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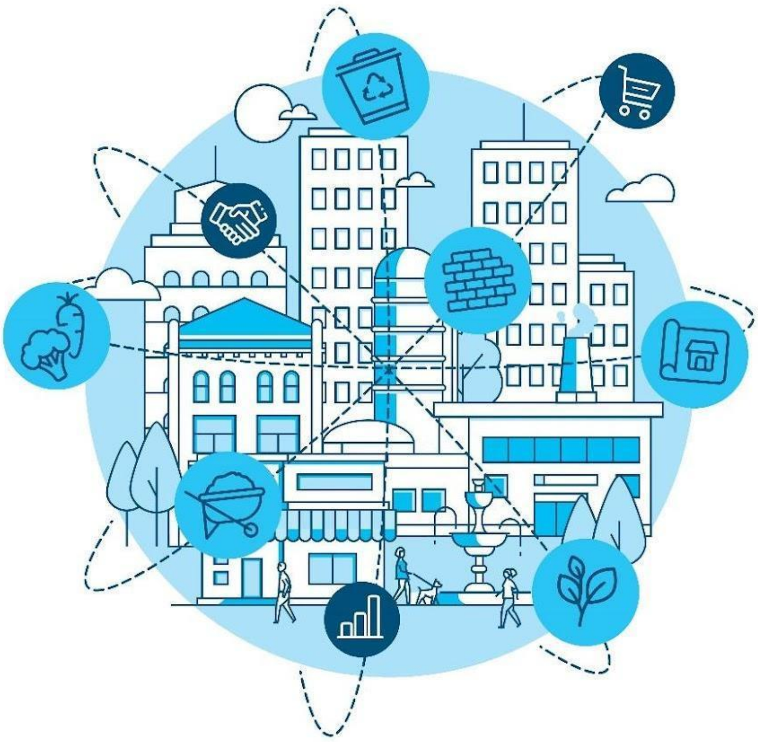
# CIRCULAR Bio-waste in Seville

## Demonstration Report

**Municipality of Seville**



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| Abstract | This demonstration report explains how the demonstration actions, in the Bio-waste stream, have taken place, how the instruments and activities have been implemented and what benefits, barriers and lessons learned have arisen during the implementation of those actions. |
| Keywords | Bio-waste; Demonstration; Implementation; Actions, Instruments |
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# 1. Executive summary

The CityLoops project brought together seven European cities – Apeldoorn, Bodø, Mikkeli, Poto, Seville, Høje-Taastrup and Roskilde - to pilot a series of demonstration actions to close the loop of two of the most important waste streams in Europe: Construction and Demolition Waste, and Bio-waste. The ultimate aim was to become circular cities in which no resource goes to waste, driving the transition to the circular economy. The project started 1.10.2019 and ended 30.9.2023. The project was coordinated by ICLEI – Local Government for Sustainability and it received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 821033.

City Council of Seville, LIPASAM, IDENER and EMASESA were responsible for the project implementation in Seville. This report presents Seville´s demonstration actions of bio-waste stream – their implementation, results and lessons learned, as well as replicability and future perspectives.

**Introduction**

In order to comply with the current European objectives in the field of municipal waste management, the local cluster of Seville is seeking to implement various tools and actions, to advance the deployment of separate collection systems for bio-waste in the city of Seville, its ulterior treatment and valorization as well as the optimisation of its logistics, awareness of households and large generators. Two demonstration actions were carried out in Seville. Demostration action 1 was focused on the implementation of a bio-waste selective route in an area of Seville with improvements in their associated elements (containers, communication campaings, etc.) and Demonstration 2 consisted of the evaluation of the bio-waste collected as a potential feedstock for an anaerobic digester for biogas production.

Both demonstrations were conducted in collaboration with the main local stakeholder groups. The main stakeholders LIPASAM, EMASESA, IDENER, City Council of Seville, ABORGASE (operator waste treatment plant), citizens and commercial establishments.

**New approaches/instruments**

Demonstration action 1: Implementation of a bio-waste collection route in a neighborhood of Seville.

In this demonstration action, the local cluster of Seville has implemented different actions that have sought to improve circularity, in a holistic way, in the management of bio-waste. In summary, they have been:

- Use containers for selective collection that are more “circular”, through the incorporation of recycled material in its manufacture.
- Achieve a greater amount of bio-waste collected with the implementation of communication campaigns, through different communication methodologies.

- Achieve a greater purity of bio-waste through the incorporation of access control technologies in the separate collection bins.
- Achieve optimisation of the city's bio-waste management, through an IT tool to be developed in the project.
- Achieve the minimization of food waste in large generators, and therefore, less generation of bio-waste that should be collected at a later stage.

Demonstration action 2: Biomethane production from bio-waste in co-digestion with sludge.

- Evaluate the biomethanization potential of the bio-waste collected in Seville, taking advantage of the existing anaerobic digestion facilities in one of the treatment plants in the city of Seville.
- Evaluate possible methods and strategies for managing bio-waste in digesters.

**Results and lessons learned.**

The local cluster of Seville achieved the expected outcomes associated with both demonstration actions:

At the end of the report there is a specific section on results and lessons learned. The most relevant are listed below.

In demonstration 1:

- A good response has been obtained from the market regarding the specifications of recycled material in containers. The containers purchased are made from 50% recycled material.
- A generation of bio-waste on the established route similar to that expected has been achieved, around 100,000 kg of bio-waste have been collected during the demonstration.
- The purity of bio-waste obtained has been highly variable, and similar to other experiences in the city of Seville (around 51 - 58%). These data are partly due to the access control method and technology implemented, having this room for improvement, both technologically and operationally
- It has been verified that the use of IT tools to improve bio-waste management is interesting i.e., a 14.36% reduction of costs, and energy demand by route optimisation. Additionally, there is good room to continue developing, incorporating variables such as traffic, incidents on routes, etc.
- The communication campaigns have been very well received by the citizens and commercial establishments in the area of operation. 10,728 households have been reached and 8,675 people have registered participation during the campaign. Additionllay, the IT tool show more than 50,000 visits of citizens in the last 12 months.

- The campaign focused on food waste has been carried out in 30 commercial establishments (large generators of bio-waste). 11,200 packages for food leftovers have been distributed. Moreover, this initiative has been widely accepted by the establishments.

In demonstration 2:

- The technical feasibility of digesting bio-waste collected separately in the city of Seville has been verified, both jointly with sluge and in isolation.
- About the quality of the gas, the parameters and characteristics of the gas obtained have remained at normal values.
- The need, on a larger scale, for bio-waste pre-treatment equipment has been confirmed, in order to avoid blockages and damage in the process.

**Scalability and replicability**

Many tools and activities demonstrated in Seville can be replicated in other cities.

Recommendations for replicating both demonstrations in other cities are given at the end of this report. In that section you can find recommendations at a general level, related to the organization and planning of demonstration actions, as well as specific ones related to:

- Technologies applicable to bio-waste management.
- Communication campaigns.
- For the applicability and treatment of waste.

In Seville, the results of CityLoops demonstrations have been disseminated at the city level, as well as regionally and nationally. Upscaling and replication of the results and practices continues in other collaboration initiatives with stakeholders.

# 2. City context

Seville is the fourth most populous city in Spain (684,234 inhabitants in 2021), and it is the capital and the most populous city of the region of Andalusia, in the south of Spain. It is a large monocentric city and part of a polycentric agglomeration, the metropolitan area of Seville. The extension of the city is 141,42 $km^2$ and has a density of 4,818 of Inhabitants per $km^2$. The main economic sectors of the city are commerce, food and restaurants, mainly due to tourism. Additionally, the agriculture sector has a significant importance when considering the broader metropolitan area of Seville.

The City Council of Seville is responsible for the public street cleaning services, waste collection and treatment, carried out by Limpieza Pública y Protección Ambiental S.A.M (LIPASAM), which is 100% public owned. The waste treatment process is carried out in collaboration with the "*Mancomunidad de Los Alcores*", a consortium that comprises the City of Seville and surrounding municipalities for the treatment of municipal solid waste. The waste treatment facility is located at the Montamarta-Cónica, in the municipality of Alcalá de Guadaíra.

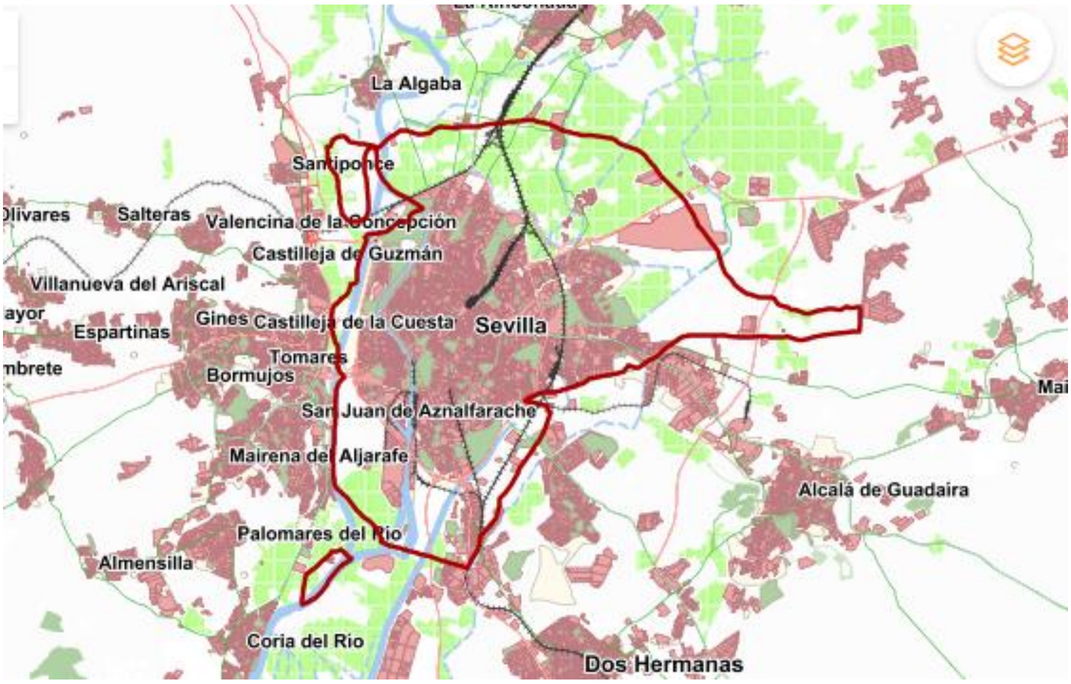



*Figure 1. Seville City boundaries.*

In order to comply with the current European objectives in the field of the municipal waste management, LIPASAM and the City Council of Seville are seeking to implement various tools and actions. Their goals are to promote the deployment of separate collection systems for bio-waste in the city of Seville, while optimizing the logistics involved in waste collection and raising awareness of households and large generators.

The waste collection system comprises large capacity containers installed in the public street, although due to diversity of the morphology of the city, nowadays, different systems are coexisting. The containerization model implemented in the city of Seville is based on the collection of four different fractions: light packaging, paper-cardboard, glass and mixed waste (rest and organic matter).

In mid-2017, within a broad roadmap for the selective collection of bio-waste, the collection of these in large generators, specifically in markets, began and expanding it incipiently to citizenship. Now, including the area selected for CityLoops Demo action 1, there are five bio-waste selective collection routes implemented in the whole city.

In 2021, the production of MSW in the City of Seville amounted to 329,121 tons. The prevailing collection model for MSW in the city covers four fractions (glass, light packaging, paper and cardboard and organic waste + rest), although there are some areas with a collection model of five fractions (including bio-waste). It is estimated that around 106,000 tons of organic matter (bio-waste) is still collected in a mixed fashion, with only 5% being recovered through composting. Around 15,000 tons of compost[1] and soil amendment[2] are being produced each year. Nowadays, only 2% of that material (compost + soil amendment) is commercialised, while the rest of these materials are used for landfill restoration and as cover material.

Seville is focused on advancing in accomplishing the targets established by the European Directive 2018/851 (recycling 55% of municipal waste by 2025, in addition to implementing bio-waste separate collection before 2024) and the Waste National Law 2022/7 which embedded these targets, and even it is more ambitious in some of them.

In the case of Seville, to attain the aforementioned objectives with respect bio-waste, it is necessary to capture a larger fraction of this waste stream, in addition to other selective fractions. This can be achieved by reinforcing the existing selective collections and introducing them in those areas where they do not exist. Given the diverse nature of the city, various collection system alternatives must be assessed for their feasibility depending on the urban areas and generators in question. The aim is always to implement the smartest and most efficient system possible.

For its treatment, future actions should be considered following the guidelines of the European hierarchy on waste management, maximising the recovery of resources contained in waste and minimising landfilling.

These general lines of action are supported by relevant local strategies such as the:

- Strategic Plan for Seville 2030. Horizon 2030.
- Local waste prevention and management Plan of Seville (currently in draft status).
- Management Program of LIPASAM.

