PlastiCircle

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7.6 Sustainability Assessment

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Abbreviations

GHG – Green House Gas

LCA – Life Cycle Assessment

LCC – Life Cycle Cost

LCIA – Life Cycle Impact Assessment

NFC – Near Field Communication

PCR – Product Category Rule

S-LCA – Social Life Cycle Assessment

Partners short names

1. ITENE: INSTITUTO TECNOLÓGICO DEL EMBALAJE, TRANSPORTE Y LOGÍSTICA
2. SINTEF: STIFTELSEN SINTEF
3.
4. AXION: AXION RECYCLING
5. CRF: CENTRO RICERCHE FIAT
6. UTRECHT: GEMEENTE UTRECHT
7. Las Naves: FUNDACION DE LA COMUNITAT VALENCIANA PARA LA PROMOCION ESTRATEGICA EL DESARROLLO Y LA INNOVACION URBANA
8. ALBA: PRIMARIA MUNICIPIULUI ALBA IULIA
9. MOV: MESTNA OBCINA VELENJE
10. SAV: SOCIEDAD ANONIMA AGRICULTORES DE LAVEGA DE VALENCIA, Spain
11. POLARIS: POLARIS M HOLDING
12. INTERVAL: INDUSTRIAS TERMOPLÁSTICAS VALENCIANAS
13. ARMACELL: ARMACELL Benelux S.C.S.
14. DERBIGUM: DERBIGUM N.V.
15. PROPLAST: CONSORZIO PER LA PROMOZIONE DELLA CULTURA PLASTICA PROPLAST
16. HAHN: HAHN PLASTICS Ltd.
17. ECOEMBES: ECOEMBALAJES ESPAÑA S.A.
18. KIMbcn : FUNDACIÓ KNOWLEDGE INNOVATION MARKET BARCELONA
19. PLAST-EU: PLASTICS EUROPE
20. ICLEI: ICLEI EUROPASEKRETARIAT GMBH
21. PICVISA: PICVISA OPTICAL SORTING

21.1. CALAF: CALAF INDUSTRIAL

22. SINTEF AS

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Publishable summary

PlastiCircle aims to develop and implement a holistic process to increase recycling rates of packaging waste in Europe. This will allow to reprocess again plastic waste in the same value chain (i.e. Circular economy; closure of plastic loop). This process is based on four axes: collection (to increase quantity/quality of packaging collected), transport (to reduce costs of recovered plastic), sorting (to increase yield and purity of recovered plastics), and valorisation in value-added products (i.e. foam boards, automotive parts, bituminous roofing membranes, garbage bags, and urban items such as retention grids).

This deliverable shows a specific evaluation for the waste management systems down the PlastiCircle approach in Valencia, Utrecht and Alba Iulia throughout sustainability evaluation based on LCA, LCC and S-LCA developed on parallel deliverables. This report is resumed on a spider diagram representation on which PlastiCircle impact is evidenced down a comparison between situation before and after the pilots.

Introduction

PlastiCircle has developed and demonstrated technologies for improved plastic packaging recycling in three pilot cities (Valencia, Alba Iulia and Utrecht). In these pilots it has been assessed the sustainability based on environmental, economic and social criteria and the results already available in the specific-related reports D7.3 (for LCA), D7.4 (for LCC) and D7.5 (for S-LCA). The present report integrates the outcomes of those specific assessments into one sustainability evaluation of the whole PlastiCircle approach.

However, this report reflects mainly the outcomes for the fully implemented pilot in Valencia city (Spain), while partially integrates some data collected in the other two pilots in Utrecht (The Netherlands) and Alba Iulia (Romania). There were some reasons for such decision, as only partial implementation of the PlastiCircle technologies has been done in Utrecht (eco-driving module only) and the pilot in Alba Iulia was done on mixed wastes instead of for the specific plastic packaging waste fraction.

