Improvement of the plastic packaging waste chain from a circular economy approach

Acronym: PlastiCircle

Grant Agreement No: 730292

PLASTICIRCLE DELIVERABLE REPORT D6.5 - Results on the integration of the whole PlastiCircle approach

- *M46*

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730292.

Factsheet

Document name:

Responsible partner: SINTEF

Work package: 1

Task: 6.5

Deliverable number: D6.5

Version: v1

Version date: 2021-03-16

Date due: 2021-04-01

Dissemination level	
X	PU = Public
	PP = Restricted to other programme participants (including the EC)
	RE = Restricted to a group specified by the consortium (including the EC)
	CO = Confidential, only for members of the consortium (including the EC)

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Abstract

-This deliverable is based on the results of T6.5 with the goal to sum up the achievements of PlastiCircle

-The report gives a description of the achievements on collection, transport, sorting and recycling in an integrated manner based on the project's defined KPI's.

Abbreviations

API: Application Programming Interface

CAN bus: Controller Area Network bus

CB: CardBoard

CDW: Contruction and Demolition Waste

COVID-19: Coronavirus Disease 2019

CO2: Carbon dioxide

D: Deliverable

DoW: Document of work

E-LCA: Environmental Life Cycle Assessment

GPS: Global Positioning System

HBO: Higher Professional Education

HDPE: High Density Polyethylene

ID: Identification

IoT: Internet of Things

ISO: International Organization for Standardization

KPI: Key Performance Indicator

LDPE: Low Density Polyethylene

LoRA: Long Range Wide Area

LP: Light Packaging

LPW: Light Packaging Waste

NIR: Near InfraRed

NFC: Near-Field Communication

OBD II: Onboard Diagnostics Two

PAYT: Pay-as-you-throw

PC: PlastiCircle Software

PE: PolyEthylene

PET: PolyEthylene Terephthalate

PMD: Plastics, metals, beverage cartons

PP: PolyPropylene

PVC: PolyVinyl Chloride

Q&A: Questions and Answers

RDF: Refuse derived fuel (fraction of residual waste to energy)

RFID: Radio Frequency Identification

RPM: Revolutions per Minute

SPSS: Statistical Package for the Social Sciences

SQL: Structured Query Language

S-LCA: Social Life Cycle Assessment

T: Task

UNEP: United Nations Environment Programme

WEEE: Waste from Electrical and Electronic Equipment

WP: Work package

2D: Two Dimensions

3D: Three Dimensions

Partners short names

CRF: CENTRO RICERCHE FIAT SCPA

ECOEMBES: ECOEMBALAJES ESPAÑA S.A.

ICLEI: ICLEI European Secretariat GmbH

INTERVAL: Industrias Termoplasticas Valencianas S.A.

ITENE: INSTITUTO TECNOLOGICO DEL EMBALAJE, TRANSPORTE Y LOGISTICA

PICVISA: PICVISA MACHINE VISION SYSTEMS, S.L.

POLARIS: Polaris M Holding

SAV: SOCIEDAD ANONIMA AGRICULTORES DE LAVEGA DE VALENCIA

SINTEF: SINTEF Industry and SINTEF Community

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Publishable summary

PlastiCircle has aimed to improve the circular economy of plastics by developing a holistic process to reintroduce household packaging in the plastics value chain. This was achieved by innovation in the four stages associated with treatment of plastic packaging waste: collection, transport, sorting and recycling.

To achieve this, local citizens were involved from the start in the pilot cities in activities related to sorting improvements and testing smart containers. Filling-level sensors were tested and installed in waste containers. The sensors communicated with the transport software and routes were optimized.

Collection and transport pilot trials was carried out in selected areas of three municipalities (Valencia, Alba Iulia and Utrecht), allowing the analysis of post-consumer materials for possible use in subsequent processes of sorting and recycling.

In Figure we sketch roles and activities in the project.

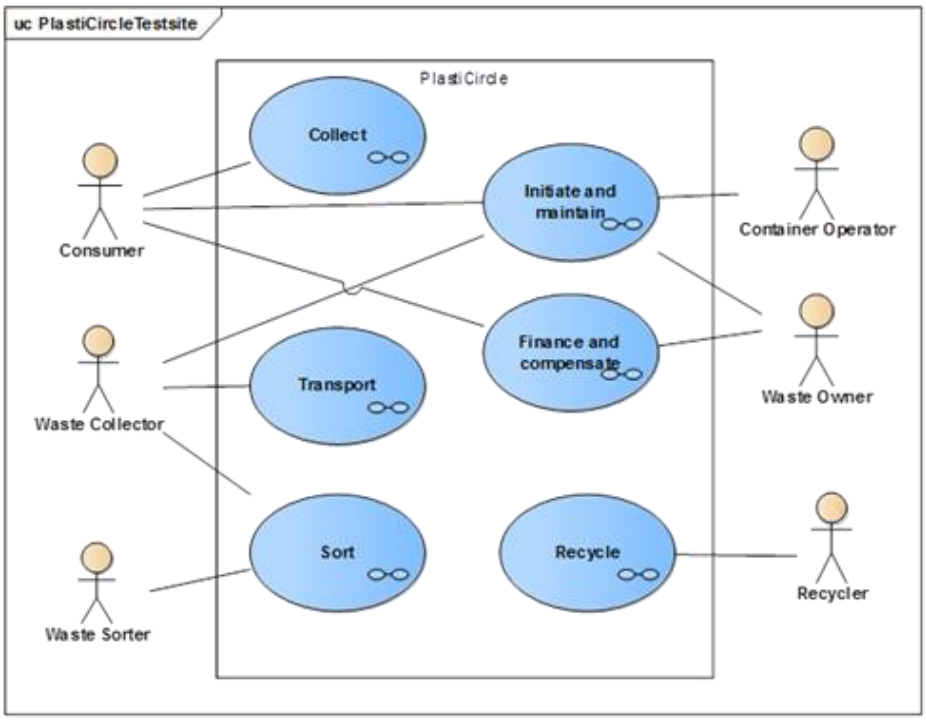

Figure Roles and activities in PlastiCircle

After the tests in each city, questionnaires were sent to all involved parties for assessment and analysis of results.

Life cycle analysis provided information on social impact of plastic packaging waste management systems of the three cities. The comparison between the situation before and after the implementation of the pilot have served to obtain information on the social benefits of applying the PlastiCircle concept to the waste

management systems in the European countries.

1. Introduction

WP6 was focused on the integration and validation of the whole PlastiCircle approach on collection (WP2), transport (WP3), sorting (WP4) and recycling (WP5).

With this objective, WP6 carried out collection and transport trials in the three municipalities Valencia (Spain), Utrecht (Netherlands), and Alba Iulia (Romania).

After the pilot tests in each city, questionnaires were sent to all involved parties for assessment. The individual pilot cities, ECOEMBES and ICLEI helped SINTEF in the preparation of the questionnaires and the subsequent analysis of results. SAV and ITENE as well as cities and waste managers Utrecht, Las Naves, Polaris transferred the information associated with the results on collection and transport to SINTEF. Results were also analyzed by the follower city Velenje (Slovenia) and used in their replicability webinar.

The main target of this report is to present post-pilot activities. We shortly summarize each pilot before we present results based on questionnaires, repeated sampling procedures and the last results on transport optimization.

2. Pilot cities

The pilots were executed with Valencia starting in April 2019 till January 2021 when the third pilot in Alba Iulia closed. The latter was significantly delayed due to covid restrictions but finished still well within the time from of the project.

Also, covid caused the ecodriving part in Utrecht to stop, and, at this time, the execution of this task depends on local Dutch restrictions. The status will be communicated and discussed with the Project Officer.

In the following, we briefly recapitulate some key points of the work on each pilot city.

2.1 Valencia

The location was the San Marcelino district in Valencia with the pilot being promoted by Super Marcelina – Fig. 1.

Figure 1 Super-Marcelina promoting the Valencia pilot

25 smart containers were installed in the pilot area as shown in the figure below.

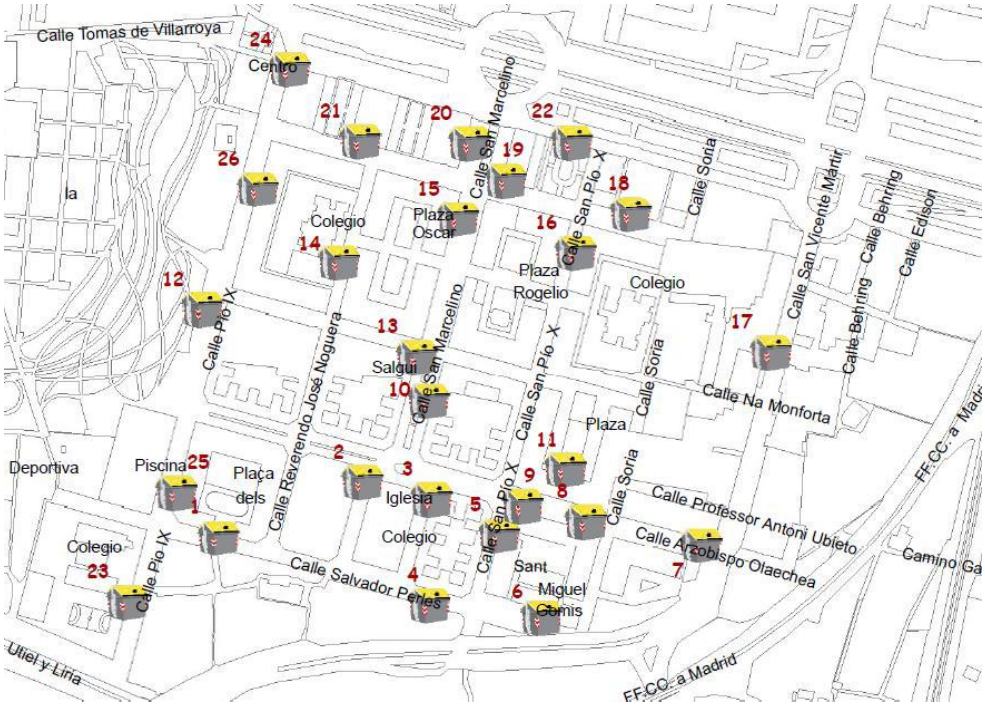

Figure 2 View of the San Marcelino neighbourhood showing the locations on the packaging waste containers

The pilot started in April 2019 and the final report, D6.2, was presented in January 2020.

25 smart containers were installed, and during the pilot period.

The technical equipment was modified, and the robustness improved.

More than 500 users were registered on the IoT platform.

Communication actions reached a wide group – 10.000 citizens. Actions included visits to schools and sport centers.

Figure 3 PlastiCircle promoted in schools

As data for the total amount of plastics packaging used in the neighbourhood was missing, a new KPI was defined as fraction of collected plastics packaging in the yellow containers to total plastics in yellow+grey containers.
Road works in pilot area during pilot period caused delay for the transport and ecodriving in the last part.

2.2 Utrecht

The pilot area was chosen as Terwijde with 3.500 households with a neighbouring reference area.

The pilot was represented by 'Madame plastics' – Fig. 4.

Figure 4 Madame Plastics promoting the Utrecht pilot

The Utrecht pilot was scheduled for the period September – December 2019. The transport part was continued in 2020 but covid restrictions have deferred

the ecodriving activity. A change of covid restriction may allow this task to be performed before project end.

Emphasis was put on the communication activity which included:

- Recruiting done by social media and off-line in the pilot area
- Kick-off workshop including panel discussions.
- Goody bag with useful information.
- Weekly assignments
- Newsletters
- Videos
- Technical visit and panel discussion
- Glossy magazine

The figure below shows the pilot district and the reference area.

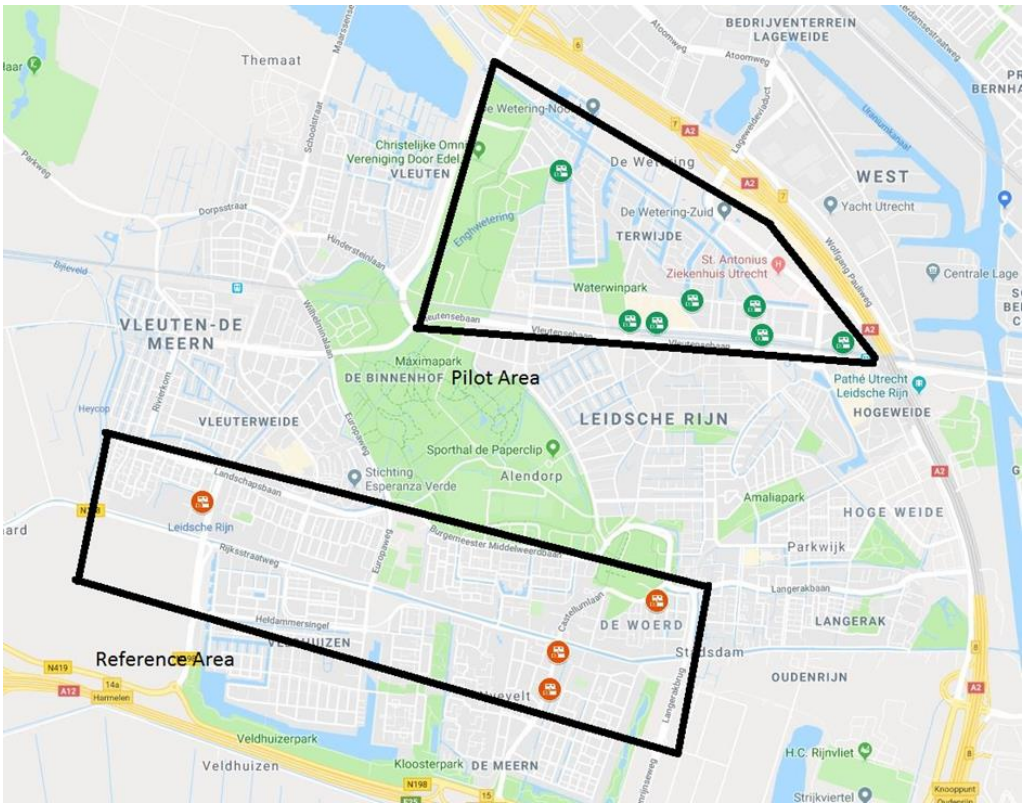

Figure 5 Pilot area and reference area

65 participants registered for the pilot. This is in line with previous problems in recruiting households to participate in 'plastic' or 'waste' challenges.
Due to privacy issues, waste bags could not be linked to participants. Thus, there was no compensation on individual level in Utrecht. No label dispenser, NFC card or LoRa connection was required. Compensation was given on the neighbour level.

The Utrecht pilot consisted of 3 parts:

- Main pilot area in the western part of the city (door to door collection of mini-containers)
- Reference area in the western part of the city (door to door collection of mini-containers)
- Reference area in the eastern part of the city (mechanically separation of plastics packaging after collection)

There were 43 underground containers in the pilot area with installed filling level sensors.
The pilot was coordinated with the city's waste program with 3700 containers.
The city has implemented dynamic forecasting and route optimizations. Because of this, they were able to collect 30% more waste.
In PlastiCircle Utrecht was used as a case for upscaling of results from Valencia on transport optimization and they worked with ITENE and SAV on data for pilot comparison on waste collection and transport.
Waste characterization was done for pre-pilot, mid-pilot, and final part along the same line as in Valencia.
Conditions for waste export to Picvisa were clarified. An alternative was chosen consisting of providing data from general waste characterization to Picvisa so that samples with the same composition could be made in Spain.
Eco-driving was to be conducted using the PlastiCircle system, and the technology is expected to work on trucks in Utrecht. This was stopped in 2020 due to the covid situation. The hope for 2021 is that a change in the covid restrictions may allow for the task to be carried out.

2.3 Alba Iulia

Arnsberg – Goldis zone with 4000 families was chosen as the pilot area. The pilot was presented by the slogan "you select because you care."

Figure 6 Slogan representing the Alba Iulia pilot

The pilot was operated, starting registration in May 2020 till January 2021. Pilot start-up was delayed from January till May due to Covid-19. Further delays were also experienced.

PlastiCircle fits in as an extension of its Smart City project. From previous experience, a priority was given to citizen information and training on correct recycling.

Communication material - posters, labels, roll-ups, flyers, brochures) reaching over 3000 people - was printed. Dedicated web page, including all explanations, terms and conditions, confidentiality terms and info was successfully integrated with the PlastiCircle platform. Face to face meetings were replaced by Q&A Facebook session or webinars. Still, 254 families were registered, representing 476 citizens, despite Covid restrictions.

Weekly Skype meetings since January 2020 with project partners took place discussing pilot planning and status providing info and support.

An initially uncertain situation about waste management was settled, and the project partner Polaris operated as waste manager.

Alba Iulia had assistance from Valencia on installation of equipment and training from March 2020. The implementation of all technical solutions was successful, with the filling level sensor reading frequency adopted to collection routines and identity modules adapted to local containers. The IoT platform from Valencia was adopted to local use. In this way, results were monitored in Valencia.

To facilitate project tasks, one added 20 dedicated, PlastiCircle smart containers

to the city's existing containers for respectively wet and dry waste. Their locations are shown in the figure below.

Figure 7 The Alba Iulia pilot area with positions of containers (existing and new locations) and data gateways (initial , supplementary)

A dedicated video giving a virtual pilot study tour was organized as a web event with ICLEI assistance during European Circular week.
Individual and general waste characterization pre- and during pilot done; post-pilot waste characterization had to be dropped due to covid restrictions on manual handling of waste.
Valuable testing of project technology resulted from the pilot and PlastiCircle eco-driving system installed after initial problems were solved.

Received positive feedback from citizens together with data regarding quantities and types of plastic, thus addressing first steps to a circular economy.
2 participant surveys carried out targeting: citizens, block administrators, administrative personnel and, waste company.

Individual characterization shows effect of information to the public as seen from the numbers on 'pilot users' in the table.

Table 1 Pilot data on waste characterization in Alba Iulia

		PRE-PILOT	PILOT USERS	PILOT NON-USERS
K7.1	Unwanted, in number (%)	22	**8.9**	18.6
K8	Non-empty, in number (%)	12.6	**8.1**	11.2
K9	Stacked, in number (%)	13.4	**7.2**	12.3
K10	Compacted, in number (%)	19.6	**64**	20.1

Like for Utrecht, general waste characterization provided data to Picvisa for them to build equivalent waste fraction in Spain to serve in testing their sorting technology. Based on project results, elements from the smart container, route optimisation and eco-driving are considered critical for the success of near future systems to be installed in the city.

3. PlastiCircle achievements

The project succeeded to complete three pilots and deliver final reports during the project period, despite covid restrictions.
254 participants registered in Alba Iulia where the pilot was strongly impeded by covid restriction!
Communication campaigns lead to increased public awareness. More than 10,000 reached in Valencia.
For citizens' waste sorting, we obtained positive impact of the pilot on the participants' sorting habits which in a next step can lead to improved quality of recycled materials.
Technology developed and adopted related to users'and administrative platform, smart containers and transport optimization. The intelligent devices were tested in a real environment. Substantial improvements achieved. Local adoptions were done as required.
Software on route optimization developed in Valencia was up-scaled in Utrecht and compared favourably with the commercial software used there.
Eco-driving and route optimization gives important savings on emissions and labour resources.

We also found there are important learning in comparing pilots. CO2 emissions per ton are lower in Valencia than in Utrecht, as seen in the table below.

Table 2 Effect of the size of the pilot area

KPI	Valencia	Utrecht	Alba Iulia
K4.1 - kg CO2/ tonne	26	51	19

Looking more into the details we find for the two cases that:

– Utrecht: 72 kg plastics / container - 1.51 km between containers
– Valencia: 32 kg plastics / container - 0.34 km between containers
– Alba Iulia: 22 kg plastics / container – 0.19 km between containers

Thus, the difference seems to relate to local parameters – demography, container type etc.

In route optimization the commercial software used from the start in Utrecht was compared with the software developed in Valencia. The functionality of the latter was extended from dealing with one truck to being valid for several trucks. A special feature with the Valencia software is that routes can be optimized either with respect to time or distance.
After this development, the Valencia software was applied to data from Utrecht and used in simulations based on measured filling levels from Utrecht as reported in the table below.

Table 3 Comparison of transport software – Utrecht version and PlastiCircle

Route 1	Time cost (s)	Distance cost (m)	Improvement (%)	
Utrecht	13242	78830	Time	Distance
PC per time	11493	70758	13.21 %	10.24 %
PC per distance	11721	63984	11.49 %	18.83 %

As seen, significant improvements on both time and distance were obtained using the PlastiCircle software (PC). The PlastiCircle solution thus offers potentially important savings.

4. Pilot repeatability

Apart from the individual characterisation, general characterisation on PlastiCircle users' and general waste was assessed to evaluate the quality of the collected packaging waste. This waste sampling was repeated for Pre, Mid and final pilot, to know the final composition of the packaging waste collected in each city pilot.

In Valencia and Utrecht, waste characterization was performed on the same packaging containers for all the characterisation while main comparison on Alba Iulia pilots, was assessed between the dry fraction and the new specific PlastiCircle containers installed at the start of the pilot.

On the following figures representation of main fractions and situations during the pilot are laid out. However, more detailed information on all the characterisations can be checked in Annex 1.

