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Abstract

Through holistic approach, the PlastiCircle project aims to improve plastic packaging waste (collection, transport, sorting and recycling) and get better quality of collected and sorted plastic for recycling companies.

This initial guide presents findings and introduces recommendations for cities who wish to develop and implement the PlastiCircle approach, based on the pilot in Valencia. A final replication guide will follow, once the three pilots (Valencia, Utrecht and Alba Iulia) are finalised.

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

21.1 CALAF

22. SINTEF AS

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Executive Summary

Twenty European organisations have joined forces to reinvent the way we treat plastic packaging. PlastiCircle aims to promote the transition towards a circular economy, and to contribute to the European Union's waste management and recycling targets to 2030. At present, more than 25.8 million tonnes of plastic waste are produced per year in EU Member States, with only 29.7% being recycled. PlastiCircle's efforts will focus on one particularly important component of this plastic waste, namely plastic packaging waste.

While rethinking various phases in the life of waste – from collection to transport, sorting to recycling – PlastiCircle ultimately aims to transform waste into valuable products. The consortium is reinventing the plastic packaging treatment process to obtain higher recycling rates, better quality and cheaper secondary raw materials, as well as better recovery and valorisation within the same value chain.

In particular, the consortium is focusing on the development of smart containers for separate waste collection, on the improvement of transport routes, and of sorting and reprocessing technologies, eventually converting packaging waste into value-added products such as foam boards, automotive parts, roofing membranes, garbage bags, asphalt and urban furniture.

The PlastiCircle approach is to be tested in three pilot cities: Valencia in Spain, Utrecht in the Netherlands, and Alba Iulia in Romania.

This document presents, at first, one way of including some solutions/methods implemented during the pilot in Valencia (Spain) in the fields of sorting and transport to waste management. The step by step approach is described, outlining the complications occurred during the pilot activities. The aim of the Guide is to present new solutions and some gaps that are arising in plastic's circular economy.

In order to facilitate the replication of projects aimed at improving the efficiency of the plastic waste management process and promoting circular economy principles in the core of local governments strategies, key activities within these phases can be adjusted. Cities should carefully analyse at which stage they are in relation to the implementation of specific solutions or projects.

Each stage has further sub-steps that help fostering integrated management and the development of projects aimed at promoting circular economy in local management practices.

1. Introduction

There is wide consensus among researchers that resource production and use – from raw material production to manufacturing, use and finally discard – are main drivers for climate change, biodiversity loss, eutrophication, oceans acidification and resource depletion (IRP, 2018; The European environment—State and outlook 2020, 2020; UNEP, 2012; UN-Habitat, 2016). Moreover, resource distribution, the distribution of wealth and the management of externalities largely determine people's (non-) access to health and educational services and is thus key determinant for well-being (cf. United Nations, 2016). Hence, decoupling resource use from economic activity is of utmost importance when striving to limit its adverse impact onto the natural environment while promoting and sustaining a good quality of life for all.

The EU has recognised the importance of more circular production and consumption patterns, including increased share of secondary materials, product lifetime extension and more intensive use of products. The new Circular Economy Action Plan for the European Union (EU CEAP) does address some of these issues, promising support, e.g. legislation concerning sustainable products, such as the 'right to repair', the sustainable product policy, establishing mandatory Green Public Procurement (GPP) criteria and targets (EC, 2020), or providing solutions for cross-cutting integration of circular economy with other priority topics, such as climate change. With plastics being one of the priority sectors, the CEAP also proposes mandatory requirements for recycled content and waste reduction measures for key products such as packaging, construction materials and vehicles, also taking into account the activities of the Circular Plastics Alliance.

In this, the CEAP responds to a key discrepancy in the European plastics market: more than 25.8 million tonnes of plastic waste are produced per year in the EU-28 with only 29.7% being recycled. This represents a clear gap in the effort to close the loop for plastics in Europe and goes hand in hand with an economic loss of approximately €10.56bn. Moreover, this goes against the EU legislation on waste (high environmental impact; 23.8 Mt of CO_2). Recovery rates for plastic packaging waste highly vary in the EU-28, with the highest being more than 50% (Czech Republic) and the lowest Finland with approx. 25%. The Netherlands and Spain are among the countries with higher recycling rates of around 45%. Romania is in the lower third, with rates close to 30% (Plastics – the Facts 2017, Plastics Europe 2018)

Low recycling rates of plastic are mainly due to the situation of packaging waste (i.e. main plastic waste fraction), since it is mainly domestic residue and consequently the quality of the material collected depends on the system of segregation available and the environmental awareness of citizens.

This is where the PlastiCircle project comes in, aiming to improve the circular economy of plastics. 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 of packaging collected), transport (to reduce costs of recovered plastic), sorting (to increase quality of recovered plastic), and valorisation in value-added products (i.e. foam boards, automotive parts like engine covers/bumpers/dashboards, bituminous roofing membranes, garbage bags, asphalt sheets/roofing felts and urban furniture like fences/benches/protection walls). More concretely, it sets out to develop solutions including smart containers, route optimisation

patterns, optimisation of sorting technologies, and scoping and development of products from recycled plastic waste. It further aims to multiply and to extend the PlastiCircle approach across Europe.

2. Objectives of the Replication Guide

This initial Replication Guide supports the goal of improving circular economy of plastics by building on the experience of the implementation of the pilot project in the city of Valencia (Spain), where these solutions were tested. Measures included are the increase in packaging collection, the reduction of the costs with transport, the increase in the quality of recovered plastic and added value to new product from recycled plastic.

This guide is written particularly for political and technical decision-makers of local governments that seek to include circular economy principles in their plastic waste management processes.

The objectives of this Replication Guide are to provide cities across Europe with a set of recommendations to replicate and upscale the PlastiCircle approach, deploying the solutions developed and tested as part of this EU-funded project, in order to sustainably and efficiently increase the recycling of plastic packaging waste across Europe.

In addition, this report aims:

- to create awareness of the importance to include circular economy principles in the plastic waste management and planning processes on a local and regional level;
- to leverage the role of smart technologies as key drivers, increasing the efficiency of the plastic waste and the solid waste management process on local level, and
- to provide inspiration to local governments, engaging citizens in the plastic waste management process.

3. Cities implementing the pilots

The three cities implementing PlastiCIrcle pilots are: Valencia (Spain), Utrecht (the Netherlands) and Alba Iulia (Romania). At the moment this guide was written, the cities of Valencia and Utrecht have finalised the execution of the project, while Alba Iulia was in the preparation stages to start the implementation. In the case of Utrecht, some data was still being processed and this is why it has not been included in this guide.

THE PLASTIC CIRCULAR ECONOMY STEPS

Figure 9: The PlastiCircle approach

In Figure 1, the focus (four axes) of PlastiCircle can be visualised: 1) development of smart containers to separate waste collection, 2) improvement of transport routes, 3) sorting and 4) reprocessing technologies, eventually converting packaging waste into value-added products, such as foam boards, automotive parts, roofing membranes, garbage bags, asphalt and urban furniture.

For each pilot, the first requirement was to identify activities and involved actors including their roles. Schematically, the PlastiCircle project can be described as in Figure 2.