The CityLoops project, with the two demonstration actions implemented in Seville, focusing on the separate collection of bio-waste, optimisation of logistics, and raising awareness among citizens. The goal is to analyse and pilot actions that can be replicated in the city, with a view to meeting the current European and national waste management objectives. Through these demonstration actions, the CityLoops project is helping Seville to progress towards becoming a more circular city, in line with the declaration that the city itself led in 2017, together with more than 200 municipalities in Spain, which underlines the importance of Local Governments to be committed, as well as their need to implement the Circular Economy.

[1] Compost: sanitized and stabilized organic material obtained from the aerobic and thermophilic biological treatment of separately collected bio-waste.
[2] Soild amedment: sanitized and stabilized material obtained from the aerobic and thermophilic biological treatment of organic matter from mixed waste.

# 3. Implementation

**Demo action 1: Implementation of a bio-waste collection route in a neighbourhood of Seville**

Currently, the selective collection of bio-waste is incipient in the city of Seville, for the most part in terms of quantity is collected from large generators through back loading collection [3]route and 5 side loading collection [4]routes (including CityLoops), mainly focused on households.

Both services have different characteristics, both due to the type of truck to be used, as well as the personnel resources necessary to carry out the service.

*Table 1. Example of types of waste collection systems in Seville, machinery and personnel asociated.*

| Type | Machinery | Personnel |
|---|---|---|
| Back loading collection | Back loading waste truck | 1 driver y 2 operators. |
| Side loading collection | Side loading waste truck | 1 driver. |

A selective bio-waste collection route has been demonstrated within CityLoops in a city neighbourhood by LIPASAM, the municipal waste management company of Seville.

This project aims to improve both the quantity and purity of the bio-waste collected by the city.

A set of bio-waste collection containers were installed, for exclusive access to neighbourhood citizens and commercial establishments, with an information and awareness-raising campaign to accompany this. A software tool designed to optimise the logistics of bio-waste collection is also being developed and was tested in the demonstration neighbourhood.

Alongside the demonstration action a further (mainly digital) awareness raising campaign will be launched across the whole city aimed at encouraging people, mainly large generators such as Horeca bodies (HOtels, REstaurants, and CAtering) to reduce food waste.

After end the demonstration action 1, the outcomes expected are:

- Strengthened alliances with relevant local and regional actors in the field of bio-waste circularity.

[3] The back loading collection consists of the mechanical emptying of the waste contained in the back loading containers and / or bins, inside the hopper of the vehicle where they are compacted. During the collection maneuver, the driver stops the vehicle as close to the location of the containers and / or bins. The operators move the containers and / or bins to the elevator, which is activated by one of them to dump its content into the collector's hopper and subsequently compact it. The containers and / or bins are returned to their location and left with the lid closed.

[4] Side loading collection consists of the mechanical emptying of the waste contained in the side loading containers, inside the hopper of the vehicle where they are compacted. In the collection maneuver, the driver stops the vehicle right next to the container. With the help of the monitors located inside the cabin, he activates the mechanisms that pick up the container and elevate it to the compactor, where the waste is dumped. Subsequently, the container is deposited in its same location.

- Raised awareness among citizens about the implantation, collection and segregation at source of bio-waste, as well as its benefits.
- Raised awareness among large bio-waste generators, mainly in the HORECA sector (hotels, restaurants and catering), about minimising food waste.
- More sustainable containers deployed in the city as a result of the inclusion of circular specifications in tender documents and contracts.
- Increased amount of material that is recovered/recycled, and therefore reduced amount of material that is deposited in landfills. In particular:
    - 0.6% increase in the separate collection of bio-waste in the city compared to the amount collected in 2020.
    - Reduced food waste from HORECA entities.
    - Increased quality of bio-waste collected compared to the quality of bio-waste at the start of the demonstration action.
- Significant transport energy and cost savings in the waste management system, which will serve as the basis for assessing the potential expansion of the demonstration action to the rest of the city.
- Reduced carbon footprint from waste collection activities.

## 3.1 Implementation Activities Demonstration action 1

### 3.1.1 Activity 1 Preliminary diagnosis and development and lab testing of OMSW flow optimisation tool.

**Preliminary diagnosis report**

A **preliminary diagnosis report** was the first step taken in Demonstration Action 1. The aim of this report is to analyse the current flow of bio-waste in the city (in terms of quantity and quality – both separate bio-waste collection and organic matter in mixed waste), together with an overview of the current collection and treatment systems, the legal framework, and environmental and financial factors. It concludes with an implementation plan for Demonstration Action 1.

This report was prepared in collaboration with the local stakeholder group (LIPASAM, EMASESA, Seville City Council and ABORGASE), and in conversations with City Council members and socioeconomic agents.

The steps that were taken to map and engage with the mentioned stakeholder were the following:

1. To identify potential stakeholders to recap their comments and experiences, a value chain approach was adopted. This approach covered the entire process from material extraction to manufacturing, transformation, use and final waste management. The critical activities within the value chain were highlighted, identifying areas where stakeholders' involvement was potentially necessary.

2. Once those activities that were considered critical were selected, we proceeded to identify groups of stakeholders based on their *activity profile* in the value chain. For instance, in the waste management stage, the activity of "Waste treatment" was identified as a critical activity, and therefore, the team proceeded, using a *brainstorming method*, to identify organisations that carry out this activity in the area of Seville. The same procedure was done with the rest of the stages of the value chain and critical activities in those stages (Transformation - Food manufacturing, consumption, distribution, and trade, etc.). A list of possible organisations was prepared and contacted by phone. In these phone calls, the reason for the call, the description of the CityLoops project and the interest in the organisation being part of the project's stakeholder group were briefly explained. Likewise, these calls were used to ask these organisations if they were aware of other companies and / or associations that had the same activity and potentially had an interest in being involved in the project or at least in this preliminary diagnosis.
3. This initial contact was followed by individual phone calls for one-to-one informal interviews to share a general project overview and get initial feedback from stakeholders for the diagnosis. During these phone interviews several additional stakeholders were identified through snowball sampling. After these individual discussions with each stakeholder, an in-person meeting was organised in February 2022. The aim was to have stakeholder feedback after some time of reflection and analysis of the demonstration actions planned to do in Seville in the framework of CityLoops.
4. The information, data and reflections of the group of stakeholders were compiled and used for the elaboration of the preliminary diagnosis, based on an in-depth review of the legal framework related to waste management, available resources, data on the production of waste streams as well as future trends. The diagnosis concluded with a proposal of general lines of action for the future, where the activities, instruments and demonstration actions developed in the city of Seville are framed.

*Recommendations*

- The revision of relevant European, national, regional and local regulations provides information on the objectives and targets to be considered in the field of waste management.
- The waste generation processes need to be first determined to assign them with their generators, distinguishing at least households and large generators. Additionally, it would be also relevant to connect these flows to the type of collection and treatment.
- A comparative analysis of collection and treatment systems implemented in other cities and regions can provide valuable insights to support decision making and develop a strategy or plan for the city.
- An evaluation of the economic and environmental costs are key elements when developing a strategy or plan based on the Preliminary Diagnosis.

*Lessons learned*

- It was important to carry out the diagnosis to have different stakeholders that represented the value chain of the flow of bio-waste in Seville. In this case, the number of people/organizations to be contacted initially was limited, so that this was manageable (around 15 - 20 organisations were contacted).

- Different communication channels were used to contact the different stakeholders (email, telephone, physical meetings), with relative frequency. The stakeholders themselves commented during these contacts that the preferred channel was face-to-face meetings.

*Link to instrument*

**https://public.3.basecamp.com/p/23HdEM1twCqt3AtwMfgU5NEV**

**OMSW flow optimisation tool**

The second step taken in the Demonstration Action 1 was the development of a digital tool with the aim of optimising the management of the routes for Organic waste collection in Seville. Data is shown through a web portal, with one interface for citizens to instruct them on the separate collection of organic waste implemented in Seville, and one interface for Lipasam managers to help them in the decision-making process on routes and further implementation of new routes. Data collected on the stocks and flows of Organic waste can be used to continuously optimise their management.

The OW flow optimisation tool has contributed to the following outcomes:

- Advance in the fulfilment of the European, national and regional objectives, in selective collection, recycling and not disposal in a landfill, marked by Directive 851/2018 and 850/2018.
- Strengthen the education, awareness and knowledge of citizens and other socio-economic agents related to the bases of the circular economy in relation to the improvement of bio-waste management.
- Show potential economic and energy savings by optimising collection logistics, making better use of the resources contained in the waste.
- Show potential reduction the carbon footprint of waste collection activities.

*Citizen's platform*

Visit the platform here (OMSW flow optimisation tool)

When the users enter the OMSW platform, they will encounter the navigation panel with the text inputs for the user's district, zip code and the different type of municipal collected waste. Below the navigation panel, the user will select in the map the origin point (location) to find the closer organic bin. Additionally, detailed information about the other bins and different type of collected waste will be shown for the selected district. Two buttons are found at the bottom of the form: one that submits the form (the one labelled "Search") and the other one to reset all the text boxes.

Once the citizen fills in every input and hits the "Search" button, a column with the results will appear between the original form and the map. In this section, the citizen will see the information of each type of municipal collected waste in the selected district. Also, the citizen will se information about the three closer organic bins from the selected location, as well as information on annually waste collected both in total amount and per waste types (Fig. 2).

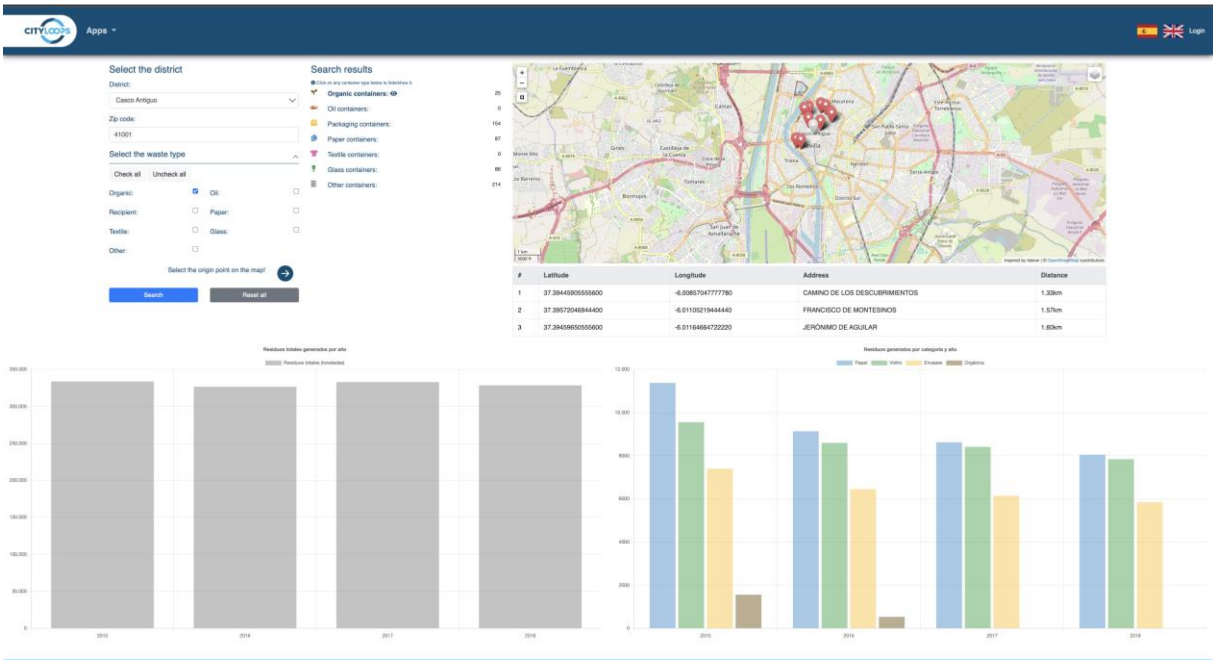



Figure 2. Citizen platform visualization.

## *Manager platform*

The manager platform has several pages to perform actions related to the management of the application and its resources (Fig.3).

