization of labelling' through reducing the number of different labels, which could reduce regional fragmentation, as well as ease the understanding and adaptation of various certification and eco-labelling schemes among stakeholders.

6. Conclusions

Plastics are evidently an indispensable part of our society. They contribute to resource efficiency, play an important role in maintaining many basic functions (for instance, transportation, health, and food preservation), as well as a high standard of living. However, the linear economy and its unsustainable practices have provoked a call for change. In this discourse, moves to utilize renewable feedstock and transitioning to more circular practices involving plastics are necessary. The key to overcoming these challenges is neither simple nor straightforward, and no one 'right' SEOL option exists. Rather, different alternatives should be encouraged in a complementary way, considering multiple factors relevant to supporting legal and policy decision-making.

With that in mind, technical, legal, and policy solutions and choices should draw from reliable knowledge and support coordinated actions that promote sustainability. Consequently, from the legal point of view, both public and private regulation should be based on accountable LCA that is holistic and based on harmonized international standards. Private law and governance tools are currently the legal areas where more efforts need to be made towards this direction. On the one hand, as research literature indicates, tools such as certification and eco-labelling schemes, whether they are eco-labels, certifications, or EUCM, are very effective in driving stakeholder behaviour towards one direction or the other. On the other hand, however, as they currently stand, they are often non-regulated or insufficiently regulated in terms of their regulatory dimensions (especially in case of voluntary tools). Indeed, the current decentralization of the system, accompanied by fragmented ownership of legal tools like certifications and control of their use, present inevitable challenges. Instead, certification and eco-labelling schemes for plastics should principally focus on conveying accountable information about environmental impacts over the whole life cycle of plastics by using holistic LCA that is based on harmonized technical standards; that is, 'solid' types of certification and eco-labelling schemes.

For this purpose, the complexity and pitfalls of methodologies such as LCA need to be recognized and resolved and the ability to conduct LCA by stakeholders equalized. For instance, LCA as a methodology requires substantially more science-based input data together with specified standards and it needs to be coupled with inter alia economic, social, resource efficiency, and material circularity indicators. Furthermore, certification and eco-labelling schemes could benefit from containing both LCA and a substantiated biodegradability or mass balance test.

This approach would decrease the number and regional fragmentation of existing certification and eco-labelling schemes, reduce possible overlap between them and, ultimately, increase their credibility, ease adaptation, and foster comprehensibility by different stakeholders, ranging from public to private actors. Indeed, in this way LCA could also be the driver of public law actions related to, for example, waste management and circularity of plastics and be used in collaboration with private governance tools (not only exclude deception) to ensure the efficient transition from the linear to the circular economy.

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