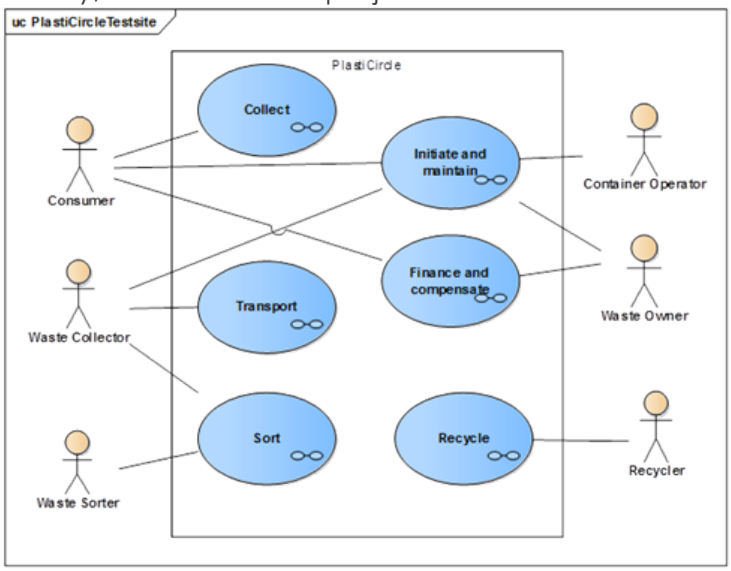


Figure 10: The PlastiCircle project sketched

3.1 Valencia

Valencia is a city on the east coast of Spain. It is the capital of the autonomous community Comunidad Valenciana and the third-largest city in Spain after Madrid and Barcelona. Valencia has a population of 790,201 inhabitants (2016) with 5,868.56 inh./km² population's density. The city represents 16% of the population of the Valencian region.

Collection is being performed using a combination of different methods: D-t-D system[1] for commercial cardboard, BB[2] system for almost every domestic waste (domestic paper & cardboard, glass, light packaging, organic and other waste) and, finally, fixed or mobile CA for other kind of materials (bulky waste, oil, WEEE[3], etc.).

The collection system for the fraction of light or plastic packaging is by lateral load with the collection model of "areas of voluntary contribution". The containers of this fraction coexist next to containers of other fractions as paper and cardboard, as well as glass and organic fraction in some cases.

Figure 11: Containers of Valencia

The autonomous regions of Spain prepare their own plans and programmes that have to follow at minimum of the national plan requirements.

The plastic life cycle of Valencia city is composed of the following stages:

[1] Door-to-door collection
[2] Bring banks
[3] Waste electric&electronic equipment

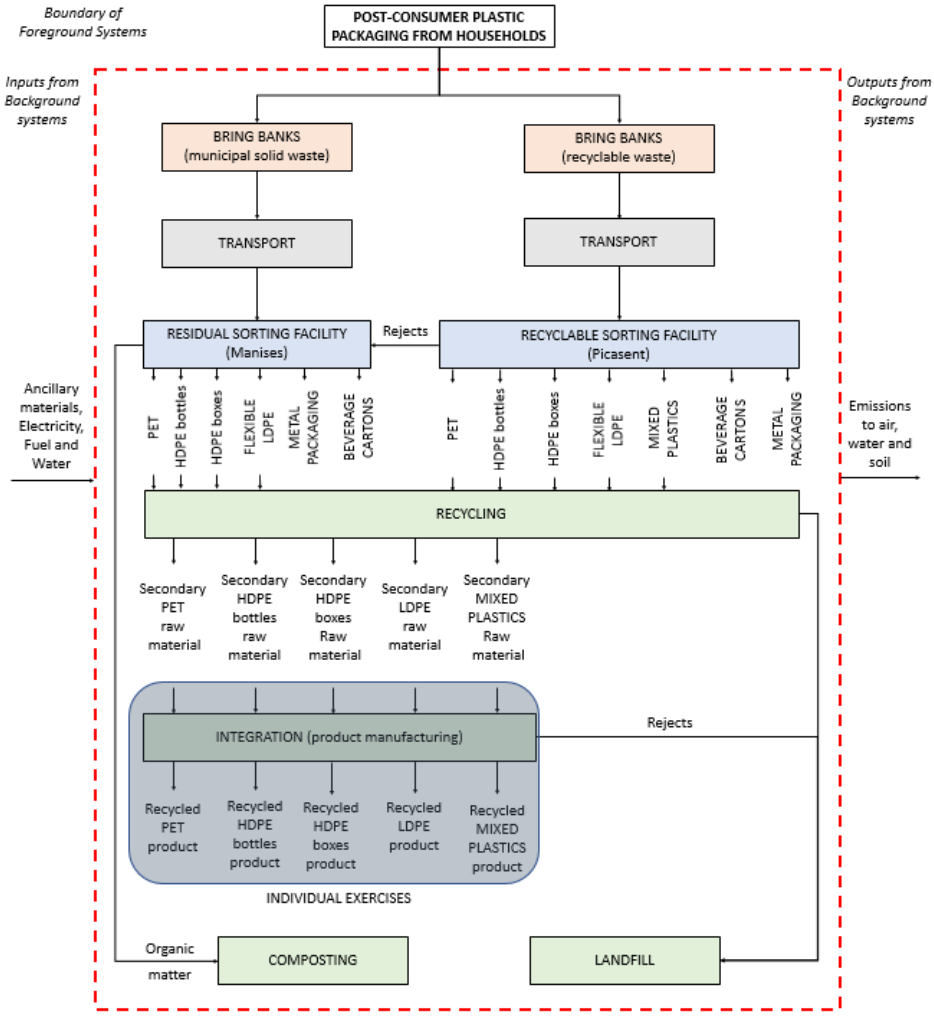


Figure 12: Life cycle diagram of plastic packaging waste management system of Valencia city

3.1.1 Collection

Valencia collects separately the light packaging waste (LPW) (yellow container) from the other recyclables like paper/cardboard and glass. The fraction included in the LPW includes plastic packaging, metal packaging and beverage cartons. Citizens carry their packaging waste to the BB located closer to their houses (normally flats).

3.1.2 Transport

The frequency of collection in Valencia varies depending on the waste stream. It is established a daily collection for organic and rest fraction and a three days per week collection for packaging waste streams (paper and cardboard, LPW and glass). SAV and FCC are the two waste management companies in charge of the collection of the different waste fractions, except for glass packaging, which is collected directly by Ecovidrio.

Different waste fractions are collected by trucks with lateral or back charge, and top load, and then it is transported to the waste treatment plant.

3.1.3 Sorting

In the Packaging Sorting Plant, the different packaging materials are sorted into different fractions (PET, HDPE bottles, HDPE boxes, Film, Mixed Plastics, metal cans and beverage carton) manually in a pick station and automatically in different sorting stations. This situation results into a high yields and plastic recovery percentage.

In the MSW treatment plant, they recover mainly organic matter, although they also recover some packaging materials (PET, HDPE boxes, HDPE bottles, Film, Metal packaging and Beverage carton).

Once the different packaging materials have been sorted into the main packaging materials (beverage cartons, Metal packaging, PET, HDPE bottles, HDPE boxes, Film and Mixture plastics), these are stored until its transportation to the proper recyclers' facilities. Then, the remaining waste is sent to landfill located in Dos Aguas.

3.1.4 Recycling

In the recycling stage, each recycler is responsible for the process of the specific material to obtain pellets of recycled material. These secondary raw materials can be used by transformers to make new products from the recycled material. In the study, we only consider the integration processes of the plastic raw materials which are the object of the project.

3.2 Utrecht

Utrecht is a city in the central Netherlands with a population of 345,080 (2017) and population density of 3,658/km2. Due to its central position within the country, it is an important transport hub for both rail and road transport.