1. Environmental, economic and social assessments outcomes

1.1 LCA

An environmental assessment was performed in the deliverable D7.3 to assess the impacts from PlastiCircle project on the city pilots (Valencia, Utrecht and Alba Iulia). The LCA study focused on the environmental impact differences induced by the use of the new PlastiCircle technologies (i.e. labelling device for citizens; filling level sensors; transport route optimizations; eco-driving) and the improvement of the packaging waste quality because of the better selective collection by improved segregation of waste by the citizens (i.e. rewards system based on a labelling device for citizens).

The LCA evaluated the impacts from the of the plastic packaging waste collected in each city per tonne of waste collected. The LCA comprised all the collection & transport activities, as well as the sorting/conditioning operations prior to subsequent converting by plastic manufacturers. To do so, the "cut-off" method was used which means that primary (i.e.: first) production of materials is always allocated to the primary user of a material. Therefore, if a material is recycled, the primary producer does not receive any credit for the provision of any recyclable materials. Life cycle assessment impacts were calculated with the life cycle impact assessment (LCIA) method ILCD 2011 Midpoint+ V1.06 / EU27 2010, [equal weighting]. This method uses 12 different impact categories to analyse the potential environmental impacts of a wide range of effects on the environment. For the sake of clarity in this report are only considered those impact categories internally classified as relevant. All these impact categories are shown in Table 1. The criteria for such selection are mainly the prescriptions of the Product Category Rule (PCR) for Plastic Waste and Scrap Recovery (Recycling) Services from Environdec, as well as the knowledge/awareness of the general public on these impacts.

Table 1 – Categories selected for evaluation on environmental impact

Impact Category	Acronym	Units for measurement
Climate change – Carbon Footprint	CC	kg CO_2 eq
Ozone depletion -- Impact on Ozone Layer	OD	kg CFC-11 eq
Acidification	AC	molc H^+ eq
Land use – Use of Land	LU	kg C deficit
Water resource depletion – Use of water	WRD	m^3 water eq

Table 2, presents the environmental impact results for pre- and Post- pilot in the city of Valencia, which is the most representative example from the project. However, result and impacts from the other PlastiCircle pilots can be found in D7.3 (see references).

Table 2 – Results on environmental impact for PlastiCircle Valencia pilot (from collection to the sorting/conditioning of plastic packaging waste). Converting processes of recycled materials into new products are deliberately excluded.

Impact Category	Units	Pre-Pilot	Post-Pilot	Difference (%)
Climate change	kg CO_2 eq	1177	945	-24.55
Ozone depletion	kg CFC-11 eq	0.00013	0.00011	-18.18
Acidification	molc H^+ eq	4.33	3.64	-18.96
Land use	kg C deficit	13.98	17.45	19.89
Water resource depletion	m^3 water eq	0.18	0.22	18.18

With regard to Climate Change category, the impact is reduced by 20% in comparison to the situation before the pilot implementation. This effect is mostly related to the improvement on the quality of the waste generated since less unwanted material is found in the collected fractions. This means that less material is being sent to landfill per tonne of material sorted from the packaging waste container. Therefore, lower (and better) ratios of energy used per kg of material recovered were found. Furthermore, the improvement on waste transport eco-efficiency and route optimization strategies have also a remarkable effect on the reduction on the Green House Gas (GHG) emissions.

Other impact categories such as Acidification and Ozone Layer depletion shows also reductions of 13 and 16% respectively, due to the same reasons mentioned above.

On the other hand, land use and water resource depletion show an increase for the post-pilot as compared to the pre-pilot. Such increases are associated to the integration of IoT system (use of devices with batteries, Near Field Communication (NFC) cards, label per bag, energy embedded on the system, *inter alia*). Due to the cut-off method used for the LCA, the avoided material obtained by recycling processes is not considered here and the direct impacts from technology use and implementation cannot be compensated. If avoided impacts were accounted, then the benefits from PlastiCircle implementation might offset the impacts giving positive impact results, although this possibility has not been assessed.