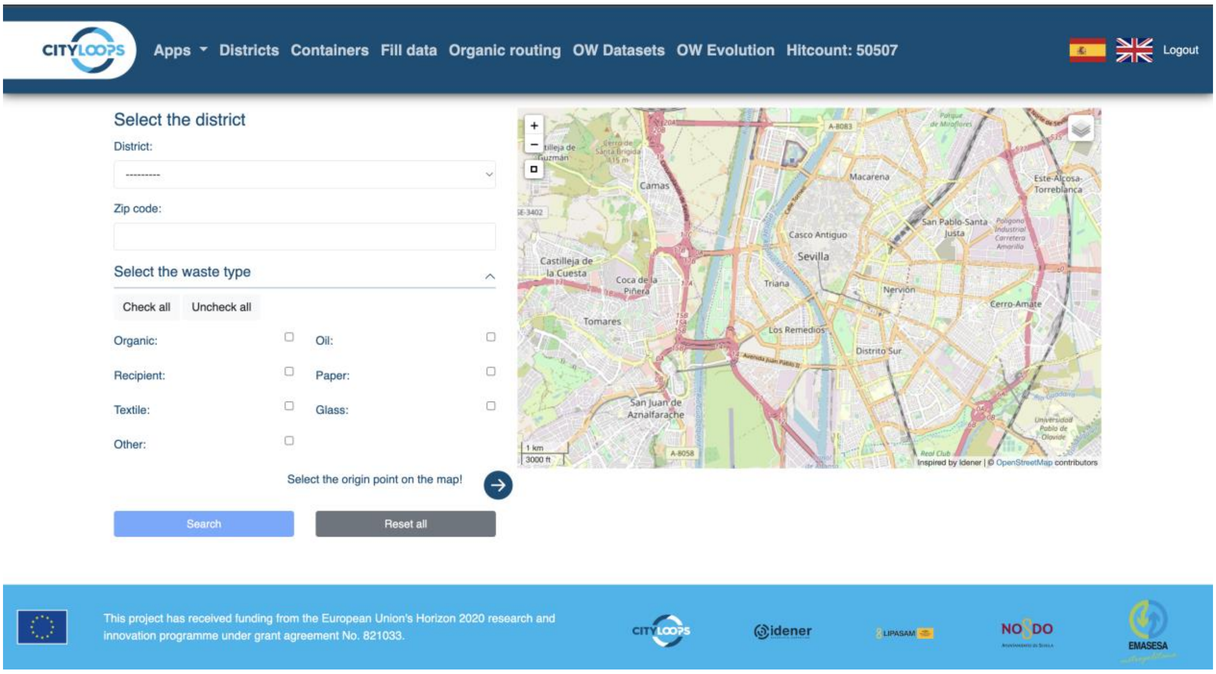



Figure 3. Manager platform (Home view).

The Manager platform for Seville´s organic waste (OW) collection has two main goals: the identification and selection of potential districts to implement new OW collection routes; and the optimisation of both location of bins and routes. The software tool for managers combine data regarding economic, social, and demographic with waste data on current waste collection routes. This way, the tool is used as a helping decision-making process on the identification of those districts to implement the new OW collection, optimal location of new OW bins, optimal design of new OW collection routes, and optimisation of current OW collection routes.

When the Managers enter the platform to study potential districts to implement new OW collection routes, they will enter in the OW evolution panel. In this panel, manager will use the updated dataset in order to study and compare the different districts of the city with those that already include organic waste collection. This way, the IT tool identify and classify the city districts according to similarity degree with the districts with separate organic waste collection. In the navigation panel, managers should select the dataset, number of clusters in which they want to classify the city districts and the district with separate organic waste collection implemented to compare the rest of the city districts.

Once the manager fills in every input and hits the “Search” button, a graphic with the results will appear with a score of the districts to order them from the most potential one to implement a new organic collection route to the less potential one. In this section, the manager will see the information of different indicators used in the machine learning analysis (Fig. 4).

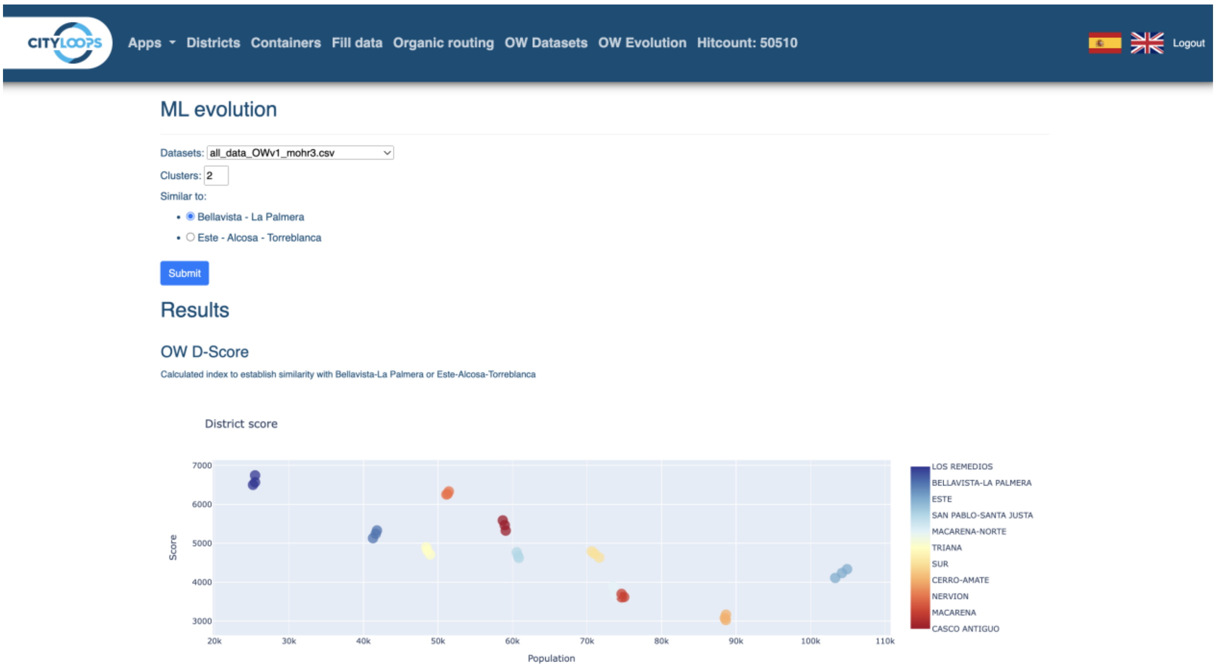



*Figure 4. Manager platform (OW evolution view).*

When the Managers enter the platform to study optimization of the route collections, they will enter in the Organic routing panel. In this panel, manager will encounter the navigation panel with all the implemented organic containers. They can select each organic route separately in the dropdown menu above the containers and then select all containers of the route at the same time or select the required ones for the study manually. The selected containers will appear in the map at the right of the panel. Then, the manager has to indicate the fuel cost for the route in euros per litre and consumption indicator in litres per 100 kilometers. Finally, manager has to select the start point of the route in the map.

Once the manager fills in every input and hits the "Calculate route" button, the optimal route will be shown in the map with detailed indicating. Also, information of the total distante, estimated time of route, fuel consumption, fuel cost, and $CO_2$ equivalent emissions will be shown in a table below the map (Fig. 5).

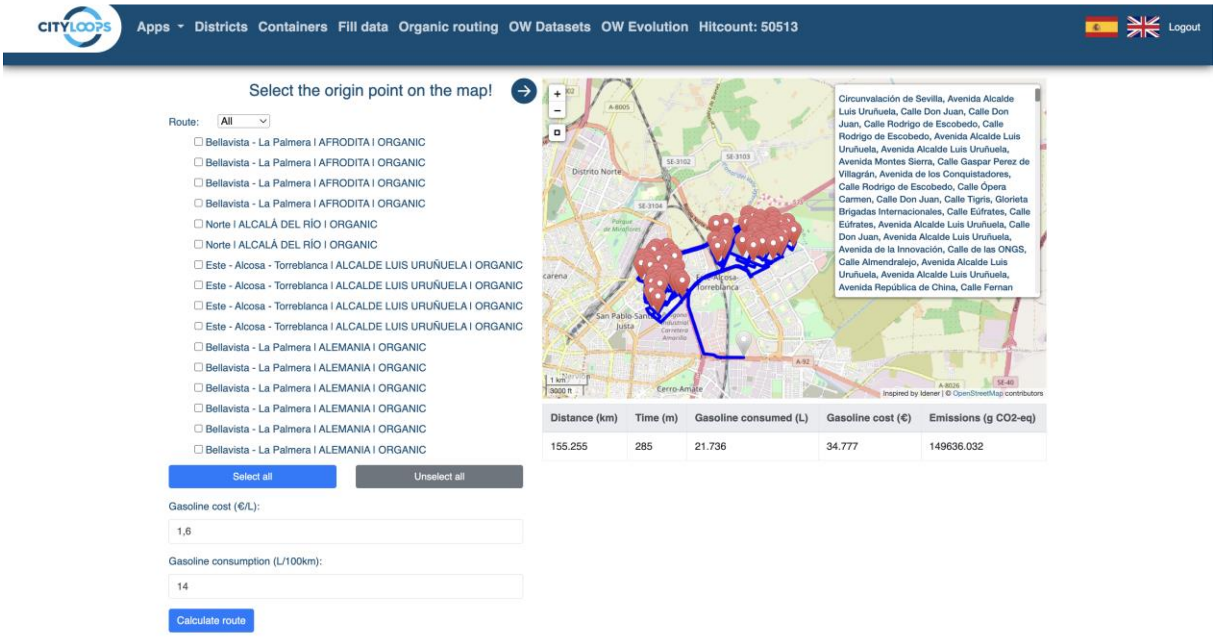



*Figure 5. Manager platform (Organic rounting view).*

The Optimisation OMSW flow tool was lunched before summer 2022 after a preliminary testing period by the managers of Lipasam. Several modifications have been developed after the preliminary testing process taking into account the suggestions from the members of the local cluster in Seville. Those modifications have the main objective to increase the user friendliness of the tool for both manager and citizens.

The use from the citizens is focused on the identification of the closer organic bin according to their location. After a period of use, information of the location for the others type of waste (map visualization) have been added to the tool in order to increase the use of the tool.

The use from the Lipasam managers is focused on the routing optimization and obtain a district's scoring of the potential location for new routes in the city, increase the dataset of the tool and monitor the predictions.

Good results were observed considering the short period of implementation and collected information. Good maintenance of the dataset and a sound evaluation of results could be shown beyond Project implementation.

During demonstration action 1, some modifications and new functionalities were implemented considering the suggestions from the local managers. These modifications and new functionalities are identified below:

- Internationalisation: Using the built-in internationalisation functionality in Django it was possible to translate the application from English to Spanish. This is done by adding a specific tag in Django's templates wherever a translatable text appears. Then, by using a Django command, the application generates a file for each language implemented with all the translatable text, where the translated text could be entered so the application can replace the original text whenever the app language is changed.

- Footer: A footer was added to the base HTML template to show the partners involved in the application and the H2020 funding statement.

- Hit count: A hit count was added to the application header that indicates the number of times any page of the application has been visited. To do this, the method that registers the visit was added as a "middleware". Middleware methods are executed for every request to the server, so it's totally independent of the page the user is accessing.

- Citizen form result visual improvements: Added icons to the container type list using the Font Awesome library. Users can now hide/show containers of a specific type by clicking on each type in the container type list in the result view.

- Differentiation of organic containers based on availability to citizens: The container model was updated with a new parameter "IsCitizen", which indicates if the container is available for public use. Containers with said parameter set to false would appear on the map with a red coloured marker, so the user knows that they are not available for public use.

- Added graphs of waste data to citizen form result: After a correct form submission from the user in the citizen form, the page displays several graphs representing waste collection from previous years. This was implemented using the chart.js library. Chart.js is a JavaScript library used to represent graphs.

- Added option to backup containers saved in database: In the container list view, a button was added to let the user download a backup of the containers located in the database in csv format.

- Added Filled bins data analysis functionality: Added Sensoneo data upload and waste collection recommendation based on said data. Managers can now upload the container opening data collected in the Sensoneo application to the OW application and view the data historic, apart from a new column that displays the collection recommendation.

- ML results visual improvements: Several fixes were applied to the result view of the ML page.

- Visual improvements for organic routing page: The container list in the organic routing view was very large, so its style was changed to add a scroll bar and not extend the page.

- Added functionality for Porto: Adapted the models and views so the app could be used in another city.

*Optimisation of the other routes already implemented.*

Different simulations have been made by Lipasam's managers who keep increasing the dataset with internal data on new routes or updates of implemented bins. Below is shown the optimisation of all the separate organic collection routes implemented (Table 2). There are 4 routes of separate organic collection, Routes 1 and 2 were implemented before the CityLoops project implementation, Route 4 was implemented outside of the project CityLoops, and Route 3 is the route implemented through the CityLoops project implementation. Results from the optimisation showed a reduction in the distance traveled as well as cost-associated and $CO_2$-equivalent emissions. The optimal CityLoops route (Route 3) showed a decrease in the cost and emissions of 14.36% in comparison with the current route. Results of the routes optimisation highlighted that the experience on the field is critical because the old routes (Routes 1 and 2) showed less decrease in their cost and emissions. Therefore, the optimisation process of a collection route gained with the field experience can be speed-up with the tool. Results will definitely help in the decision-making process to take the advance of this information and optimise routes not only for separate organic waste collection but also for the other kind of municipal waste. Finally, a sound experience of the managers and workers improves the accuracy of the tool and increases the optimisation of the routes.