The city of Utrecht is among the best waste recyclers cities of the Netherlands. Residents can divide their waste into five types of waste (paper; glass; organic waste; plastic / cans / packing (PBP); residual waste or rest). In residential areas with low population density, the collection system is through personalised collection (D-t-D system), but in areas with high-population density, the collection system is through BB systems and CA located in different areas of the city.

Figure 13: Utrecht underground container

The waste processors in the Netherlands do not accept the collection of the light packaging fraction denominated "plastic, blik en pak" (PBP) in grey opaque bags due to the preclusion to determine of the quality of the segregated material. Utrecht is thus encouraging the use of transparent bags for door-to-door collection among its neighbours.

3.3 Alba Iulia

Alba Iulia is a Romanian city, placed in the Transylvania Region, which counts a population of 74,000 inhabitants (2017), with an extension of 103.6 km2 and a density of 566 inhabitants/km2.

The population in Alba Iulia lives mainly in flats and individual houses distributed almost equally. According to the statistics provided by the municipality, 31,921 people lived in 172 associations of apartments in flat buildings. Other part of the population is distributed among 14,548 individual houses.

Polaris is the authorised company for individual houses' waste services for the entire city. For individual houses, a yellow bag is used for paper, glass, plastic and cans. Polaris is sorting locally and sending sorted materials to specialised companies. Low-quality waste and garbage are sent to dump. For associations of apartments in flat buildings, the yellow container is usually for recyclable materials, but waste quality is sometimes low, being mixed with garbage. More than that, there are persons without economic resources gathering PET bottles left near containers for selling them to recycling companies for a very small fee. Local companies selling packed goods must have recycling contracts with Polaris or other authorised companies. These companies are sorting useful materials and have contracts for delivering them to processing units.

4. The Valencia pilot

The pilot in Valencia was divided into three parts:

- Preparation/pilot planning
- Implementation
- Evaluation

Stakeholders were families living in the pilot area of Sant Marcel·lí. It covers an area of 0.33 km2, where 10,000 inhabitants live.

The minimum of 25 containers were included in pilot . They were equipped with filling-level sensors to measure the fulfilment with waste and with labelling system for users.

4.1 Planning and Preparation

The initial time originally planned of six (6) months had to be extended into eight (8) months to meet the requirement of a six (6) months monitoring period. The extension had a direct impact in the planning of following actions:

- **Communication:**
  - Pre-monitoring actions
  - Monitoring period
  - End of the pilot and closing event

- **Installation**:
  - Smart devices, including the user identification module, label dispenser and communication module
  - Label dispenser with communication module
  - Boxes with modules aggregated to the filling level sensors

- **Training:**
  - Two learning activities were planned: one focused on the trucks communication system and route optimisation addressed to waste truck drivers, and another one based on the characterisation protocol addressed to drivers and operators

- **Characterisation protocol**
  - PET bottles (clear), PET bottles (coloured), PET trays (clear), PET trays (coloured), HDPE bottles (natural), HDPE bottles (coloured), PP bottles, PP pots, tubs and trays, PE films, PP films, Multilayer films, Other plastics, Unwanted material, Compacted bottles, Stacked packaging, Non-empty packaging
  - Three characterisations were done pre- mid- and late- pilot (Several characterisations were done:
    - General Characterisation: analysing % of general waste on light-packaging and MSW containers
    - Individual characterisation: this one is done to know how the citizen has recycled and then apply the compensation procedure
    - PICVISA characterisation: separate 2D and 3D material to test specific sorts performance

- **Questionnaires** sent to involved parties

The pilot in Valencia was planned to be developed in four (4) months but it was extended to six (6) months due to some challenges in technical solutions regarding the implementation of more receiving antennas; and due to the two summer months period to meet the requirements of four months monitoring period. The delay had a direct impact on the planning of following actions:

4.1.1 Sites selection

The initial location chosen to receive the pilot was the Sant Marcel·lí district in Valencia.

Figure 14: Location of pilot district Sant Marcel·lí in Valencia

The consequent reduction in number of containers, pilot's participants, collections of waste, etc. were regarded as not relevant for the purpose of the project.

4.1.2 Definition of KPIs

Stakeholders were families living in pilot area.

For the environmental evaluation of the project, six (6) environmental key point indicators (KPI) were selected:

- Distance
- Time travelled for trucks
- Fuel consumption
- Related CO2 emissions
- Collection performed (in comparison with tones collected and driven distance), and
- Performance (costs in comparison with tones collected, personal and energy costs/t collected and % of inappropriate materials RSU containers).

For the citizens characterisation, four (4) KPIs were selected:

- Percentage of not packaging waste

- Percentage of no empty packaging
- Percentage of stacked packaging, and
- Percentage of compacted bottles.

4.1.3 Citizens engagement

The involvement of the citizens in the project consisted of:

- registration and receiving an NFC card;
- using the NFC card at the label dispenser;
- attaching the label to the bag;
- characterisation of content, and
- compensation according to the characterisation's results.

Figure 15: Citizen involvement in PlastiCircle

The KPIs identified in Communication Plan were:

- **K14** Number of people registered and number of participants in the project
- **K15** Number of visits in web supports
- **K16** Number of followers and engagement in social media
- **K17** Number of people attending meetings organised, such as events or conferences.

The final number of families registered and the number of the participations in the project were:

Registrations	**554**
Citizens	1462

It can be appreciated the high number of registrations done "manually", which means neighbours registered through the information office. This fact confirms the previous studies stating the high digital diverse rate of the neighbours of Sant Marcel·lí due basically to the average age of its population.

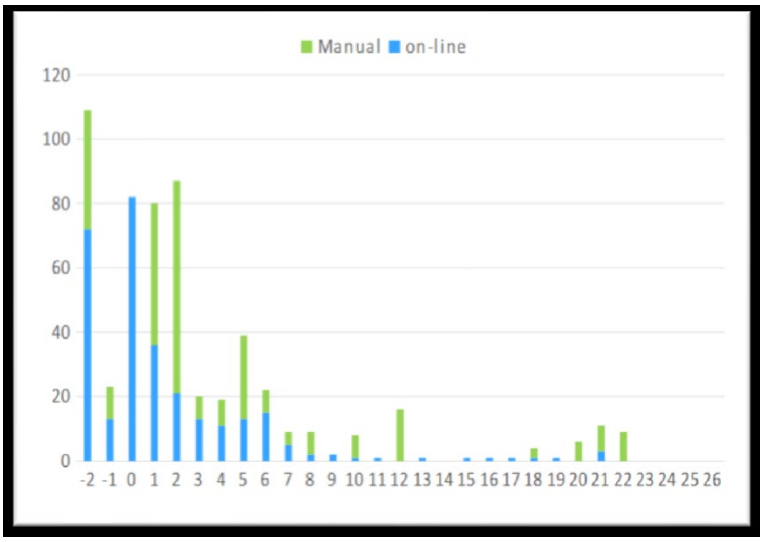


Figure 16: Manual vs. online registration (Axis X: number of registration; Axis Y: Pilot Week)

4.1.4 Communications Plan

A diverse set of communication tools was launched in each of pilot period (pre-pilot, monitoring and post-pilot period) aimed at:

- informing about how to participate in the pilot action
- training about the right waste sorting at home
- raising awareness about the importance of circular economy

These three objectives were not treated separately, but as a whole in every dissemination action of the campaign.

a) Pre-Pilot Actions

- **Campaign Visual Identity:** A specific brand and visual identity were designed to boost the identification of the neighbours with the project, but without losing the link with the Plasticircle project. The campaign name used both official languages (Valencian and Spanish) and corporative colours of Plasticircle project.
- **Webpage:** A dedicated webpage (https://supermarcelina.com/) was launched in pre-pilot weeks to start informing and registering interested neighbours of Sant Marcel·lí.
  The webpage included:
  - Information about how to participate
  - Online registration platform
  - Dissemination of main events and achievements of the pilot

User's profile management, so that the participant can follow up in real time their performance and, hence, their points

Administration platform to monitor the progress of the registration process and participants management

Platform to eventually redeem points with presents at the end of the pilot.