1.2 LCC

The economic impact of PlastiCircle's technologies by comparing the situation prior and post implementation of developed solutions, has been presented in the deliverable D7.4. This section describes the main findings and results that will be used, together with environmental and social outcomes, as an input to the sustainability assessment.

The scope of the economic assessment of the pilot includes the plastics waste management value chain, beginning at the households generated plastic waste until the production of final recycled plastic materials (e.g. flakes, pellets) as the output of the recycling process. Thus, the following steps are included in this evaluation:

1. Collection (including transportation to sorting facilities).
2. Sorting into different plastic resins.

3. Transportation of the sorted plastic resins to recycling facilities and other management options.
4. Processing of sorted materials into secondary raw materials for subsequent recycling at the converters
5. Final disposal or energy recovery of plastic waste not collected for recycling and plastic waste from sorting and recycling operations.

The results obtained for the pilot in Valencia indicate that the recycling costs were higher than the collection costs followed by the sorting costs. However, recyclers generate revenues from the sales of the plastic granules which cover the recycling costs and provide them a profit.

The Municipality, who is responsible for the collection and the sorting, receives a remuneration from Ecoembes (responsible for the EPR system in Spain) to compensate for the incurred costs. This remuneration was estimated using costs data used for the payment models included in the Agreements with local entities provided by Ecoembes (Ecoembes, 2021). The compensation received by the municipality of Valencia from the EPR system offsets the collection and sorting extra costs. The results reveal a financial benefit for the Municipality however some uncertainties exist as some activities (e.g. pre-sorting step to reduce impurities prior sending the waste to the sorting plant, costs of hiring the service company SAV) have not been accounted. Indeed, as reported in the literature there is a lack of transparency over costs actually borne by the municipalities and there is a risk of overestimating the overall costs due to the system's reliance on reference rather than actual costs (Bio by Deloitte, 2014; Watkins et al., 2017).

PlastiCircle's technologies resulted in higher amount of plastic packaging recovered and a reduced volume of waste to be disposed, as less unwanted materials and contaminations are collected. The pilot study displayed slightly higher costs for the collection but significantly lower sorting costs due to lower disposal (Table 3). However, recycling cost were increased for the post-pilot compared to the pre-pilot mostly due to higher volumes of plastics to be processed. On the flip side, PlastiCircle's technologies allowed lower management costs, higher remuneration to the Municipality and higher revenues from granule sales outweighing the increased recycling costs.

Table 3-Multi-stakeholder cost-benefit analysis for the management of plastic packaging in 1 tonne of collected packaging waste and 1 tonne of plastic packaging collected (Pre and Post-pilot Valencia)

	€/t collected packaging waste **Pre-pilot**	€/t of collected waste **Post-pilot**	Difference (%)
Collection & Transport	80	82	3.38
Sorting costs	105	84	-25.00
Remuneration Municipality	372	411	9.49
Recycling costs	162	189	14.29
Revenues sales of granules	307	351	12.54

1.3 S-LCA

S-LCA results for the waste management systems in Valencia (Spain), Utrecht (The Netherlands) and Alba Iulia (Romania) and an extrapolation of the results calculated showing the results on the European level has been presented in the deliverable D7.5.

S-LCA focuses on social aspects analysing the social impacts in a LCA context. To achieve this objective, the methodology proposed by Guidelines for Social Life Cycle Assessment of Products (UNEP / SETAC, 2009) has been followed. Generic data based on literature as well specific data obtained from stakeholders involved (citizens, citizens associations, waste managers and municipalities) through questionnaires has been used depending on the characteristics to be evaluated.

Questionnaires were prepared and sent to relevant project participants and plastic waste management actors. In order to compare the pre- and post-pilot situation, relevant data from all stakeholders were collected. Indicators selected were identified and linked to impact categories. Results of this social impact assessment after the full evaluation of the answers obtained from the stakeholders in the Valencia pilot are shown in the Table 4. This score has been calculated on a scale from 0 to 5, where 5 would be the highest possible score.

