

## Article

# Social Life Cycle Assessment of Product Value Chains Under a Circular Economy Approach: A Case Study in the Plastic Packaging Sector

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Received: 24 June 2020; Accepted: 12 August 2020; Published: 18 August 2020



**Abstract:** Environmental and economic impact assessment of products have a long record, while social performance analysis of products have less references in the scientific literature due its particularities and the adaptations needed for the features of the studied subject. In addition, there is a lack of a methodological framework of its application in the analysis of value chains, with the aim of estimating the impacts of technical innovations from the social point of view. This paper describes the theoretical framework and impact assessment approach for the Social Life Cycle Assessment of product value chains under a circular economy approach by applying a scoring system in different subcategories and indicators, considering the plastic packaging sector as a case study. Twelve subcategories have been chosen, because of their relevance to the case study, related to the impacts on the labor conditions, consumers' well-being, end-of-life of the product, local community conditions, technology and suppliers, among others. The validation of the methodology in the plastic packaging sector is done by considering the main stakeholders involved in the value chain and the particularities of the sector.

**Keywords:** social life cycle assessment; product value chain; plastic packaging; social impact assessment; sustainability; circular economy

## 1. Introduction

Worldwide, plastics production has surged over the past 50 years, increasing from 15 million tonnes produced in 1964 to 311 million tonnes in 2014. Moreover, it is expected that this value will double again over the next 20 years. The most common plastic materials used are polystyrene (PS), polypropylene (PP) and vinyl polychloride (PVC), which represents 36%, 21% and 12%, respectively, of the total non-fiber plastics production. Plastics are used in many applications, with the packaging, i.e., the element used to contain, protect, handle, deliver and present goods, being the largest one, which represents the 26% of the total volume of plastics used. In the plastic packaging sector, the main materials used are non-fiber plastics, mainly PP, PE and polyethylene terephthalate (PET) [1].

Europe is the second largest producer of plastic materials in the world, producing 20% of thermoplastics and polyurethanes materials. This percentage represents the manufacturing of, approximately, 65 million tonnes of plastics [2]. Within the European market of plastics manufacturing, the most important sector is the packaging. In fact, packaging represents 39.5% of the European plastics demand. In 2014, 28.5 Mt of post-consumer plastics waste ended up in the waste stream, being 69.2% recovered by recycling or recovering process and the remaining 30.8% sent to landfill [2].

Following the guidelines of the Waste Framework Directive (Directive 2008/98/CE) [3], the European Union launched, in 2014, an initial circular economy package. As part of this package,

in December 2015, the European Commission presented an action plan for the circular economy and four legislative proposals amending the existing related legislation [4]. One of the priority sectors of the action plan is plastic, where some solutions were proposed, such as an amendment of the Packaging Waste Directive, which sets targets for various packaging materials [5]. The target set for plastic packaging for 2025 was 55% of recycling or re-use of plastic packaging waste.

The transition into a circular economy needs not only technical developments, but also new collaboration mechanisms that bring together stakeholders along the value chain and new methods for the assessment of the benefits in terms of sustainability, in order to have a holistic vision, considering its three pillars: environment, economy and society [6]. From these three pillars, social sustainability is a wide concept, which covers several definitions, stages and stakeholders. These features make social sustainability a difficult aspect to be evaluated, because there may be just as much methodologies as existing systems [7–9]. In other words, the Social Assessment from a Life Cycle perspective will depend on the subjects that are going to be assessed [10]. Thus, the Life Cycle Approach is one of the most widely used for the evaluation of those aspects which has been standardized by the ISO 14040:2006 [11] and 14044:2006 [12]. It must be noted that the Life Cycle Assessment (LCA) is an approach that aims to assess the whole life of a product. This includes the raw materials extraction, the manufacturing, the use and the end-of-life (EOL) stages.

Different authors have evaluated the environmental impacts of the plastic packaging value chain using LCA. In this way, a large group of products have been evaluated. Among those relevant, Pauer et al. (studied the environmental assessment of food packaging [13]; Maga et al., of plastic trays [14]; Vercastelen et al., of plastic cups [15] and Siracusa et al., of plastic film [16], among others. On the other hand, Life Cycle Costing Assessments (LCCA) of plastic packaging are less common than the environmental ones. However, there are some studies related to the subject. Aikaterini-Nafsika studied the Life Cycle Costing of different plastic packaging wastes [17]; Accorsi et al. studied a series of reusable containers for food packaging [18] and Amienyo studied different packages for the beverage sector [19]. Finally, an even smaller number of Social Life Cycle Assessment (S-LCA) studies have been found in the scientific literature. As an example, Yildiz-Geyhan et al. have assessed the social impacts of different packaging waste collection systems [20], but not of specific products.