- **Street Informers:** Trained staff walked the district two (2) days per week during the month of April to inform citizens about the upcoming launch of the pilot action. Leaflets and posters were circulated among citizens.
- **Events:** During pre-pilot phase the format of the events was Info Stand where informers were able to enlighten citizens, register new participants and raise awareness about the importance of the right waste sorting. Nine (9) activities/events were planned before and during the pilot action: four (4) for adults, one (1) children's workshop, one (1) activity for teenagers, two (2) events for journalists and citizenship in general and one (1) technical event for entities and sector.

b) Monitoring Period

Pilot monitoring period started from 1 May and lasted until the end of October. Because of one-month delay and consequently two summer months, it was extended to 6 months.

c) Post Pilot Period

After the monitoring period (31 October), communication efforts focused on informing users about the process of exchanging points for gifts. To this end:

• A period was established (1-10 November) so users could check and ask for information and even request rectification of their points if they considered that any anomaly had occurred.

• After this phase, a period of two weeks (11-24 November) was opened for users to exchange points online.

• To facilitate manual redemption, two face-to-face sessions were organised in the neighbourhood to help users in the process.

Once the list of winners and requested gifts was obtained, a public event was organised in the neighbourhood on 14 December, where users could collect their prizes. The event was designed to include activities and workshops aimed at all residents, not just those who participated in the pilot. Users who were not able to collect their gift in person received it by post.

After the monitoring phase, when new data was collected, some evaluation was made. The aim of monitoring and supervision was to test the sample and compare data from the two periods. In case of the Valencia pilot, the basic data was taken before the pilot.

The evaluation of results helped waste manager to get information on how to optimize collection of waste and its transport. More about evaluation results is written in next paragraph and can be found below.

4.2 Implementation (4 steps)

In line with the results supposed to be provided by the pilot, its activities were divided into four steps: Collection, Transport, Sorting and Revalorisation.

4.2.1 Collection

Regarding waste collection, nowadays Valencia City is collecting eight different kinds of domestic waste streams:

- Paper & cardboard
- Light packaging: plastic, cans and beverage carton
- Glass
- Used oil
- WEEE
- Bulky products
- Other waste
- Organic

Waste management is legislated by the Municipal Ordinance called *Ordenanza Municipal de Limpieza Urbana de Valencia*. The company for waste collection also depends on the waste stream: glass is collected directly by Ecovidrio, while all the other different waste streams are collected by Fovasa, SAV and FCC, three waste management companies.

After collection, garbage and organic waste is transported to a treatment plant in Manises, in exception to the packaging plastic fraction contained in garbage:

- PET
- HDPE Bottles
- HDPE Boxes
- Mixed plastic
- Film

These fractions are sold to the packaging manager company 'BINARIA'.

It is also directly sold to 'BINARIA' the packaging fraction separate collected corresponding to plastic, cans and beverage cartons. Finally, paper & board is directly sold to a paper manager in Alzira.

➢ **Smart Container Identification module**

After the installation of the first functional prototype of the device in the container, some problems were found, and different approaches were applied to solve them.

- Rain filtration through the outer box seal, was solved by a reinforcement of the box joint and the use of plastic stickers.

- Obstruction of the label at the exit of the device was solved by enlarging the slot through which the labels are dispensed.

- Occasional malfunctions in the reading of RFID cards were solved by repositioning the RFID card reader in the device.

On the other hand, regarding the anti-vandalism systems that were implemented, there was a positive result. Not a single electronic part of any device was manipulated. However, the biggest problem experienced was the breakage or manipulation of the

label tape, either by vandalism or due to the poor rotation flow of the tape or caused by misinformation of the users operating the device. When pulling out the label in the middle of the process could cause a lack of tension on the label belt causing problems to the next user.

- **Filling level sensor**

The sensors installed on the containers were TST waste commercial sensors. They were installed on the top of the container (see Figure 9). The information of the filling level in the container was sent to the IoT platform every 8 hours.

Figure 17. Filling level sensor installed in Sant Marcel·lí

The readings of the sensor were monitored in order to prevent possible mistakes in the sensors' measurements. The filling level was checked weekly during all pilot. This measure allowed to correct the formula that converts the measurements of the sensors into percentage of filling level, as well as guarantee a good performance in the optimisation of the collection when sensors or communication failed.

Once sensors were adjusted, the next step in the pilot was to analyse the information obtained by the filing level sensor to extract the behaviour and the filling speed of the containers in the pilot area.

Within this analysis, it was concluded that there are three different types of behaviour depending on the filling speed of the containers:

- High frequency containers
- Medium frequency containers
- Low frequency containers

- **Definition of Technology (used in Valencia)**

Users received NFC cards for their identification at the container. The NFC reader was included in the same module as the label dispenser. In this way, the dispensed label was associated with the user ID, time, etc. The module sent the information by LoRa, Low Power Wide Area Network, to a gateway or receiver node installed in the pilot neighbourhood. Its installation required permission from the City Council.

Figure 18: LoRa components installed in the container module

TSwasTe was chosen as the filling-level sensor. This is a stand-alone device supporting different network technologies: GPRS, Sigfox, WiFi or ZigBee. Data from the filling level sensors are sent to a cloud server by GPRS (Figure 11). This was tested successfully in April in Valencia. One of the same sensors was also tested and concluded to work in Alba Iulia with the Spanish SIM card. Data received in the cloud serveries stored in a PostgreSQL database to be visualised in the IoT platform.

Figure 19: Data from the filling level sensors sent to a cloud server by GPRS

4.2.2 Transport

The preliminary transport system included the cloud platform, route optimisation, characterisation protocol, compensation procedure, traceability and driving guidance. It was planned to be finished at the beginning of March 2019 in order to test it in real conditions at the end of March, make possible changes during April and collect the defined KPIs before starting the pilot activity the 1st May in Sant Marcel·lí(Valencia).

The route optimisation had three phases:

1. Measure and analyse the current route performed by the driver
2. Optimise the current route collecting all the containers in order to minimise time and cost
3. Optimise the route based on the filling level of the containers, skipping those containers which were not full the collection day.