*Table 2. Optimisation of the separate organic waste collection routes*

| Route | Current Distance traveled | Optimal Distance Traveled |
|---|---|---|
| Route OW 1 | 110.78 Km | 96.87 Km |
| Route OW 2 | 115.84 Km | 114.95 Km |
| Route OW 3 | 104.89 Km | 89.83 Km |
| Route OW 4 | 117.73 Km | 103.69 Km |

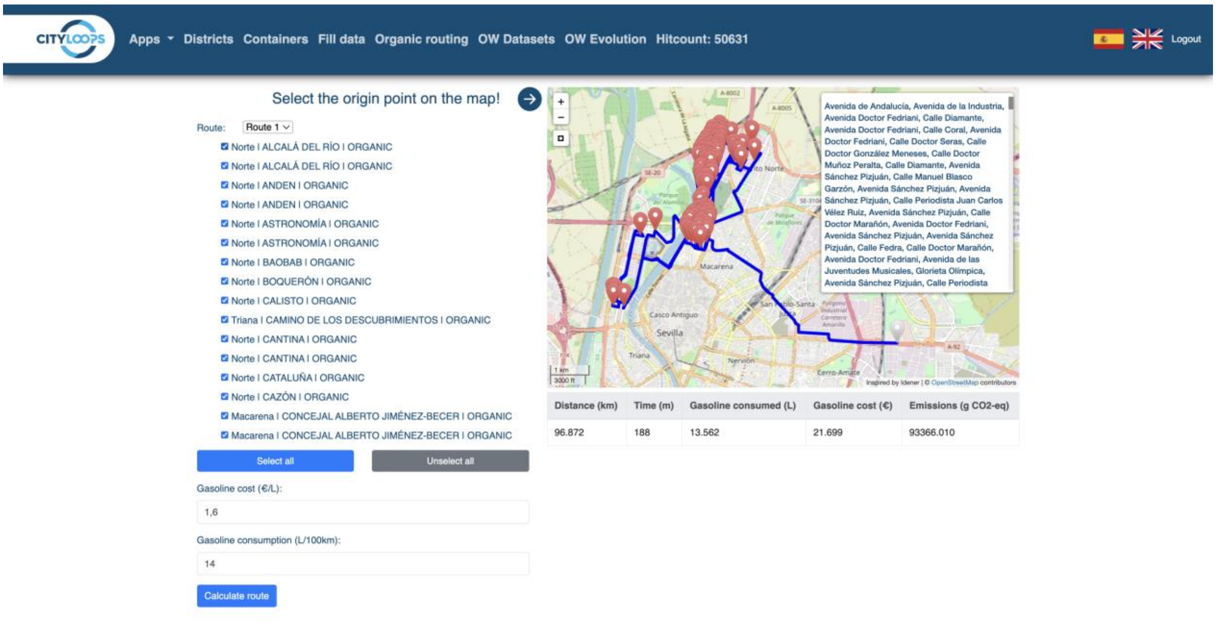



*Figure 6. Optimisation Route 1.*

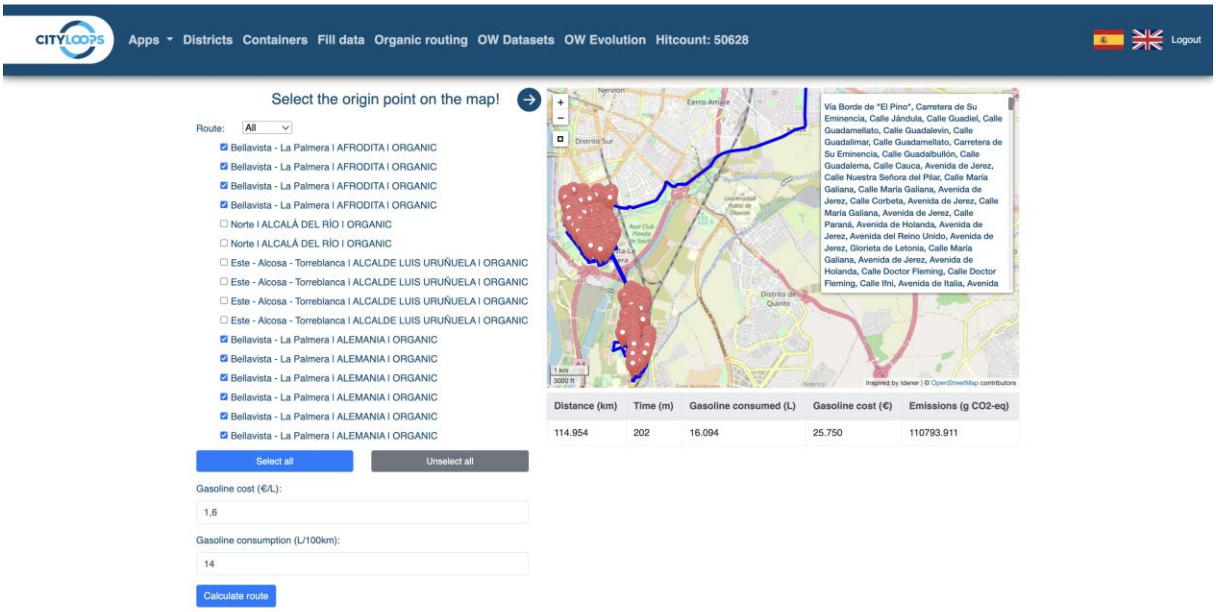



*Figure 7. Optimisation Route 2.*

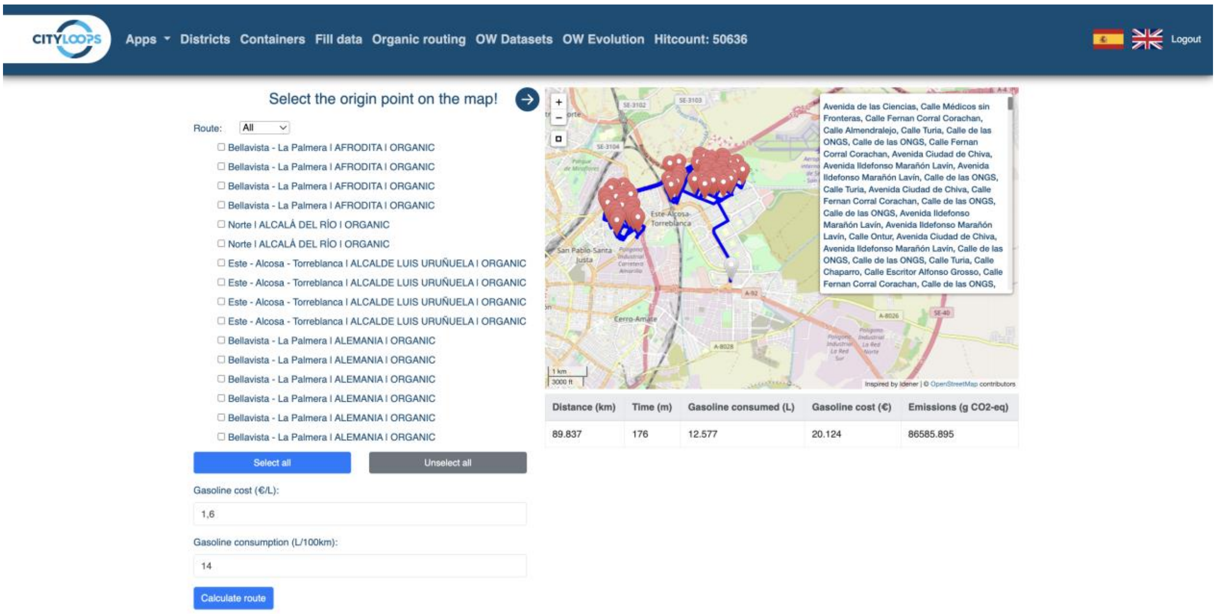



*Figure 8. Optimisation Route 3.*

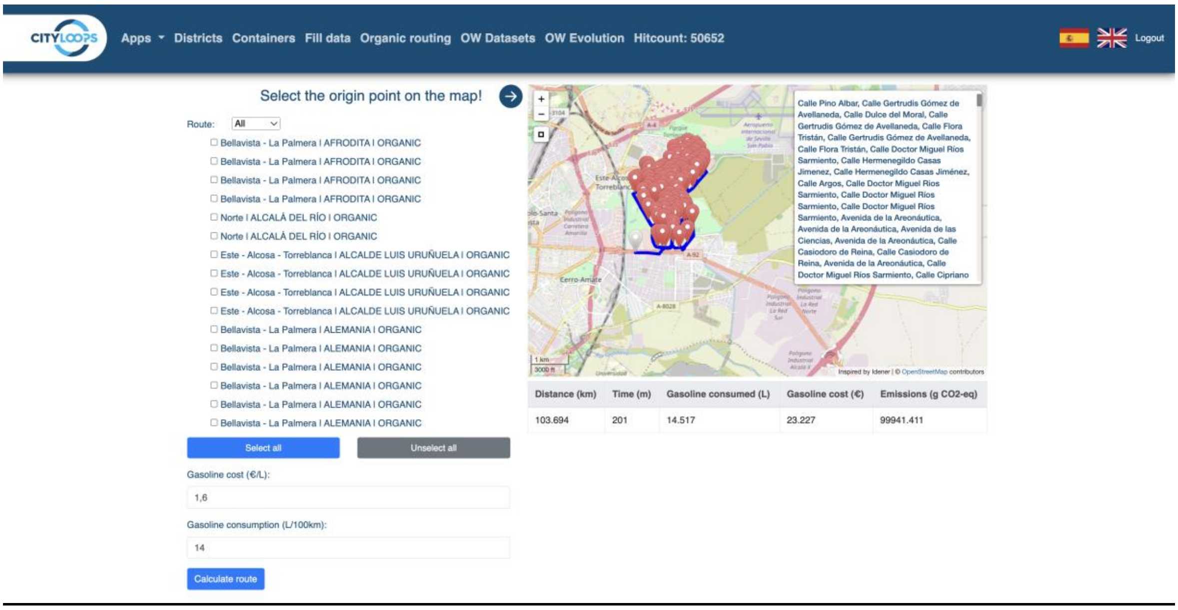



*Figure 9. Optimisation Route 4.*

## Added functionality for Porto (Routing Optimisation)

A manager profile with a new dataset and focused on the Porto city location has been developed for Porto local cluster. This replication work has been made after the cross-collaboration between Porto and Seville local clusters. The main functionality of the profile es the calculation of the optimal routes for the waste collection in Porto. Additionally, the optimal routes are shown with detailed data on the total distante, estimated time of route, fuel consumption, fuel cost, and $CO_2$ equivalent emissions will be shown in a table below the map (Fig. 6).

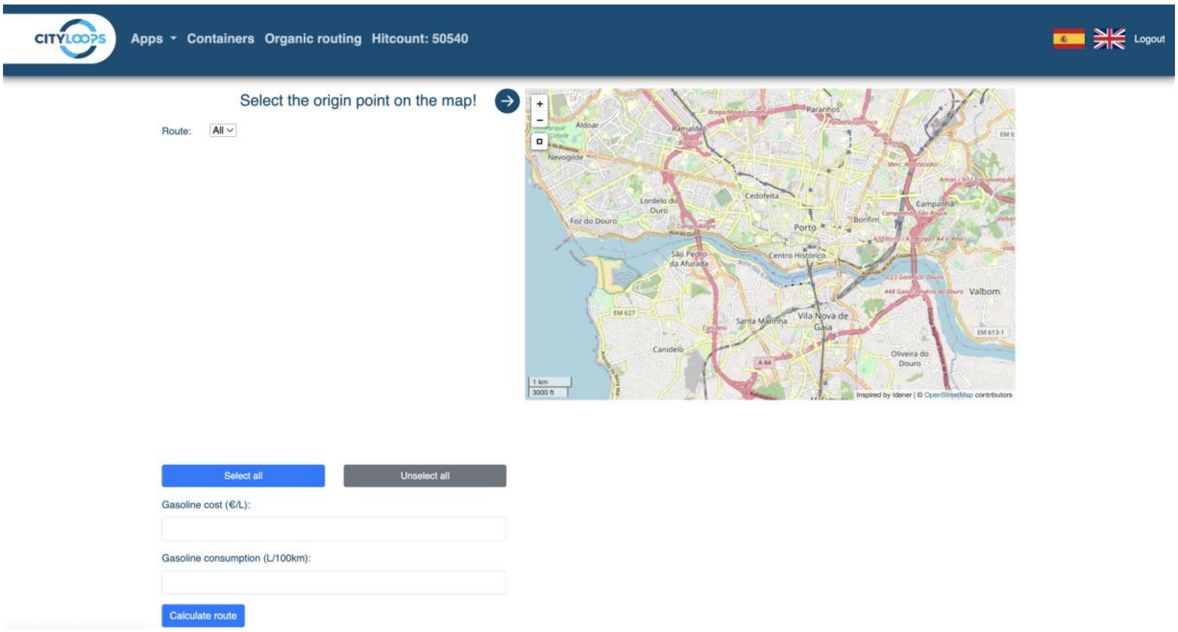



*Figure 10. Manager platform (Organic rounting view).*

*Filled bins data analysis functionality.*

Lipasam implemented some filling sensors in some of their bins in order to go a step beyong the optimisation on their collection routes. So, a new functionality has been developed in the IT tool to monitor and predict the frecuency of collection of bins accroding to the filling data colleted by the sensors. This way, the IT tool could also help in the decion making process to manage the frecuency of collection of the routes. This functionallty show estimations of the bin’s fillings based on the historic data collected by each sensor and show the percentage of fill. Lipasam can take the advantage of this information to determine the collection frecuency of the bins considering that a bin is collected (optimally) in the 80% of fill. The IT tool predicts three different collection frecuencies i.e., every 3 days, every 2 days or daily according to the evolution of the filling precentages collected in the dataset (Fig.7).