The criteria for the application of the S-LCA methodology are not so generalized and normalized [21]. A small number of social impact assessments have been developed following the Life Cycle Approach. Thus, no relevant references were found for the Life Cycle Social Assessment of product value chains under a circular economy approach, considering also the different stakeholders involved, such as producers, workers, distributors, consumers, etc. Therefore, there are no feasible methods to be considered and few scientific publications treating the issue.








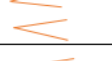


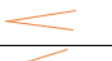




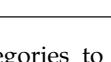


This paper describes the theoretical framework and impact assessment approach for the Social Life Cycle Assessment of product value chains under a circular economy approach. To do so, a first research stage was conducted, described in Materials and Methods section, in which a vast bibliographical research was done in order to identify and prioritize the main social issues and indicators for a Life Cycle Assessment.

Considering the consulted information, a scoring system is proposed in different subcategories and indicators, in which the most appropriate stakeholders have been chosen, considering the features of the sector and the following specific value chains: multimaterial (cardboard/plastic) packaging, plastic packaging for hygienic products and food, plastic shopping bags and plastic coffee capsules. The proposed scoring system is described in the Results section and intends to consider both potential positive and/or negative social impacts on related stakeholders within life cycle stages. This scoring system has a semi-quantitative nature, whose advantages are discussed in Section 4, Discussion. Finally, the replicability of the developed methodology for the assessment of the introduction of innovations into other industrial processes, products or projects with different features is evaluated in Conclusions.

## 2. Materials and Methods

Standards ISO 14040:2006 and ISO 14044:2006 establish a generic framework for the elaboration of LCA. However, Social Impact Assessment methodologies at product level need flexibility due to their immaturity and specific background requirements [22,23] for S-LCA. In fact, it is recommended to use a simultaneous work with both quantitative and qualitative indicators, because the former may not cover social dimensions completely [24]. Some methodologies address this by disaggregating the social aspects' stakeholders and impact categories. For example, Arcese et al. [25] developed a methodological framework for the Italian wine sector by defining the local stakeholders and their related impacts and indicators. Fortier et al. [26] established the most relevant stakeholders for the social assessment of energy justice, choosing workers, consumers, local communities and the society as a whole; and Liu et al. [27] followed the same methodology for the Social Life Cycle Assessment of buildings, choosing, in this case, workers, occupants, local community and the society. Furthermore, Bellantuono et al. [28] developed a quantitative approach in order to include the stakeholders' perception in the social assessment of Italian small- and medium-sized enterprises.

These stakeholders' categories may be defined as a group of agents, which foreseeable have common interests in accordance with their relationship with the product system under study [29]. Thus, Siebert et al. [30] established a regional context for the social assessment of the wood-based products in Germany in which the stakeholders were defined regionally, according to the German bioeconomic regions, and by economic framework, i.e., the wood sector. Subcategories are the base of an S-LCA because they are the items on which justification of inclusion or exclusion needs to be provided and they are assessed by the use of inventory indicators. The relationship among stakeholder group and impact categories was defined by the United Nations Environment Programme (UNEP). An example of this classification is shown in Figure 1.

Stakeholder's Categories	Impact Categories	Subcategories	Inventory Indicators	Inventory Data
Workers	Human rights			
Local community	Working conditions			
Society	Health and Safety			
Consumers	Cultural heritage			
Value chain actors	Governance			
	Socio-economic repercussions			

**Figure 1.** Assessment system from categories to indicators. Source: UNEP (United Nations Environment Programme).

In this context, the United Nations Environment Programme establishes a general framework aimed at elaborating a series of guidelines to be considered in the LCA, in which different aspects are considered, such as the different stakeholders [29]. Other regulations standards, mainly ISO 26000 [31] and SA 8000 [32], focus on social aspects, but they do not provide a common methodology for LCA.