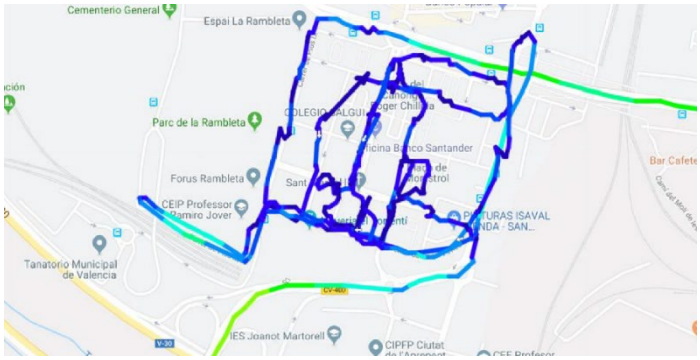


Figure 20: The route before optimisation

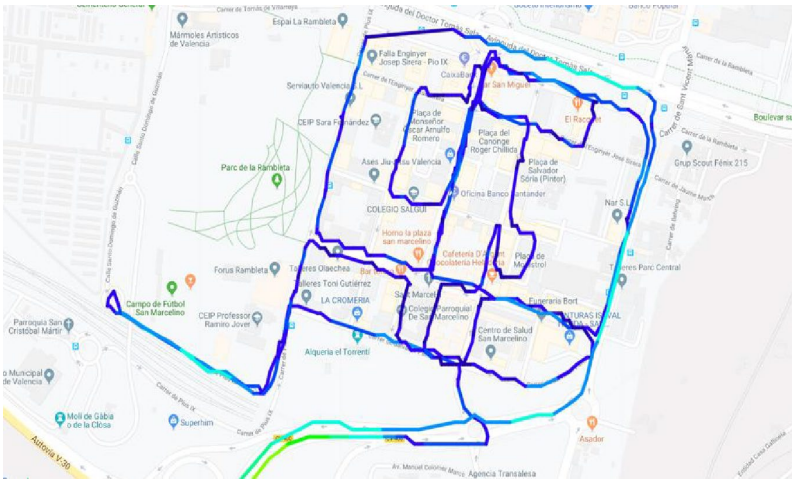


Figure 21: The route after optimisation

The optimisation of transport routes led to significant savings compared to the initial situation:

- 34% savings in distance travelled
- 28% savings in the duration of waste collection operations
- 22% savings in fuel consumption.
- 7.5% increase filling level when containers are collected

4.2.3 Sorting

The sorting of all collected waste was made before the pilot started and during its course.

➢ **Waste characterisation**

Table **1** shows good effects of the pilot versus pre-pilot as well as differences between pilot users and non-users for non-packaging waste, compacted bottles and collection rate of plastics packaging. Specifically, the collection rate shows an improvement of 12 percentage points for the pilot users.

Table 1

	Pre-pilot	Users final pilot	Non-users final pilot
K7.1: % Not packaging waste	14	3	18
K8: % No empty packaging	1.14	1.61	0.87
K9: % Stacked packaging	1.2	1.3	1.7
K10: % Compacted bottles	32	74	28
K11: % selective collection rate	30	38	26
K12: Compaction -kg/m3	30	-	-

In order to give response to all the KPIs set in this section, two different characterisations were done during the pilot: evaluation of bags individually, performed by SAV, and characterisation of the whole collection of the neighbourhood, subcontracted by SAV and Las Naves.

➢ **Individual characterisation of bags**

Characterisation of users and non-users of the pilot. This characterisation included the evaluation of at least 25 labelled orange bags (bags from citizens participating in the pilot, users) per week of the pilot, and at least 50 non-labelled, non-orange bags (bags from citizens not participating in the pilot, non-users) per month.

This characterisation was also used to assign the eco-points to the pilot participants.

Results obtained in the individual characterisations of bags

Unwanted material (%)	**Non-empty (%)**	**Stacked (%)**	**Compacted (%)**
Pre-Pilot	**13,83**	**1,14**	**1,22**
Users	**2,96**	**1,61**	**1,30**
Non-Users	17,31	0,87	1,69

4.2.4. Reprocessing (characterisation)

Seven characterisations of the whole neighbourhood waste were carried out by an external accredited entity (four light packaging characterisations, and three residual waste characterisations):

- Pre pilot (2),
- Mid pilot (2), and
- Final pilot (3): labelled orange bags, and non-labelled, non-orange bags were characterised separately (in light packaging containers).

In order to calculate the selective collection rate, the characterisation of the residual waste containers was also done pre-pilot, mid-pilot and final-pilot. To this end, the weight of the plastic packaging waste in the lightweight packaging container (yellow) and the

weight of the plastic packaging waste in the residual waste container (grey), as well as the total weight of the waste collected in both containers, were considered.

The results obtained from the light packaging characterisation pre-pilot were anomalous (12% of unwanted material), and it was decided to repeat the test in a reference neighbourhood since the pilot in Sant Marcel·lí had already begun. The population, the social class and the fact that the organic collection was already implemented, were the three variables considered in the selection of the reference neighbourhood.

Table **2** shows the light packaging containers characterisations results obtained. No significant differences were found during the pilot. The differences obtained between reference (21.59 % of unwanted material) and final pilot (24.08 %) can be considered as a normal variability in the methodology.

Table 2:General characterisation of the light packaging containers in the neighbourhood

	REFERENCE	MID PILOT	FINAL PILOT (%)		
	(%)	(%)	Non-Users	Users	TOTAL
PET Packaging:	**23,29**	**31,63**	26,62	30,46	**27,96**
PET	15,49	26,76	25,76	23,15	26,31
PET Multilayer	7,81	4,87	0,86	7,31	1,65
HDPE Packaging:	**13,40**	**9,71**	7,81	8,00	**8,09**
Natural HDPE	9,34	6,76	5,62	6,84	5,95
Colour HDPE	3,61	2,94	2,19	1,16	2,14
Injection HDPE	0,45	-	-	-	-
Mixed Packaging	**6,42**	**7,49**	6,41	9,17	**6,94**
Metal Packaging:	**9,85**	**7,98**	9,22	13,57	**10,03**
Brick (Food & Beverage)	**11,59**	**7,17**	10,20	14,63	**11,06**
Film	**13,86**	**12,36**	12,28	15,46	**11,82**
TOTAL LIGHT PACKAGING	**78,41**	**76,33**	**72,54**	**91,29**	**75,92**
Organic	-	**3,15**	2,40	1,48	**2,37**
Paper & Cardboard	**5,03**	**2,44**	4,33	1,23	**4,11**
Wood	-	**1,60**	2,01	0,03	**1,51**
Glass	**1,05**	**1,88**	2,10	0,14	**1,45**
Metals	**4,16**	**1,76**	3,37	0,48	**3,07**
Textile	**2,66**	**3,44**	5,63	0,97	**5,27**
Others	**8,68**	**9,41**	7,61	4,39	**6,30**
TOTAL UNWANTED MATERIAL	**21,59**	**23,67**	**27,46**	**8,71**	**24,08**

Plastic packaging selective collection rate

Table 3: Plastic packaging selective collection rate

	REFERENCE	MID PILOT	FINAL PILOT (%)		
	TOTAL (%)	(%)	Non-Users	Users	TOTAL
Plastic Packaging in the lightweight packaging container (%)	**68,56**	**68,36**	63,32	77,73	**65,68**
Plastic Packaging in the residual waste container (%)	**7,47**	**8,44**	*	*	**7,93**
Lightweight packaging container selective collection rate (%)	**30,41**	**30,32**	25,51**	37,63**	**29,13**

*Plastic packaging in the residual waste container for users and non-users cannot be measured. The grey container was not included in the pilot.
**Data estimated. Estimation based on the following hypothesis: the different quantity obtained between reference and users/non-users is the decrease/increase of the annual waste production in the residual waste container, and the increase/decrease of the annual waste production in the lightweight packaging container.

4.3 Success factors and key implementation challenges

4.3.1 Sucess factors

Based on the experience of PlastiCircle during the planning process of the project, the key drivers for success included:

- **Communication:** In the frame of communication, it must be considered how to address, connect and engage stakeholders regarding separate waste collecting. They must know why and how to separate the waste. The protection of personal data must be taken into consideration.