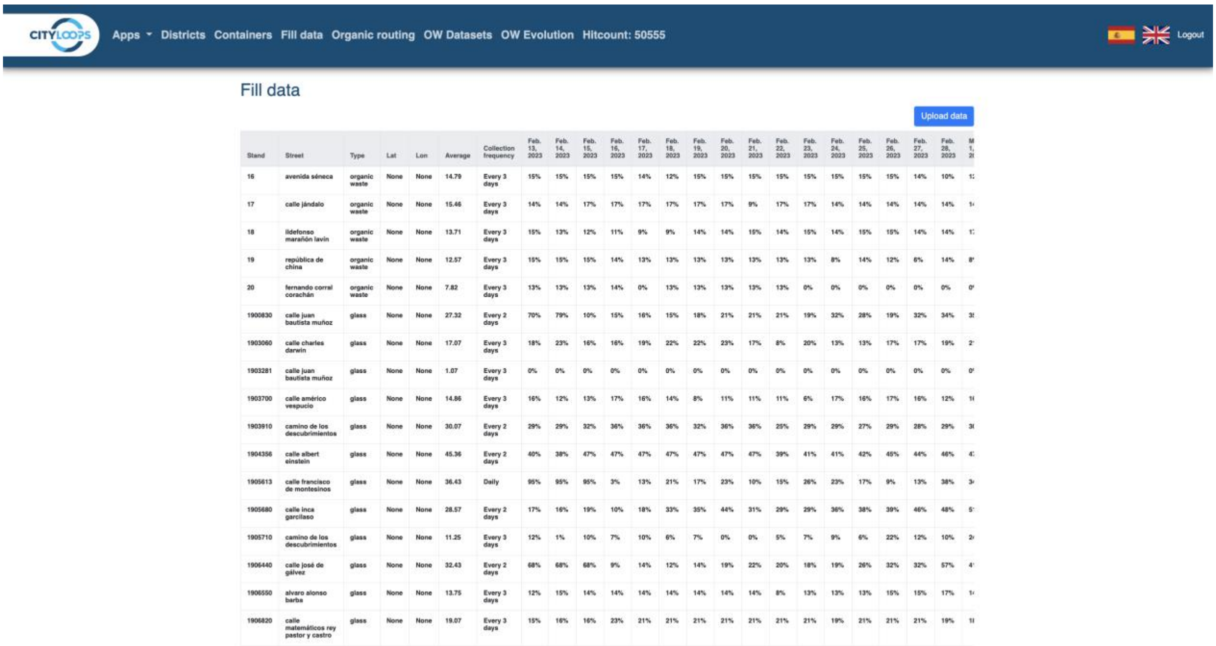



*Figure 11. Manager platform (Filled bins data analysis functionality view).*

*Organic Waste Collection Evolution.*

Different simulations have been made by Lipasam's managers who keep increasing the dataset with internal data on socio-economical and environmental data of the districts. Below is another example of the ML analysis (a previous one is shown in Fig. 4). The analysis of the organic waste collection has as a reference one of the routes implemented previously in the CityLoops project implementation. Then, a dataset with demographic data and environmental information on municipal waste collection is used to determine the similarity degree between the districts of the city. This way, the ML analysis gives a score of the different districts of the city to prioritise the implementation in those districts with higher similarity with the districts that have already the separate organic waste collection implemented. According to the results showed in the different scenarios set by manager, the ML analysis set the district “Los Remedios” as the good one to implement a new route for the separate organic waste collection.

Managers can select the reference of the analysis as well as the number of clusters to be considered in the ML analysis. Therefore, the ML analysis is highly resilient to the personal experience of managers and the update of the dataset. Results will definitely help in the decision-making process to take the advance of this information and prioritise the implementation of new routes according to the observed success in the districts with the previous routes. Finally, a sound experience of the managers and workers improves the accuracy of the tool. An interdisciplinary work group is required in other to determine a good dataset with the critical data to evaluate the success of the waste collection performance.

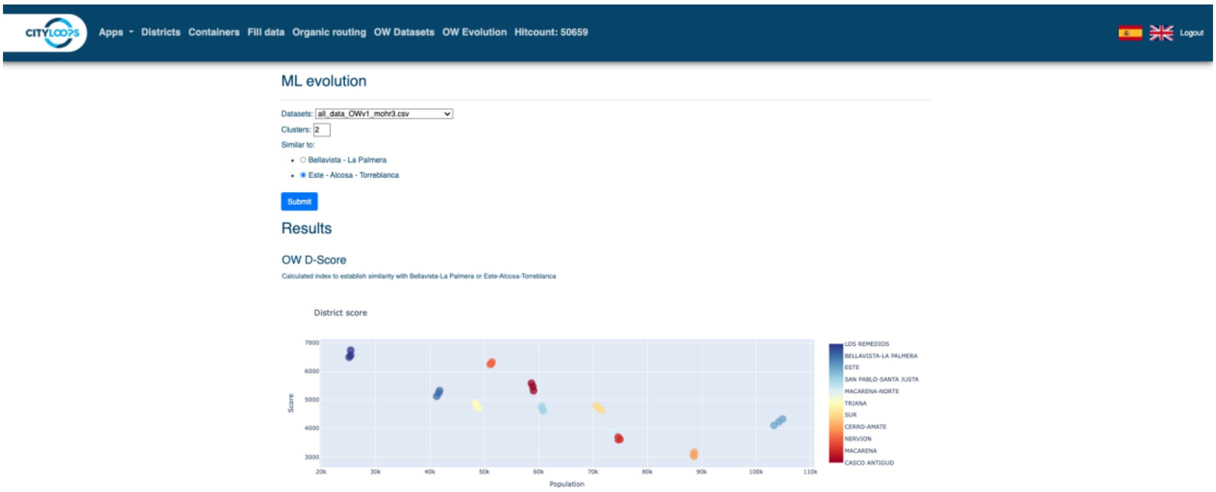



*Figure 12. Machine Learning Analysis on Organic waste collection.*

<u>*Stakeholders' identification. Public and private.*</u>

The platform for each use case within Seville have two versions, one for managers and authorities; and one for citizens.

The platform version for citizens has only visualisation capabilities and widgets using data provided by managers or results from the corresponding Cityloops platform for partners.

Therefore, the applications for managers will consist, at least, in a data collection tool where managers will provide the data to power up the data-driven applications or the visualisation widgets in the platforms for citizens. Additionally, the platforms for managers may have additional capabilities for decision support. The applications for citizens where show interactive visualizations of the data provided by managers and will use the available widgets to get information about specific questions regarding OW.

In a society in which an inexhaustible amount of information is within reach of a click on your mobile phone, there is a growing need to use different means of dissemination to reach the widest range of people with information that helps make the transition to a circular economy as successful as possible. Therefore, the development of IT tools that help municipal managers makes decisions is of great help since they analyse a large amount of data and can advance data analysis and different future scenarios, thanks to the methodologies of Machine Learning. However, deploying these tools with public information for citizens and users of public services not only helps maximize the dissemination of the actions carried out by the municipality in the circular economy but also contributes to increasing the social commitment of citizens and the increase in the use of services at their disposal. Results showed this increase in the number of visits to the IT tool i.e., 50,663 visits in the last year of the project implementation.

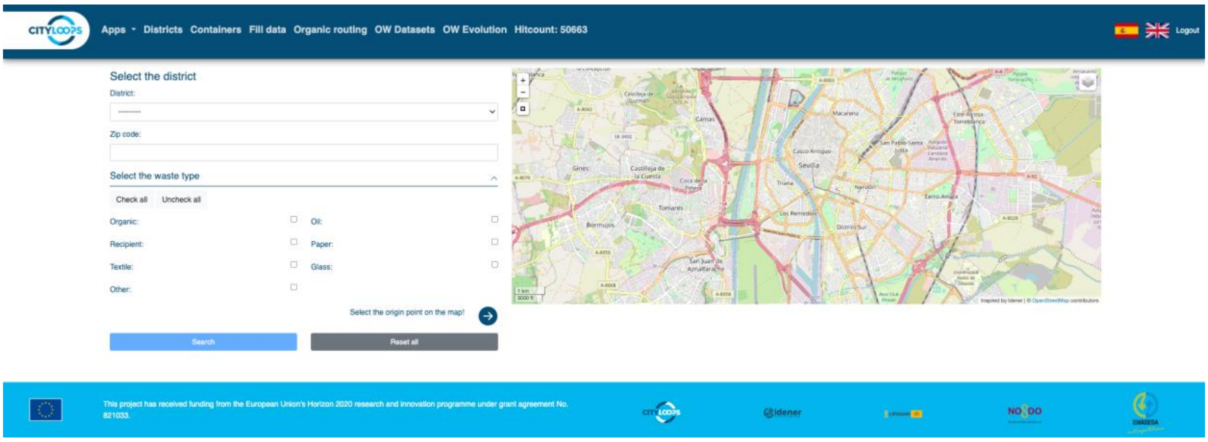



*Figure 13. Front-end OMSW optimisation tool.*

To see in more detail the technology used for the development of the platform and a detailed description of its functionalities, please see 0. Annex I.

*Lessons learned*

- Having historic socio economic data as well as enviromental data is important in order to reach to more accurate results.
- The collaboration of partners is crucial for data collection, since there is not always relevant data, at the necessary scale, in open data platforms, the aforementioned collaboration is necessary.
- The tool and the data analysis methodology need to be adapted to the available data, which should help to cover any data gaps.
- The optimisation of route collection waste reduces the cost of collection as well as the environmental impact.
- The implementation of new routes could be priorized according to the classification made by the ML functionality of the tool.
- The sensoring of the filling of bins could be implemented in the tool to predict the frecuency of collection contributing to the optimization of the collection routes.
- The visualisation of the information regarding the waste collection of the city as well as the reduction of emissions with the implementation of the organic waste collection improve the commitment of citizens and the IT tools could increase the dissemination of these information.

*Link to instrument*

https://ow-app.idener.es/

### 3.1.2 Activity 2 - Installation and management of separate waste collection containers in one neighbourhood.

A specific area of the city has been identified for the installation of separate bio-waste collection containers (side-load containers) of 2,200 litres of capacity with the particularity of an access control through an electronic lock and cards for citizens.

As has been mentioned before, the waste collection system in Seville is based on large capacity surface containers placed in public areas. To maintain this model and citizens waste disposal behaviour, the city has decided to introduce also surface container to collect bio-waste separately.

The selective collection of bio-waste aims to promote a robust market of compost, produced after the treatment of this fraction. The quantity and purity of the bio-waste collected are key factors to successfully conduct this activity.

Given the uncertainty about the public's response to this new container, the city has opted for a container with an electronic lock for opening / closing, through a card that is distributed to citizens who voluntarily want to use it, with the idea that those people who use it voluntarily intend to collaborate correctly in the new system.

Moreover, the implementation of this kind of technology gives the opportunity to advance on systems based on payment for waste generation (bonus/penalties), that can promote cultural-environmental changes.

**Procurement stage: Containers, smart locks & cards**

From a procurement perspective, the following tenders have been launched to support the implementation of this activity:

- Supply of **100 plastic containers** for the selective collection of bio-waste. This tender was part of a framework contract titled: “Supply of side-loading containers (metal and plastic) of various capacities through a framework agreement with a single company”. For the particular case of plastic containers, the folllowing circular criteria were introduced:

    - Recycled materials are used in the manufacturing process. The proportion of these materials must be clearly and unequivocally indicated. When virgin materials are used, it is important to state the origin of these recycled materials and the process of cleaning and granulation to which they have been subjected before incorporation and mixed with virgin material. The incorporation of material will be positively valued as recycled if they comply with the technical characteristics required in the European standards EN 12574.

    *As a results of this tendering process,* the container procured from the winning bid includes had a recycled content of 50%. This criterion had a weight of 2 points out of 100. The supplier is ROTOTANK S.L.