Therefore, the proposed methodology framework consists, on one hand, in the identification of the most relevant subcategories from the UNEP guidelines and, on the other hand, in the scheme of research phases designed by Sousa-Zomer et al. [33], which consist in three stages: literature analysis, proposal development and proposal verification. The resulting proposed methodology is described hereafter:

- Identification: The elaboration of a general impact subcategories compilation from previous experiences and bibliography was elaborated. As well as the United Nations Environment Programme, more specific publications related to the application of the social indicators in the industry were reviewed [34–36].
- Pre-selection: Definition of the scope and selection of social impact categories/subcategories and social indicators for the plastic packaging sector based on the following criteria: (i) geographical relevance, (ii) data availability and (iii) bibliography validation. As the study is focused on a European framework, where existing labor legislation promotes equal opportunities and avoids abusive situations, such as forced labors, subcategories regarding workers have been chosen accordingly. So, subcategories like child labor are dismissed, whereas gender issues continue to the prioritization stage. It has to be noted that the social indicators subcategories selection has been driven to capture potential social risks and benefits related to innovations developed under a circular economy approach. In this sense, specific training and workers' health and safety have been taken into account, because changes in technology and manufacturing under the circular approach could affect them. End-of-Life Responsibility is also one of the most important issues from the point of view of the circular processes, as the effectiveness of the innovations will depend on social behaviors and awareness about sorting and recycling. For this reason, this indicator has also been pre-selected.
- Prioritization: Prioritization of subcategories through a materiality analysis considering the criteria of actors involved in the value chains of the packaging sector, mainly manufacturers, consumers and waste managers [28]. Participation of stakeholders in early stages of the social assessment allows a broader discussion regarding social features significance, expectations and interests depending on regions or stakeholders' categories. The materiality analysis consists of a questionnaire in which stakeholders rank the subcategories according to their relevance for each step of the value chain. This is done by using a scoring system: High-Moderate-Low. An example of the questionnaire sent to the stakeholders for the multi-material packaging (cardboard) is presented in Appendix A (Figure A1). The aim is to complement the identification of subcategories and indicators assessing the relevance of social topics according to the stakeholders' perspective. An example of materiality analysis is presented in Figure 2.
- Scoring system: Once the subcategories and indicators have been established, a scoring system was defined in order to assess the social impacts arising from the innovations introduced under the circular economy approach, which evaluates efforts and behaviors instead of quantifiable aspects. These innovations are mainly based on the substitution of conventional plastics by biodegradable and compostable bioplastics, with high content of renewable sources, and the improvement of the end-of-life performance, by means of improving recyclability and recycling rates.

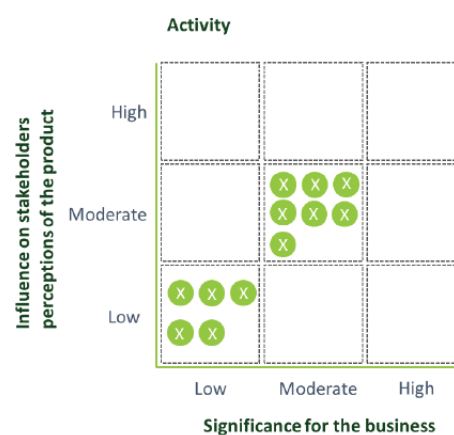


Figure 2. Examples of materiality results.

As the goal of the Social Life Cycle Assessment is to include and assess the social aspects of sustainability [37], the scoring system is based on a five-point scale between  $-2$  and  $+2$ , where 0 represents the baseline conditions, positive values represent an improvement and negative values represent a deterioration in comparison with the baseline conditions. The scoring system was defined by making a deep review of the previous methodologies related to the Social Impact Assessment, as can be seen in Table 1.

**Table 1.** Characterization methodologies review.

Reference	Methodology	Type	Data	Results
	Hsu et al. [38]	Quantitative	Statistics data to compare. Quantify efforts.	Score 1 to 5 Score 0 to 1 0 to 20%
	Foolmaun and Ramjeeawon [39]	Qualitative	Transform qualitative into quantitative (percentages). All indicators have the same importance.	21% to 40% 41% to 60% 61% to 80% 81% to 100%
Quintana, Busset, Sablayrolles, Montreju-Vignoles and Belaud [34]	Franze and Ciroth [40]	Quantitative, qualitative, semi-quantitative	Sum indicators and results.	Color system
	Manik et al. [41]	Social expectation and perception	Weighting sum. Multi-criteria decision analysis. Experts assign score according to importance.	Gap between expectation and perception
	Vinyes et al. [42]	Sustainability assessment	Weighting sum (percentages).	0 to 20% 21% to 40% 41% to 60% 61% to 80% 81% to 100%
Fontes [22]	Handbook for Product Social Impact Assessment	9 types of methodologies	Various (depending on the methodology).	Different results
Rafiani et al. [9]	Karklina et al. [43]	Quantitative	Multi-criteria analysis approach. 7 scenarios.	Score 0 to 1
	Papong et al. [44]	Quantitative	Impact per energy unit	Unit: GJ
	Ekener-Petersen et al. [45]	Qualitative	Aggregated by risk.	High and very high risk
	Corona, Bozhilova-Kisheva, Olsen and San Miguel [46]	Quantitative and qualitative	Hotspot analysis. Rules and weighted results.	Score $-2$ to 2

There are many different S-LCA approaches depending on different aspects, such as: the origin of social impacts, S-LCA can establish a casual correlation between impacts and processes or impacts and company behavior; the allocation, share of impacts among the product systems; the system boundaries, which depends on the scope of the assessment; and the social indicators, which can be quantitative or qualitative [47].