- **Installation:** of technical equipment, the place where it can be installed, its rage, its endurance.

- **Training:** It is important to train experts, who will contact the users to teach them about the necessity of separation of waste and about quality sorting of waste.

- **Characterisation protocol**: Who will do it, which technology will be used to get the desired fractions and to sort as much as possible.

In addition, during the implementation of the PlastiCircle process, the following factors of success where identified:

- **Collection:** It is first important to define some technical equipment – smart devices (filling level sensors, labelling system, and receiver nodes) to connect the containers with your data computer and their installation. In addition, another important aspect is the communication and registration of the citizens. It is necessary to find different ways to communicate with the citizen, including the creation of an app or a website. It can be advantegous to offer the possibility of paper registration. If there are enough possibilities to register citizens and to communicate with them, more citizens will participate.

- **Transport:** The preliminary transport system included the cloud platform, route optimisation, characterisation protocol, compensation procedure, traceability and driving guidance. An optimised route may affect reduced fuel consumption and carbon footprint. It may also affect on the number of employees or working hours.

  The route optimisation had to be divided into three phases:

  - Measurement and analyses of the current route performed by the driver
  - Optimisation of the current route collecting all the containers in order to minimise time and costs
  - Optimisation of the route based on the filling level of the containers, skipping those containers, which are not full on the collection day.

In the transport process, it is recommendable to monitor the driving behaviour system and the truck traceability. For this, two things should be considered:

1) to measure the driving behaviour of the driver during some months in order to know which actions the driver should improve, through the truck traceability system, and

2) to implement an alarm system (speed, RPM, excessive idling, acceleration and braking, power take off) that alerts the drivers when they are not driving in an eco-way.

- **Sorting:** When we think about sorting, we have to consider the way (technology) of sorting waste. New technologies based on optical Near-InfraRed-Hyperspectral-Imaging technology and specifically on the adaptation of material feeding system, identification ranges and ejection systems are available. Here are important material losses, precision of sorting and the amounts of separated fractions.

In addition, to these factors of success, other aspects have to be considered, including:

- Current framework (local policies, equipment, technologies...)
- Public participation and citizen engagement: name activities to engage citizens in the use of the measure to be implemented.
- Capacity building of city staff: name training aspects for city staff related to the project. Name if participation of external advisors needs to be considered.
- Identifying stakeholders (local office managers, waste collectors, citizens)
- Implementation plan: name aspects of the implementation plan, management tools and licences. Name project risks and define mitigation options. Name how the plan is shared/ agreed with stakeholders and how they engage in the implementation.
- Procurement model: name aspects of the design and implement an end-to-end procurement model including budget definition, scope and targets; tender design, launch and partner selection.
- Contract negotiation and management: name mechanisms for effective negotiation and design of contract (risk allocation, performance, revenue, payment, penalties). Name how the contract is managed and concluded.

For each of them try also to answer the following questions?

- What are your main issues?
- What do you want to achieve?
- Which stakeholders do you need to involve?
- Which channels and tools can you use to engage stakeholders?
- What is the proposed timeline?

4.3.2 Challenges for implementation

The improvement of domestic packaging waste collection and treatment is a basic key to increase packaging waste recycling rates in Europe.

Some of the key challenges identified during the planning and implementation include:

1. Citizens engagement (How to persuade the citizens to collect and separate the waste properly, the identification of user, education of citizens of how to separate the waste properly, to raise awareness of necessity of recycling waste)
2. Complex regulatory framework (how to unify and simplify it)
3. Technology readiness (possibility of including different Iot solutions)
4. Technology adoption (to identify some standards)
5. Monitoring and evaluation (identification of key indicators that had to monitored and evaluated on regular basis)
6. Adoption to city law and management (how to persuade decision makers)
7. Sorting (better identifying of different fractions, automation)

5. A Guide for Replication

The replication of any process or project on a local level should follow a standardised approach and a step-by-step process that could allow any city or stakeholder to advance on implementation, while adapting these steps to a local context. ICLEI's Integrated Management Cycle (IMC) has been developed and used by local authorities for more than 20 years to coordinate and embed long- and short-term objectives and policies effectively and sustainably into urban governance structures and processes.

5.1 Steps

This management cycle, has five major stages or phases, namely:

Figure 22: Management cycle

In order to facilitate the replication of projects aimed at improving the efficiency of the plastic waste management process and mainstream circular economy principles in the core of local governments strategies, **key activities** within these phases can be adjusted.

Policy and regulatory screening and adopting to new EU plastic strategy which has adopted a material-specific life cycle approach to integrating circular design (including through safe by design and safer chemical composition), use, reuse and recycling activities into the plastic value chain.

The second key is to **set targets and goals** that you want to achieve and some indicators to measure them.

The third important key is to **plan well** all the activities. Cities should carefully analyse at which stage they are in relation to the implementation of specific solutions or projects.

Next important key is **public participation and citizens engagement**: They are the first one that sort and collect waste and it is important that they know how to do it and they are willing to do it. So you have to educate and make sure that they see the added value. Currently, traded European plastic waste could provide substantial amounts of potential (secondary) material resources for the European manufacturing industry. In addition, recycling in the EU would also provide a net benefit for the European economy, through jobs and added value, and for the environment.

Each stage has further sub-steps that help fostering integrated management and the development of projects aiming to mainstream circular economy in local management practices. Based on the experience gained through PlastiCircle, the sub-steps which have been identified and are highly recommended for any city willing to implement circular economy and plastic waste management projects are:

Phase 1: Preparation of the implementation framework

OBJECTIVE

Set the basis for a successful implementation of the measure

KEY ACTIVITIES

- Policy and regulatory screening
- Project monitoring
- Project evaluation
- Internal and external reporting stakeholder's roles definition

Figure 23: Phase 1

Implementing the EU plastic strategy and the Single Use Plastics Directive will push the EU in this direction by reducing plastic waste with low value and high environmental impact, while improving the quality of plastic waste. This will enable more environmentally and economically sustainable plastic waste management in the EU. Civil society, the scientific community, businesses and local authorities have a decisive role to play in making a difference, working together with regional and national governments to bring about positive change.

Phase 2: Project inception, planning, performance and finance

OBJECTIVE

Outline key structural aspects for the framework implementation

KEY ACTIVITIES

- Governance designation
- Targets and goals setting (short- to long-term)
- Technology and infrastructure planning
- Definition of key performance indicators (KPIs)
- Cost-benefit analysis
- Business and financial model definition

Figure 24: Phase 2

With good planning we can evaluate better our results, recognise all the gaps that may occur and make our project feasible. It is a good base to develop quality standards for sorting plastic waste and recycled plastics.

Phase 3: Political approval and stakeholder engagement

OBJECTIVE

Obtain and maintain political and stakeholder commitment for the implementation

KEY ACTIVITIES

- Political commitment
- Strategic intermediaries
- Public participation and citizen engagement
- Capacity building of city staff

Figure 25: Phase 3

The most important is to adequately motivate, educate and involve all key actors - stakeholders in the project. The primary issue is to identify who are the stakeholders and their level of involvement in the project. If there is too little involvement of relevant stakeholders, the project may not be defined properly or achieve its goals; if there is too much involvement, the project may get bogged down in "process" and "communication," with little work being completed.