The container procured has a capacity of 2,200 litres, made of rotationally moulded high-density polyethylene with:

- Lid system for the emptying operation.
- Discharge cover blocking device.
- Locking device for the user lid by gravity.
- Cushioned user lid.
- Side handle and pedal.

*Table 3. Milestones of supply of 100 plastic containers for the selective collection of bio-waste tender.*

| Publication of tender | Award | Contract | Reception of containers |
|---|---|---|---|
| 31/03/2021 | 01/10/2021 | 04/11/2021 | 31/03/2022 |

Price: 67,500.00 € VAT not included (100 units). Period of amortisation: 5 years.


*Figure 14. Bio-waste container procured for CityLoops.*

- Supply, installation, data management and integral maintenance of **100 smart locks for containers**. The purpose of the tender is the acquisition, installation, start-up, data management and comprehensive maintenance of 100 new electronic locks for the aforementioned containers. In addition to the electronic lock itself to control access to the containers, the contract includes the transmission of the registered access data, as well as the management of the software and maintenance of the entire system for at least two years.

As a result of these call for tenders, 1 bid was received from SAYME MONITORIZACIÓN ESTRUCTURAL S.L The control access unit, with industrial encapsulation and IP67 degree of protection, in combination with the lock and fittings adapted to the container model, allows integrated control and monitoring of the containers' activity.

The electronic access control unit will guarantee that in any situation of non-use the containers are always closed and cannot be opened by any other means. The opening can be only done using a digital key (card) for the exclusive use of the people who make use of each container. The device is powered by non-rechargeable batteries that allow a service cycle of more than 4 years or 100,000 openings. Also, it supports NB-IoT communications, as well as Wifi or BLE for updating and maintenance.

*Table 4. Milestones of Supply, installation, data management and integral maintenance of 100 smart locks for containers tender.*

| Publication of tender | Award | Contract | Installation of smart locks |
|---|---|---|---|
| 02/11/2021 | 20/12/2021 | 18/01/2022 | 15/04/2022 |


*Figure 15. Details of Smart lock collection system installed for CityLoops collection route.*

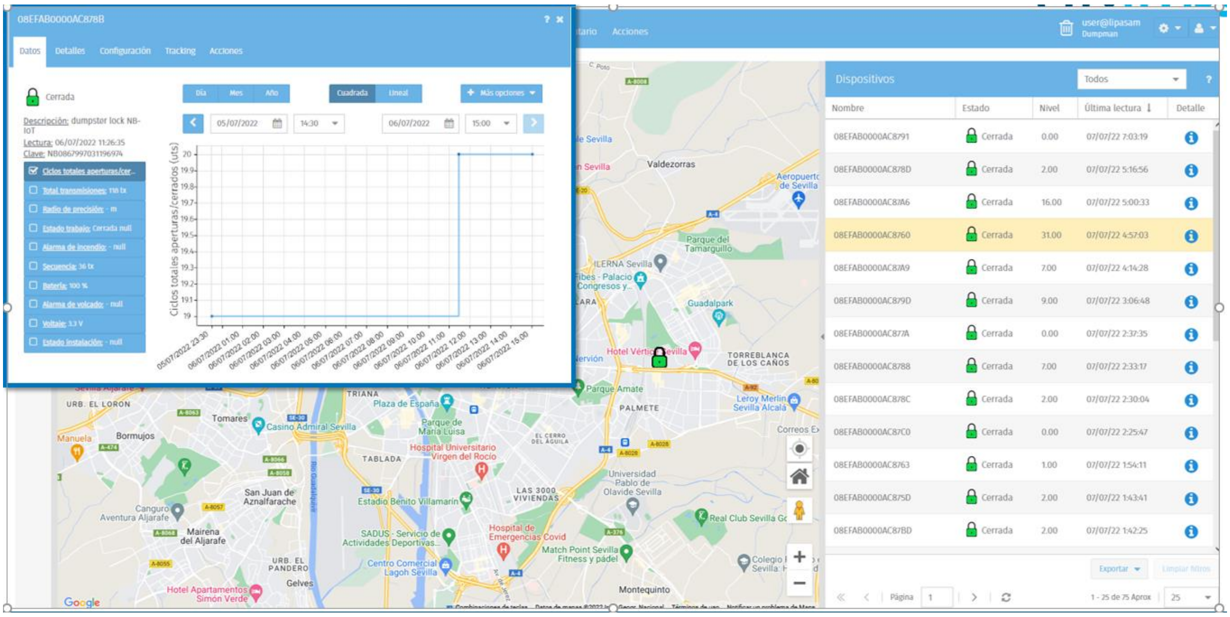



*Figure 16. Front-end web-app of Smart Collection System.*

Price: Inversion 31,000.00 € VAT not included (100 units). Period of amortization: 4 years.

Maintenance (communications, hosting, etc.): 7,400.00€ per year

- Supply of **cards (digital keys)** for opening electronic locks installed on containers. The main characteristics are that it must be a 1K NFC MIFARE type proximity electronic card (contactless), with a frequency of 13.56 MHz, in accordance with ISO/IEC 14443 A protocol. Likewise, the card is screen-printed with the company logo and images and messages related to the use of the card itself, types of materials admitted in the container and waste disposal instructions.


*Figure 17. Electronic cards distributed in CityLoops demonstration action.*

*Table 5. Milestone of supply of cards (digital keys) for opening electronic locks installed on containers tender*

| Offers request | Award | Contract | Reception of cards |
|---|---|---|---|
| 02/11/2021 | 20/12/2021 | 18/01/2022 | 15/04/2022 |

Price: 5,250.00€ (20,000 units).

**Level sensors**

Finally, there has been the installation of 5 volumetric filling sensors for containers. However, it was not necessary to purchase them for the project, since LIPASAM, has been conducting product tests with technological providers. The company running these tests, ECOURBES, signed a collaboration agreement with LIPASAM to test several devices at no economic cost during the course of the demonstration action.

The purpose of having volumetric filling sensors is to try to correlate in a more precise way the level of filling with the contribution of its users. The filling level measurement is performed by ultrasound and the communication protocol used for data transmission is SIG-FOX. The collaboration agreement also includes the use and exploitation of the platform/software where the sensor data is reported.


*Figure 18. Detail of level sensor installed in a container from Seville CityLoops route.*

Price: None, due to collaboration agreement with a supplier to test several of his devices. As a general rule, the cost of this type of device varies greatly depending on the business model in which you are interested (purchase or rental), as well as the number of devices. Currently the market price fluctuates in a range of €60 - €80 per unit and year, which includes the device and its maintenance (communications, operating platform, replacement, etc.).

**Determination of the demo action area stage**

Parallel to these actions for contracting the necessary resources to start up the demonstration action, other actions were carried out.

The first of them was the determination of the area where to implement the project.

After several proposals made by the LIPASAM Planning Department, and meetings held with other services involved from the City Council (mainly, Municipal districts), the neighbourhoods of Parque Alcosa and Santa Clara were selected. Both neighbourhoods are located in the eastern part of the city, close to each other but with some differences.

The Parque Alcosa neighbourhood has a population of around 23,000 inhabitants, with an urban configuration made up of high-rise and dense buildings. Most of the residential buildings are from the 1970s. On average, the neighbourhood's income is in the medium-low range.

The Santa Clara neighbourhood has a population of around 8,000 inhabitants, with a dispersed urban configuration, made up of houses and chalets from the 80s and 90s. On average, the income of the neighbourhood is in medium-high values.

These differences are one more factor to be analysed in the results of the demonstration action, which will be measured through participation in the system (number of uses of the containers and purity of waste obtained through physical characterizations - to see Demonstration action 2).

**Installation stage**

Then, after determining the areas and purchasing, configuring and assembling the different elements of the containers, they were installed on public streets. These containers were placed together with other containers for selective fractions (light packaging, paper and cardboard, glass), forming an “island” for selective collection with 4 different containers.

The purpose for creating a separate island, while keeping the "rest" fraction away in another location is twofold: first, to clarify to citizens that bio-waste is a distinct material from the "rest" fraction, which has historitcally been collected mixed together; and second, to encourage and facilitate the separation of other types of waste by allowing citizens deposit multiple fractions of selective collection in one location without having to move.

For the installation of the containers, it is necessary to carry out previous actions such as indicating the definitive location of the container physically, and if necessary, communite with the mobility areas of the City Council, so that some areas of the road are reserved for the placement of the container, in order to avoid problems, such as parked cars, that make installation impossible.

The installation is carried out with a chassis-cab vehicle of 3,500 Kg MMA, with a crane hook installed. The rate of installation is about 15 containers per work shift (7 hours per work shift).


*Figure 19. Installation of a bio-waste container in Parque Alcosa, part of Seville CityLoops route.*

The container installation began on June 14, 2022, and ended on June 28, 2022. As of those dates, users could access the containers.

In Santa Clara have been installed 30 containers, and 44 in Parque Alcosa.


*Figure 20. Area selected for Seville CityLoops route. Two neighborhoods have been selected for Seville demonstration action 1. Parque Alcosa (44 containers), Santa Clara (30 containers).*

*Figure 21. Completed "selective" island in Parque Alcosa (CityLoops route)*

## Operational stage

### Collection and data from Smart locks

During the operational stage of the pilot, the bio-waste was collected every 3-4 days, depending on the fill level detected both by the fill sensors installed in a small sample of the route, and based on the driver's experience when physically seeing the fill level in the containers. There was an average participation of 2,671 monthly openings in the collection system. On average, 9,109 kilograms have been collected monthly, although as shown in the table below, there has been a significant variation in some of the months that the pilot has lasted. The month with the highest production and openings was August 2022, which coincides with the “novelty” effect of the first part of the campaign. In the months of November and October a slight rebound is observed, which may be due to the second part of the campaign that was carried out in those months.

*Table 6. Collection and smart lock data from CityLoops route during the pilot.*

| **Months** | 07-22 | 08-22 | 09-22 | 10-22 | 11-22 | 12-22 | 01-23 | 02-23 | 03-23 | 04-23 | 05-23 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Opening containers** | 1.181 | 2.878 | 2.562 | 1.803 | 1.423 | 2.023 | 1.379 | 2.373 | 1.041 | 1.112 | 2.410 | 32.055 |
| **Kilograms** | 3.100 | 17.440 | 10.700 | 8.460 | 10.740 | 12.460 | 2.240 | 13.980 | 3.420 | 3.800 | 10.600 | 100.200 |

The correlation coefficient between both variables (kilograms and openings) yields a value of $R^2$=0.8, so it can be said that there is a strong correlation, as well as an expected one, between both variables.

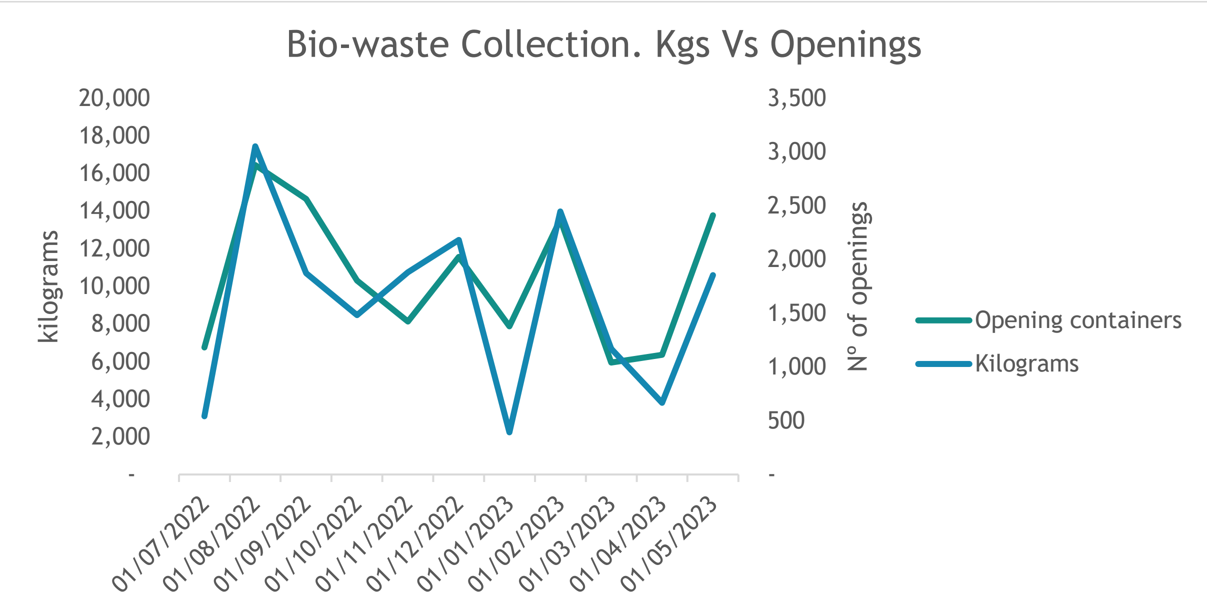



*Figure 22. Comparison between Kilograms collected and number of openings in Seville demonstration action 1.*

Upon comparing the piloted route in CityLoops (C. L01-RB0370-5205.RTPC.305) with other routes sharing similar characteristics, including the number of containers, for the period spanning July 2022 to March 2023, no notable distinctions are currently identified.