Table 4. Classification of subcategories evaluated in Valencia pilot.

No.	Sub-category	Valencia score
1	Consumer privacy	3.50
2	Community engagement	4.75
3	Service satisfaction	4.25
4	Access to immaterial resources	4.38
5	Local employment	3.38
6	Feedback mechanism	3.25
7	Public commitment to sustainability issues	3.75
8	End of life responsibility	3.88
9	Technology development	3.25
10	Contribution to economic development	3.63
11	Transparency	2.75
12	Health and safety	3.00

In order to carry out the social impact analysis, different impact sub-categories were evaluated in the S-LCA (e.g. consumer privacy, local employment, technology development). In the sake of clarity, these sub-categories were grouped into categories according to their typology (Table 5): health and safety, consumer satisfaction, transparency, socio-economic repercussions and sustainability awareness.

Table 5. Grouping of sub-categories used in S-LCA and final categories chosen for this report.

Subcategories from S-LCA	Categories
Health and safety	Health and safety
Service satisfaction	Consumer satisfaction
Consumer privacy	
Feedback mechanism	Transparency
Transparency	
End of life responsibility	
Access to immaterial resources	
Local employment	Socio-economic repercussions
Community engagement	
Technology development	
Contribution to economic development	
Public commitment to sustainability issues	Sustainability awareness

Based on these categories, values have been re calculated. This calculation has been made only for Valencia pilot.

Social impacts were scaled from 0 to 10, where 10 would be the highest impact grade and 0 no impact grade. These results are summarized in Table 6.

Table 6. Evaluation of impact categories for pre- and post-pilot social score in Valencia pilot.

	Pre-pilot score	Post-pilot score	Difference (%)
Health and safety	3.54	5.56	57.06
Consumer satisfaction	2.97	6.88	131.65
Transparency	3.26	7.02	115.34
Socio-economic repercussions	3.45	8.29	140.29
Sustainability awareness	2.51	7.21	187.25

As can be seen, all the categories studied have improved compared to their initial situation. Therefore, it can be confirmed that there is a global positive influence on the social issues evaluated during the implementation of the pilot.

The best effect has been observed in Sustainability awareness where an improvement percentage of 187.25% has been reached, mainly due to an increase of 91% in the number of public commitments actions by waste managers.

This category was followed by Socio-economic repercussions, Consumer satisfaction and Transparency where improvement percentages of 140.29%, 131.65% and 115.34% were performed, respectively. These percentages have been achieved mainly due to a greater number of meetings between community stakeholders, better public knowledge of which products can be put in the yellow bin and which can not, and an increase of 600% in the number of community education initiatives regarding waste management or environment since the beginning of the project.

The last category of the list by percentage achieved is Health and safety with a difference of 57.06%. However, this is a positive value mainly due to a decrease of consumer complaints identified by waste managers of more than 85%.

2. Sustainability assessment

Based on the specific results presented in the previous section, the three cornerstones of the sustainability have been integrated to visualise the potential improvement achieved with PlastiCircle's technologies.

2.1 Methodology

A quantitative decision-making tool to consider multiple environmental, economic and social criteria, and evaluate the overall sustainability of PlastiCircle has been adopted. This consists of a normalised spider chart which include different indicators shown in Table 7 for each dimension as following:

Table 7. List of indicators evaluated in PlastiCircle's Sustainability Assessment.

Environmental	Economic	Social
• Carbon footprint • Impact on the ozone layer • Acidification • Land use • Water use	• Collection & Transport • Sorting costs • Recycling costs • Remuneration Municipality • Revenues sales of granules	• Health and safety • Consumer satisfaction • Transparency • Socio-economic repercussions • Sustainability awareness

For each indicator, the scores are displayed as percentage where the highest score is the system with the lowest performance and vice versa.