In the case of the scoring system, the result is obtained following a number of characterization criteria that have been grouped as qualifying rules in tree diagrams, as approached by Corona et al. [46].

An example of the scoring system can be seen in Figure 3. It can be observed that the scoring results depend on the evolution of a series of indicators, the branches of the tree, over time.

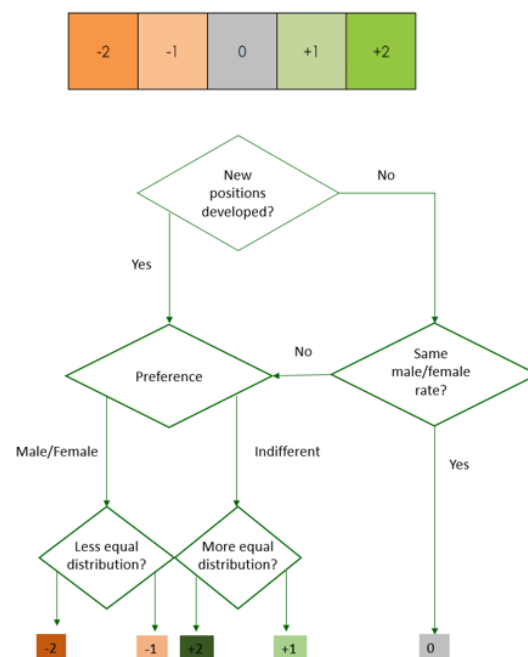


Figure 3. Example of a scoring system for the Gender Issues subcategory.

### 3. Results

According to the results obtained during the identification, pre-selection and prioritization phases, a series of indicators and units for each subcategory were selected, considering the features of each stakeholder and subcategory.

A diagram of the value chain for the substitution of a fossil plastic by a biodegradable one, including stages and stakeholders can be found in Figure 4.

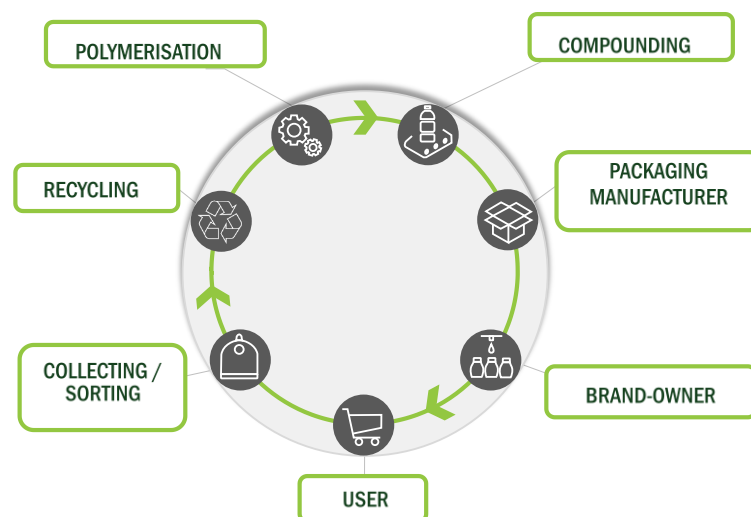


Figure 4. Overview of the studied value chains.

The biopolymer has been introduced in the manufacturing processes of different packaging products, more specifically: packaging for powder detergent, packaging for liquid detergent, plastic carrier bags, fresh food trays and films, automotive components, coffee capsules and absorbent hygiene products.

Following the criteria explained in the methodology, the identification of impact categories subcategories resulted in a final number of 12: Equal Opportunities/Discrimination, Training and



Education, Workers' Health and Safety, Consumers' Health and Safety, End-of-Life Responsibility, Consumers' Well-Being, Community Access to Material Resources, Safe and Healthy Living Conditions, Local Employment, Community Engagement, Technology Development and Suppliers' Relationships.

These impact categories, their impact subcategories and indicators are shown in Table 2. Some indicators are quantitative, such as training hours and male/female rates, whereas others, such as protective equipment availability and corporate social responsibility are qualitative.