*Table 7. Number of Bio-waste containers installed in Seville per route.*

| Routes | Zones | Number of containers |
|---|---|---|
| 5.205.301 | Macarena Norte | 91 |
| 5.205.302 | Bellavista – Bermejales | 163 |
| 5.205.303 | Sevilla Este | 126 |
| 5.205.305 | Parque Alcosa – Santa Clara (CityLoops) | 71 |
| **Total general** | | **480** |

Similarly, the exercise of comparing the first 8 months of production of each of the routes since its establishment has been carried out, observing, on average, a slightly higher production on the route established in cityLoops with two of the previously established routes (302 and 303), although without a marked difference

### 3.1.3 Activity 3 - Neighbourhood communication campaign on the separated collection system.

Campaigns related to bio-waste collection have always been associated with the installation of the system in new neighbourhoods focused on activities targeting residents and households.

However, as an innovative element, in the CityLoops project, the focus is broadened, in addition to the above, awarnesss raising campaigns have been expanded to include schoolchildren (schools and institutes). The aim was to educe younger members of the community about the benefits, how the implemented collection system works, its positive impact on the environment, etc. By targeting this younger demographic, the project hopes to drive behavioural change in households from the ground up.

The communication actions included were:

- Previous information to the Municipal District and neighbouring entities from the implantation area: Meetings were held with the different municipal districts to explain what the project consisted of the types of containers to be installed, the operating mechanism, as well as to agree on container placement points. In these meetings, in addition to LIPASAM and the political leaders of the districts, neighbourhood associations and trade associations from the area also participated.
- Placement of informative posters in residential buildings: Posters were placed on building portals, bus shelters, commercial establishments and facades informing about the new bio-waste collection system in the areas surrounding the container installation.
- Mailing. Mailing of informative brochures on the waste collection system implemented (type of container, admitted materials, operation of the container, etc.). The brochure includes a card to access the container and information to request a free recycling kit, consisting of a 10-litre aerated bucket, a roll of compostable bags, and a pack of 3 bags for collecting paper and cardboard, light-packaging and glass.

- Door-to-Door Information Action in commercial establishments in the implantation area: Commercial establishments in the area were visited to inform them about the placement of containers, the operating mechanism, materials allowed in the containers, etc.

- Digital marketing campaign, on the internet and social networks.

- Information points in differents locations:

    - Information points on public streets.
    - Information point in food markets and supermarkets.
    - Information point in educational centres in the area.

    In general, information points typically included:

    - Tent or similar element with minimum dimensions of 4 x 5 metres, approved and with fire protection.
    - Two banners with a minimum size of 2 x 1 metres, printed in full colour, with messages about the communication campaign.
    - Inside the tent, several printed and audiovisual graphics showcasing the entire process, from selective collection of bio-waste to its treatment, and the environmental benefits it brings. These materials aim to aid in dissemination and education.


*Figure 23. Image during a communication campaign in a school of the area selected for demonstration action 1*


*Figure 24. Example of an informative poster of the communication campaign deploye*

The meeting with the Municipal District and neighbouring entities of the implantation areas took place in January 2022. The rest of the actions were implemented in the following stages:

- **Mailing and posters in buildings:** 10,728 households have been mailed. 199 commercial establishments have been visited. 476 posters have been installed.

- **Information points:** 27 "information points" were set up, mainly in schools, being this part new compared to other campaigns in the past. Two environmental monitors were used schools for a period of 3-4 hours to present the importance of the differentiated separation of bio-waste. A total of 20 schools from both areas participated, with a total number of 8,675 participants. The same number of "waste kits" have been distributed. Those kits consisted of a 10-liter aerated bucket for the kitchen, a roll of compostable bags and a pack of 3 raffia bags for paperboard, glass and light packaging waste. This action was implemented in two stages due to the holiday period, a first part in July, and a second part in October - November 2022.
- **Digital marketing campaign:** Publication on the internet and social networks about the installation of the new system.

In order to evaluate the impact of this campaign, a comparison between the different routes has been carried out during the first 8 months after installation. The data shows a slightly higher waste separation in the CityLoops route compared to routes 302 and 303, but without differences with respect to route 301. These similarities and differences are not very significant and may be due to factors such as population density, socioeconomic factors, special circumstances such as the Covid 19 pandemic, etc. (some of these routes were installed pre-pandemic, others in the middle of the pandemic), so the differences found are not conclusive.

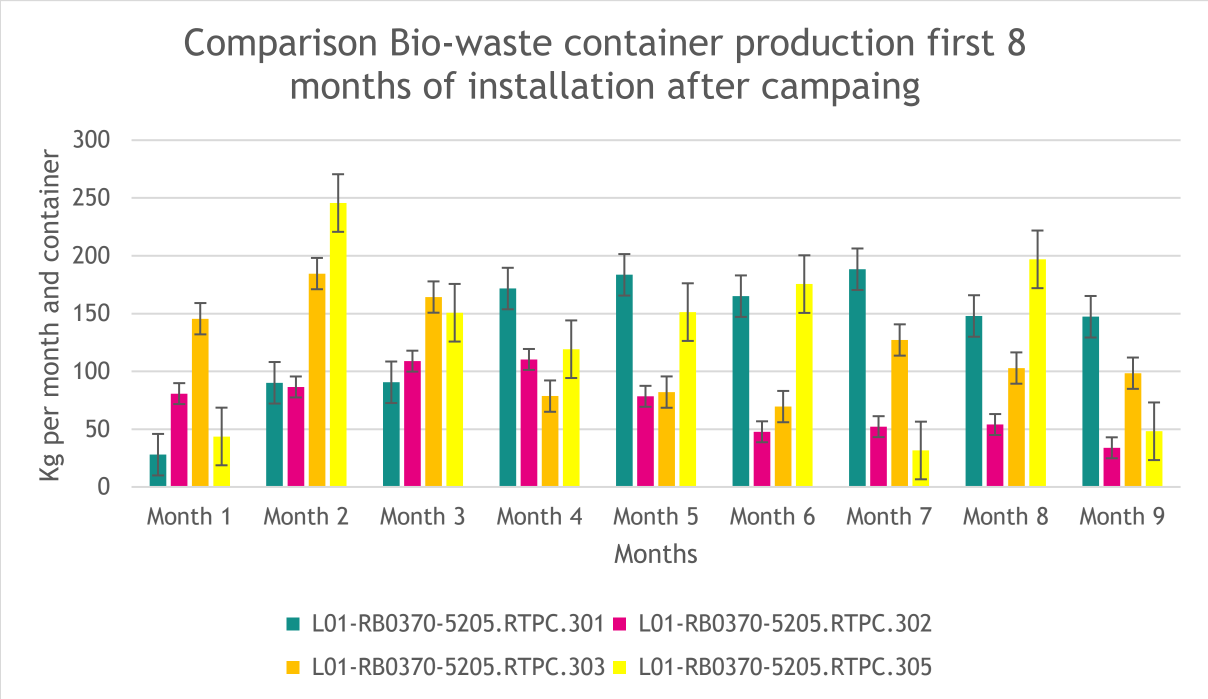



*Figure 25. Comparison between differetns Bio-waste routes production in the first 8 months of installation after campaing*

Price: The price of the campaings (excluding "waste kits") has been:

- **Mailing and posters in buildings**: 17,950.00 € VAT not included (1.67 € per unit, mainly households).
- **Information points:** 9,400.00 € VAT not included (348.00 € per information point)

### ▪ 3.1.4 Activity 4 - Citywide communication campaign on reducing food waste.

One of the key aspects to reduce the amount of bio-waste collected both in homes and large generators is waste prevention. In this case, within the CityLoops project, the establishment of an awareness campaign to reduce food waste has been explored for the first time in the city by the waste management company.

The design and decision-making for the planning and execution of this campaign has taken more time than initially planned, since different types of campaigns have been explored over time. This type of communication campaign has been carried out for the first time in the organization (LIPASAM), so the support received by Portoambiente, a partner in the CityLoops project, has been crucial. Their support was received in relation to the approach that should be taken, as well as expected results and technical requirements for its execution. Various meetings have been held with Portoambiente in order to refine the design of the communication campaign.

The final objectives of this communication campaign were:

- “Sow a seed” of awareness on the minimization of food waste in large generators, mainly the HORECA sector (Hotels, restaurants and catering).
- Supply and distribution of material to promote the minimization of food waste.

The target audience for this communication campaign is:

- HORECA sector establishments (Hotels, restaurants and catering).
- Customers of the mentioned establishments.

The communication campaign developed has been broken down into the following actions:

- "Door-to-door" communication action in HORECA establishments through:
    - Informative talks and delivery of informative brochures aimed at both establishments and customers.
    - Supply and distribution of leftover food packaging for customers.

- Development of a digital micro site in LIPASAM web with information about the communication action.

*Figure 26. Leftover food packaging distributed during the communication campaing,*

The actions described were developed in the catering establishments (HORECA) of the main shopping centers of the city:

- Lagoh Shopping Center (13 establishments).
- Nervión Plaza Shopping Center (5 establishments).
- Torre-Sevilla Shopping Center. (8 establishments).
- Los Arcos Shopping Center. (3 establishments).
- Alcampo Shopping Center (1 establishments).

Before implementing communication actions within establishments, the management entities of each shopping center were informed about the communication strategy through in-person meetings. This approach was well received. For instance, during these meetings, the "Lagoh" Shopping Center commented that this action was aligned with its Sustainability Plan.

The communication campaign was carried out using 2 monitors, both in the morning and in the afternoon, always trying to minimize possible inconvenience to the establishment.

Additionally, the following was distributed during the campaign to establishments:

- Information brochures:
  - 11.200 units of information brochure with good practices for minimizing food waste aimed at HORECA establishments.
- Food leftovers
  - 11.200 units of leftover food packaging for free delivery to the customers of each establishment. On each unit there is a sticker with a QR code.

Also, a digital micro site of the campaing, linked to LIPASAM website has been developed where establishments and clients can consult information of the campaign, which is accessed through the QR code on the packaging sticker. The development of the microsite web was undertaken by LIPASAM's Communication department staff.


*Figure 27. Example of digital publication deployed during the campaign.*

*Figure 28. Image of the deployment of the communication campaign. Two monitors giving information to one establishment.*

Price: 12,600.00 € VAT not included (420.00 € per establishment).

## 3.2 Implementation Activities Demo action 2

The methane production capacity of the bio-waste collected from Demo Action 1, was tested through a process of co-digestion with sewage sludge in a wastewater treatment plant (WWTP) belonged to EMASESA, as a first step of analysis for exploring alternatives to the current collection and transportation of bio-waste for composting.

The aim of this action is to reduce the distance travelled by the bio-waste (and consequent fuel consumption and $CO_2$ emissions) and increase the energy self-sufficiency of the WWTP.

Currently, the bio-waste collected in the city of Seville is transported directly to a waste separation, classification and treatment plant for composting. This treatment plant is located 37 km away from the city. LIPASAM, manages a transfer plant nearby to the city in order to optimise logistics to the final treatment plant. As the number of routes and quantity of bio-waste to be collected increases in the future, so will logistics costs.

EMASESA, the municipal company that carries out the comprehensive water management in the city, has facilities less than 10 km from the city. For several decades, the city's wastewater treatment plants have had biogas production systems based on an anaerobic digestion of their sludge. Furthermore, in recent years, EMASESA has opted for the co-digestion, together with its sewage sludge, of other industrial effluents with significant biodegradable organic matter content, to increase the production of renewable biogas.

## 3.2.1 Activity 1: Detailed planning for the testing process.

The bio-waste needs to be as pure as possible for the biomethane test at pilot plant. In order to test this, the following steps were taken:

- Conducted 4 physical characterizations and sample collection. The manual separation performed during the characterizations helped to already obtain pure bio-waste.
- Processed bio-waste samples into a pulp using an EMASESA industrial blender.
- Conserved of the bio-waste samples by freezing them.
- Conducted laboratory analysis of COD, BMP and other parameters to determine the capacity of methane production and prepare test at pilot plant scale.
- Carried out two biomethane test at pilot plant scale (Feb – May 2023), one using bio-waste coming from the summer and the winter season.

The technology used for the anaerobic co-digestion tests is a 5-meter-high digester, including the ground-anchoring supports, presenting a useful height of about 4.60 meters. This digester has a jacket through which hot water circulates to keep the digested sludge at the right temperature. The operational parameters for de co-digestion test were:

- Batch feeding of feedstock (bio-waste and sludlge of different proportions during the test.
- Temperature of the digestion: Mesophilic (between 33-36ºC).
- Hydraulic retention time: 35 days.