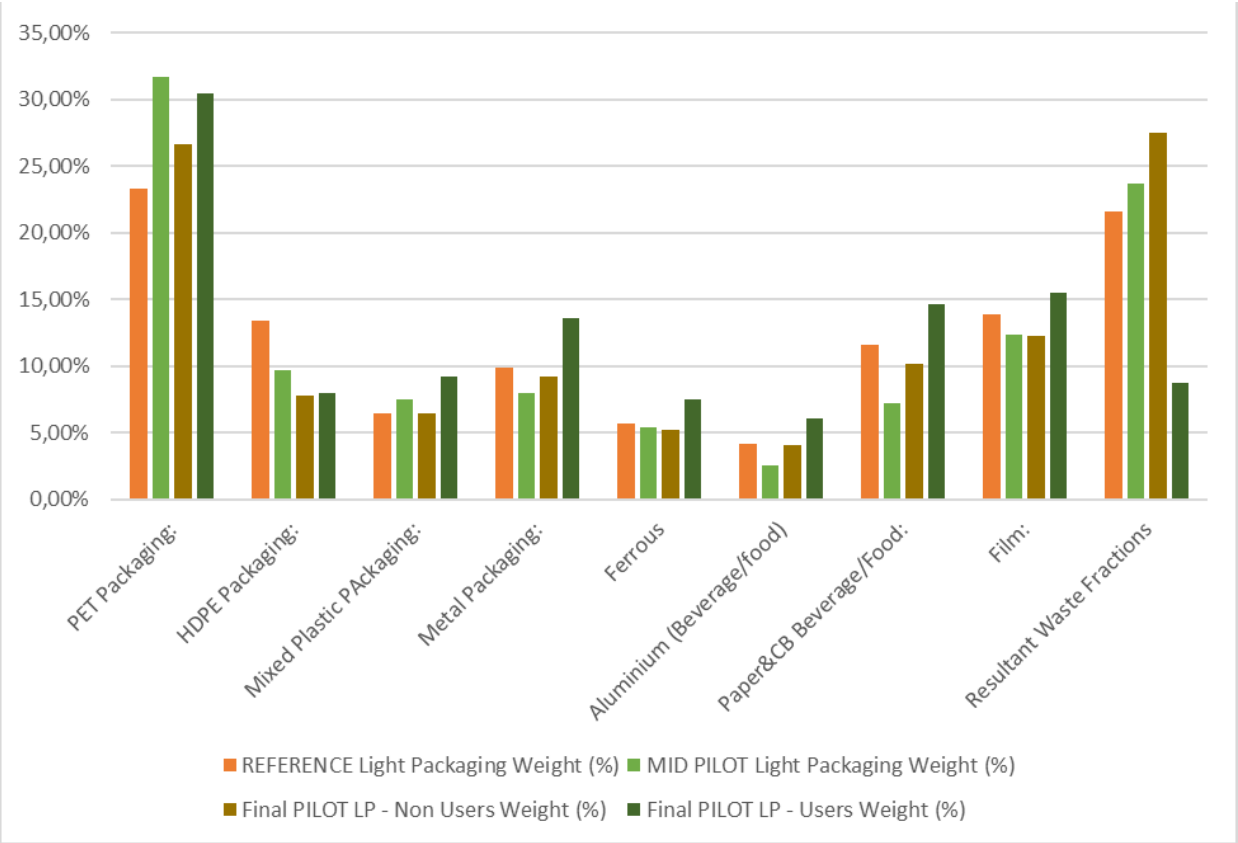

Figure 8 LPW % fraction evolution during Valencia Pilot, own graphs on information provided by SAV

Main Conclusion from **Valencia** characterisations:

- Reduce resultant waste fraction (non-recyclables) from 20-25% to 8% at the end of the pilot on PlastiCircle participants.
- Increase on PET, film and mixed plastics collection.
- Less HDPE (could be due to seasonality)

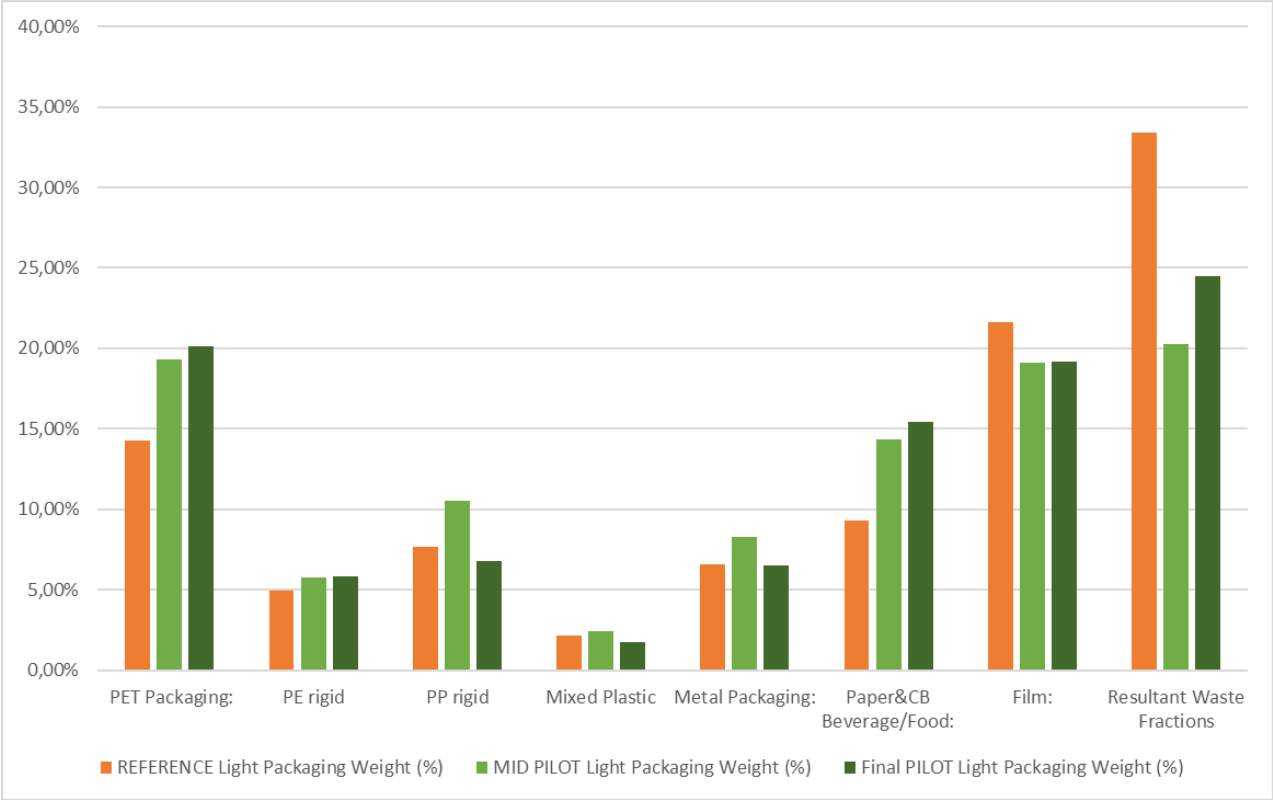

Figure 9 *LPW % fraction evolution during Utrecht Pilot, adapted from info provided by Utrecht*

Main Conclusion from **Utrecht characterisations**:

- Individual characterizations were not performed (ethic requirement) and low participation mean results on characterization are not direct consequence for PlastiCircle project,
- However, it is valuable data to know quality from waste on Utrecht underground containers.

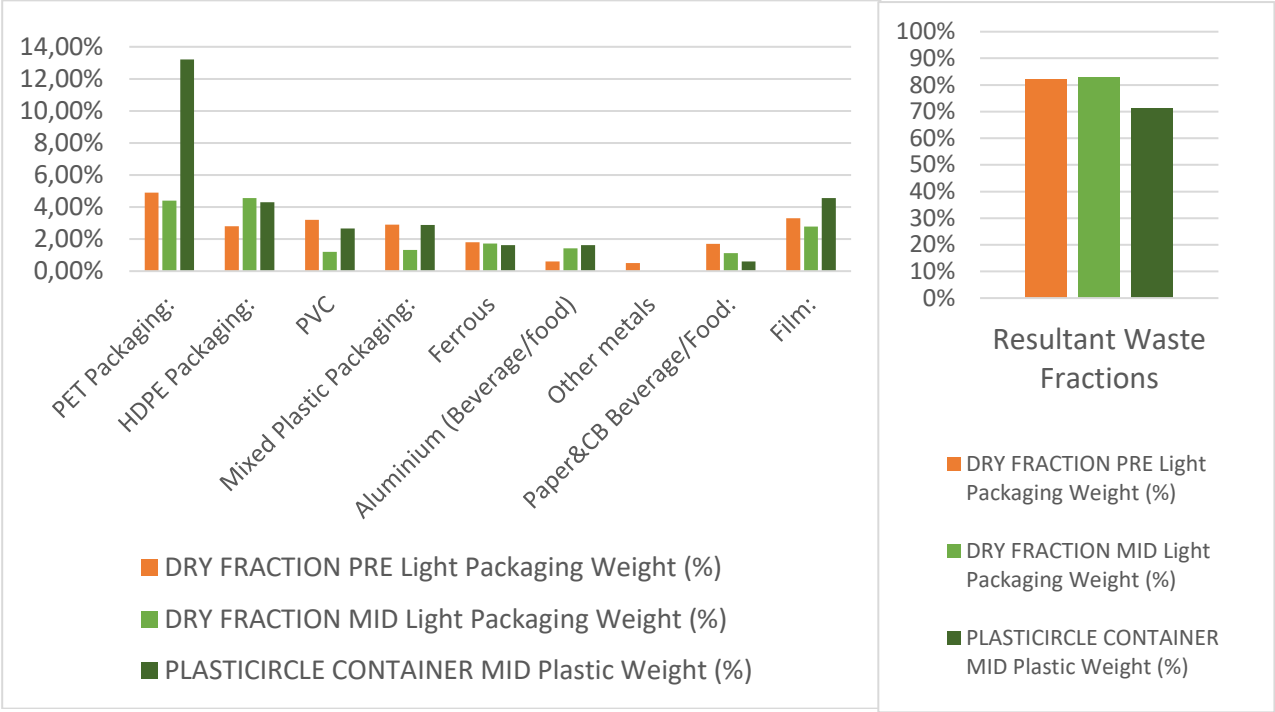

Figure 10 *Dry fraction evolution (in %) during Alba Iulia Pilot compared with PlastiCircle container. Information from Alba Iulia/Polaris characterization.*

Main conclusions from **Alba Iulia Characterizations**:

- Alba Iulia Characterisations performed on dry fraction container and specific PlastiCircle one.
- Resultant Waste Fractions (organic waste and other fractions apart from packaging) exceeded the scale value on the graphic, thus it is laid out on right hand graph.
- Low presence of plastic packaging in the dry fraction container (as organic and other fractions represent high % weight)
- Increase of plastic packaging (mainly PET and films) on PlastiCircle container in comparison with the dry fraction container.
- High content on PVC, while practically no PVC was found in Valencia and Utrecht.

5. Summary of results obtained in the of sorting tests by Picvisa

The background for the task was defined by the PlastiCircle Objective:

Material loss in sorting <20%. Precision in sorting >95%.

Fractions separated; PET, rigid PE, PE film, rigid PP, PP film, and plastic mixes. Rejects in sorted PE film and PP film will be < 5%. The final reject fraction will have a content of PET, rigid PE and PP-PE films respectively lower than 7%, 6% and 8%. Presence of biodegradables and PVC in sorted fractions <0.3%.

The results are summed up in more detail in the deliverable D4.5.

Valencia

As a general observation for Valencia, the results showed that the pilot has had a moderate effect on the citizens in terms of specific materials collected. In this respect, PET was an exception which has increased significantly by approximately 10% of the total waste.

The separation scheme used for the pilot tests is the same as the one used in the initial phase of the process development with a first step separating according to size above and below 300 mm, i.e. 2D or 3D.

The material collected in the pilot had to be pre-processed following the indications described in D4.5 (section 2.2 Protocol pre-treatment material). Then, with the two well differentiated flows, the 2D must be processed by blowing identified PE Film in two passes through the optical sorter (NIR).

For the test pilot, five specific polymers were analysed and sorted. These were:

- PET bottle
- PET trays
- HDPE
- PP
- LDPE films

The ejects and rejects from the sorter were manually separated and then weighted. The sorting tests were carried out for each material using the methodology from D4.5 to calculate yield and purity.

In the following section we present analyses of the results obtained on each target material from the tests carried out on waste collected before and during the pilot.

In this way we wanted to evaluate the technological improvements made by Picvisa and the effect the pilot may have had on the separation technologies.

PET

Results from pre-pilot and pilot PET sorting are given in the table below.

Table 4 PET sorting results from Valencia pilot

Fraction	% composition PRE-PILOT	% composition PILOT
PET	92%	96%
HDPE	0%	2%
PP	0%	0%
OTHERS	3%	2%
BRICK	3%	2%
FILM	1%	1%
PAPER	0%	0%
Yield	85%	92%
Purity	92%	96%

Thus, the data obtained in the pilot with the combination of technological improvements and citizen education allows us to reach values of 92% recovery and 96% purity.

Tray PET results

The present market value of this fraction is hard to estimate since recycling is complicated and expensive. Anyway, all the recovered fractions of this material were sent to ITENE where they were going to be washed and granulated to analyze what recycling possibilities it may have in the market. The use of tray PET and its modification using chain extenders were also reported in WP5.

HDPE results

HDPE was sorted as part of the rigid PE fraction.

Table 5 HDPE sorting results from Valencia pilot

Fraction	% composition PRE-PILOT	% composition PILOT
PET	2%	0%
HDPE	91%	95%
PP	1%	1%
OTHERS	2%	1%
BRICK	1%	1%
FILM	3%	2%
PAPER	0%	0%
Yield	90%	94%
Purity	91%	95%

We then see that the improvement for HDPE is like what was achieved for the PET fraction.

PP results

PP has generally not been sorted in Spain. In the sorting of pilot waste from Valencia, PP was also collected as part of the 3D material.

Table 6 PP sorting results from Valencia pilot

Fraction	% composition PRE-PILOT	% composition PILOT
PET	4%	1%
HDPE	1%	1%
PP	92%	95%
OTHERS	1%	2%
BRICK	1%	0%
FILM	1%	2%
PAPER	0%	0%
Yield	75%	94%
Purity	92%	95%

A question can be raised concerning the difference in yield between the material of the pre-pilot and the material of the pilot if this can be due to some error of characterization. There is no such difference neither in the obtained purity nor in the balances of the material.

LDPE films

This fraction is no longer obtained from the 3D material, but from the 2D material. The separation configuration of this fraction is detailed in section 2.4.3 of D4.5.

Table7 LDPE sorting results from Valencia pilot

Fraction	% composition PRE-PILOT	% composition PILOT
LDPE	88%	91%
OTHERS	12%	9%
PAPER	0%	0%
Yield	85%	89%
Purity	88%	91%

T

LDPE films is the fraction that has obtained greater values of improvement in recovery and purity has obtained, thanks to the technologies applied, but above all the new prototype of stabilization of light materials on the conveyor belt.

Utrecht and Alba Iulia

Results on waste characterization like for Valencia could not be obtained for Utrecht and Alba Iulia, due to both export restrictions on waste and covid restrictions.

Alternatively, Picvisa will do simulations of the two cases based on waste from Spain collected according to the reported waste characterization from Utrecht and Alba Iulia.

These results are in this moment not available but will be reported before the end of the project.

Picvisa will base their sorting trials on data on waste composition for the pilots as presented in the table below.

Table 8 *Picvisa's mass balance assumption made to simulate the waste compositions*

	VALENCIA % Composition	PRE-PILOT ALBA IULIA DRY FRACTION	% Composition	PILOT ALBA IULIA PLASTICIRCLE	% Composition	UTRECHT % Composition
PET	39%	14,5	40%	26,08	54%	37%
HDPE	14%	5,7	16%	8,5	18%	11%
PP	10%	4,15	12%	2,85	6%	20%
OTHERS	8%	4,15	12%	2,85	6%	5%
BRICK	29%	4	11%	4	8%	22%
FILM	2%	1,54	4%	1,798	4%	3%
PAPER	1%	2	6%	2	4%	3%
	103%	36,04	100%	48,078	100%	101%

In the table we have had to "assume" some values for some materials, since we understand in the different characterisations carried out they have been collected with different concepts.

Thus, the considerations taken are as follows:

Alba Iulia - PP: There is no PP value in the characterisations, so we collect the Mix + PS material and put half in PP and the other half in Others.
Alba Iulia - Film: They have the fractions of Film and Bags, but there is no pre-treatment of 3D and 2D. So we have added the fractions and applied an 80% yield of the ballistic separator, to leave 20% in the 3D.
Utrecht - Brick: This fraction does not exist as such in its characterisation, We have added these containers to the plastics fraction and adapted the proportion in the rest of the plastic content. We have also adapted the proportion of Foils-Packaging to a 10% that would reach our process after ballistic separation.

These assumptions are approximate, but we had to rely on objective data to establish the tests, so this is the solution taken by Picvisa.

The data in the table show some common trends but also specific difference between the pilots.
There was also a high fraction of unwanted waste in Alba Iulia which was removed in pre-processing. This relates to what was pointed out from the start of the project that citizen education and awareness was a prioritized task for the city of Alba Iulia.

Sorting – conclusion

Based on testing done on waste from Valencia, satisfactory levels of both yield and purity were achieved with the combination of better pilot collection and sorting technology improvements.

Basic differences between pilots in waste composition are seen but this is not expected to have consequences for the sorting trials at Picvisa.

6. Pilot city questionnaires

6.1 Social life cycle assessment

The objective of the social life cycle assessment (S-LCA) was to make a social comparison of the current management of plastic packaging waste compared to the potential results in waste management of plastic packaging after pilots of PlastiCircle project. The ultimate objective is to know if the perception of people improves with the new waste management system offered by PlastiCircle.

Methodology

Data was collected from groups of citizens who participated to the pilot studies, citizens associations (or block administrators), waste managers and municipalities (city hall workers).

Whereas the citizens completed pre- and post-questionnaires for both WP6 (evaluation of the pilot studies) and WP7 (S-LCA), the other stakeholders (Citizens associations, waste managers and city authorities) were asked to fill in questionnaires only related to WP7, to avoid repetitions and work overload.

Questionnaires were completed in order to ask these groups of people questions to assess the social impact of the waste management systems in each city. Questions were prepared according to the UNEP *Guidelines for Social Life-Cycle Assessment of Products* (2020) which correspond to ISO 14040 and 14044 standards for *Life-Cycle Assessment*.

Answers compilation

It was not possible to obtain the same homogeneous number of responses in the pre- and post-pilot. In the case of citizens, this fact was due to the fact that not all citizens who enrolled on the pilot were active until the end of the pilot.

In general the number of responses obtained in the post-pilots was lower than those obtained in the pre-pilot due to the COVID-19 situation. Pre-questionnaires for the citizens were common to WP6 and WP7 and adapted to the specific city situations and the evaluation of the pilots.

Figures 11 and 12 presents the data concerning the total answers obtained to the questionnaires in Valencia and Alba Iulia.

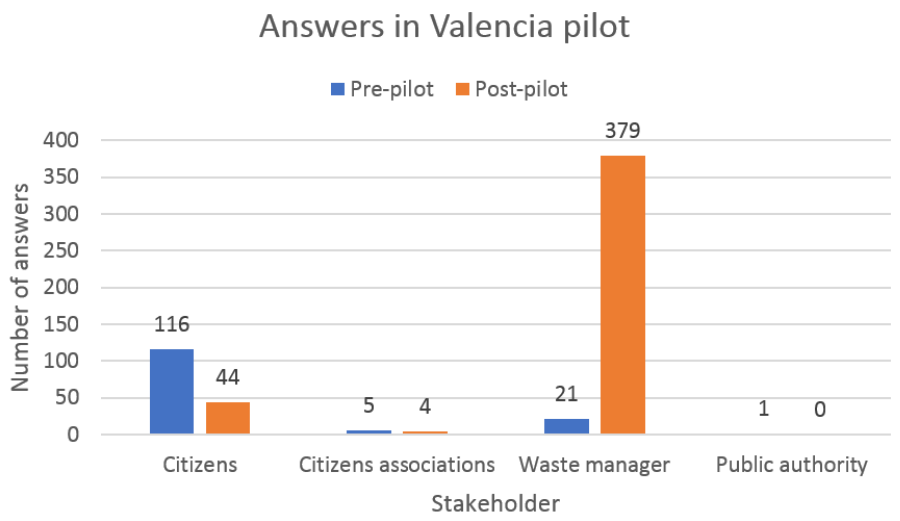

Figure 11 Number of answers by stakeholder in Valencia pilot.

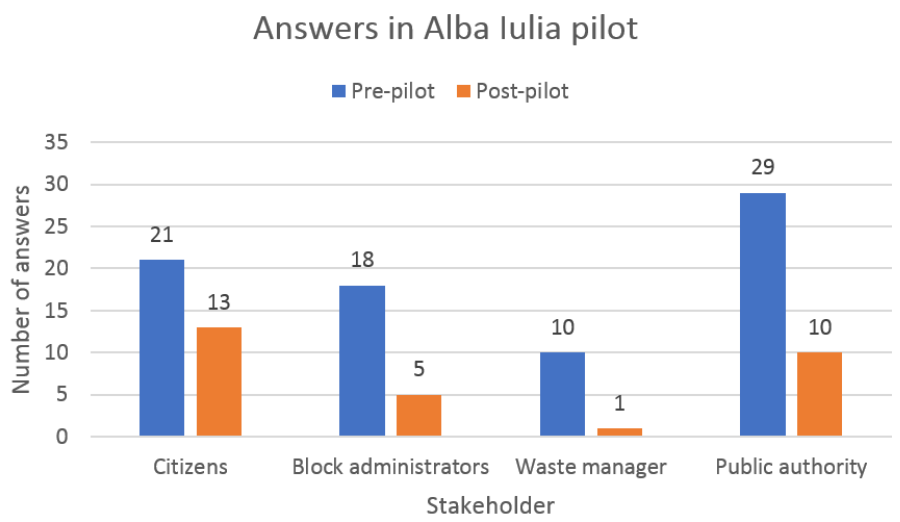

Figure 12 Number of answers by stakeholder in Alba Iulia pilot.

In the case of Utrecht, ITENE was working with Municipality of Utrecht to collect sufficient S-LCA questionnaires to have representative study. However, the social evaluation was not carried out due to low user participation and because the participating users could not to be identified for ethical reasons. Consequently, the questionnaires could not to be sent to the involved stakeholders.

6.2 Citizens: Evaluation of the project.

SINTEF was responsible for the design of the questionnaires to be carried out among the citizens who participated in the pilot studies in the three cities. Questionnaire to cities and waste managers are reported in D7.5.

The objective of these questionnaires was to evaluate the citizens' opinion on

the pilot studies carried out in the three cities and to examine their attitudes towards recycling behaviour.