2.2 Results and conclusions

The main conclusions from the environmental, economic and social assessments are highlighted in the following bullet points:

- Climate Change, impact on Ozone Layer Depletion and Acidification are categories where impact decreases with around 10 to 20% when PlastiCircle approach is implemented. However, other categories such as Land Use or Water Resource depletion increase due to the extra impacts from the implementation of intelligent collection technologies (i.e.: label dispenser, etc.).
- Management costs on collection and transport appear to be balanced as extra cost on technologies investments are offset by the saving from optimized transport. Although higher recycling cost is incurred, revenues increase due to the recovery of higher quality material (less unwanted material per tonne) but also more material to be recycled per tonne of packaging waste collected.
- On Social impacts, all parameters are improved as shown by the results from

questionnaires with special attention in Transparency and Socio-economic repercussions.

For the pre- and post-pilot situations, the integration of the results obtained for three cornerstones of the sustainability namely environmental, economic and social have been integrated and displayed in the spider diagram shown in Figure 1. The spider diagram with the largest surface area means the less sustainable scenario while the smallest surface area the most sustainable solution. The categories displayed on the diagram can imply a positive or negative effect (i.e. climate change, the higher the worse; while Revenue, the higher the better), and that is the reason some categories were reversed to have them all aligned.

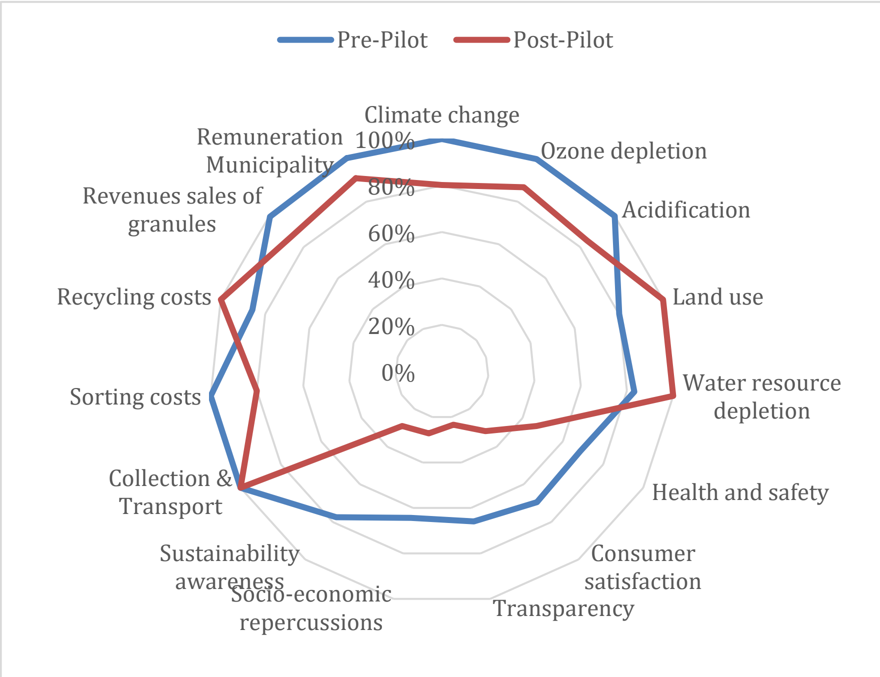

Figure 1. Spider diagram for PlastiCircle impact categories in Pre- and Post-Pilot situation.

As can be drawn from the spider diagram, t pilot depicts a smaller surface area compared to the one obtained for the pre-pilot (Figure 1). This indicates that the implementation of PlastiCircle's technologies has achieved a significant improvement by rendering the recycling of plastic packaging waste more sustainable than the pre-pilot situation. Indeed, PlastiCircle was well received by the citizens and provided several societal benefits, as can be seen from the SLCA results from Valencia. Furthermore, the project contributed to reduce most of the environmental impacts while it improved the economic benefits associated with the recycling.

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D7.3 PlastiCircle Life Cycle Assessment

D7.4 PlastiCircle Life Cycle Cost

D7.5 PlastiCircle Social Life Cycle Assessment

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