**Table 2.** Subcategories and indicators for Social Life Cycle Impact Assessment.

Impact Categories	Impact Subcategories	Indicators
Equal Opportunities/Discrimination	Male/female rates Preference for the positions New positions developed	% male/female Male/female/indifferent Yes/no
Training and Education	Training for workers Training program Specific training due to innovations Additional training regarding innovations	Hours/year Yes/no Hours/year Yes/no
Workers' Health and Safety	Lost days for health and safety reasons Safety training Protective equipment availability Severe accidents	Days/year Hours/year Yes/no Number/year
Consumers' Health and Safety	Information available regarding features More demanding storage conditions	Yes/no Yes/no
End-of-Life Responsibility	Clear information about EOL options Impact on domestic waste management	Yes/no More difficult/same/easier
Consumers' Well-Being	Quality expectation/performance and usability User friendliness/convenience and acceptance	Better/same/worse Better/same/worse
Community Access to Material Resources	Certified environmental management system Materials origin	Yes/no % virgin % recycled/re-used
Safe and Healthy Living Conditions	Corporate social responsibility policy Effort to minimize use of hazardous substances	Yes/no Yes/no
Local Employment	Workforce hired locally Local suppliers	Number of employees %
Community Engagement	Annual local events/workshops Impact in social media	Number/year People reached/year
Technology Development	Involvement in technology transfer Investment in technology development	Yes/no Yes/no
Suppliers' Relationship	Seal of quality/management system required for suppliers Suppliers from countries with high estimated proportion of modern slavery	Yes/no % suppliers (monetary terms)

The chosen scales for each subcategory are described in the following sections. In all cases, the definitions for the established subcategories can be found in specialized literature [30,48].

### 3.1. Equal Opportunities/Discrimination (Gender Issues)

This category focuses on equal opportunities management practices or presence of discrimination within workers based on gender. In order to obtain a result, two aspects are taken into account:

- The first aspect to consider is the recruiter's preference for positions to be occupied. No preference is considered the best option and an improvement, as it means that gender is not valued at the

time of choosing a candidate for the tasks that are going to be developed. However, a preference for one gender, either female or male, is considered as a negative result in the scoring system, because it denotes a discrimination for that position.

- The other issue to consider is the males/females rate in the company. As this scoring system is aimed at assessing the impacts related to an innovation or a change introduced in the value chain, both the initial and the resulting rate must be assessed. In this sense, if the innovations serve to bring the value of this rate closer to the 50%/50%, it will be considered as a positive result; whilst a rate with a big difference between both genders leads to a negative impact.

### 3.2. Training and Education

This subcategory focuses on potential training and education proposed, required or expected for workers due to innovations and changes within the value chain processes. In the scoring system for this subcategory, there are two possibilities and, thus, two different scales: a first one for those cases in which manufacturing process is modified by the innovations and a second one for those other cases in which the manufacturing process remains unchanged. However, in both cases there are two main aspects to be considered:

- On the one hand, the number of training hours must be considered. In this case, an increase of the training hours for workers during the period under study causes a positive impact, while a decrease would mean a regression.
- The other aspect considered is the specific training about the innovations introduced in the value chain. The introduction of novelties in the training program explaining the functioning of the changes in the process is viewed as a positive impact, while the lack of this kind of specific training could result in a negative scoring result, when it occurs at the same time than a decreasing in the training hours.

### 3.3. Workers' Health and Safety

The subcategory "Workers' Health and Safety" focuses on the potential rise or reduction of workers' risks and/or prevention measures modification due to the innovations and changes within the value chain processes. As in the case of "Training and Education", in this subcategory, there are two possibilities: a first one in which innovations involve or increase the risks in the value chain and a second one in which the manufacturing process is not affected.

Apart from the appearance of new risks, the main aspects to consider are the following:

- Specific safety training hours: As in the previous cases, an increase in the hours of safety training is considered as an improvement, while a decrease would mean a negative result. The same number of hours represents the baseline conditions.
- Average number of lost days per worker and year due to health and safety reasons: Another important indicator to take into account is the average number of lost days per year for workers by health and safety reasons.
- Availability of specific protective equipment: The lack of specific protective equipment is considered as a negative result by the scoring system due to the associated danger to the workers' health and safety.
- Average number of severe accidents per worker and year: When the process is not modified by the innovations and no relevant changes are expected, the number of severe accidents per worker and year is another important indicator in order to assess if the innovations have had positive impacts in this subcategory. If the value decreases, a positive scoring result would appear.