Methodology

The methodology is based on the Theory of Planned Behaviour (Ajzen, 1991) that provides the theoretical framework for identifying determinants of recycling behaviour (Khan et al., 2019, Tonglet et al., 2004, Cheung et al., 1999, Park & Ha, 2010, Greaves et al., 2013, Botetzagias et al., 2015, Mahmud & Osman, 2010, Oztekin et al., 2017, Nigbur et al., 2010, Yin et al., 2014). The theory showed that attitude, subjective norms, and perceived behavioural control are decisive for predicting pro-environmental behavioural intention. Nigbur et al. (2010) and Greaves et al. (2013) demonstrated the importance of involving the population in new recycling processes to ensure relevant behaviours and to make the citizens identified themselves as recyclers. Pro-recycling attitudes are influenced by knowledge about negative consequences and access to facilities (Tonglet et al., 2003 and Cheung et al., 1999). Sociodemographic variables predicting plastic practices are gender, income, and education; women being more willing to shift to eco-friendly alternatives than men (Sharp et al., 2010; Jeżewska-Zychowicz & Jeznach, 2015).

Concerning the effectiveness of the Pay-as-you-throw principle and recycling incentives, previous studies showed positive effects such as increased awareness and recycling rates. The Pay-as-you-throw (PAYT) principle implies that consumers who throw away more, should pay more. This principle was successful in many European countries and beyond, for example, to reduce the amount of single-use plastic bags (Botetzagias et al., 2020, Chamizo-González et al., 2018, Wagner, 2017, Elia et al., 2015). The introduction of PAYT charge also operates as stimulus for waste reduction and incentive for illegal dumping (Botetzagias et al., 2020). The European Environment Agency (2019) also stated that although the single use plastic bag charge provided impressive results, countries should be encouraged to diversify their implemented measures (EEA, 2019). Other successful incentives such as refusing to pick up contaminated recycle bins have shown good results (WasteZero, 2020). Bans and increased costs as well as awareness interventions seem to be adapted measures to reduce plastic consumption and increase return and recycling behaviour.

Questionnaires

The participants were asked to answer a questionnaire before and after the pilot. The pre-questionnaire evaluated the citizens' opinion on the current waste management system in their city and their habits and attitudes regarding plastic waste and recycling in general. The objective of the post-questionnaire was to evaluate the pilot, the easiness of sorting the recyclables and taking them to a container, the label dispenser and orange bags developed during the project. The participants were also asked to evaluate the compensation system and the training sessions organised in their own city.

The pre-questionnaires were common to WP6 and WP7, whereas the post-questionnaires presented below were only part of WP6 and were adapted to the specific city situations and the evaluation of the pilots. Each questionnaire was prior discussed with the pilot managers.

Descriptive statistics were used to reveal the characteristics of the sample. The results are analysed with the IBM SPSS statistics 25 software. By convention, the cut-off point for the statistical results is a p-value of 0.05.

6.2.1 Valencia

The results for the city of Valencia are presented in a scientific article published in the Waste Management & Research journal in 2021 (Roche Cerasi et al., 2021).

6.2.1.1 Samples

The response rates were of approximately 21% for the pre- and post-questionnaires in Valencia: 116 and 114 citizens answered respectively the pre- and post-questionnaire and 54 of them completed both questionnaires.

Table 9 below presents the demographic data concerning the citizens who answered the questionnaires in Valencia.

Table 9: Socio-demographic data of citizens who answered the pre- and post-questionnaires.

Citizens		Number		%	
		Pre	Post	Pre	Post
Gender	Female	71	72	61.2	63.2
	Male	33	33	28.4	28.9
	No answer	12	9	10.3	7.9
Age groups	18-24	3	3	2.6	2.6
	25-34	22	14	19.0	12.3
	35-44	30	23	25.9	20.2
	45-54	27	29	23.3	25.4
	55-64	15	26	12.9	22.8
	65-74	10	10	8.6	8.8
	≥ 75	0	0	0.0	0.0
	No answer	9	9	7.8	7.9
Education	Primary school	19	15	15.5	13.2
	Secondary school	44	52	37.9	45.6
	University	45	42	38.8	36.8
	Doctorate	1	3	0.9	2.6
	Other	7	2	6.9	1.8
Total		116	114	100	100

Females in the two samples are slightly overrepresented with the proportions of 61.2% and 63.2%.

Differences between genders should be therefore interpreted with cautious since the high number of women might affect the reliability of the results. Differences in gender, age and education levels were not found significant between the two samples. Previous research studies have shown that women are more likely to participate in return and recycling actions (Hall, 2014; Brough et al., 2016).

Concerning the age groups, the samples are composed of individuals between 18 and 74 years old. The results showed that more than 60% are middle-aged adults (35-64 years old). For the education level, 54.3% and 58.8% had a basic education level (Primary, secondary school, and professional formation). According to the municipality, the population living in the San Marcelino district is mostly composed of working-class households with basic education levels.

6.2.1.2 Pre-questionnaire

Domestic waste management

Figure 13 below shows that a large share of the pre-sample (68.1%) was in

general satisfied with the domestic waste management system in their municipality. They also believed that the municipality treats their data with confidentiality.

Of the 116 respondents, 61.2% strongly agreed or agreed that they are well informed about the current waste system. About 67.2% thought that the packages they separate from the rest of their waste are effectively recycled. Only 7.8% believed that the waste they separate at home is going to be sorting again at the sorting plant and 9.5% that the trash is all mixed up together again at the sorting plant. In addition, only 50% stated that they are aware of recycling initiatives in their municipality.

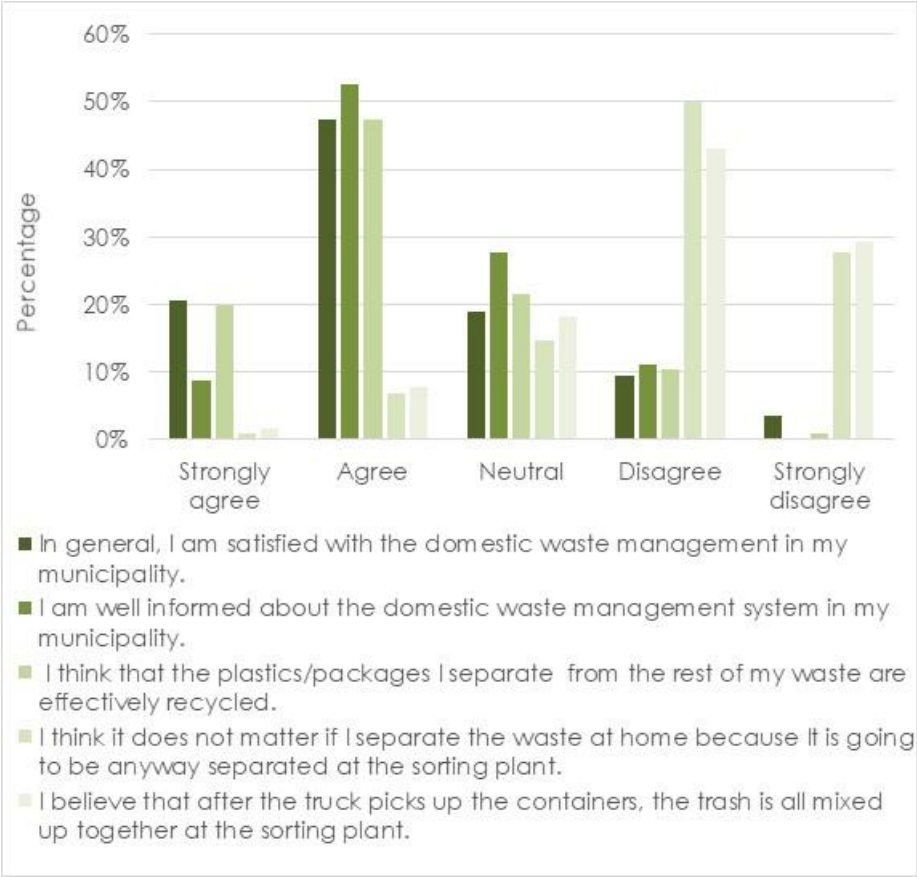

Figure 13 Citizens' satisfaction of the current domestic waste management system and beliefs about the recycling chain (n=116).

Sorting the packages selectively

Concerning the selective waste separation, 84.5% stated that they knew how to sort their waste at home according to the local law of their municipality. A large share of the pre-sample confirmed that they always or often sort their packages at home (93.1%), and they put the packages in the yellow container as they should

do (92.2%).

The respondents had to select items to be put in the yellow container. The municipal containers are of different colors according to waste type: solid waste (grey), light packaging, plastic, cans, and beverage cartons (yellow), glass (green) or organic waste (brown). Figure 14 below shows that the items they selected are in general correctly selected; 97.4% selected the milk cartons, 96.5% the cans, and 92.1% the shampoo bottles. However, there are more uncertainties concerning the sprays (69.3%), the plastic pots (40.4%), toys (28.1%), diapers (4.4%) and electric items (0.9%). The introduction of these products in yellow containers affect the effectiveness and efficiency of the whole recycling chain by increasing the number of rejected items.

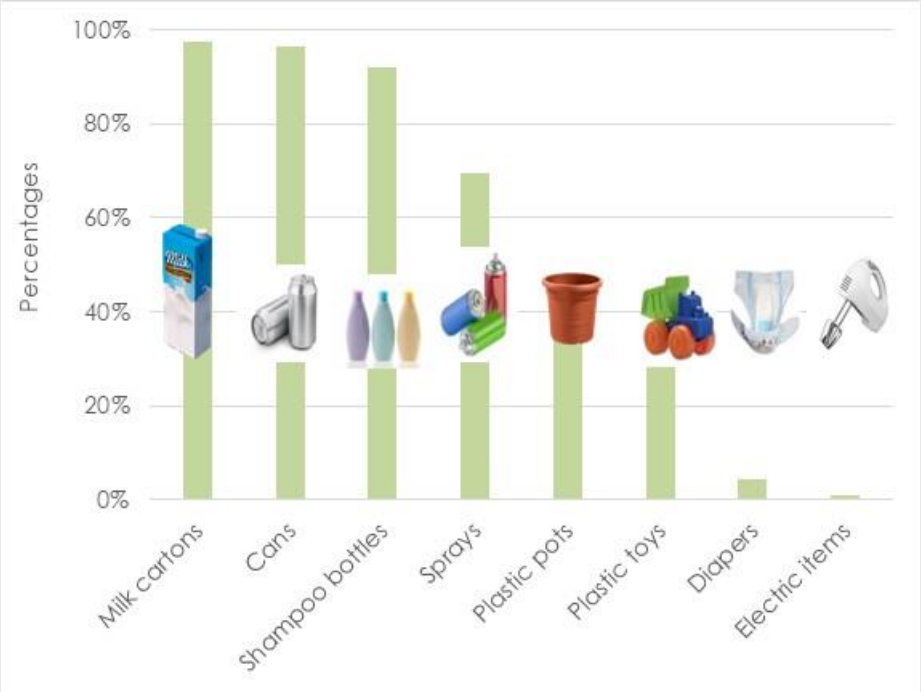

Figure 14: Households' selection of items to be put in the recycling containers (n=116).

Plastic packaging collection

Concerning the number of times, the citizens have to go to the containers to put their recyclables, the results are spread from "Once a day" to "Once in two weeks". As expected, the frequency increases significantly with the number of persons composing their households. Of the 116 respondents, 35.1% stated that they put their recyclables in the container once in three days, 34.2% once a week and 17.5% once in two days. Distance to containers has an impact on citizens' disposal behaviour. For 91.4% of the respondents, it takes them

between 2 and 5 minutes to go to the container, which is considered as a short and reasonable time.

Willingness to pay for waste management

There are no clear results concerning the respondents' willingness to pay for the costs generated by the management of their waste. About 35.3% thought that their taxes cover the costs, 29.3% did not think that it is the case and 35.3% had no opinion. The results are the same concerning their opinions about the "pay-as-you-throw" principle. About 36.2% thought that households should pay according to the amount of waste they generate, whereas 32.8% thought the opposite. As expected, 87.1% of the respondents stated that they should be rewarded for separating their waste properly.

6.2.1.3 Post-questionnaire

Easiness of the label dispenser

The label dispenser was especially developed for the project and Valencia was the first pilot to use it. There were some technical issues at the beginning of the pilot due to malfunctions of the RFID card reading, damages caused by the rain and vandalism. The participants also pulled out the label in the middle of printing process, making the system inoperable for the next user. We cannot evaluate to what extend each participant was affected by these malfunctions. These technical problems have been rapidly identified and a new 2.0 device version was developed to avoid critical issues.

Figure below shows that of the 114 respondents of the post-sample, 71.9% stated that the label dispenser was very easy or somewhat easy to use, whereas 16.7% experienced the opposite (n=19).

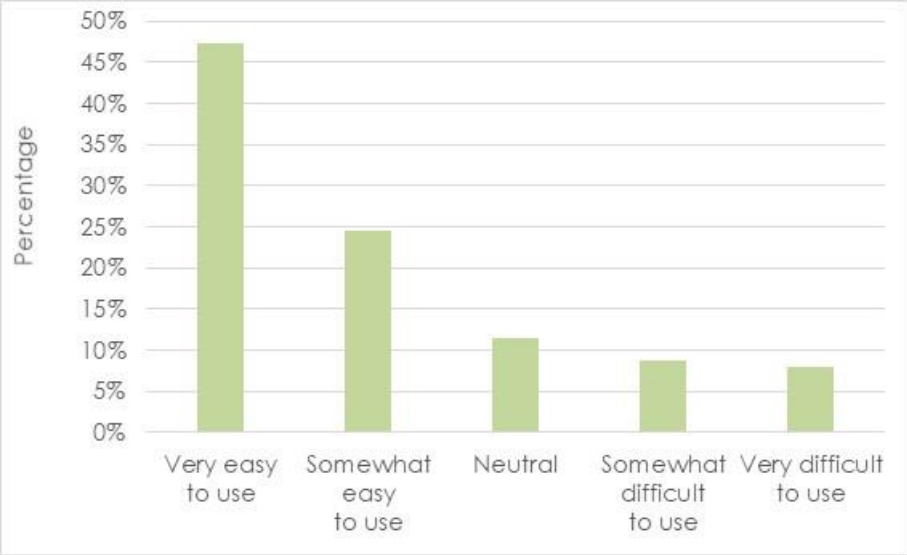

Figure 15: Respondents' satisfaction with the label dispenser (n=114).

Concerning the technical issues with the label dispenser, the respondents were asked to explain the difficulties they experienced. The results are presented in Table 10 below.

Table 10 Experience with the label dispenser (n=19).

Experience with label devices	Count	%
I had to go at least once to other containers nearby.	16	84.2 %
I was unable to use once or several times the device because the label tape was broken, and the label was not coming out.	15	78.9 %
I experienced once or several times that the label did not come out at all.	14	73.7 %
I experienced that the label did not come out in one piece once or several times.	9	47.4 %
I experienced once or several times that my ID keyring was not working properly.	4	21.1 %
I think that it takes too much time for the label to come out from the device.	4	21.1 %
It was difficult to keep the label stuck on the bag	1	5.3 %
I experienced once or several times that my user ID card was not working properly.	1	5.3 %
Other comments	5	26.3 %

Easiness of filling the orange bags with the recyclables

The total number of bags collected over the pilot weeks was of 12488. An average of 500 labelled bags was registered per week (71 bags per day). The results showed that 99.1% of the post-sample strongly agreed or agreed that it was easy to remember which recyclables they must put in the dedicated orange bags developed by INTERVAL S.A. This is a good result for the pilot, showing that the communication strategy and training sessions have been effective.

In addition, 93.0% stated that the bags were easy to use; only 1.8% disagreed and commented that the bags could not be easily closed; a cord was missing in the conception of the product.

As expected, the time it takes for the respondents to fill one bag significantly decreases with the number of persons composing households. Figure 16 below shows that of the 114 respondents in the post-sample, 43.0% stated that it took them 3-4 days, 28.9% 1-2 days and 19.3% 5-6 days to fill one bag.

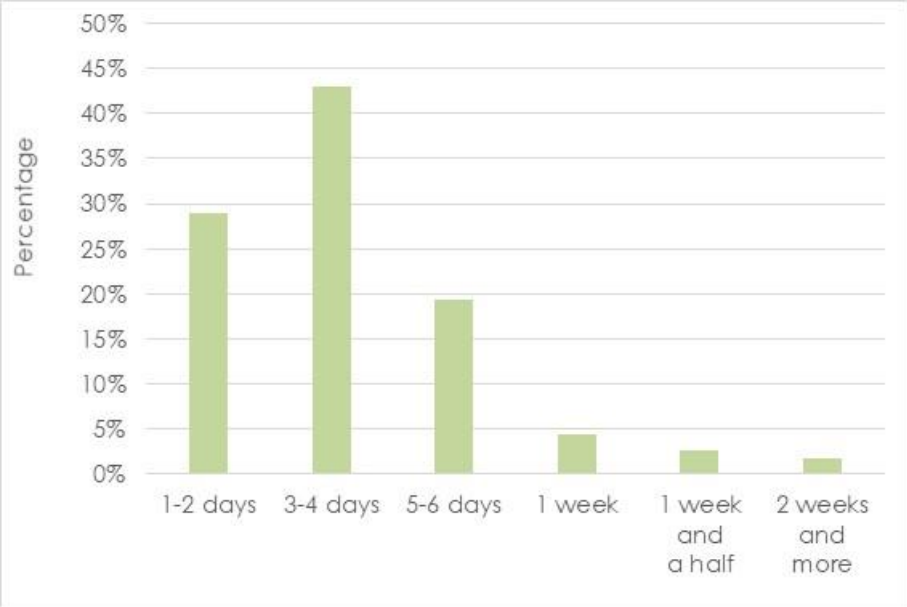

Figure 16: Average time required to fill one labelled bag with recyclables (n=114).

The respondents in the post-sample were asked how frequently they throw a bag in the yellow container. Figure 17 below shows that 31.6% of the respondents threw a labelled bag in the container once a week, 30.7% once in three days and 25.4% once in two days. Of the 114 respondents, 84.2% put only one bag and 14.9% two bags at the same time in the yellow containers.

The containers are placed in a short walk distance to the households. The pre-

sample stated that it took them between 2 and 5 minutes to walk to the nearest container. The distance did not require any additional effort, the participants had not to keep their waste in their apartments for longer time than they were willing to do. They could throw their waste when leaving their home.

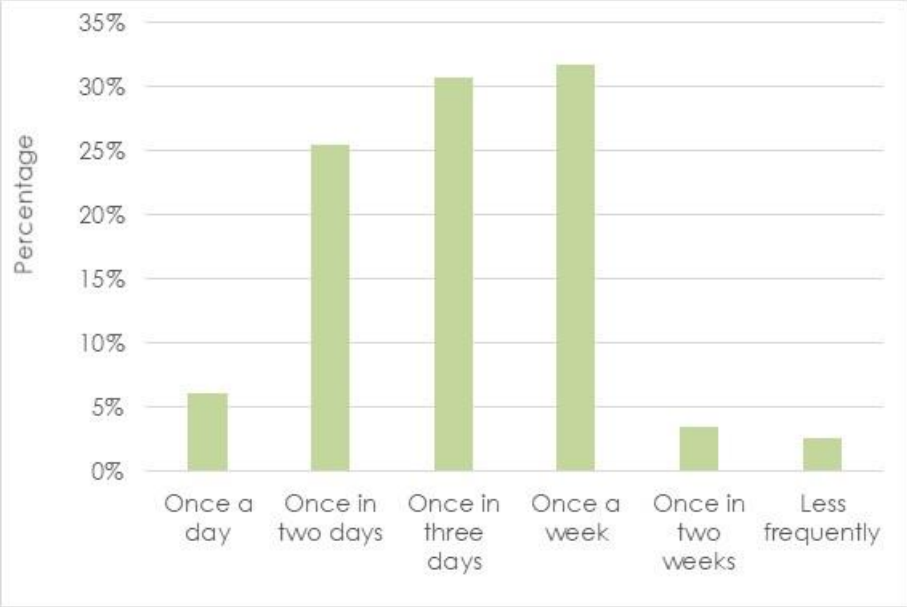

Figure 17 Frequency of respondents' disposal behaviour (n=114).

Communication and training sessions

Figure 18 below shows that of the 114 respondents of the post-sample, 83.3% strongly agreed or agreed that the activities and workshops organized in the neighbourhood have been very useful to learn about recyclables and how to use the label device. Around 15.8% had no opinion.

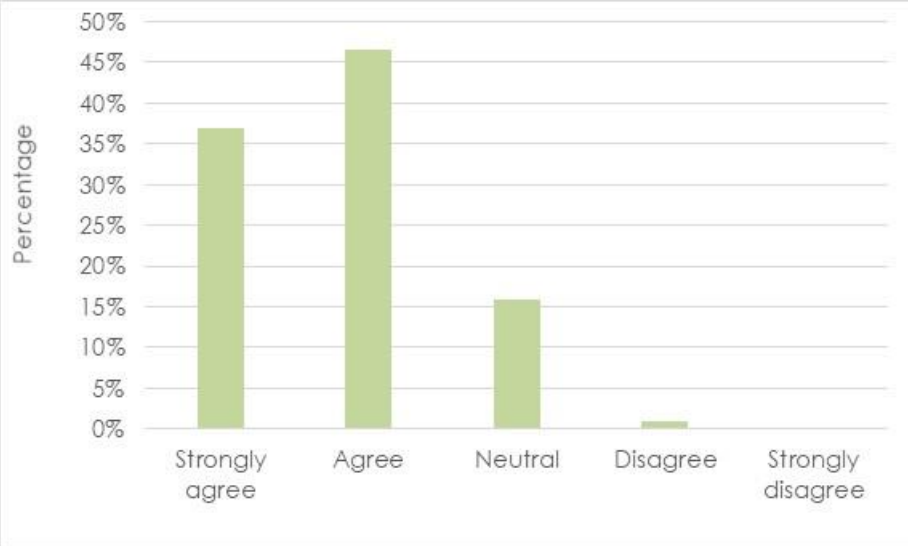

Figure 18 Respondents' satisfaction with communication and training sessions (n=114).

Knowledge about recycling

Figure 19 below shows that 95.6% of the post-sample strongly agreed or agreed that they knew why it is important to put only recyclable materials in the yellow containers. In addition, they also stated that they knew that some materials look like recyclable but cannot be put in the yellow container.