Phase 4: Project implementation

OBJECTIVE

Plan the effective implementation of the framework

KEY ACTIVITIES

- Implementation plan
- Procurement model
- Contract negotiation and management

Figure 26: Phase 4

A municipality must develop an implementation plan which details how the targets set in the goals will be attained, as well as what resources will be required to attain the targets in the project. In this instance, the implementation plan has been developed in a manner that summarises the entire planning process in order to demonstrate how each of the steps fits into each other. Once the project has been approved, the implementation plan should be a living document that will be used to deliver day to day waste management services so targets set in the project can be met. This applies also to the next phase.

Phase 5: Monitoring and progress evaluation

OBJECTIVE

Plan the monitoring, evaluation and reporting of the implementation of the measure

KEY ACTIVITIES

- Project monitoring
- Project evaluation
- Internal and external reporting

Figure 27: Phase 5

Monitoring and evaluation helps tracking and assessing the results of the interventions throughout the project's life. Monitoring and evaluation will help deciding how to collect data to track indicators, how monitoring data will be analysed, and how the results of data collection will be disseminated. Data alone is not useful until someone puts it into use. Monitoring and evaluation will help make sure data is being used efficiently to make the project as effective as possible and to be able to report on results at the end of its implementation.

5.2 Cost-benefit analysis (CBA)

Before implementing any action at local, regional or national level, stakeholders should develop a cost-benefit analysis to assess useful information on desirable and undesirable effects of projects. This analysis is a systematic process that helps the decision-making in any business and involves adding the benefits of an action and then comparing it with the costs associated with it.

In general, the costs analysis should address the following factors: city resources, personnel, direct and indirect costs (Overhead), depreciation, and annual costs. Benefits, on the other hand, should evaluate the services, capabilities, and qualities of the project. In the case of PlastiCircle, the benefits analysis can cover citizens and the organisations involved, in the short and long term.

The main benefits of PlastiCircle can be divided as follows:

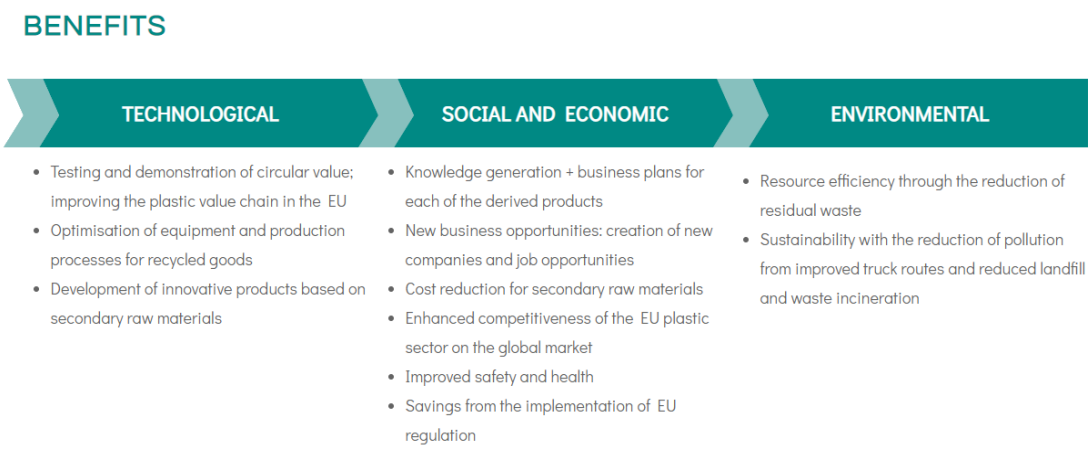


Figure 28: Benefits

It is paramount that the CBA report is transparent and all information addressed is available and easily accessible. The methodology should be sound and consistent, as the CBA refers to methods, tools and all the hypotheses used and mentioned throughout.

When preparing your CBA on the PlastiCircle approach, we suggest to follow the steps below:

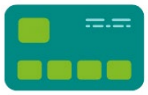
1. Goal Setting:

Clearly define PlastiCircle's objectives and its expected results in your city, taking into consideration the variables that can be affected by the project and how to measure them. It is particularly important to identify if and how PlastiCircle can help your City achieve specific objectives of EU regional or cohesion policy.

With the objectives, answer the following questions:

- Can it be said that all the improvements obtained are supposed to be resulting from a project worth the costs incurred?
- Have all the most important direct and indirect socio-economic effects of the project been taken into account?
- Have other indicators related to the defined objectives been identified if it is not possible to measure all direct and indirect social effects due to lack of data?

2. Project identification



Present PlastiCircle's general concept and logical framework, with all the costs and benefits identified on the previous step, and compare with your local regulations and legislation to assess if any restrictions may arise to the full execution of the project.

The goals must be:

- Clearly defined purpose of the project

- The definition of the project must comply with the regulations
- The financial constraints set by the regulations must be observed

3. Financial analysis

Provide information on how to analyse the financial aspect of PlastiCircle, including tables of financial flow which contains the whole investment rate, costs and income; identify different sources of financing that can cover the investment costs; provide an analysis of financial flow. The starting point is to work on the basic tables, complementing them with text explanation and definition of the most important elements included in the tables and calculations of return on investment and capital.

From the technical point of view, the following are especially important for the preparation of the analysis (must be part of financial analysis):

- Choice of time period;
- Definition of total costs (total values);
- Determination of total revenues;
- Definition of the residual value of the project in the last year;
- Setting the inflation rate;
- Providing sources of funding (financial coverage);
- Selection of an appropriate discount rate;
- Method of calculating financial and economic rates of return and their application in project evaluation.

4. Economic analysis

This comes from the financial analysis and the cash flow table in order to determine the standard methodology for the three steps required to produce the final table in the economic analysis.

Economic analysis must include:

- Tax/subsidy adjustments;
- Corrections due to the influence of external factors (externalities);
- Determination of converters (correction factors) (for instance the conversion of market prices into accounting prices and thus the integration of benefits and costs in society).

This analysis focuses on how to calculate costs and benefits from a societal perspective and how these can affect to the results. It provides a guide on how to calculate the economic rate of return and helps us understanding its economic significance in the project evaluation

5. Multicriteria analysis

This methodology is particularly effective when costs and benefits cannot be expressed in monetary terms. Address the various possible situations where the rate of return is too low as a decisive indicator, and therefore an in-depth analysis and presentation of key factors needs to be made.

In the case of the PlastiCircle approach, consider, for example, scenarios with low citizen engagement, difficulties to access the required technologies, issues with collecting materials or transportation routes, and so on. These losses or problems may result on a negative net present value that cannot be specifically defined in numbers but can be predicted by the project evaluator. To compensate that, this analysis needs to include also the sustainability impact of the project.

For example, assuming that this analysis shows a negative net present value of EUR 1 million at a 5% discount rate, the project evaluator anticipates that the project could be financed from the Funds, as it "has significant positive effects on the environment" which cannot be expressed in money.

6. Comparison of alternatives

Compare the alternative solutions to treat plastic waste with PlastiCircle, illustrating with tables and graphs so as to facilitate the decision-making process. When the costs and benefits for each competing alternative have been discounted, compare and rank the discounted net value (discounted benefit minus discounted cost) of the competing alternatives.

The option with the lowest costs and highest benefits is clearly the best alternative.

7. Sensitivity analysis

Define and investigate how sensitive PlastiCircle would be to different variables, such as the positive or negative changes that can directly affect costs and benefits whose definition is not straightforward or is not easy to be exactly defined. The sensitivity analysis considers those input parameters that have the greatest influence on the outcome, repeats the analysis with different input parameter values, and evaluates the results to determine which, if any, input parameters are sensitive.