### 3.4. Consumers' Health and Safety

The subcategory "Consumers' Health and Safety" focuses on the final performance of products and necessary efforts needed to address consumer health and safety due to the innovations and changes within value chains' processes. For these reasons, two aspects are considered in the scoring system:

- Information or labeling: the main aspect to be considered in this subcategory is the existence or absence of information or labels in the product about its features. If the product contains information of any kind, the scoring result in this subcategory will vary from 0 to +2, depending on the changes on the storage conditions. However, if the product does not contain any information about this topic, the scoring result will be negative, regardless of the changes on the storage conditions.
- Storage conditions: the second aspect to be considered in this subcategory is the storage conditions. In the plastic packaging value chain, innovations are supposed to improve its features, also in terms of product preservation conditions. Thus, if the storage conditions become more versatile, they will improve the scoring result.

### 3.5. End-of-Life Responsibility

The subcategory "End-of-Life Responsibility" focuses on modifications of final performance of products and necessary efforts needed to address consumer health and safety due to the innovations and changes within value chains' processes. For these reasons, there are two aspects to be considered in the scoring system for this subcategory, which are described below:

- Domestic waste management: The main subject to be checked is the evolution of the domestic waste management due to the changes in the value chain. It can become easier, more difficult or maintain the same conditions. If it becomes more difficult, the scoring result will be negative, as the changes in the value chain would have not reached the expected objective. However, if it becomes easier or maintains the baseline conditions, the scoring result could vary in a broad range depending on the following and second indicator.
- Information on end-of-life: The second aspect related to this subcategory is the information about end-of-life options. In this way, if the product contains information about the attitude that the consumer should adopt regarding to the product, e.g., throw it into the plastic recycling container, the scoring result will be positive, unless the domestic waste management had become more difficult.

### 3.6. Consumers' Well-Being

The subcategory "Consumers' Well-Being" focuses on consumers' perception on final products due to the innovations and changes within value chains' processes. For these reasons, as in the previous cases, there are two aspects to be considered in the scoring system for this subcategory, which are described below:

- Quality and performance: This indicator refers to the changes in the quality and/or the performance of the product. These features can become better, worse or maintain the baseline conditions. If it worsens, the scoring result will be negative, as the innovations in the value chain are supposed to improve these aspects.
- Convenience: It refers to the convenience of the purchase of the product for the consumer. It complements the first indicator, conditioning the scoring result.

### 3.7. Community Access to Material Resources

The subcategory "Community Access to Material Resources" focuses on potential risks or benefits related to resources consumption and depletion with regard to the value chains' processes and

innovations. It refers to the producers and, therefore, the indicators that condition the scoring result for this subcategory are:

- **Certified environmental management system:** The environmental management systems are the more extended tool aimed to organize the design, distribution, consumption and end-of-life responsibility of the producers with a life cycle perspective. For this reason, it is the main indicator to consider in this subcategory.
- **Intention to implement it:** If the producer has not implemented a certified environmental management system yet, the next question to be answered is if it has the intention to do it.
- **Recycled materials use rate:** The third aspect relates to the use of recycled raw materials. As the innovations in the plastic packaging value chains are related to the introduction of new and more sustainable raw materials, it is expected that the use of recycled raw materials increases.

### 3.8. Safe and Healthy Living Conditions

The subcategory “Safe and Healthy Living Conditions ” focuses on potential risks or benefits related to impact on community safety and health, e.g., water drainage, pollution, hazardous material generation, etc., with regard to the value chains’ processes and innovations. The indicators for this subcategory are similar to the ones related to the “Community Access to Material Resources” subcategory and are described below:

- **Existence of a corporate social responsibility policy:** The corporate social responsibility refers to the efforts carried out by the company in order to contribute to the social development. It is similar to the environmental management systems but it is related to the social pillar of sustainability instead of the environmental one.
- **Intention to implement it:** Again, if the company has not implemented a corporate social responsibility policy yet, the next question to be answered is if it has intention to do it.
- **Use of hazardous substances:** The third indicator for this subcategory is the use of hazardous substances, which is expected to decrease due to the innovations or changes in the value chain. If, on the contrary, it increases, the scoring result will be worse.

### 3.9. Local Employment

The subcategory “Local Employment” focuses on potential (direct or indirect) impact on local employment due to the innovations applied to the value chains. The indicators for this subcategory are two:

- **Rate of local employees:** The rate of local employees may vary due to the innovations. Some new positions could appear and an increase of the rate of local employees would be seen as a positive impact.
- **Rate of local suppliers:** The same criteria is followed with the suppliers. An increase on the local suppliers’ rate would be seen as a positive result, while a decrease would suppose a recoil.