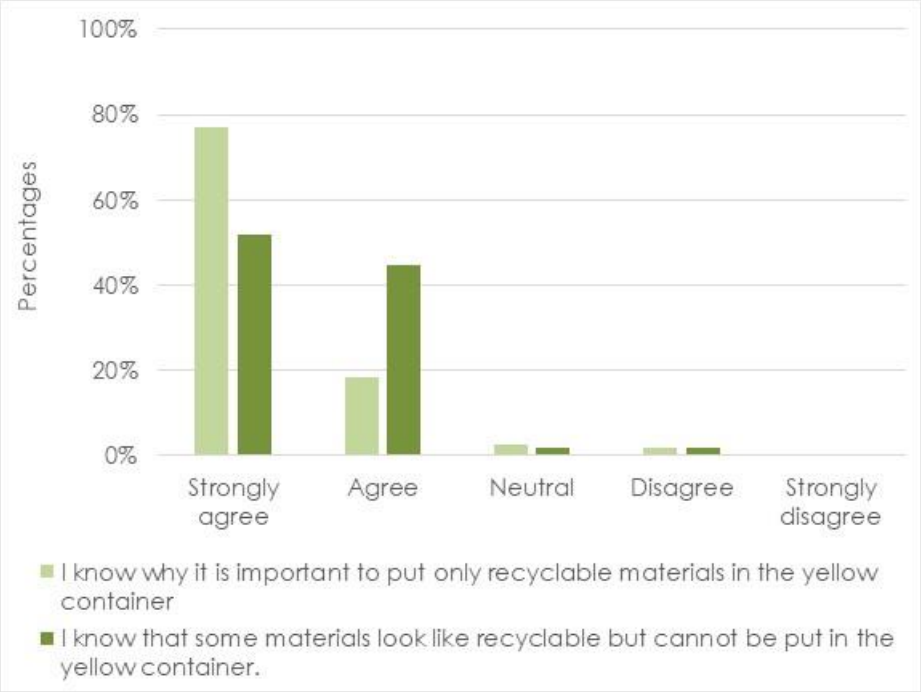

Figure 19: Respondents' knowledge about recyclables.

Compensation system

Of the 114 respondents of the post-sample, 96.5% strongly agreed or agreed that households should participate more in recycling. However, as the pre-sample, 89.5% of the post-sample stated that they would like to be rewarded for properly separating their recyclables and putting them in the right containers. The results showed that rewarding the citizens in the first stage of a new collection system would be beneficial.

Table 11 below shows the prizes that would be most suitable for the citizens. About 56.1% would like to get benefits for the whole neighbourhood, 50.9% to get discounts at local shops, 49.1% to pay less tax, 46.5% to get free transport tickets and 36.0% gifts. The consignment system for plastic bottles already in place in several countries (Norway, Sweden, Germany, and Denmark) was often mentioned in comments left by the respondents and considered as a good solution for increasing recycling rate.

Table 11 Opinion about the compensation system

Compensation	Count	%
Getting benefits for the whole neighbourhood	64	56.1%
Discount coupons for local shops and services	58	50.9%
Paying less tax	56	49.1%
Public transport tickets	53	46.5%
Getting point to exchange them against gifts	41	36.0%
Other comments	4	3.5%

Concerning the Pay-as-you-throw principle, 50.0% of the post-sample strongly agreed or agreed that the citizens should pay according to the waste they generate, whereas 21.9% disagreed with this principle. The results showed that the post-sample is more willing to pay than the pre-sample.

General opinion on the PlastiCircle project

Figure 20 below shows that 93.9% of the respondents in the post-sample had a very positive or a positive opinion on the project.

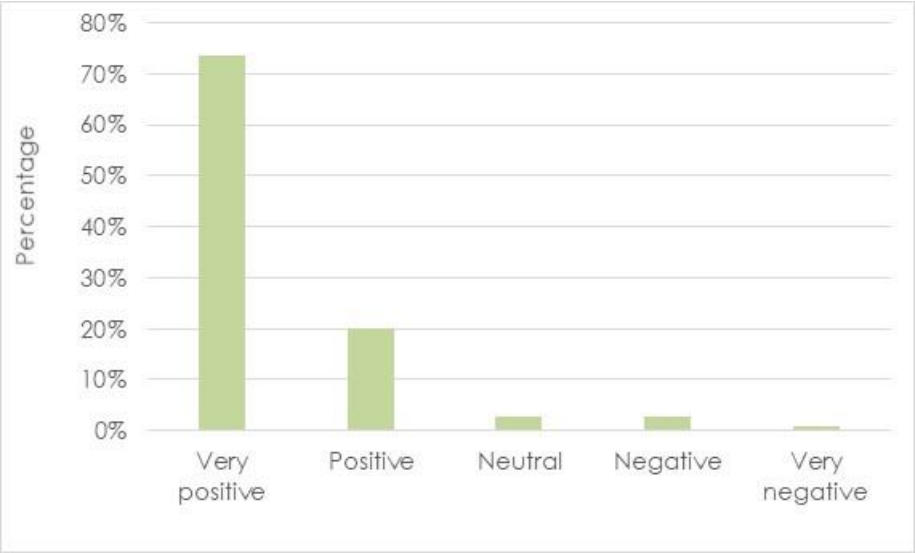

Figure 20: Respondents' opinion about the project (n=114).

The responses the most cited about what they liked the most about the project were the increased awareness of recycling in the neighbourhood. However, they would have liked to perceive an effect at the city level.

Regarding what they liked the least, they commented that the pilot study was not long enough, and they would have liked more time to get used to new sorting process. They also commented that the project focused too much on

recycling and not enough on the importance of reducing households' plastic consumption and reusing plastic at home.

6.2.1.4 Conclusion

The results for the pilot study in Valencia showed that the Spanish citizens had positive attitudes towards sorting recyclables at home to increase the number of recycled products. The impediment factors were the lack of citizens' awareness and knowledge, as well as the lack of facilities for levering their recyclables. The results confirmed a high trust of the citizens in the way the municipality handle their recyclables. However, they also need evidence that the products they put in the containers are effectively recycled. By creating targeted campaigns and training sessions, Valencia addressed the citizens' concerns and provided the necessary information individuals needed to actively participate in the recycling chain. The smart technologies (filling level sensor, label dispenser and smart ID card) improved the current plastic collection system and contributed to encourage the citizens to sort and recycle better. The labelled bag for the recyclables was found to be useful and could be further improved by being biodegradable and with a cord to easily close it. Concerning the prototype of the label dispenser developed for the project, there were few technical and vandalism issues at the beginning of the pilot. However, the whole system provided good results by facilitating the data collection for the compensation process. Concerning data privacy, the participants did not have any major concerns. However, a system extended to the whole population may cause some resistance concerning information collected about household waste. This issue could be avoided by evaluating the waste at a neighbourhood level and by rewarding households with lower local taxes and local infrastructure (plants, children's play areas, etc.). The results indicated that for ensuring a successful long term recycling rate, it will require to introduce monetary incentives to increase the citizens' participation. The participants of this study were willing to make efforts to reduce the amount of their non-recyclable waste in order to get some benefits. Public debates are recommended on charging solutions for polluters and non-recyclable waste reduction, adapted to the local reality and household income levels.

6.2.2 Utrecht

6.2.2.1 Sample

The pilot started at the end of September 2019 and ended at the beginning of January 2020. Citizens from the pilot area were invited to join the kick-off meeting (September 25th, 2019). As a result, 65 enlisted (2% of total households in pilot area). Utrecht did not use the label dispenser, the filling sensor for the underground container and the identification code for the participants.

The response rate for the questionnaire was of 40.0% in Utrecht. We do not present here the results of a pre- and post-questionnaire, since for the citizens, there were only very slight changes in the pilot study in Utrecht.

Table 12 below presents the demographic data concerning the citizens who answered the questionnaire. Females are slightly overrepresented with the proportion of 53.8 %.

Table 12: Socio-demographic data of citizens who answered the questionnaire.

Citizens		Count	%
Gender	Female	14	53.8
	Male	10	38.5
	No answer	2	7.7
Age groups	18-24	1	3.8
	25-34	3	11.5
	35-44	10	38.5
	45-54	9	34.6
	55-64	2	7.7
	65-74	0	0.0
	≥ 75	0	0.0
	No answer	1	3.8
Education	Primary school	1	3.8
	Secondary school	1	3.8
	Higher professional education (HBO)	13	50.0
	University	10	38.5
	Other	1	3.8
Total		26	100

As specified for Valencia, differences between genders should be interpreted

with cautious since the high number of women might affect the reliability of the results. Concerning the age groups, the sample is composed of individuals between 18 and 64 years old. The results showed that more than 70% are middle-aged adults (35-54 years old). For the education level, 7.6% had a basic education level (Primary, secondary school) and 88.5% a higher education level (HBO or University).

6.2.2.2 Questionnaire

Domestic waste management

Figure 21 below shows that a large share of the sample (65.4%) was in general satisfied with the domestic waste management system in their municipality. They also believed that the municipality treats their data with confidentiality (76%).

Of the 26 respondents, 76.0% strongly agreed or agreed that they are well informed about the current waste system. About 60.0% thought that the packages they separate from the rest of their waste are effectively recycled. Only 16.0% believed that the trash is all mixed up together again at the sorting plant. In addition, only 52.0% stated that they are aware of recycling initiatives in their municipality.

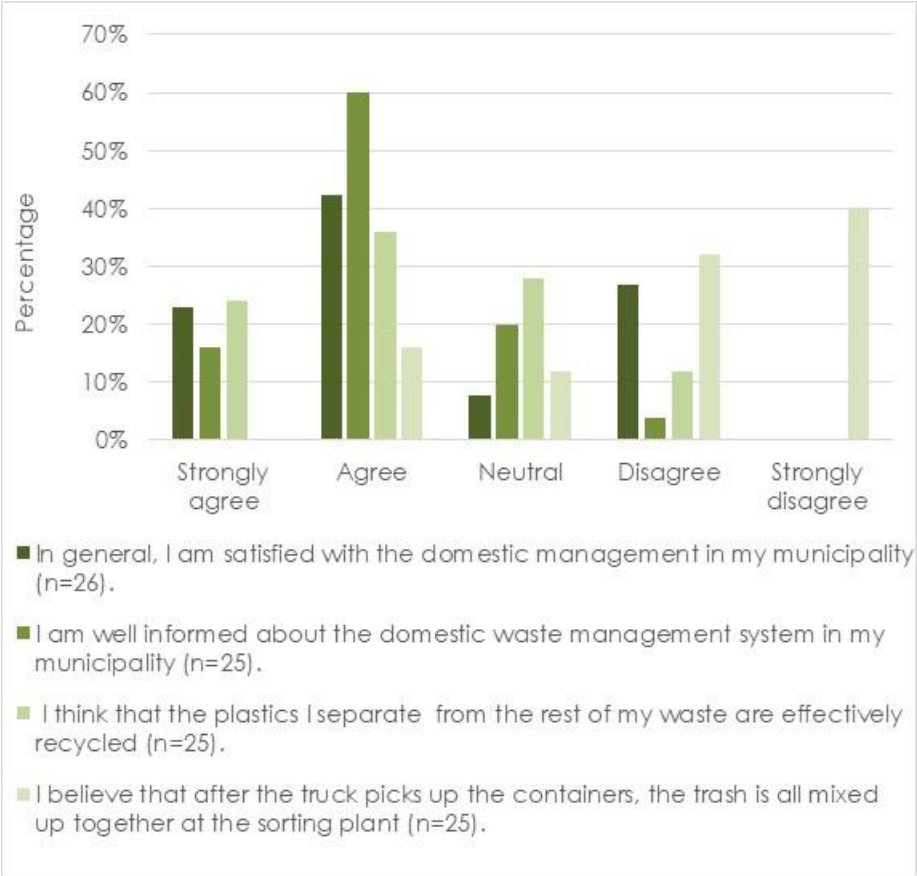

Figure 21 Citizens' satisfaction of the current domestic waste management system and beliefs about the recycling chain (n=26).

Sorting the packages selectively

Concerning the selective waste separation, 80.8% stated that they knew how to sort their waste at home according to the local law of their municipality (n=26). A large share of the sample confirmed that they always or very often sort their packages at home (92.3%) and put them in the orange containers as they should do (91.7%, n=24).

The respondents had to select recyclable items to be put in the orange containers. Figure 22 below shows that items correctly selected are milk cartons (96.2%), plastic bottles (88.5%), yogurt packaging (84.6%), cans (80.8%), plastic trays (61.5%) and films (61.5%), shampoo bottles (53.8%).

Of the 26 respondents, only 38.5% selected the toothpaste packaging, which is a recyclable product that can be put in the orange containers.

There are also uncertainties concerning other selected items that are not recyclables, plastic pots (46.2%), aluminum foils (26.9%), chips bags and pharmaceutical blister (19.2%), and diapers (3.8%). None of the respondents selected the sprays and electric items, which is a good result. The introduction of these last non-recyclable products in containers affect negatively the recycling chain.

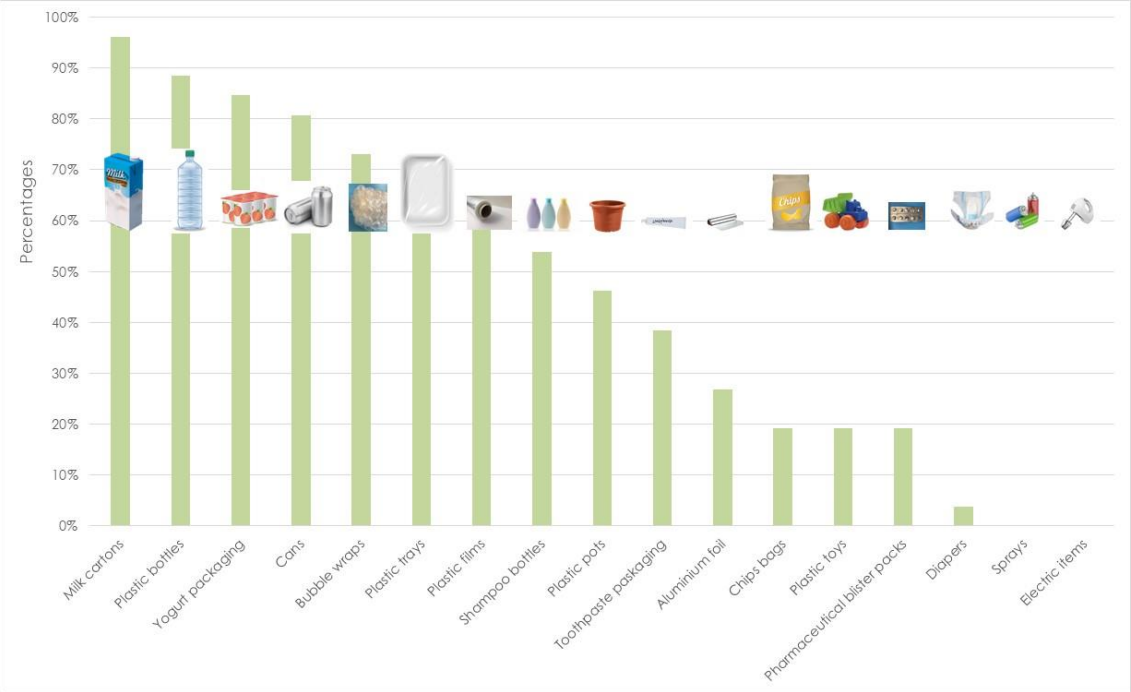

Figure 22 Households' selection of items to be put in the recycling containers (n=26).

Plastic packaging collection

Of the 26 respondents, 65.4% strongly agreed or agreed that they are satisfied with the plastic packaging collection in their municipality. Concerning the number of times, the citizens have to go to the containers to put their recyclables, the results are spread from "Once a day" to "Once in three weeks". Of the 24 respondents, 29.2% stated that they put their recyclables in the container once a day, 20.8% once a week or once in two weeks and 16.7% once in three days. As stated before for Valencia, distance to containers has an impact on citizens' behaviour. For 40.0% of the respondents, they have a container for their home and 28.0% have a mini container for personal use. For 16.0% of the 25 respondents, it takes them either between 2 and 5 minutes or between 5 and 10 minutes to go to the container. For 84.0% of the households, the containers are very close to their home, under 5min walk. The results shows that the citizens have a reasonable distance to walk between their homes and the containers.

Willingness to pay for waste management

As found for Valencia, there are no clear results concerning the respondents' willingness to pay for the costs generated by the management of their own waste. About 32.0% thought that their taxes fully cover the costs for processing their waste, whereas 16.0% did not think that it is the case and 44.0% had no opinion.

The results are the same concerning their opinions about the "pay-as-you-throw" principle. About 44.0% thought that households should pay according to the amount of waste they generate, whereas 16.0% thought the opposite. Concerning a potential compensation system, 68.0% strongly agreed or agreed that households should be rewarded for sorting their waste properly.

6.2.2.3 Qualitative evaluation

- A workshop organised in September 2019, explained to the participants the project objective and the platform put at their disposal. A panel discussion was organised, and the results showed that the participants had three main concerns regarding the frequency of their waste collection, the number of

underground containers for plastic, and the best way to recycle plastic packaging. In the framework of PlastiCircle, the third question was planned to be answered by providing relevant information to the citizens about the whole recycling chain and the importance of recycling for the environment and society.

To encourage the participation of the citizens, they were asked to fulfil some assignments.

The first assignment was to ask them to count their amount of daily plastic packaging. This task was important to make them aware of the amount and types of packages they bought and threw away in containers after use. The results showed that the participants opened on average 20 plastic packaging every week. After ten weeks, the amount was reduced to 16. They were also aware of their increasing waste during specific periods such as Christmas.

They also had different ways to store their plastics at home; some of them stated that they sorted them in a separate way by using either bins or bags. However, some households also explained that they do not have enough space at home.

They also stated a lack of information concerning plastic recycling in general. They also agreed that some packages should be forbidden such as black packages, over packaging or packaging that are not recyclables. Plastic packaging should be also provided information about their level of recyclability and in which materials they are made of. This information should be standardized inside the European Union.

Participants also shared some ideas about how-to re-use plastics. They also stated that they stopped using shopping bags, lunch bags or disposable plastic plates and cups.

Most of the participants continued to sort their plastic packaging after the end of the pilot study in Utrecht.

- On December 2019 two citizens participated in a panel discussion with the PlastiCircle partners where 5 themes were discussed:

1. The separation of waste packaging is not standardised and varies according to the region or country. As an inhabitant of Europe, you really do not know how to meet the requirements.

   "We agree that the differences in legislation and execution are difficult to understand."
2. There are too many types of plastic packaging waste. Europe should require standardisation in order to simplify the whole system.

   "The difficulty is not the amount of waste types, but the challenge lies in the lack of information about how to recognize and recycle plastic packaging. It should be possible to recognize and recycle every type of waste in a simple way."
3. Plastic packaging that are not recyclable must be prohibited.
4. The municipality I live in is not acting sufficiently [⋯].

   "The municipality has the objective to increase the frequency of door-to-door collection and the number of underground containers. More and better communication about this subject should be also provided."
5. Europe (government and producers) should invest money in the separation of packaging waste out of residual waste. This should be more efficient and cheaper at the end.

   "Yes, it simplifies the system".

The conclusion concerning this panel discussion with two participants was: "*Plastic packaging should be made for recycling. Therefore, what happens at home should be in line with collection and treatment / recycling of waste".*

6.2.2.4 Conclusion

The main changes for the citizens in Utrecht was an increased knowledge about plastic packaging and recycling and consequently a better recycling behaviour. The weekly activities and newsletters provided the missing information needed to understand how to separate packaging from the residual waste. The information from the platform explained which packages look like recyclables but should not be dropped in the recycling container.

Comments left about the project showed that the citizens were satisfied with the objective of PlastiCircle. Some of them mentioned that "*the project brought more awareness about how much plastic they use every day and which*

packaging can be put in the recycling container and more attention to the separation of plastic from the residual waste". One participant mentioned that he/she liked the assignments organised by the municipality and the information about *"where we are at the moment".* However, other participants also stated that they did not learn so much and there were too many assignments and they could not see any concrete changes in their neighbourhood.

6.2.3 Alba Iulia

6.2.3.1 Samples

Due to the COVID-19 sanitary crisis in 2020 and the number of citizens who participated actively in the pilot study in Alba Iulia, the response rates of the surveys (8.2% for the pre-questionnaire and 6.2% for the post-questionnaire) were quite low despite the repeated requests of the pilot manager.

After registration, the citizens received the request to fill the pre-questionnaire and 21 respondents did it. At the end of the pilot, 16 answered the post-questionnaire. Five participants responded both questionnaires. The questions about the socio-demographic data were not included in the questionnaires. However, the identification code allowed to relate the answers to the person who had registered his/her family in the platform. Table 13 below shows the profiles of the registered citizens. Households registered in the platform were composed on average of 1.8 members.

Table 13 Profiles of the registered citizens in the platform.

Citizens		Number		%	
		Pre	Post	Pre	Post
Gender	Female	14	10	66.7	62.5
	Male	6	6	28.6	37.5
	No answer	1	0	4.8	0.0
Age groups	18-24	1	0	4.8	0.0
	25-34	5	3	23.7	18.8
	35-44	7	7	33.3	43.8
	45-54	6	5	28.6	31.3
	55-64	1	1	4.8	6.3
	65-74	0	0	0.0	0.0

	≥ 75	0	0	0.0	0.0
	No answer	1	0	4.8	0.0
Education	Primary school	0	0	0.0	0.0
	Secondary school	8	6	38.1	37.5
	University	12	10	57.1	62.5
	Doctorate	0	0	0.0	0.0
	Other	1	0	4.8	0.0
Total		21	16	100	100

As found in Valencia and Utrecht, Females in the two groups are slightly overrepresented with the proportions of 66.7% and 62.5%. Concerning the age range, the two groups are composed of individuals between 18 and 64 years old. The results showed that large proportions of young adults (25-34 years old and middle-aged adults (35-64 years old). For the education level, 38.1% and 37.5% had a secondary school education level, and 57.1% and 62.5% had a bachelor level.

6.2.3.2 Pre-questionnaire

Domestic waste management

Figure 23 below shows that a large share is not in general satisfied with this system (71.4%).

Figure 23: Citizens' satisfaction of the current domestic waste management.

Those you replied that they are dissatisfied with the waste management system

(n=15), were asked to choose the most important improvement they thought the municipality should focus on. They could choose one option and propose their own improvement. Table 14 below shows that 40.0% would like in general waste recycling be improved and 33.3% with new containers for recyclable materials.