On the PlastiCircle approach, for example, a sensitivity analysis should consider the different citizens' and stakeholders' role in the whole process, separately evaluating each one of them and identifying if any can be more sensitive than the other, so the analysis can predict how to deal with it if a problem arises.

6. Conclusions

Based on the experience of the PlastiCircle project and the key lessons learnt from the pilot's design in the three cities, and the implementation in Valencia, key conclusions can be extracted:

- **Embedding plastic circular economy principles** in the core of the solid waste management strategies of the city. The implementation of the solutions from PlastiCircle suggests that cities with advanced systems of waste management can find alternatives to implement the measures.
- **Alignment with national and regional policies and goals on environment, climate and circular economy**. Cities should work and dedicate efforts to align their circular plastic projects and initiatives to the existing policies and initiatives. This may facilitate the access to funding for implementation.
- **Analysis and identification of key regulatory frameworks** to facilitate replication: circular plastic management processes must include a deep understanding of regulatory barriers that could influence measures of development, implementation and maintenance.
- **Specialisation in circular economy and plastic waste management.** Cities should work with standardised methodologies and KPIs in order to put in value the sustainability benefits of the implemented circular economy projects for plastic management. This will allow them to assess correctly the sustainability impact of measures implemented, meet their local targets and access to new funding opportunities for new projects development.
- **Cost benefit analysis to enhance business models sustainability.** Implementation plans for measures that are aimed to be replicated should include the development of CBAs as a tool to enhance the sustainability of business models of circular economy and plastics management projects.
- Finding synergies with other EU-funded projects for implementing new projects: Cities should **explore the synergies** with several measures implemented due to the existence of other EU-funded projects, for example smart city projects, climate change or other environmental funded projects. Cities should work towards the development of successful project proposals to access funding for replication and upscaling.
- **Development of innovation schemes** for circular economy and waste management projects. Innovation funds for smart solutions tackling local environmental challenges have emerged in the last years. The replication of measures could also be enhanced, if new and innovative projects can be designed including smart and sustainability components in their process.
- **Develop citizen-centred solutions:** Replication of measures in cities require a deep understanding of citizens' needs, hand to hand with local governments. Experience showed in PlastiCircle, highlights the importance of involving citizens to make them active participants of projects. The use of technologies and gamification mechanisms are key to involve them and obtain good results.
- **Alliances with local businesses and entrepreneurs**: Replication is linked to the availability of technological solutions and the market scenario in particular cities. Local governments should foster the creation of innovation ecosystems for the creation of new products and services on waste management, CE and environmental innovation.

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8. Annexes

Annex 1: Results of the Communications Plan

Webpage:

ReciPlàstic SANT MARCEL·LÍ

Qué es | Oficina Informativa | Participa | Sistema de puntos | Próximos eventos | Actualidad | VAL

Inicio / Participa

Participa

En este piloto pueden participar todas las personas mayores de edad de la ciudad de València, siempre y cuando utilicen los contenedores ubicados en Sant Marcel·lí.

Para poder participar, las personas interesadas deben registrarse en este mismo apartado o a través de uno de los sitios informativos a pie de calle.

Una vez realizado el registro, se le hará entrega de número de usuario y una tarjeta NFC, junto a un kit de bienvenida. Todas aquellas personas que se registren online, en un plazo aproximado de una semana recibirán estos mismos elementos en la dirección especificada durante el registro.

Recuerda, se puede participar tantas veces se quiera, pero para poder empezar a acumular ecopuntos, mínimo se debe haber depositado dos bolsas llenas durante todo el piloto. Además, solo hacemos entrega de una tarjeta NFC por domicilio.

¡Ayúdanos a completar el círculo!

¿Cuáles son los plazos para apuntarse y para participar?

Puedes empezar a registrarte desde el día 17 de abril, pero solo podrás empezar a depositar tus bolsas en el contenedor amarillo desde el periodo comprendido entre 1 de mayo y 31 de octubre.

¿Cómo empiezo a participar en el piloto?

¡Es muy sencillo! Acércate a tu contenedor amarillo más cercano. Sólo tienes que coger tu tarjeta o llavero NFC y meter tus envases ligeros en la bolsa naranja que se te ha facilitado en el kit de bienvenida. Una vez en el contenedor, solo tienes que leer las instrucciones ubicadas en el dispositivo que encontrarás en el lateral del contenedor.

No te olvides que puedes participar utilizando una tarjeta NFC o un llavero NFC, ambos funcionan igual y son entregados de manera aleatoria a los usuarios.

Annex 2: Some events organised before the pilot started:

Workshop at an Elementary School

- Date: 11th April
- Target Groups: Kids (parents by extension)
- Actions: Information and training about right waste sorting

Info-Stand in Medical Center

- Date: 17th April 2019
- Target: housewives, elder people
- Actions: Information, registration and training about waste sorting

Info-Stand at Rambleta's Parc

- Date: 24th April
- Target Groups: Families
- Actions: Information, registration and training about waste sorting

Annex 3: Citizens engagement

The following table shows how many people registered per week and through which channel.

Dates		Week	TOTAL	on-line	Manual
15-abr.	**21-abr.**	**-2**	109	72	37
22-abr.	**28-abr.**	**-1**	23	13	10
29-abr.	**5-may.**	**0**	82	82	0
6-may.	**12-may.**	**1**	80	36	44
13-may.	**19-may.**	**2**	87	21	66
20-may.	**26-may.**	**3**	20	13	7
27-may.	**2-jun.**	**4**	19	11	8
3-jun.	**9-jun.**	**5**	39	13	26
10-jun.	**16-jun.**	**6**	22	15	7
17-jun.	**23-jun.**	**7**	9	5	4
24-jun.	**30-jun.**	**8**	9	2	7
1-jul.	**7-jul.**	**9**	2	2	0
8-jul.	**14-jul.**	**10**	8	1	7
15-jul.	**21-jul.**	**11**	1	1	0
22-jul.	**28-jul.**	**12**	16	0	16
29-jul.	**4-ago.**	**13**	1	1	0
5-ago.	**11-ago.**	**14**	0	0	0
12-ago.	**18-ago.**	**15**	1	1	0
19-ago.	**25-ago.**	**16**	1	1	0
26-ago.	**1-sep.**	**17**	1	1	0
2-sep.	**8-sep.**	**18**	4	1	3
9-sep.	**15-sep.**	**19**	1	1	0
16-sep.	**22-sep.**	**20**	6	0	6
23-sep.	**29-sep.**	**21**	11	3	8
30-sep.	**6-oct.**	**22**	9	0	9
7-oct.	**13-oct.**	**23**	0	0	0
14-oct.	**20-oct.**	**24**	0	0	0
21-oct.	**27-oct.**	**25**	0	0	0
28-oct.	**3-nov.**	**26**	0	0	0

KPIs related route optimisation

KPI	Pre-pilot	During pilot	Final pilot
K1: Distance travelled(km)	8.6	7.0	5.9
K2: Time travelled(s)	3,564	2,916	2,614
K3: Collection performed(number of containers collected)	26	26	19
K4.1: CO2e/Tonne collected(kg/Tn)	25	26	26
K4.2: CO2e/driven distance(Kg/km)	2.33	2.71	2.95
K5.1: energy cost/tonne collected(€/Tn)	12	12	12

K5.2: (personal & energy) cost/tonne collected(€/Tn)	43	47	51
K5.3: % inappropriate materials in the RSU containers	74	67	67
K6: Fuel consumption(L)	7.7	7.3	6.7
K13. % fill level when truck unloads	51.64	-	59.11