### 3.10. Community Engagement

The subcategory “Community Engagement” focuses on the inclusion of community stakeholders (affected by actions or products) in the decision-making process with regard to value chains’ innovations. The main aspects to be considered for this subcategory are:

- **Number of events:** This indicator refers to the number of events developed by the company each year, in order to disseminate the innovations.
- **Impact in social media:** This indicator measures, in number of followers, the scope of the activity of the company in the social media, i.e., the number of people reached by the sent messages.

### 3.11. Technology Development

The subcategory “Technology Development” focuses on the development of efficient and sustainable technology, as well as technology transfer and broadening possibilities. There are two main indicators related to this subcategory:

- Previous involvement in transfer programs: It refers to the previous involvement or intention to participate in technology transfer programs.
- Investment in technology development: This indicator aims to quantify the evolution of the investment in R&D during the period under study. If the investment in R&D increases, the scoring result will be positive, while if it decreases, the result will be negative, since one of the main objectives of the innovations, which is the development of new technologies, would have failed.

### 3.12. Suppliers’ Relationships

The subcategory “Suppliers’ Relationships” focuses on the potential improvement or worsening regarding relationships between value chain actors, due to the innovations proposed. The main indicators regarding to this subcategory are described below:

- Request of a quality management system to the suppliers: It refers to the obligation of having a quality management system that a company may demand from their potential suppliers.
- Suppliers from countries with high proportion of modern slavery: It quantifies the rate of suppliers from countries with high proportion of modern slavery, according to the Global Slavery Index [49].

## 4. Discussion

The United Nations Environmental Programme [29] establishes a vast list of categories that could be considered in a Social Life Cycle Assessment. Scoring systems provide quantitative information about the subcategories, measuring improvements or deteriorations, comparing with the baseline conditions. A positive value in the scoring system result means an improvement in that subcategory, while a negative result suggests a deterioration. The quantitative information provided by the scoring system can be complemented with the results given by the materiality matrices, which provide qualitative information about which are the most relevant categories for each value chain and sector, as they consider the criteria of all the involved stakeholders, as shown in Figure 5, where each letter represents a stakeholder’s category—see acronyms in Appendix B—and the colors represent information about the degree of importance of each subcategory, being:

Green: low.

Yellow: moderate.

Red: high.

Influence on stakeholders' perceptions of the product	Multi-material packaging (Cardboard)				Cosmetics plastic packaging (bottle)					Plastic bags			Food trays (Tray + multilayer film)						Automotive components		Coffee capsule		Absorbent Hygienic Products							
	A	B	C	D	A	B	C	E	E	A	C	E	A	B	C	E	E	A	D	A	C	A	B	D	B	B	B	D		
Discrimination (Gender issues)																														
Workers training and education																														
Workers' health and safety																														
Consumers' health and safety																														
End-of-Life responsibility																														
Consumers' well being																														
Community access to material resources																														
Safe and healthy living conditions																														
Local employment																														
Community engagement																														
Technology development																														
Suppliers relationships																														

Figure 5. Stakeholders’ perception of the product.

Each letter in Figure 5 represents an answer from a stakeholder of the value chain. Letter A represents the manufacturing stakeholders, i.e., the company in charge of the industrial process of each product; letter B represents the packer stakeholders; C the brand-owner; and D and E represent the recycling and collecting or sorting processes, respectively. These are the key stakeholders identified for the specific value chains under assessment, and a total amount of 10 companies within these categories participated in the questionnaire, some of them interviewed in the assessment of different value chains. The fact that the first implementation of this proposed methodology is carried out on the assessment of innovative pilot products, which are not already in the market and therefore, not well known to the industry, restricted the number of stakeholders able to participate and provide a reasoned response. Therefore, when the methodology was applied to the assessment of other types of market-ready products, the number of companies addressed under each stakeholder category can be higher. In the adaptation of this methodology for the assessment of other products or systems, the identification of the value chain and its main stakeholders, from manufacturing to the end-of-life, is the first and crucial step.

There are, apart from the mentioned stakeholders (letters A to E), three primary stakeholders to provide feedback: consumers, workers and suppliers [29]. As future work, these three missing stakeholders' survey results can complement the S-LCA subcategories' prioritization to complete materiality analysis with their perception, obtaining a comprehensive approach and a comparison with business' perspective. Furthermore, to validate, evaluate and improve results, as well as to contextualize the results, workshops and round tables with sector professionals and the scientific community are proposed to be developed and included in future research work.

For example, the scoring result of the Workers' Health and Safety subcategory in the automotive component's value chain was +1, as the safety training hours increased as a consequence of the introduction of the circular innovations. Another relevant result was the improvement in the "End-of-Life" responsibility subcategory, which obtained positive results in most of the processes, except the plastic bags and the automotive component's ones, due to the addition of new information about the End-of-Life options or the improvement in the domestic waste management. Following the described methodology, this result must be framed in the materiality matrix context, where the subcategory "End-of-Life Responsibility" was considered as a critical one in all the manufacturing processes of the products, while the "Workers' Health and Safety" was considered as critical in the automotive components' manufacturing but less relevant in the rest of the manufacturing processes.