Table 14 Most important improvement the respondents thought the municipality should focus on. (n=15)

Most important improvements	**Count**	**%**
Increase the frequency of garbage collection	0	0.0
Improving waste recycling in general	6	40.0
Establish new containers for recyclable materials in the city	5	33.3
Provide more information about recyclable waste	1	6.7
Other: - *"In our city there are no containers for recycling. [...] So, the possibilities for improvement are maximum"* - *"Educate the population, automate the collection for other types of containers, respectively waste, apply fines."*	2	13.3

Knowledge about the four new fractions

The respondents were asked if they were aware about households being soon required to separate their waste in four new fractions, instead of using two waste containers, one for dry waste, another for wet waste. Of the 20 respondents who answered the question, 70.0% stated that they have heard about this initiative and 30.0% that they did not. However, they all would like to know more about it.

Access to the containers

Concerning the current containers, 95.0% stated that the containers are easy to access and to use and 5.0% the opposite. The respondent who was not satisfied, commented that the containers are dirty because some citizens put high volumes of various waste near or in containers; even emptied daily.

Waste collection

Concerning how often the citizens place their trash bags with recyclables in the dedicated container, the results are spread from "Once a day" to "Rarely". Of the 20 respondents, 25% stated that they put their recyclables in the container once a day, 25.0% once in three days and 25.0 % once a week. When asked at

what time of the day, they usually throw their garbage bags in the containers, 30.0% in the evening, 25.0% in the afternoon and 20.0% in the morning. For the others, the question was not found as relevant.

The citizens were asked what they do when the container they would like to use is full, Table 15. The results showed that 52.6% go to another container and 5,3% come back later. Of the 19 respondents who answered this question, 26.3% know when the containers are empty, so they do not have to experience such a situation. Unfortunately, 10.5% just leave their bags by the full container and 5.3% put them in another container even knowing that it is not the right one.

Table 15 Citizens' behaviour when containers are full. (n=19)

Citizens' behaviour	Count	%
It never happens because I know when the containers are empty.	5	26.3
I come back later.	1	5.3
I go to another container in the same area.	10	52.6
I leave my garbage bags by the container.	2	10.5
I put my garbage bags in another container, even if it is not the right one	1	5.3
Total	19	100

Knowledge about recycling

Figure 24 below shows that 68.4% of the respondents strongly agreed or agreed that they are well informed on recyclable materials and correctly separate their waste. They also agreed that they know which products are recyclable or made of recycled materials (84.2%).

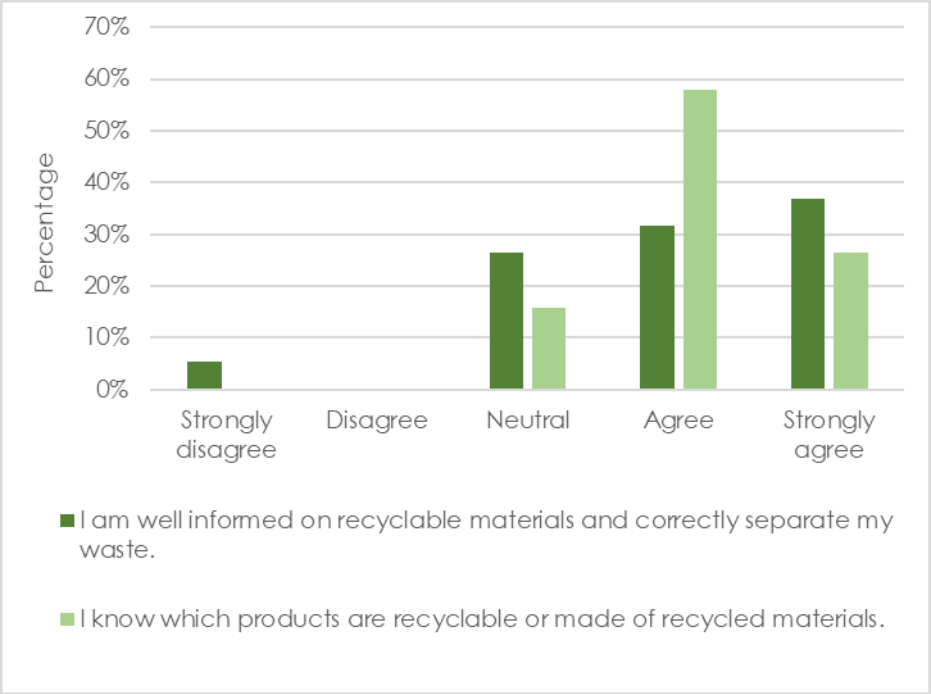

Figure 24 Citizens' knowledge about recycling. (n=19)

Concerning their behaviour as consumers, the results below in Figure 25 shows that the respondents used to buy recyclables or recycled products.

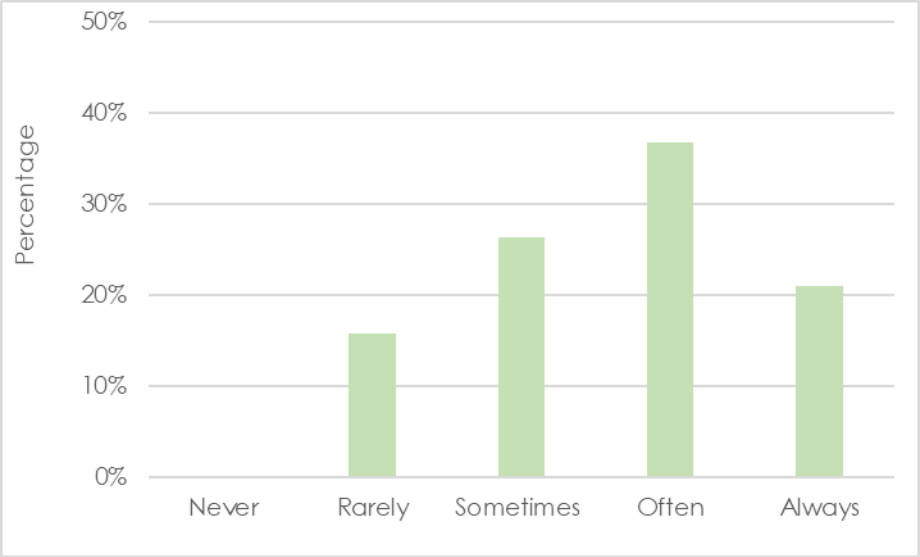

Figure 25 Citizens' purchase of recyclables or recycled products.

Benefit for the society

Concerning recycling of plastic materials, 100% of the 19 respondents who answered the question, thought that plastic recycling is important for society and the environment. In addition, they also strongly agreed or agreed that plastic recycling increases economic development and creates jobs, and is important for them, their family, and the city (100%).

Willingness to pay for waste management

About 52.6% believed that their taxes cover the costs, 10.6% did not believe that it is the case and 36.8% had no opinion. Concerning their opinions about the "pay-as-you-throw" principle, 57.9% believed that they should pay according to the amount of waste they generate, whereas 10.6% thought the opposite.

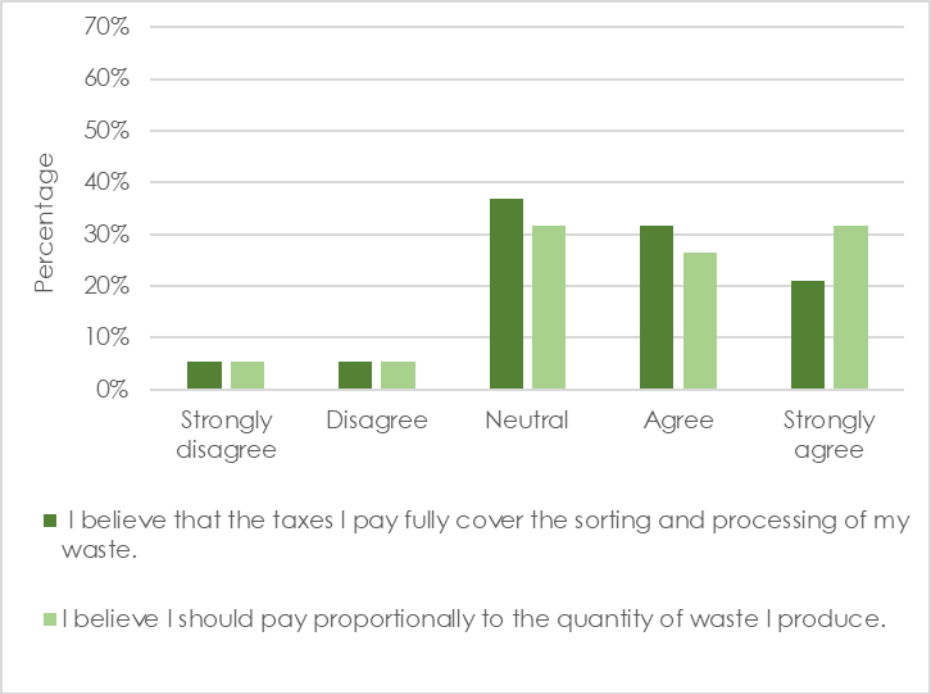

Figure 26: Respondents' willingness to pay for waste management. (n=19)

Opinion about PlastiCircle

The respondents were asked if they thought that it was a good idea for their municipality to participate in the European project, PlastiCircle, focusing on recycling plastic materials; 100% of the 19 respondents who answered this question, strongly agreed, or agreed that it was a good idea.

Few comments were left by the respondents:

- "I am glad that there is a project, even a pilot, and I would like a large-scale implementation of recycling system in the city, at least plastic and paper separately."
- "When will this project be implemented? I look forward to it and I want to contribute to this beautiful initiative."
- "System for recycling plastic bottles."
- "[…] I personally and my family have been separating the plastic for many years. […] we should care about everyone in nature."
- "Why is this project adopted only on certain streets in the city? It should be implemented throughout the city, no one should throw garbage on the shore."
- "Where and when can you get hold of recycling bags?"
- "Very good project."

6.2.3.3 Post-questionnaire

Easiness of the label dispenser

The results showed that 6.3% stated that they had no problems with their card and the label dispenser on the container. However, 43.8% stated that the label did not come out once or several times. In addition, 12.5% commented that sometimes it took a long time to remove the label from the dispenser, or the label did not come out properly or complete once or several times. Concerning the user card, 6.3% indicated that their card did not work once or several times. Two additional comments were left: *"unfortunately I did not use the card because I lost it on the first day." and "If the world were more civilized, it would be better."*

Easiness of filling the orange bags with the recyclables

Concerning their opinion about the labelled bags, 86.7% stated that the bags were fit for purpose, large enough, durable, and easy to use; only 13.4% disagreed and commented that the bags were not large enough or not strong enough. One respondent added that he/she could press 20-21 pieces in the bag, however he/she only recycled water bottles.

In addition, 93.8% strongly agreed or agreed that they had read the information about plastic recycling and understood which packages they should put in the labelled bags.

Figure 27 below shows that of the 16 respondents in the post-sample, 43.8% stated that it took them one week, 25.0% more than a week and 18.8% 5-6 days to fill one labelled bag.

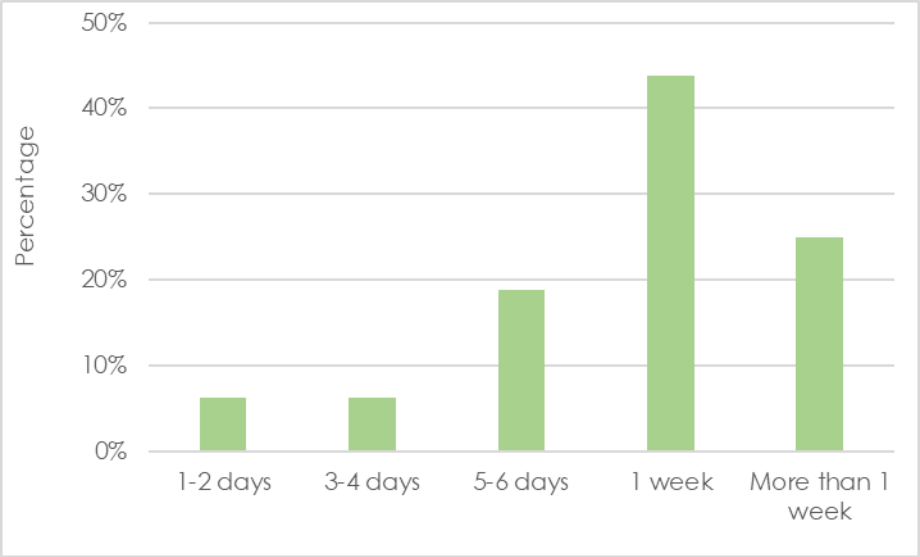

Figure 27: Average time required to fill one labelled bag with recyclables. (n=16)

Communication and training sessions

Of the 16 respondents of the post-sample, 75.0% strongly agreed or agreed that the project platform was easy to use for finding activities and allocated ecopoints. Around 18.8% had no opinion.

About 93.8% thought that they received enough information and support to sort the plastics and use the containers properly. Figure 28 below shows that 43.8% of the respondents thought that the project activities (questionnaires, online meetings, information from kiosks) were very helpful; 37.5% thought that they were somewhat helpful and 18.8% extremely helpful.

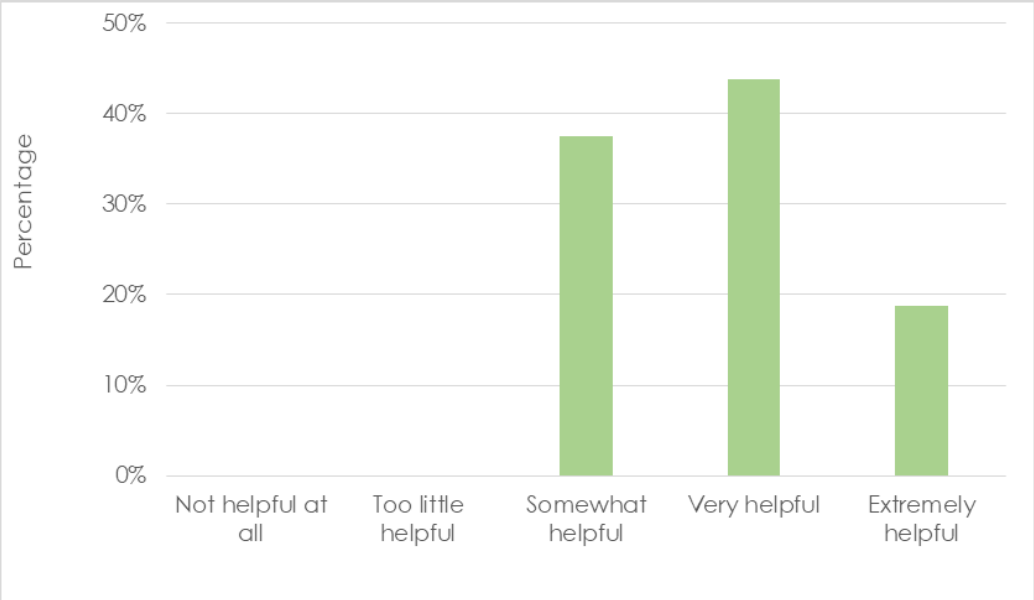

Figure 28: Respondents' satisfaction with the project activities. (n=16)

Knowledge about recycling

Concerning their knowledge about recycling, all the respondents strongly agreed or agreed that they knew which products are recyclables or made of recycled materials. In addition, they also agreed that the project helped them to understand the importance of recycling and the impact it had on their life, their family, and their city. They also believed that plastic recycling improves the environment, economic development and creates jobs.

Compensation system

As part of PlastiCircle, citizens received symbolic rewards in line with the points they had accumulated, based mainly on the quantity and quality of the plastic they had sorted. The respondents were asked their opinions about this compensation system. Table 16 below shows the types of compensation, the respondents would like households to have. About 37.5% would like households to pay taxes based on the amount of waste they produce and whether they sort their recyclables correctly, 25.0% to receive discount coupons at local shops and services, 18.8% to get improvements for the neighbourhood, 12.5% to pay lower taxes on waste if it is properly recycled.

Table 16: Opinion about the compensation system (n=16).

Compensation	**Count**	**%**
Households should pay taxes based on the amount of waste they produce and whether they sort their recyclables correctly.	6	37.5
Households should get points and then be able to exchange them for gifts or receive discount coupons for local shops and services.	4	25.0
Rewards should be used to improve the neighbourhood (children's playground equipment, parks, trees, green spaces, etc.).	3	18.8
Households should pay lower taxes on waste if it is recycled properly	2	12.5
Households should be rewarded for properly separating recyclable materials at home and disposing of them in appropriate containers.	1	6.3

General opinion on the PlastiCircle project

After their experience with PlastiCircle, the citizens were asked their opinion about the project; 75.0% of the respondents stated that their opinion was positive or very positive. There is only one negative comment: "*It is a poorly*

implemented project. The containers are open, the label dispenser does not work, and Polaris empties these containers over the household waste in the truck. I keep washing plastic packages and pressing them, but if they come mixing all in the truck, I do it for nothing."

All the respondents strongly agreed or agreed that after the project, they would like to continue sorting their waste.

The responses the most cited about what they liked the most about the project were their increased awareness of plastic recycling and how plastic is affecting the environment and nature. They would have also liked to see the project applied on a large scale in the city. They were also aware that increased knowledge and behaviour change are still required.

Regarding what they liked the least, they commented that the containers should have been closed to avoid that non-participants could throw household waste in the containers.

They commented that the label dispenser did not work as expected and that the containers were sometimes full. They would have liked that the containers could only be opened with the smart identification card. However, they also commented that they were pleasantly surprised to see non-participants putting non-labelled bags filled with plastics and plastic bottles in the containers.

They also would like larger containers, marked with colours to easily identify them, and understand their specific role.

6.2.3.4 Conclusion

The situation in Romania was quite different from the ones in Spain and the Netherlands. Romania is a country with early-stage recycling schemes and the cities need to focus on shaping the social norms for ensuring relevant behaviours. All the comments left by the citizens confirmed that they are willing to participate more in recycling, and they are aware of the challenges the municipalities are facing with irresponsible behaviours and unorganised waste management.

A large share of the citizens who participated in PlastiCircle were not satisfied with the current domestic waste management (71.4%). Even if they stated that

the containers are somewhat easy to access, they would like to see them clean and to be used properly. They also confirmed that they need to put recyclables quite often in the containers spread from once a day to once a week. They used the containers at different times of the day according to their needs. Around 26% are aware of the time periods when the containers are always full. Unfortunately, around 10% stated that they leave their trash bags by the container when they could not put them in the container and 5% in any container even if it is not the right one.

A large share also stated that they already know which products are recyclables or made of recycled materials (84.2%). They all agreed that recycling is important for them, their family, and the society in general. The results showed that they are conscious of environmental and economic issues. This is a good result showing that they are ready to make efforts to participate more in recycling schemes. This is confirmed by their enthusiasm concerning the participation of the municipality in PlastiCircle. They understood the opportunity of a large-scale implementation of a new plastic waste management and extending the pilot study to a city level.

The participants experienced some technical issues regarding the use of the label dispenser. Concerning the bags to fill with recyclables, they answered that the bags were fit for purpose, large enough, durable, and easy to use. For 43.8% of the post-group, it took them a week to fill one bag.

They also appreciated the information and support provided by the municipality to explain how to sort the plastics and use the containers properly. Questionnaires, online meetings, the project platform, and activities as well as the information provided by the kiosks were found useful. These results confirmed the importance of involving the citizens when putting in place new waste systems or recycling schemes. Symbolic rewards provided to the participants based on the quality and quantity of the plastics they sorted at home and delivered in the containers, are stimulating. However, they would like to get other types of compensation such as to pay less tax, to get discount coupons, or discounts at local shops. Improvements for the neighbourhood were also found as attractive.

All these results showed that the citizens are willing to change their behaviour, and to make more efforts to sort their plastics at home. However, they would like to see in place a functioning plastic recycling chain.

6.3 SLCA

This S-LCA have provided information on social impact of plastic packaging waste management systems of the three cities involved on PlastiCircle project: Valencia, Alba Iulia and Utrecht. The comparison between the situation before and after the implementation of the pilot have served to obtain information on the social benefits of applying the PlastiCircle concept to the waste management systems in the European countries.

This assessment has adapted the UNEP *Guidelines for Social Life-Cycle Assessment of Products* (2020) which correspond to ISO 14040 and 14044 standards for *Life-Cycle Assessment*. Indicators were identified and linked to impact categories. 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. Results of this social impact assessment after the the complete evaluation of the answers obtained from the stakeholders are shown in the Table 17.

Table 17. Classification of subcategories evaluated in PlastiCircle.

No.	Subcategorie	Valencia score	Alba Iulia score	Project score
1	Consumer privacy	3.50	4.75	4.13
2	Community engagement	4.75	3.25	4.00
3	Service satisfaction	4.25	3.13	3.69
4	Access to immaterial resources	4.38	3.00	3.69
5	Local employment	3.38	3.88	3.63
6	Feedback mechanism	3.25	3.75	3.50
7	Public commitment to sustainability issues	3.75	3.25	3.50
8	End of life responsibility	3.88	3.08	3.48
9	Technology development	3.25	3.63	3.44
10	Contribution to economic development	3.63	2.63	3.13
11	Transparency	2.75	3.38	3.06
12	Health and safety	3.00	2.75	2.88

The social impact of PlastiCircle project has been calculated as average of Valencia and Alba Iulia score, determining that the best evaluated impact categories have been "Consumer privacy“ (4.13), “Community engagement“ (4.00) and “Service satisfaction“ (3.69).

This S-LCA has provided a consistent view of social hotspots along the life cycle or value chain; ensuring hotpots are understood rather than overlooked in product sustainability efforts; and resulting help focus stakeholder questionnaires on certain aspects and add depth to sustainability reports. Finally, performed together with E-LCA, helps to understand the intersection of social and environmental issues, better aligning environmental sustainability efforts with social efforts.

7. Transport – Alba Iulia

The transport pilot in Alba Iulia was delayed due to several reasons. The first due to COVID situation and lockdown, all the pilot activities were postponed until summer. The installation of the can-bus in the truck was another delay. Alba Iulia municipality contacted several companies to install the can-bus in the truck without success. Finally, after several weeks they manage to install the device, in a situation without pandemic the installation would have been done by technicians from SAV travelling to Alba Iulia.

Once the pilot started, a communication problem between the CAN-bus and the platform started. The CAN-bus reader lost its internal configuration, then it was unable to send the data to the IoT platform. In addition, the mobile phone chose to run the app did not have stable 3G connectivity and the driver did not receive the indications to follow the routes.

The CAN-bus reader was uninstalled and sent back to SAV facilities to repair it. Once, it was repair, the CAN-bus was sent again to Alba Iulia to be reinstalled. All these shipments make a big delay in the transport part.

Finally, both route optimization and ecodriving were tested in Alba Iulia.

The route optimization 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 costs.
3. Optimise the route based on the filling level of the containers, skipping those containers which are not full the collection day.

The driving behaviour system had two phases:

1. 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.
2. Implement the alarm systems that alerts the driver when they are not driving in an eco-way.

IoT platform collected data and information from the pilot.

7.1 Route optimization

The route optimization is developed in three phases. In the first phase the traceability of the non-optimized route is recorded. These recorded routes will be the baseline for comparison of the following stages. In the second phase, the route is optimized using the PlastiCircle technology. The third phase includes the optimized route skipping the containers not full.

In Alba Iulia, the containers are small and need to be emptied every day, but there are some tentative containers able to be skipped.

In the following image (Figure 29), the position of the containers in the pilot area can be seen. The potential containers to skip are in blue.

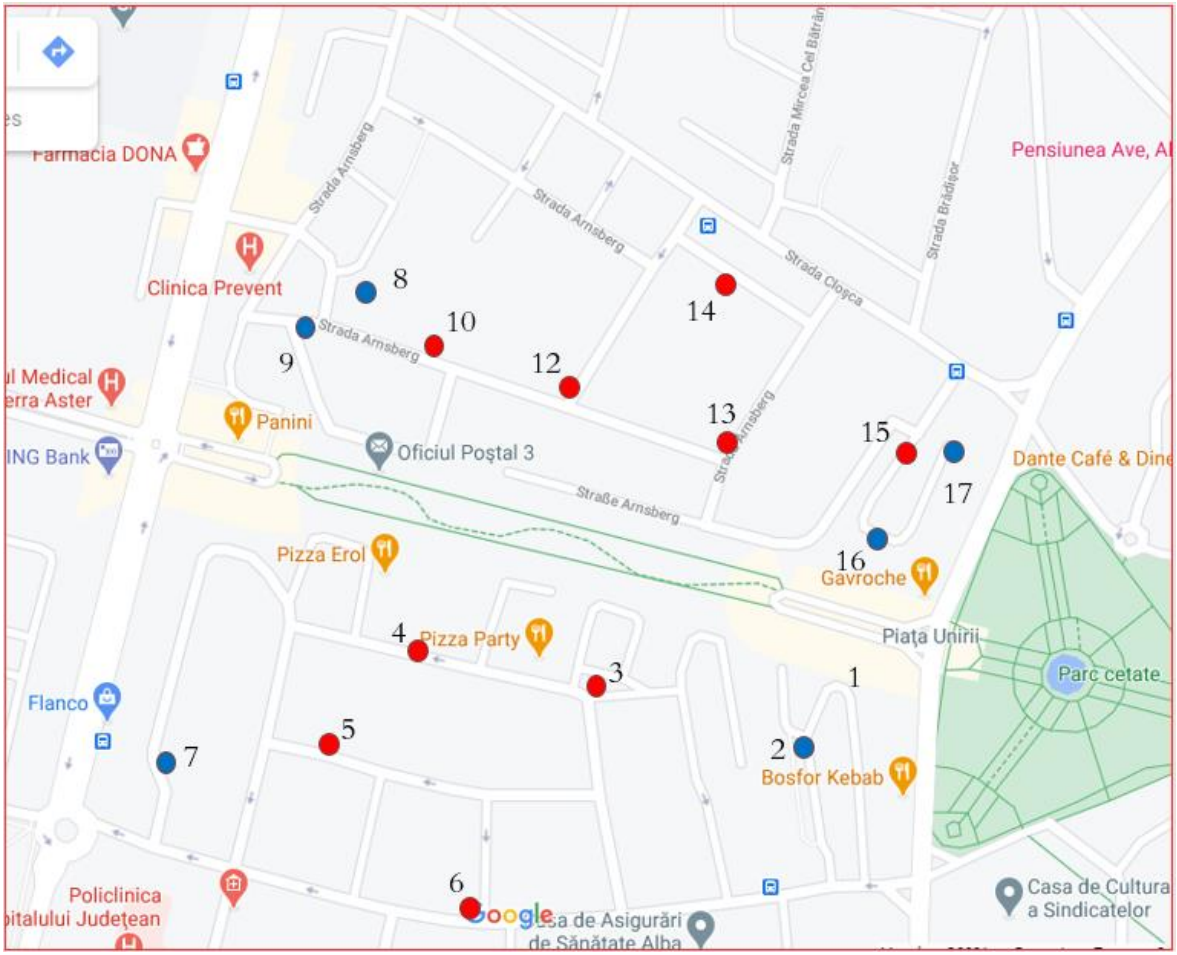

Figure 29. Position of the containers in pilot area. Locations 1 and 16 have 2 PlastiCircle containers

Phase 1: Measurement and analysis of the usual route performed by the driver collecting all the containers.

Several routes are collected from the phase 1 from September to October 2020. As explained before a connectivity problem form the can-bus made a delay in the phase 2 and 3 of the transport part of the pilot which took place on January 2021.

The usual route performed by the driver is not fixed. There are three different places to start the collection route in the area and consequently, different times, distances and consumptions. The pilot area has narrow and intrinsic streets that make difficult to drive the truck in some circumstances.

In the following images are presented three routes with the different starting points.

In the Figure 29 the route started from the top and ended at the same point. In the Figure 30 the route started from below and ended on the top. In the Figure 31 the route started on the top and ended in a different point on the top.

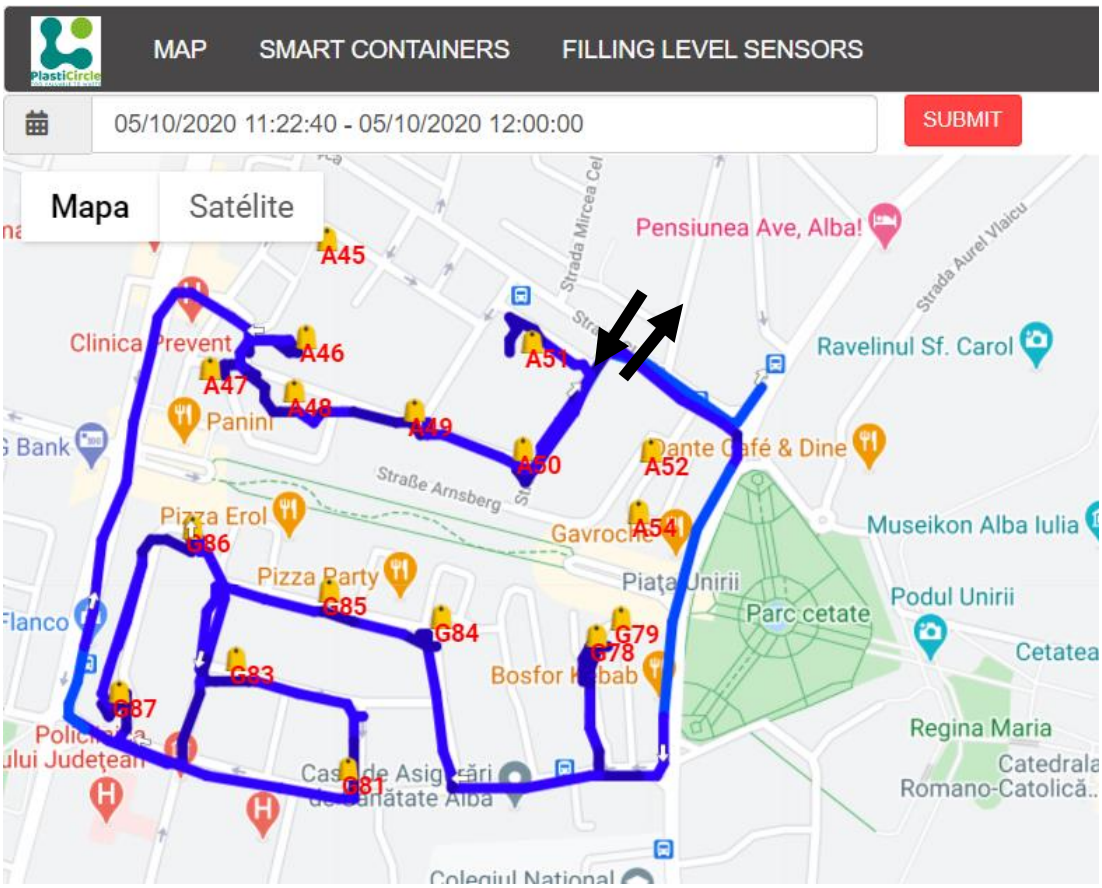

Figure 29. Image of the route without optimization starting from the top and ending at the same point.

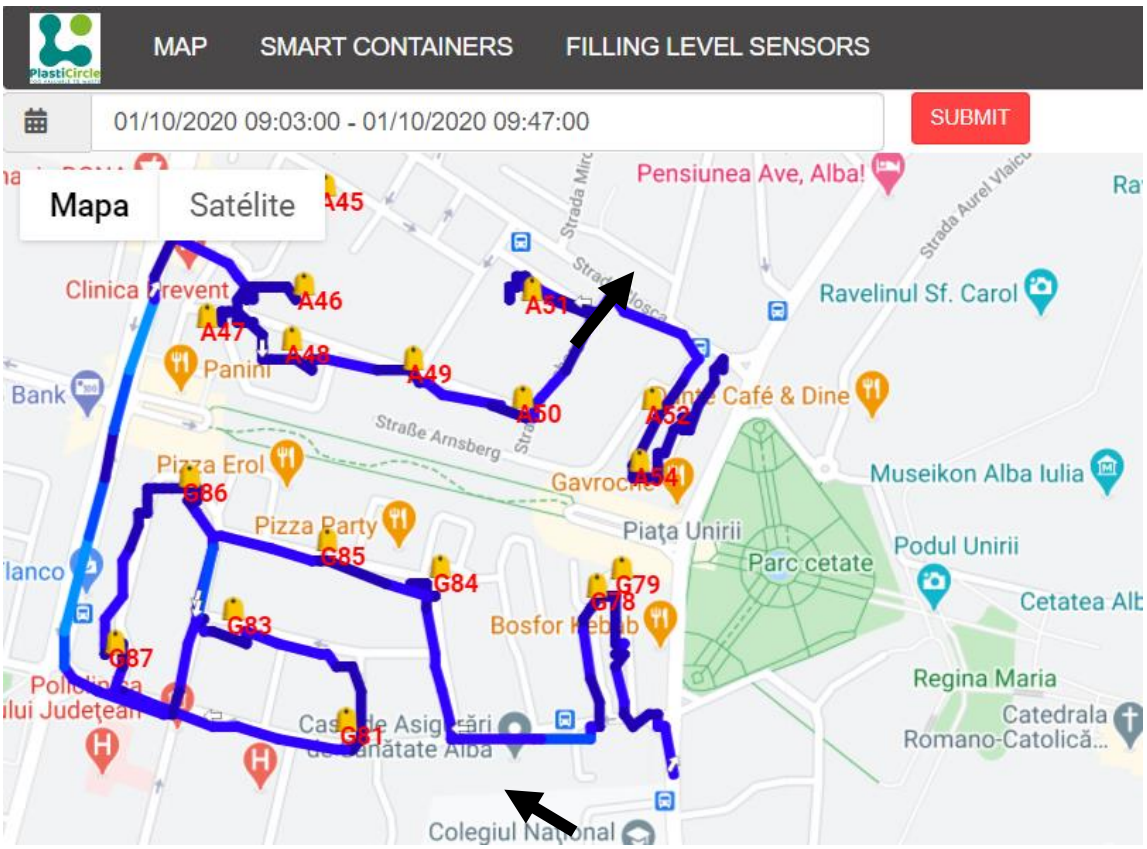

Figure 30: . Image of the route without optimization starting from the bottom.

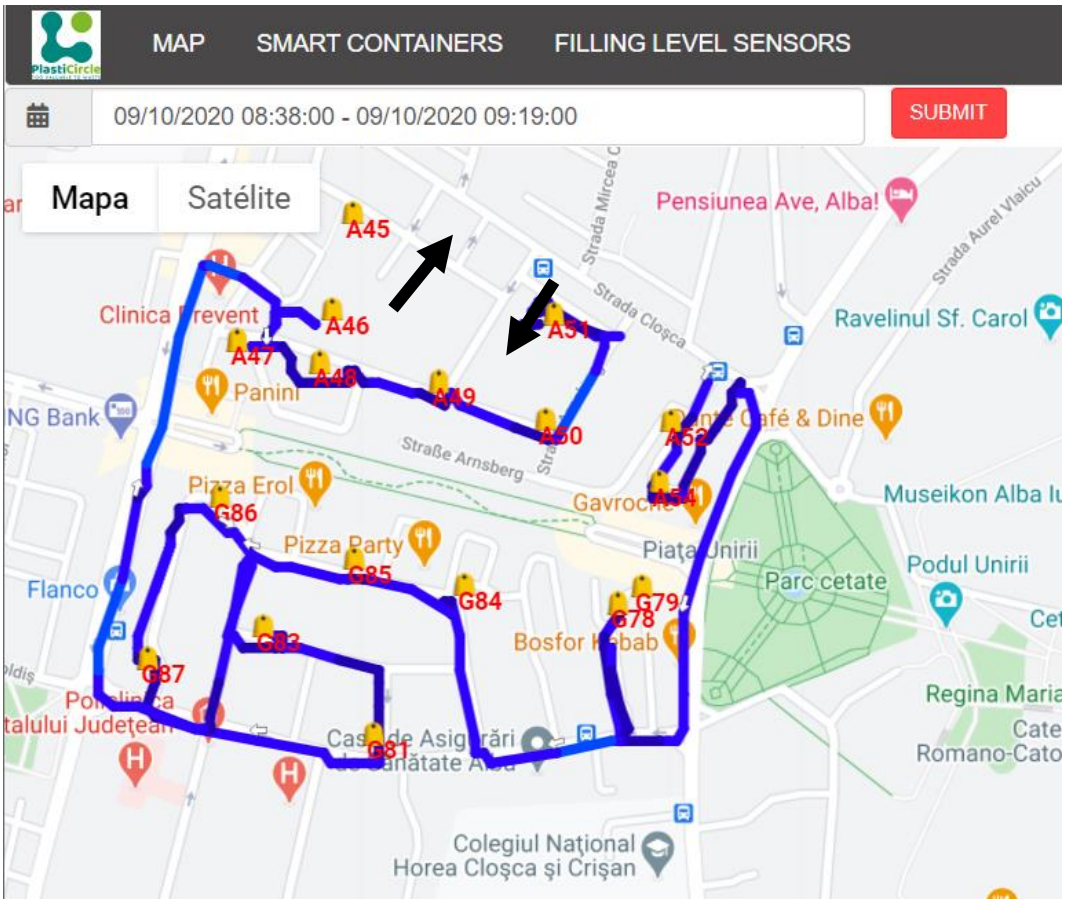

Figure 31 Image of the route without optimization starting from the top and ending at different point.

In the following table 18 are shown the characteristics of the routes and the information collected in the IoT platform.

Table 18: Data from non-optimized routes

	Distance (m)	Time (s)	Consumption (l)	Speed max (km/h)	Avg. speed (km/h)
Average	3551	1695	4,3	28,31	7,38
Min	3000	1159	2,7	20	4
Max	4001	3796	4,5	36	10

Phase 2: Optimization of the current route collecting all the containers in order to minimize time and cost.

This phase started in January 2021.

The optimized route was calculated by the algorithm, but there was another problem. The pilot area has a very intrinsic and narrow streets. This situation made that the algorithm which is feed by Google Maps API did not have well

mapped the area for a waste truck. Google Maps API is used in the eco-driving app too. Some existing streets did not appear for the algorithm and the final route optimization was difficult to implement. Due to this, the optimized route was slightly manually modified to achieve the optimised one. This is usually the work that a waste manager does to adjust the route to the real conditions of their city. The case is presented in Figure 32 and Table 19.

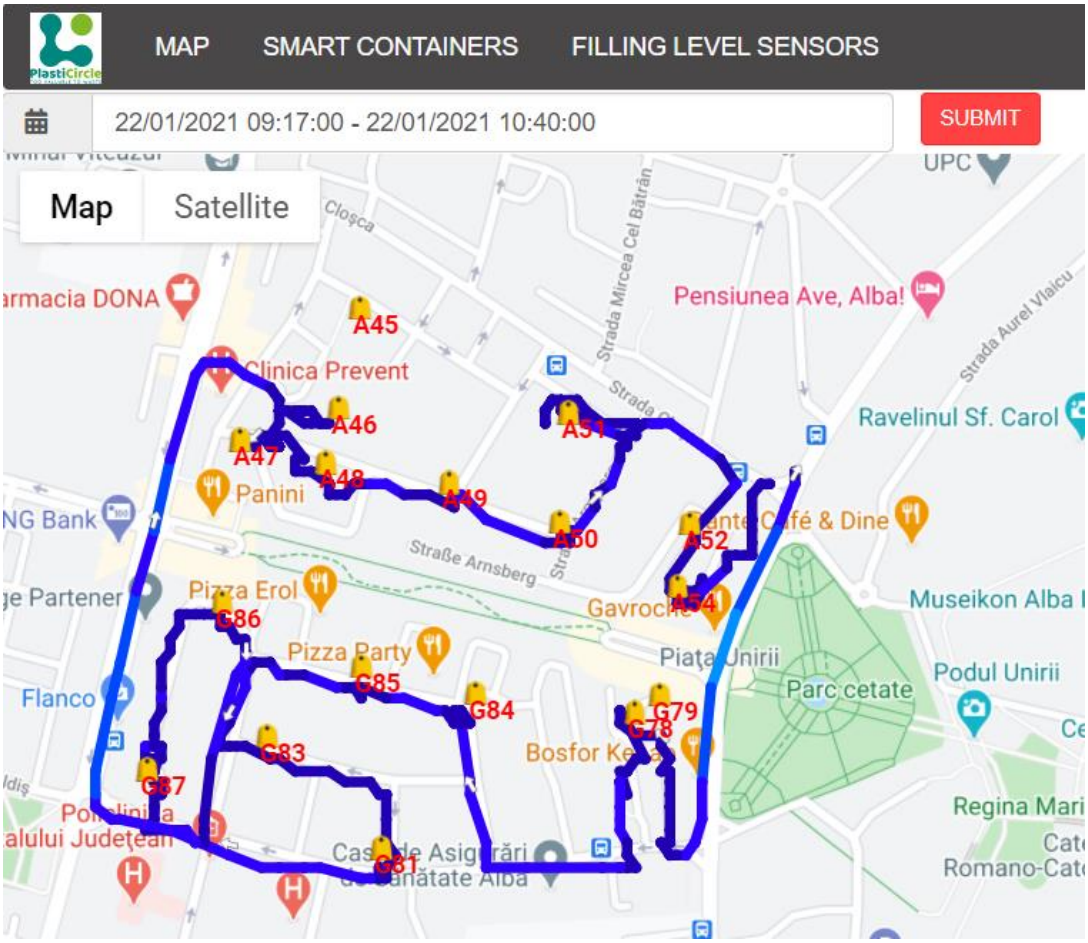

Figure 32: Optimized route performed by the truck taking the street against direction

Table 19: Results obtained on the IoT platform from the optimized route

	Distance (m)	Time (s)	Consumption (l)	Speed Max. (km/h)	Speed Aver. (km/h)
PlastiCircle route optimization	3481	1518	3.9	34	6

Due to the characteristics of the pilot area, the narrow and intrinsic streets, the route performed by the drivers was very similar to the optimized one. The results obtained from phase 1 to phase 2 provide slightly benefits. **Phase 3**: Optimization of the route based on the filling level of the containers, skipping those containers

which are not completely full.

The first step on this phase was to analyse the filling level of the containers to select the potential skipping containers.

The analysis was done with data from October 2020 when the pilot activity was running and the containers in the street only collected plastic waste. In this situation the potential skipping containers were 7. The situation changed and in January 2021 the Alba Iulia inhabitants threw away every type of waste. The filling level increased and some sensors due to the rain and the bad usage were broken. Finally, the available skipping containers with a low-medium filling level in January 2021 were 5: A54, G78, A46, A52, G87, Table 20

Table 20 Filling levels for pilot containers

Container ID	Potential Daily filling level 10/2020	Potential daily filling level 01/2021	LEVEL	SKIP?
G79	86,16%	91,92%	High	NO
G84	76,08%	105,84%	High	NO
G83	115,92%	115,92%	High	NO
A50	82,32%	105,12%	High	NO
A54	49,20%	68,88%	Medium	YES
A45	20,40%	20,40%	Low	Broken
G78	38,88%	42,24%	Medium	YES
A46	50,88%	70,80%	Medium	YES
A48	100,32%	110,16%	High	NO
G86	101,76%	101,76%	High	Broken
A51	90%	102%	High	NO
A53	72,40%	91,68%	High	NO
A52	56,16%	73,44%	Medium	YES
A49	100,80%	116,16%	High	NO
G85	89,76%	109,20%	High	NO
A47	26,16%	69,84%	Low	Broken
G87	28,32%	51,60%	Low	YES

If the truck skips A47, A46 or G87 the route would be modified but A52 and A54 did not provide a modification of the route because the truck pass in every situation in front of them, the only saving would be the truck operation time for emptying.