Thus, the combined use of materiality matrices and the scoring system may stand as a good alternative methodology for the Social Impact Assessment of a value chain, providing information about which aspects of the social assessment should be tackled first.

## 5. Conclusions

The Social Impact Assessment based on the Life Cycle Approach developed in this document may result in being applicable to evaluate the social impacts of the innovations under a circular economy approach in future studies.

This methodology allows to evaluate not only material changes, but also behaviors. This is because of the use of qualitative, quantitative and semi-quantitative indicators. Moreover, it integrates all the stakeholders in just one vision, considering a series of indicators for each subcategory. These facts may make the methodology replicable to all type of processes, value chains or products, since it promotes the stakeholders' participation in early stages, making possible the integration of their opinions and adapting the scoring system to their specific features. These steps should be followed in future works, consulting the most relevant stakeholders of the value chain, both at a local and at a national scale, in order to compare the S-LCA results.

Moreover, all these aspects enable the identification of both positive and negative trends, with the aim of knowing in which point the innovations have been effective or have created negative impacts or a regression from the point of view of social assessment. This is achieved by the combination of the pre-selection of the most relevant subcategories, considering the existing information about social impact assessment, and the scoring system, which considers more specific aspects related to the previously pre-selected subcategories. Thus, this methodological approach can be useful to communicate the results related to the impact categories with high relevance for the activities within the value chain, as well as the influence of these matters on other stakeholders' perceptions of the product (workers, consumers, local community, society and value chain actors), complementing the quantitative, objective data with the qualitative, subjective information.

Furthermore, the methodology is complementary with the economic and environmental Life Cycle Assessment, providing a holistic evaluation and accomplishing a sustainable approach. It might be a very useful tool for the decision-making related to sustainability and circular economy policies along the value chain.

However, the quality of the results will depend on the adaptation of the scoring system to each value chain, studying and explaining its features and integrating the scoring system into the business model under the circular approach.

For these reasons, in order to apply the scoring system model and to demonstrate its usability, future research work should target a second exploration period, where the methodological framework developed will be applied to assess the implementation of circular economy innovations in the value chains of different sectors.

**Author Contributions:** Formal analysis and investigation, D.R.; conceptualization and methodology, D.Z.-V. and A.S.-D.-G. All authors have read and agreed to the published version of the manuscript.

**Funding:** This contribution has been developed in the framework of the CIRC-PACK project "Towards circular economy in the plastic packaging value chain", funded by the European Union under the H2020 Innovation Framework Programme, project number 730423.

**Conflicts of Interest:** The authors declare no conflict of interest.

## Appendix A

Stakeholder related to social topic	Subcategory	Relevance of social topics related to value chains' innovations						Framework
		Multimaterial packaging (biopolymer+cardboard)						
		Manufacturing of cardboard		Manufacturing of packaging		Disposal and recycling		
		Significance for your business	Influence on stakeholders' perceptions of the product	Significance for your business	Influence on stakeholders' perceptions of the product	Significance for your business	Influence on stakeholders' perceptions of the product	
WORKER	Discrimination (Gender issues)	-	-	-	-	-	-	Process related to innovation
	Workers training and education	-	-	-	-	-	-	Process related to innovation
	Workers' health and safety	-	-	-	-	-	-	Process related to innovation
CONSUMER	Consumers' health and safety	-	-	-	-	-	-	Product
	End-of-Life responsibility	-	-	-	-	-	-	Product
	Consumers' well being	-	-	-	-	-	-	Product
COMMUNITY	Community access to material resources	-	-	-	-	-	-	Process related to innovation
	Safe and healthy living conditions	-	-	-	-	-	-	Process related to innovation
	Local employment	-	-	-	-	-	-	Process related to innovation
	Community engagement	-	-	-	-	-	-	Product
SOCIETY	Technology development	-	-	-	-	-	-	Process related to innovation
VALUE CHAIN ACTORS (not including consumers)	Suppliers relationships	-	-	-	-	-	-	Process related to innovation

Figure A1. Example of the questionnaire sent to the stakeholders for the multi-material packaging (cardboard).

## Appendix B. Acronyms

A: Manufacturing stakeholders.

B: Packer stakeholders.

C: Brand-owner.

D: Recycling.

E: Collecting/sorting process.

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