In the following images can be seen the routes skipping containers:

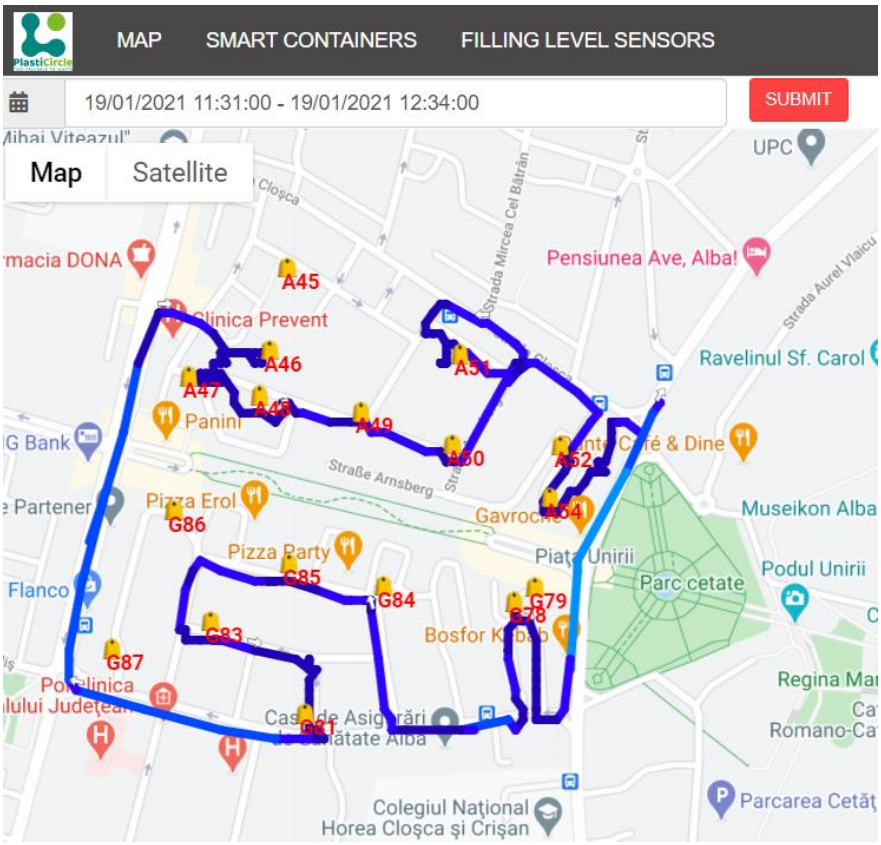

Figure 33: Optimized route skipping containers G87, G86 and A54

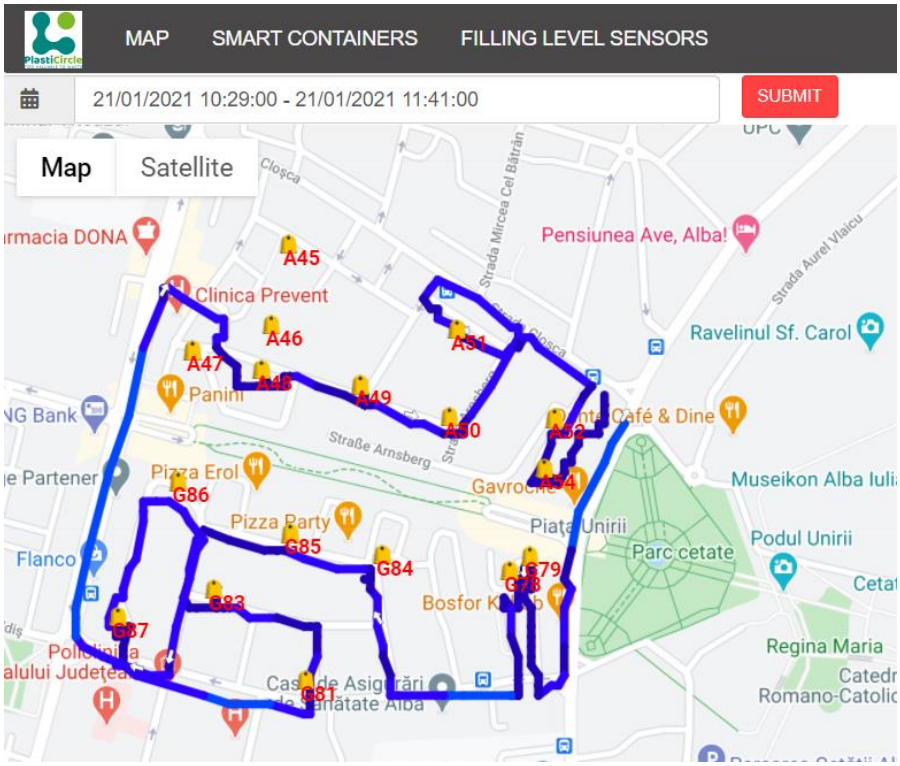

Figure 34: Optimized route skipping containers A47 and A 46

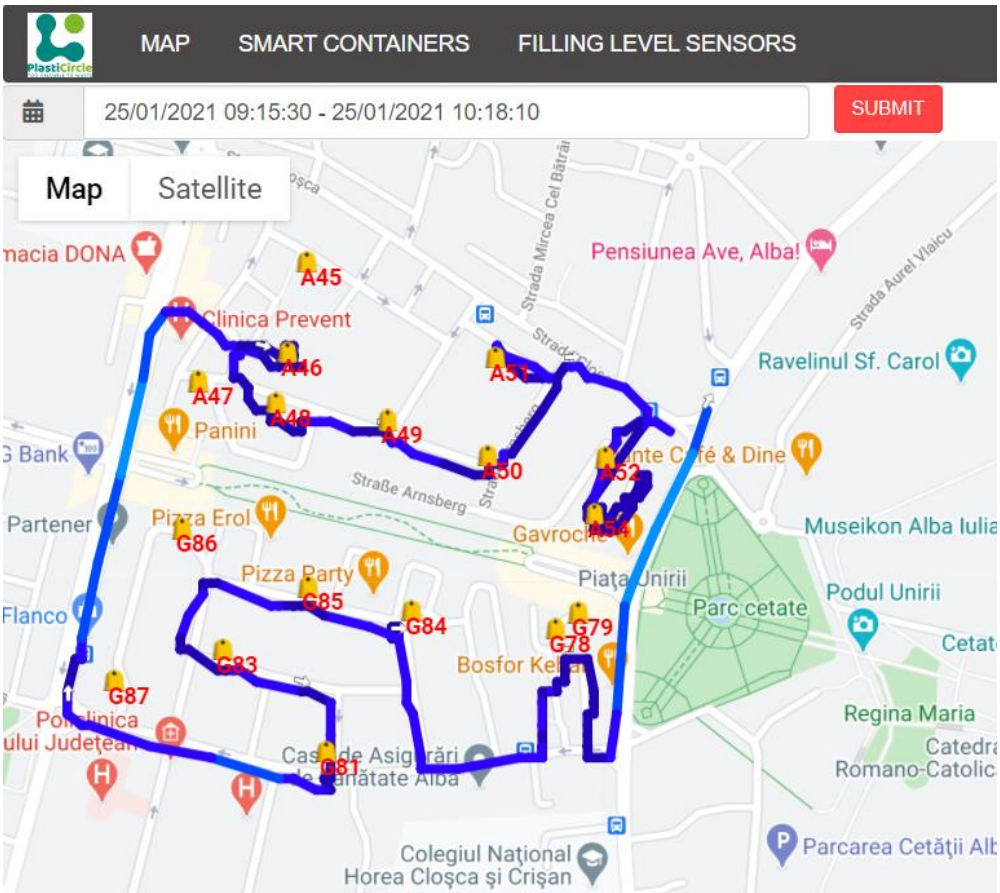

Figure 35: Optimized route skipping containers G86, G87 and A47

In the following Table 21 are shown the parameters collected in the IoT platform per each route.

Table 21: Results obtained in the IoT platform from the skipping containers routes

	Time (s)	Distance (m)	Consumption (l)	Speed Max. (km/h)	Speed Aver. (km/h)
Skipping G87	**1581**	**2744**	**5,1**	**30**	**7**
Skipping A46 and A47	**1432**	**3251**	**3,9**	**28**	**7**
Skipping G87 and A47	**1485**	**2446**	**2,5**	**36**	**7**

The phase 3 was shorter than initially expected due to the delays and due to the truck had engine problems. The minimum needed routes were performed to analyse and compare the results.

Comparing the results obtained, the optimized route skipping containers improves all the parameters in comparison to the optimized route with all the containers.

During the performance of the skipping container phase and due to the unavoidable delays, most of the filling level sensors where broken due to the rain and the bad usage. Therefore, the data to calculate the improvement of the filling level during the skipping phase cannot be obtained. Consequently, we have estimated the filling percentage skipping containers based on the daily rate. The estimation was done following the filling level in October. The containers with a filling level higher than 50% are maintained because are emptied every day. The containers with above 50% would be skipped, so in the estimation column they increased.

Table 22 Filling levels and result of skipping containers

Container ID	Potential Daily filling level 10/2020	Estimation result skipping containers
G79	86,16%	86,16%
G84	76,08%	76,08%
G83	100,00%	100,00%
A50	82,32%	82,32%
A54	49,20%	98,40%
A45	20,40%	40,80%
G78	38,88%	77,76%
A46	50,88%	50,88%
A48	100,00%	100,00%
G86	100,00%	100,00%
A51	90%	90,00%
A53	72,40%	72,40%
A52	56,16%	56,16%
A49	100,00%	100,00%
G85	89,76%	89,76%
A47	26,16%	52,32%
G87	28,32%	56,64%
	68,63%	**78,22%**

We estimated that the filling level would increase a 9,59%.

7.2 Eco-driving

As described in deliverable 3.3, an Android application was developed to receive

data from the vehicles through CAN-BUS reader via Bluetooth. The data collected from the CAN-BUS was:

- GPS location
- Speed (Km/h)
- Revolutions per minute (RPM)
- Engine load (%)

With this data, acceleration can be calculated by the numerical differentiation of the velocity. As described in D.3.3, some characteristics events as excessive idling and emptying of containers can be detected from this data. Excessive idling can be obtained when speed is cero, revolutions per minute are bigger than 0 and smaller than 800 RPM during more than 40 seconds. While emptying of containers is detected when speed is cero and revolutions per minute > 900 RPM for a period bigger than 20 seconds.

Data from the vehicle is retrieved at 1 Hz and temporarily stored in an SQLite database inside the Android application and sent to the IoT in packages of JSON arrays.

Sound alarms were emitted through the developed Android application when driver excessed the following parameters:

- Speed > 80 km/h
- Excessive idling > 120 seconds
- Acceleration and braking > 7 m/s
- Power take off > 50 seconds

In the case of the RPM the alarm is set up depending of the engine characteristics after analysing the RPM in which the engine operates. In the case of Valencia pilot, the truck was a Mercedes Atengo. In this case the RPM alarms were triggered above 1300 RPM. While in the Alba Iulia pilot, the truck used was an IVECO Eurocargo. In this case the alarm was set up above1800 RPM.

Sound alarm are emitted with a beep to advise the driver to amend the driving in a more sustainable way. In addition, the type of alarm is displayed in the screen of the app with an icon as an indication. But driver does not need to visualize this indication, since the APP is designed to advise the driver with a beep sound instead to watch this indication in the screen. Figure 36 show some of the icons displayed by the eco-driving app.

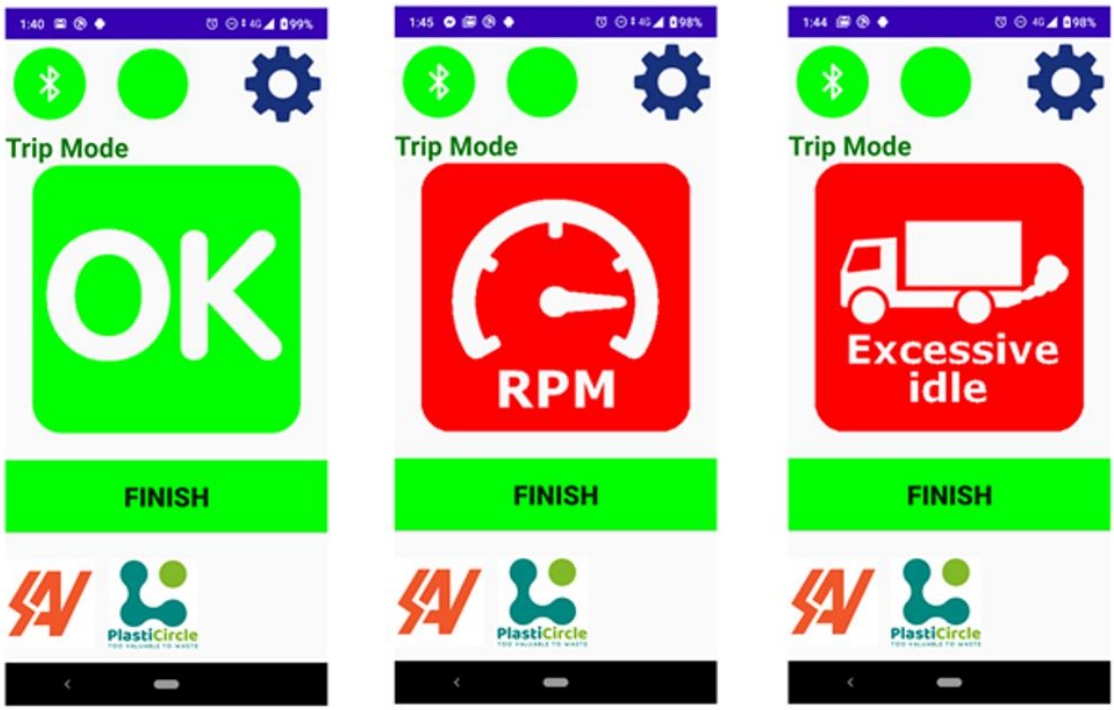

Figure 36 Screenshots of the eco-driving app showing some eco-driving indications.

The use of different types of trucks between Valencia and Alba Iulia made to use different CAN-BUS reader. In the case of Valencia, an OBD II reader was used to read data from the vehicle. But in the case of Alba Iulia, the OBD II reader was not compatible with the vehicle, then a reader connected directly with the CAN-Bus was used. In both cases the device connects to the eco-drivig APP via Bluetooth.

From the routes performed in the Valencia and Alba Iulia pilots with the eco-driving system, it was observed that the maximum speed of the truck inside the

pilot area was reduced from 52 km/h to 45 km/h in the case of Valencia pilot. But not improvement of maximum speed was detected in the Alba Iulia pilot. One important factor for this is that the pilot area in Alba Iulia is a smaller area compared to the Valencia pilot, also with more narrow streets. The average speed inside the pilot area was slightly reduced from 8 km/h to 7 km/h in the Valencia pilot but the average speed remained as 7 km/h in the Alba Iulia pilot. It was registered a considerable reduction of the RPM. The average RPM was reduced from 895 RPM to 855 RPM in the Valencia pilot while average RPM was reduced from 1179 to 1147 RPM in the Alba Iulia pilot. The excessive idling was reduced in the Valencia pilot from 81 seconds average per route in the pilot area to 61 seconds. This means a reduction of 24%. In the case of the Alba Iulia pilot, the excessive idling time was slightly reduced from 689 seconds as average in a route to 658 seconds.

7.3 Post-pilot repeated eco-driving in Valencia

The eco-driving system was tested again in Valencia in one truck during the months of September to November of 2020. The truck used in this case was an IVECO Eurocargo very similar to the one used in Alba Iulia. The CAN-Bus reader was the same used in the Alba Iulia pilot.

In order to evaluate the benefits of the eco-driving system, the CAN-Bus reader was operating in “hiding mode”, i.e. retrieving data from the truck without sound alarms to the driver. This eco-driving system operated in this mode during one month. After this period, a tablet was installed in the truck on board with the eco-driving app. The driver was trained for using this app. With the eco-driving app on board, the eco-driving system with sound alarms were used during one month more. In both modes, data from the truck was stored in the IoT platform.

Comparing the fuel consumption during the hiding mode and the mode with sound alarms, the average fuel consumption rate per route was 33.5 litres/100km in the hiding mode while the average consumption rate per route was 29.6 litres/100km in the mode with sound alarms. This means a 11% of fuel saving between both modes.

About the speed, the average speed for the routes did not change significantly between both modes but the maximum speed reached in the route decreased in

average from 90 km/h to 81 km/h between the hiding mode and the mode with sound alarms, respectively.

Same as the speed, the average RPM did not change significantly, but the maximum RPM reached in the route decreased as average from 2700 RPM to 2200 RPM.

Another important eco-driving parameter that was reduced during the use of the eco-driving system was the idling time. This was reduced from 1711 seconds as average by route before the eco-driving system, I.e. hiding mode to 827 seconds while using the eco-driving system, I.e. mode with sound alarms. This means a reduction of the 51% of the idling time.

8. Pilots' KPI summary

To evaluate the impact of the pilots in this project selected environmental key performance indicators (KPI) were chosen, as described below:

KPIs for transport:

K1: Distance travelled: the existing distance from a starting point (A) to a point of arrival (B) of the planned route and the units will be kilometres (km).

K2: Time travelled: it is the time since the vehicle leaves the waste manager depot, until it returns to the facilities once the route is completed. The units are minutes (min) or hours (h).

K3: Collections performed: number of containers collected during the route. The unit will be the total number of containers served.

K4: Relative CO_2 emission:
K4.1 = CO_2/Tonne collected
K4.2 = CO_2/driven distance (km)

K5: Performance:
K5.1 = energy cost/tonne collected
K5.2 = (personal & energy) cost/tonne collected
K5.3 = % inappropriate materials in RSU containers

K6: Fuel consumption: amount of fuel consumed by the vehicle to carry out the

programmed route. The units are litres of diesel (l).

KPIs for citizen's characterisation: The results will be based on characterisation performed to the citizens' waste bags; the main objective is to improve the citizens characterisation taking place at home.

K7: % Not packaging waste: Global percentage of unwanted material found in the characterised bags, before and after the pilot.
K7.1: % in number
K7.2: % in weight

K8: % No empty packaging: Global percentage of number of packaging that still contain product inside

K9: % stacked packaging: Global percentage of heaped packaging (one packaging inside of another)

K10: % compacted bottles: Percentage of the number of bottles compacted.

K11: % selective collection rate: fraction of plastic packaging waste collected. Global characterization of packaging waste from San Marcelino will be subcontracted by SAV.

K12: Compaction level in container – kg/m^3

K13: Filling level. % fill level when trucks unloads

Transport KPI's summary

Table 23 below summarizes the transport KPI's of Valencia and Alba Iulia, which tested the route optimisation during the pilot phase.

Table 23 Transport KPI's of Valencia and Alba Iulia

	Valencia			Alba Iulia		
KPI	**Pre-pilot**	**Optimized route**	**Skipping container**	**Pre-pilot**	**Optimized route**	**Skipping containers**
K1 [km]	8.6	7.0	5.9	3.6	3.5	2.8
K2 [min]	59.4	48.6	43.3	28.3	25.3	25.0
K3 [#]	26	26	19	16	16	14
K4						
K4.1 [kg/t]	25	26	26	9.6	8.7	8.5
K4.2 [kg/km]	2.33	2.71	2.95	3.2	3.0	3.6
K5						
K5.1 [€/t]	12	12	12	3.9	3.5	3.4
K5.2 [€/t]	43	47	51	2.89	28.5	28.4
K5.3 [%]	74	67	67			
K6 [l]	7.7	7.3	6.7	4.3	3.9	3.8
K6 [km/l]	1.12	0.96	0.88	0.83	0.89	0.74
K13 [%]	51.6	-	59.1	68.6		78.2[1]

As expected, the optimisation of transport routes as well as skipping containers that are not full has led to significant savings compared to the initial situation. Both in Valencia and Alba Iulia it yielded about:

- 21-41% savings in distance travelled (K1).
- 12-32% savings in the duration of waste collection operations (K2).
- 12-22% savings in fuel consumption (K6).
- 7.5-10% increase filling level when containers are collected (K13).

Utrecht used already route optimisation from before. However, we saw variations in the length of the route (K1) and number of containers (K3) due to seasonal changes. The end of the pilot was around Christmas where the amount of waste was increased.

Table 24 *Transport KPI's of Utrecht*

	Utrecht		
KPI	**Pre-pilot**	**Mid-pilot**	**End-pilot**
K1 [km]	68	79	78
K2 [min]	137.2	152.9	158.6
K3 [#]	45	50	50

Waste characterization KPI's summary

The table below shows good effects of the pilot versus pre-pilot as well as differences between pilot users and non-users for non-packaging waste (K7),

compacted bottles (K10), and collection rate of plastics packaging (K11). Specifically, the collection rate shows an improvement of 12 percentage points for the pilot users in Valencia compared to the non-users and

Table 25 wsate characterization KPI's of Valencia and Alba Iulia

	Valencia			Alba Iulia		
KPI	**Pre-pilot**	**Pilot users**	**Pilot non-users**	**Pre-pilot**	**Pilot users**	**Pilot non-users**
K7.1 [%]	14	3	18	22	8.9	18.6
K7.2 [%]	22	9	27	-	-	-
K8 [%]	1.14	1.6	0.9	12.6	8.1	11.2
K9 [%]	1.2	1.3	1.7	13.4	7.2	12.3
K10 [%]	32	74	28	19.6	64	20.1
K11 [%]	30	38	26			
K12 [%]	30	-	-			

The results from the Valencia pilot suggest a possible positive effect on the citizens behaviour regarding the unwanted material (K7.1) and the compacted packaging (K10) percentages: a decrease of 11 points and an increase of 42 points, respectively, were attained. The other two variables considered, non-empty (K8) and stacked packaging (K9), were not significantly affected. Both variables' values were already low at the beginning of the pilot.

Regarding Alba Iulia, the individual characterization shows a clear effect of the information campaign during the pilot as seen from the numbers on pilot users vs. non-users in the table above. All characterization KPI's are significantly improved for the pilot users.

9. Conclusions

This report sums up the final work from the pilot cities. A general description of each pilot is given as background to the reader.

The main part of the report consists of questionnaires addressed to participants. These were addressed to citizens, the city administrations and waste managers of the pilot cities. Results for cities and waste managers are reported in D7.5.

The participation in the pilots varied a lot between the cities. Citizens are willing to change behaviour. There is more awareness about recycling but there is a need for evidence on recycling of the waste and to see effects on the neighbourhood.

Life Cycle Analysis provided information on social impact of plastic packaging

waste management systems of the three cities. The comparison between the situation before and after the implementation of the pilot have served to obtain information on the social benefits of applying the PlastiCircle concept to the waste management systems in the European countries.

As a check of repeatability of the results, data from the final pilot were compared with the mid-pilot data. Improvements on waste composition were reported in Valencia. In Utrecht one had already observed that seasonal variations could dominate as the pilot included the Christmas period.

A summary of the waste sorting development reported in D4.5 is included displaying results for both yield and purity in line with project objectives.

The reported KPI's show improvements related to both citizens' waste sorting and transport. In some cases, individual aspects of the pilots make comparisons less relevant.

We include final results on transport optimization and eco-driving in Alba Iulia. These data were delayed due to covid restrictions. Covid also has led to delayed eco-driving in Utrecht. In this moment this situation seems to have improved and Utrecht results may be available to be included in updated reports before the end of the project.

10. References

Ajzen, I. (1991). The theory of planned behaviour. Organizational Behavior and Human Decision Processes, 50 (2) (1991), pp. 179-211. Available at: https://doi.org/10.1016/0749-5978(91)90020-T

Brough, A.R., Wilkie, J.E., Ma, J., Isaac, M.S., Gal, D. (2016). Is Eco-Friendly Unmanly? The Green-Feminine Stereotype and Its Effect on Sustainable Consumption. Journal of Consumer Research. Vol 43, Issue 4, Pages 567-582.

Botetzagias, I., Kevrekidou, M., Malesios, C., Jones, N. (2020). Exercising social control in PAYT (Pay-As-You-Throw) violations: The role of subjective evaluations and social capital. Waste management. Vol 15, p. 347-354.

Chamizo-González, J., Cano-Montero, E.I., Munoz-Colomina, C.I. (2016). Municipal solid waste management services and its funding in Spain. Resour. Conserv. Recycl. 107, 65-72. Available at:

https://doi.org/10.1016/j.resconrec.2015.12.006.

Cheung, S.F., Chan, D.K.S., Wong, D.C. (1999). Reexamining the Theory of Planned Behavior in Understanding Wastepaper Recycling. Environment and Behavior, 31(5), 587–612. https://doi.org/10.1177/00139169921972254

Elia, V., Gnoni, M.G., Tornese, F. (2015). Designing Pay-As-You-Throw schemes in municipal waste management services: A holistic approach. Waste management. Vol 44, P. 188-195.

European Commission (2019). A European strategy for plastics in a circular economy. Available at: https://ec.europa.eu/environment/circular-economy/pdf/plastics-strategy-brochure.pdf

Greaves, M., Zibarra, L.D., Stride, C. (2013). Using the theory of planned behavior to explore environmental behavioral intentions in the workplace. Journal of Environmental Psychology. Vol 34, June 2013, p 109-120. https://doi.org/10.1016/j.jenvp.2013.02.003

Hall, M. (2014). Women better at recycling then men. Business waste.co.uk. https://www.businesswaste.co.uk/women-better-at-recycling-then-men/

Jeżewska-Zychowicz, M., Jeznach, M. (2015). Consumers' behaviours related to packaging and their attitudes towards environment. Journal of Agribusiness and Rural Development 3 (37), 447–457. Available at: http://dx.doi.org/10.22004/ag.econ.253597

Khan, F., Ahmed, W., Najmi, A. (2019). Understanding consumers' behavior intentions towards dealing with the plastic waste: Perspective of a developing country. Resources, Conservation & Recycling 142 (2019) 49-58.

Mahmud, S.N., Osman, K. (2010). The determinants of recycling intention behavior among the Malaysian school students: an application of theory of planned behaviour. Procedia-Social and Behavioral Sciences. Vol 9, 2010. P 119-124.

Nigbur, D., Lyons, E., Uzzell, D. (2010). Attitudes, norms, identity, and environmental behaviour: using an expanded theory of planned behaviour to predict participation in a kerbside recycling programme. Br. J. Soc. Psychol. 49 (2), 259–284.

Oztekin, C., Teksöz, G., Pamuk, S., Sahin, E., Kilic, D.S. (2017). Gender

perspective on the factors predicting recycling behavior: Implications from the theory of planned behavior. Waste management. Vol 62. 290-302.

Park, J., Ha, S. (2014). Understanding Consumer Recycling Behavior: Combining the Theory of Planned Behavior and the Norm Activation Model. Family and Consumer Sciences Research Journal. Vol 42, No 3, March 2014, 578-291.

Roche-Cerasi, I., Sánchez, F.V., Gallardo, I., Górriz, M.Á., Torrijos, P., Aliaga, C., Franco, J. (2021). Household plastic waste habits and attitude. A pilot study in the city of Valencia. Waste management & Research; The journal for a sustainable Circular Economy.

Sharp, A., Høj, S., Wheeler, M. (2010). Proscription and its impact on anti-consumption behaviour and attitudes: the case of plastic bags. Journal of Consumer Behaviour 9 (6), 470–484. Available at: https://doi.org/10.1002/cb.335.

Tonglet, M., Phillips, P., Read, A.D. (2004). Using the Theory of Planned Behaviour to investigate the determinants of recycling behaviour: a case study from Brixworth, UK. Resources, Conservation and Recycling. Vol 41, Issue 3, June 2004. P 191-214.

Wagner, T.P. (2017). Reducing single-use plastic shopping bags in the USA. Waste management Vol 17, (2017) 3-12. Available at: https://doi.org/10.1016/j.wasman.2017.09.003

WasteZero.com. Pay-As-You-Throw Trash Metering. Available at: https://www.wastezero.com/payt (accessed 14 December 2020).

Yin, J., Gao, Y., Xu, H. (2014). Survey and analysis of consumers' behaviour of waste mobile phone recycling in China. J. Clean. Prod. 65, 517–525.

11. Annex 1

Here we included the details of the waste characterization from the pilots:

VALENCIA CHARACTERISATIONS	REFERENCE				MID PILOT				Final PILOT					
	Light Packaging		Residual waste		Light Packaging		Residual waste		LP - Non Users		LP - Users		Residual waste	
	Quantity (kg)	Weight (%)	Quantity (kg)	Weight (%)	Quantity (kg)	Weight (%)	Quantity (kg)	Weight (%)	Quantity (kg)	Weight (%)	Quantity (kg)	Weight (%)	Quantity (kg)	Weight (%)
PET Packaging:	**47,26**	**23,29 %**	**2,37**	**1,13%**	**66,63**	**31,63 %**	**4,08**	**1,82%**	**53,06**	**26,62 %**	**33,55**	**30,46 %**	**3,6**	**1,64%**
PET	31,42	15,49%	1,56	0,74%	56,38	26,76%	3,35	1,49%	51,34	25,76%	25,5	23,15%	2,35	1,07%
PET Multilayer	15,84	7,81%	0,81	0,39%	10,25	4,87%	0,73	0,32%	1,72	0,86%	8,05	7,31%	1,25	0,57%
HDPE Packaging:	**27,19**	**13,40 %**	**0,32**	**0,15%**	**20,45**	**9,71%**	**1,32**	**0,59%**	**15,57**	**7,81%**	**8,81**	**8,00%**	**1,09**	**0,50%**
HDPE Natural	18,94	9,34%	0,23	0,11%	14,25	6,76%	1,09	0,49%	11,2	5,62%	7,53	6,84%	0,47	0,21%
HDPE Colour	7,33	3,61%	0,09	0,04%	6,2	2,94%	0,23	0,10%	4,37	2,19%	1,28	1,16%	0,62	0,28%
HDPE Injection	0,92	0,45%	-	-	-	-	-	-	-	-	-	-	-	-
PP rigid														
Mixed Plastic Packaging:	**13,02**	**6,42%**	**2,2**	**1,05%**	**15,77**	**7,49%**	**2,05**	**0,91%**	**12,77**	**6,41%**	**10,1**	**9,17%**	**3,38**	**1,54%**
Metal Packaging:	**19,98**	**9,85%**	**1,28**	**0,61%**	**16,8**	**7,98%**	**2,51**	**1,12%**	**18,37**	**9,22%**	**14,94**	**13,57 %**	**4,56**	**2,07%**
Ferrous	11,55	5,69%	0,72	0,34%	11,35	5,39%	1,65	0,73%	10,31	5,17%	8,27	7,51%	1,46	0,66%
Aluminium (Beverage/food)	8,43	4,16%	0,56	0,27%	5,45	2,59%	0,86	0,38%	8,06	4,04%	6,67	6,06%	0,71	0,32%
Aluminium (Commercial/Industrial)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Otros metálicos	-	-	-	-	-	-	-	-	-	-	-	-	2,39	1,09%
Paper&CB Beverage/Food:	**23,52**	**11,59 %**	**0,81**	**0,39%**	**15,1**	**7,17%**	**1,07**	**0,48%**	**20,33**	**10,20 %**	**16,11**	**14,63 %**	**1,28**	**0,58%**
Film:	**28,11**	**13,86 %**	**9,99**	**4,76%**	**26,04**	**12,36 %**	**10,44**	**4,65%**	**24,47**	**12,28 %**	**17,03**	**15,46 %**	**8,08**	**3,67%**
Film Bolsa Basura	0,94	0,46%	2,29	1,09%	2,39	1,13%	2,73	1,21%	0,89	0,45%	3,77	3,42%	2,48	1,13%
Film T-Bag	6,25	3,08%	1,6	0,76%	5,25	2,49%	2,84	1,26%	6,42	3,22%	0,46	0,42%	1,65	0,75%
Film Industrial Packaging	3,14	1,55%	1	0,48%	5,58	2,65%	0,52	0,23%	2,69	1,35%	-	-	-	-
Other Film	17,78	8,76%	5,1	2,43%	12,82	6,09%	4,35	1,94%	14,47	7,26%	12,8	11,62%	3,95	1,80%
Resultant Waste Fractions		21,59%		91,91%		23,66%		90,43%		27,46%		8,71%		10,00%
Organic:	**-**	**-**	**51,82**	**24,68 %**	**6,64**	**3,15%**	**70,39**	**31,32 %**	**4,78**	**2,40%**	**1,63**	**1,48%**	**72,28**	**32,87 %**
Domestic organic fraction	-	-	50,68	24,14%	6,53	3,10%	55,32	24,62%	4,78	2,40%	1,63	1,48%	71,42	32,48%
Non-domestic organic fraction	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vegetable/garden fraction	-	-	1,14	0,54%	0,11	0,05%	15,07	6,71%	-	-	-	-	0,86	0,39%
Paper and cardboard:	**10,21**	**5,03%**	**28,81**	**13,72 %**	**5,13**	**2,44%**	**27,04**	**12,03 %**	**8,63**	**4,33%**	**1,35**	**1,23%**	**26,98**	**12,27 %**

Paper	1,69	0,83%	7,55	3,60%	0,58	0,28%	6,56	2,92%	2,28	1,14%	0,21	0,19%	6,92	3,15%
Cardboard	8,52	4,20%	21,26	10,12%	4,55	2,16%	20,48	9,11%	6,35	3,19%	1,14	1,04%	20,06	9,12%
Wood:	**-**	**-**	**1,57**	**0,75%**	**3,37**	**1,60%**	**24,11**	**10,73 %**	**4,01**	**2,01%**	**0,03**	**0,03%**	**10,23**	**4,65%**
Wood Packaging	-	-	-	-	0,01	0,00%	0,04	0,02%	0,74	0,37%	-	-	3,76	1,71%
Wood NO Packaging	-	-	1,57	0,75%	3,36	1,60%	24,07	10,71%	3,27	1,64%	0,03	0,03%	6,47	2,94%
Glass:	**2,14**	**1,05%**	**11,28**	**5,37%**	**3,95**	**1,88%**	**15,09**	**6,71%**	**4,19**	**2,10%**	**0,15**	**0,14%**	**18,16**	**8,26%**
Glass Container:	**2,14**	**1,05%**	**10,6**	**5,05%**	**3,95**	**1,88%**	**14,48**	**6,44%**	**4,19**	**2,10%**	**0,15**	**0,14%**	**17,59**	**8,00%**
Colour	1,03	0,51%	6,5	3,10%	0,94	0,45%	7,11	3,16%	1,06	0,53%	-	-	11,55	5,25%
White	1,11	0,55%	4,1	1,95%	3,01	1,43%	7,37	3,28%	3,13	1,57%	0,15	0,14%	6,04	2,75%
Glass NO Container:	**-**	**-**	**0,68**	**0,32%**	**-**	**-**	**0,61**	**0,27%**	**-**	**-**	**-**	**-**	**0,57**	**0,26%**
Metals:	**8,44**	**4,16%**	**3,89**	**1,85%**	**3,7**	**1,76%**	**3,5**	**1,56%**	**6,72**	**3,37%**	**0,53**	**0,48%**	**1,81**	**0,82%**
Ferrous:	**4,35**	**2,14%**	**0,83**	**0,40%**	**0,76**	**0,36%**	**0,07**	**0,03%**	**0,17**	**0,09%**	**-**	**-**	**1,41**	**0,64%**
Ferrous - NO Packaging	4,35	2,14%	0,83	0,40%	0,76	0,36%	0,07	0,03%	0,17	0,09%	-	-	1,41	0,64%
Non-ferrous (packaging and non-packaging):	**1,41**	**0,69%**	**0,45**	**0,21%**	**0,69**	**0,33%**	**0,26**	**0,12%**	**2,49**	**1,25%**	**0,46**	**0,42%**	**0,4**	**0,18%**
Aluminium SPRAY TYPE	0,29	0,14%	-	-	0,58	0,28%	-	-	0,08	0,04%	0,2	0,18%	0,18	0,08%
Others	1,12	0,55%	0,45	0,21%	0,11	0,05%	0,26	0,12%	2,41	1,21%	0,26	0,24%	0,22	0,10%
Scrap	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
WEEE's	**2,68**	**1,32%**	**2,61**	**1,24%**	**2,25**	**1,07%**	**3,17**	**1,41%**	**4,06**	**2,04%**	**0,07**	**0,06%**	**-**	**-**
Textile:	**5,39**	**2,66%**	**49,94**	**23,78 %**	**7,24**	**3,44%**	**40,4**	**17,98 %**	**11,23**	**5,63%**	**1,07**	**0,97%**	**52,9**	**24,05 %**
Cellulose	0,05	0,02%	6,94	3,31%	0,72	0,34%	12,38	5,51%	2,87	1,44%	0,32	0,29%	7,36	3,35%
Textiles (Wool/Leather)	5,34	2,63%	26,31	12,53%	3,9	1,85%	13,37	5,95%	8,36	4,19%	0,75	0,68%	24,55	11,16%
Sanitary textiles	-	-	16,69	7,95%	2,62	1,24%	14,65	6,52%	-	-	-	-	20,99	9,54%
Others:	**17,62**	**8,68%**	**45,7**	**21,76 %**	**19,83**	**9,41%**	**22,74**	**10,12 %**	**15,17**	**7,61%**	**4,83**	**4,39%**	**15,57**	**7,08%**
CDW (Construction/Demolition)	0,51	0,25%	24,16	11,51%	-	-	3,47	1,54%	0,49	0,25%	-	-	1,08	0,49%
Toys	1,15	0,57%	-	-	0,09	0,04%	0,11	0,05%	1,02	0,51%	0,65	0,59%	0,94	0,43%
Bottles/soothers	-	-	-	-	0,05	0,02%	-	-	0,04	0,02%	-	-	-	-
Kitchen utensils	-	-	-	-	0,65	0,31%	-	-	-	-	-	-	-	-
Medicine containers	0,02	0,01%	0,16	0,08%	0,15	0,07%	0,15	0,07%	0,05	0,03%	0,23	0,21%	0,04	0,02%
Container contents	0,23	0,11%	11,14	5,31%	8,28	3,93%	4,18	1,86%	2,34	1,17%	0,7	0,64%	2,71	1,23%
Multimaterial	4,79	2,36%	1,32	0,63%	-	-	3,25	1,45%	2,41	1,21%	0,49	0,44%	4,26	1,94%
Non-packaging plastic	9,36	4,61%	5,93	2,82%	6,67	3,17%	3,2	1,42%	6,77	3,40%	2,76	2,51%	5,06	2,30%
Commercial plastic	-	-	-	-	3,35	1,59%	0,51	0,23%	-	-	-	-		
Health care waste	-	-	-	-	-	-	-	-	1,69	0,85%	-	-		
Other ceramics	0,51	0,25%	0,56	0,27%	-	-	0,49	0,22%	-	-	-	-	0,08	0,04%

Hair	-	-	-	-	-	-	0,01	0,00%	-	-	-	-	-	-
Cigarette butts	-	-	-	-	-	-	0,02	0,01%	-	-	-	-	-	-
Cat litter	-	-	-	-	-	-	1,28	0,57%	-	-	-	-	-	-
Paint	-	-	-	-	-	-	0,92	0,41%	-	-	-	-	-	-
Filters	-	-	1,61	0,77%	-	-	-	-	-	-	-	-	-	-
Unclassifiable	1,05	0,52%	0,82	0,39%	0,59	0,28%	5,15	2,29%	0,36	0,18%	-	-	1,4	0,64%
TOTAL Light Packaging	**159,08**	**78,41%**	**16,97**	**8,08%**	**160,79**	**76,33%**	**21,47**	**9,55%**	**144,57**	**72,54%**	**100,54**	**91,29%**	**21,99**	**10,00%**
TOTAL unrequested	**43,8**	**21,59%**	**193,01**	**91,92%**	**49,86**	**23,67%**	**203,27**	**90,45%**	**54,73**	**27,46%**	**9,59**	**8,71%**	**197,93**	**90,00%**
TOTAL	**202,88**	**100,00%**	**209,98**	**100,00%**	**210,65**	**100,00%**	**224,74**	**100,00%**	**199,3**	**100,00%**	**110,13**	**100,00%**	**219,92**	**100,00%**

UTRECHT CHARACTERISATIONS	RDF Pre pilot	RDF End pilot	PMD Pre Pilot	PMD Mid Pilot	PMD End Pilot
Packaging Waste Empty	Average	Average	Average	Average	Average
Plastic Packaging including bags	9%	5%	51%	57%	54%
Drinking Cartons	2%	1%	9%	14%	15%
Metal Packaging	1%	2%	7%	8%	6%
Plastic Non Packaging					
Plastic Packaging - Rejects	*	1%	1%	2%	2%
Plastic Non Packaging	*	1%	15%	3%	8%
Contamination (non packaging)					
RDF			10%	8%	8%
RDF in bags			6%	7%	6%
Hazardous Waste			0,2%	0,1%	0,0%
RDF	87%	90%			
Total	100%	100%	100%	100%	100%
Plastic Packaging	Average	Average	Average	Average	Average
Foils - bags and sacks	30%	22%	4%	3%	(in Foils)
Foils - packaging	36%	28%	39%	30%	36%
PET bottles	9%	12%	9%	13%	16%
PET trays	6%	12%	19%	21%	22%
PE rigid	6%	7%	10%	10%	11%
PP rigid	13%	14%	15%	18%	13%
Other plastic packaging	0%	6%	4%	4%	3%

100%

* not in analysis

ALBA IULIA CHARACTERISATIONS		PRE-PILOT GENERAL CHARACTERIZATION				DURING PILOT GENERAL CHARACTERIZATION					
		Wet fraction		Dry fraction		Wet fraction		Dry fraction		PlastiCircle fraction	
	Material	kg	%	kg	%	kg	%	kg	%	kg	%
PLASTIC			15,90%		18,00%		12,57%		14,52%		26,81%
PET	Bottles	8,9	3,20%	10,3	4,40%	7,524	3,38%	8,15	4,07%	24,48	12,41%
	Multilayer - trays	4,8	1,70%	4,2	1,80%	0,76	0,34%	0,66	0,33%	1,6	0,81%
HDPE	Coloured	5,5	2,00%	4,2	1,80%	7,79	3,50%	7,95	3,97%	8,5	4,31%
	Natural	2,2	0,80%	1,5	0,60%	0	0,00%	0,22	0,11%	0	0,00%
LDPE + PP foils	Films	0,7	0,30%	1,2	0,50%	3,04	1,36%	2,92	1,46%	5,7	2,89%
	Bags	8,5	3,10%	6,5	2,80%	2,28	1,02%	2,65	1,32%	3,29	1,67%
PVC		5	1,80%	7,5	3,20%	4,56	2,05%	3,85	1,92%	3,6	1,83%
Polystyrene		0,5	0,20%	0,5	0,20%	0,54	0,24%	0,25	0,12%	0,45	0,23%
Mingled plastic		7,8	2,80%	6,2	2,70%	1,52	0,68%	2,4	1,20%	5,25	2,66%
Other			0,00%		0,00%						
Organic waste	Food	51	18,30%	48	20,60%	26,98	12,11%	20,7	10,34%	18,45	9,36%
	Vegetables/ gardens	31	11,10%	22	9,40%	46,36	20,81%	30,5	15,24%	24,7	12,52%
Paper/ cardboard	Paper	5	1,80%	2	0,90%	15,58	6,99%	12,9	6,42%	13,12	6,65%
	Carboard	14,2	5,10%	11,5	4,90%	31,68	14,22%	33,8	16,89%	30,6	15,52%
Glass	White glass	3,3	1,20%	2,5	1,10%	7,22	3,24%	6,1	3,05%	8,2	4,16%
	Coloured glass	6,9	2,50%	5,85	2,50%	3,42	1,54%	5,15	2,57%	7,65	3,88%
Metals	Aluminium cans	0,9	0,30%	1,4	0,60%	3,23	1,45%	2,85	1,42%	3,2	1,62%
	Ferrous	7	2,50%	4,2	1,80%	4,94	2,22%	3,45	1,72%	3,22	1,63%
	Other	4	1,40%	1,2	0,50%	0	0,00%		0,00%	0	0,00%
Tetrapak		3	1,10%	4	1,70%	1,14	0,51%	2,25	1,12%	1,2	0,61%
Textiles		11,2	4,00%	17,4	7,50%	4,37	1,96%	6,83	3,41%	5,28	2,68%
Wood		12,8	4,60%	0,8	0,30%	0	0,00%		0,00%	0	0,00%

Constructions	**Wall paint, rubbish, dirt**	25	**9,00%**	20	**8,60%**	11,02	**4,95%**	9,3	**4,65%**	0	**0,00%**
	Tiles	1	**0,40%**	2	**0,90%**	0	**0,00%**		**0,00%**	0	**0,00%**
Contaminated/ dangerous (chemical, sanitation, hygiene)		29	**10,40%**	20	**8,60%**	12,16	**5,46%**	15,3	**7,65%**	8,52	**4,32%**
Other		29	**10,40%**	27	**11,60%**	24,32	**10,92%**	28,8	**14,39%**	20,2	**10,24%**
Total		**278**		**232**		**222,79**	**1**	**200**	**1**	**197,2**	**1**
Initial		285		236		226		207		202	

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