*Figure 29. General view of the pilot plant in EMASESA facilities.*

The digester is composed of the following elements:

- Tank with resistors: It incorporates a tank of about 40-50 liters of capacity that contains water and two resistors to maintain the water at the desired temperature for the tests that must be carried out.

*Figure 30. Tank with resistors*

- Recirculation pump: the sludge is captured from the upper part of the digester and is once again returned to the interior of the digester from the lower part. This continuous and smooth circulation of the sludge inside the digester will allow its homogenization.

- Feed pump and feed tank made up of a tank also made of stainless steel, and connected to a delivery pump that introduces the daily feed into the digester. A siphon is installed in the upper part that allows the digested sludge to come out by overflow, which will be analyzed daily to control the process variables.

*Figure 31. Feed pump and feed tank*

- Gas flowmeter. At the gas outlet there is a flowmeter to evaluate the gas production of the digester.

*Figure 32. Gas flowmeter.*

The feeding of the pilot plant was carried out daily as follows:

1. Sampling of digested sludge.
   - Sample collection time: 8:00 a.m.
   - Stop the feed pump.
   - Check recirculation pump operation.
   - Purge recirculation tubing for 30 seconds before taking the sample.
   - Take a 0.5 L sample.
   - Set the feed pump to manual and feed the remaining sludge into the feed tank.

2. Feeding procedure.
   - Stop the feed tank agitator.
   - Take the mixed sludge sample to feed the pilot plant in the delivery pipe of the digestion pumps (8:00-9:00 a.m.) and introduce it into the feed tank. At the same time take a sample for analysis.
   - Add the volume of bio-waste selected.
   - Start the agitator that will work with the same timing as the feed pump.
   - The feed pump will work timed so that the feed tank is not exhausted in 24 hours.
   - Put the feed pump on automatic.

3. Monitoring.

The operator of the control center will monitor the plant twice per shift:
   - Water temperature
   - Sludge temperature
   - Water temperature set point
   - Checking the operation of resistors, water pump and sludge recirculation pump.
   - Gas flowmeter reading.

The person responsible for taking samples and feeding the plant will take:

- At 8:00 a.m. gas flow meter and sludge temperature according to the pilot plant probe.
- At the time of sampling the sludge from the digester, the "insitu" temperature of the digester will be measured.

### 3.2.2 Activity 2: Physical characterisation of the bio-waste collected.

5 samples were collected under the following conditions:

- Collected in resistant and watertight boxes, with lids, stackable and easily transportable.
- The samples, once collected, were transported the same day to the Wastewater Treatment Plant (WWTP) Copero. Ctra. Del Copero, Dos Hermanas, Seville.
- After, the samples were adequated (sieved and titured) and stored in an industrial freezer.

*Figure 33. Pictures taken during one of the physical characterizations carried out. Worktable, buckets with separated waste and bio-waste sample.*

5 characterizations have been carried out. The results obtained in terms of percentage of different fractions obtained in the bio-waste container have shown the following ranges:

*Table 8. Results from bio-waste physical characterization.*

| Fractions | % |
|---|---|
| Bio-waste | 50,64 - 57,36 |
| Light-packaging | 8,09 - 19,43 |
| Glass | 0,53 - 8,34 |
| Paper and board | 6,66 - 18,26 |
| Rest | 10,22 - 19,18 |

In general, the desired percentages of bio-waste purity have not been reached. The container has presented a significant number of contaminants (fractions that should not be in the container). The majority of undisired fraction is "rest", and within it, non-packaging plastics and hygienic waste.

## 3.2.3 Activity 3: Lab analysis of COD, BMP and other parameters to determine the capacity of methane production.

Two types of lab analysis have been undertaken.

- BMP bio-methane potential - parameters related to biomethane production
- COD chemical oxygen demand - parameters related to the organic concentration in the substrate

These tests were carried out by an external entity, *Instituto de la Grasa*, belonging to the Higher Council for Scientific Research of Spain (CSIC). The BMP and COD study lasted 15 days, in which the substrates (bio-waste sample of cityloops route and sludge) were characterized, these being: Inoculum of microorganisms. During this lab analysis, various proportions of sludge and bio-waste were tested, a total of 6. For these different samples, methane productivity was measured in the laboratory, after a digestion time of 7 days and 14 days, respectively.

*Table 9. Proportion of content of differentes samples tested in the lab analysis.*

| **Proportion** | % sludge (FM) | %bio-waste (MSW) |
|---|---|---|
| **White** | - | - |
| **Control** | - | - |
| **Sample 1** | 100 | 0 |
| **Sample 2** | 90 | 10 |
| **Sample 3** | 80 | 20 |
| **Sample 4** | 50 | 50 |
| **Sample 5** | 25 | 75 |
| **Sample 6** | 0 | 100 |

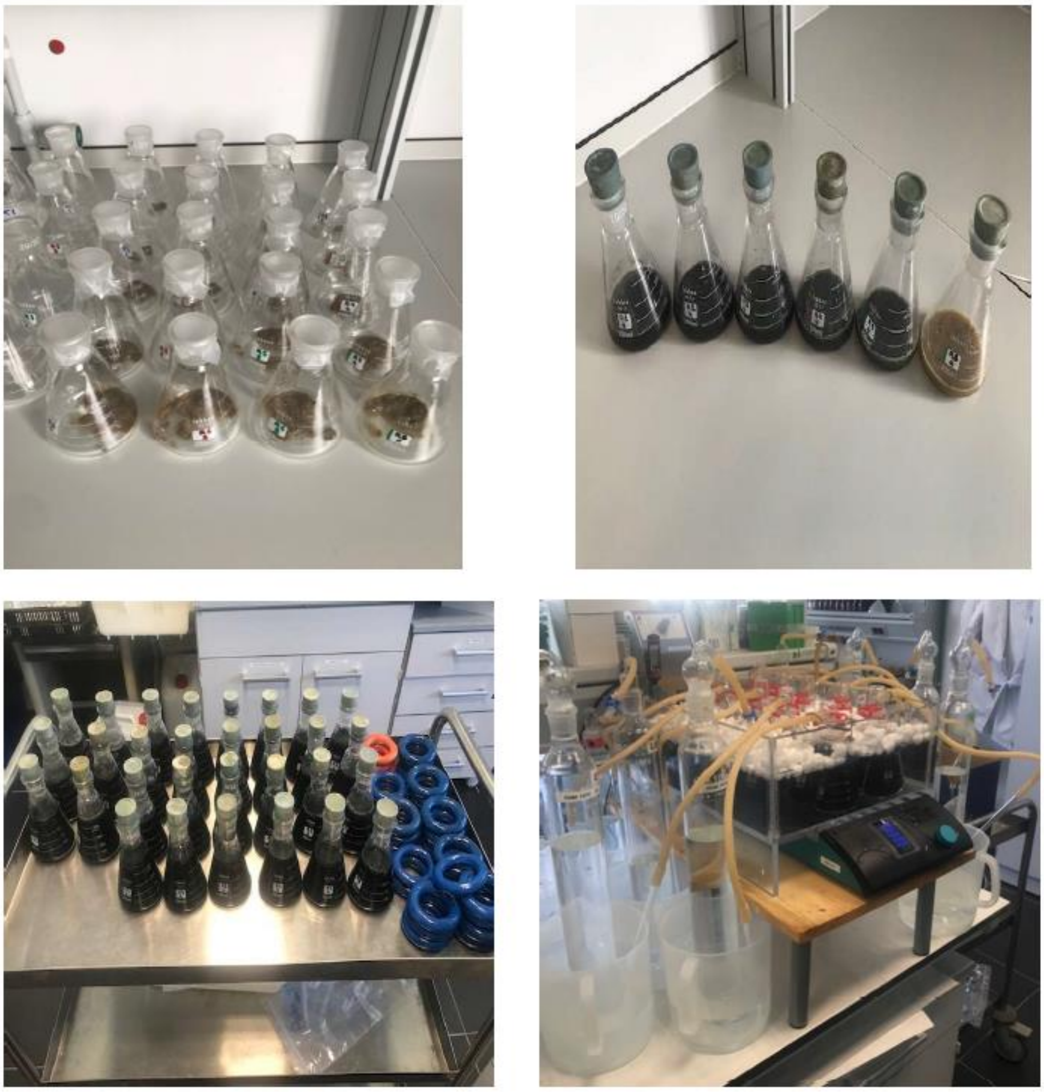


*Figure 34. Pictures of equipmet and samples used during the lab analysis.*

The results were very satisfactory, showing a significant increase of biomethane production at a higher proportion of codigested bio-waste, being the sample 6 the one that has presented a higher production of biomethane.

## 3.2.4 Activity 4: Calculation of the BW dose to introduce in the pilot plant for co-digestion with sludge.

The results from the lab analysis determined the amount of bio-waste co-digested with the sludge in order to not negatively affect the microbiome. The daily feeding volume was 13 liters. This volume was proportionally divided between sludge and bio-waste.

During this experience, two types of bio-waste were evaluated, on the one hand, bio-waste generated in the winter season, and on the other hand, bio-waste generated in the spring/summer season. The data obtained as average values of the analyzes carried out during the duration period do not show significant differences.


*Figure 35. Examples of bio-waste pre-conditioned.*

At the beginning of the tests, different work periods were defined, depending on the proportion of mixture with the sludge from the WWTP and the type of bio-waste (Winter/Summer). Staggered feeding was carried out over time, progressively increasing the proportion of bio-waste, while decreasing the amount of sludge while maintaining the process in stable operating conditions in the pilot digester. The following table shows the different work periods.

*Table 10. Differents periods of work and proportions tested during the pilot.*

| | Dates | Sludge | Bio-waste (Winter) | Bio-waste (Summer) |
|---|---|---|---|---|
| **Stage 1** | 21/02/23 - 12/03/23 | 100 % | 0 % | 0 % |
| **Stage 2** | 13/03/23 - 19/03/23 | 90 % | 10% | 0 % |
| **Stage 3** | 20/03/23 - 26/03/23 | 80 % | 20 % | 0 % |
| **Stage 4** | 27/03/23 - 2/04/23 | 50 % | 50 % | 0 % |

| | | | | |
|---|---|---|---|---|
| **Stage 5** | 3/04/23 - 17/04/23 | 0 % | 100 % | 0 % |
| **Stage 6** | 18/04/23 - 10/05/23 | 0% | 0% | 100 % |

Prior to that, the waste to be digested as it is received at the facility is subjected to sieving, in order to avoid possible clogging of the trituration equipment used later. Various materials are removed in this sieve. It is then tritured, obtaining a dough with a pasty consistency. Additionally, to facilitate the handling of the sample, the triturate is moistened until reaching a concentration in "dry matter" of 3.0%

Feeding in the pilot digester is carried out in batches on a daily basis, so previously, several samples of bio-waste have been processed, conditioned and stored under refrigeration.

The average characteristics of the sludge used to carry out the codigestion tests were:

*Table 11. Characteristics of the sludge used to carry out the codigestion tests*

| Parameters | Sludge |
|---|---|
| **pH** | 5.98 |
| **Dry matter (%)** | 3.4 |
| **Volatil matter (%)** | 70.5 |
| **Chemical demand for oxygen (mg/l)** | 38,972 |
| **Soluble Chemical demand for oxygen) (mg/)** | 1,154 |
| **Total Phosphorus (mg/l)** | 1,493 |
| **Total Nitrogen (mg/l)** | 1,354 |
| **Ammonium (mg/l)** | 120 |
| **Phosphates (mg/l)** | 276 |
| **Alkalinity (mg/L $CaCO_3$):** | 904 |
| **Volatile Acidity (mg/L $CH_3$-COOH):** | 1,007 |

The average characteristics of the bio-waste used to carry out the codigestion tests were:

*Table 12. Characteristics of the bio-waste used to carry out the codigestion tests.*

| Parameters | Bio-waste conditioned |
|---|---|
| pH | 4.89 |
| Dry matter % | 3 |
| Volatil matter% | 84.1 |
| Chemical demand for oxygen (mg/l) | 38,140 |
| Soluble Chemical demand for oxygen) (mg/) | 6,670 |
| Total Phosphorus (mg/l) | 127 |
| Total Nitrogen (mg/l) | 800 |
| Ammonium (mg/l) | 157 |
| Phosphates (mg/l) | 84.5 |
| Alkalinity (mg/L $CaCO_3$): | 850 |
| Volatile Acidity (mg/L $CH_3$-COOH): | 4,125 |

### 3.2.5 Activity 5: Measurement of the methane production. Analysis of the gas produced (sulphide, methane, CO2, etc.).

Methane measurement was carried out directly in the pilot digester, during the entire period of the 2 tests carried out (summer and winter bio-waste), from 21/02/2023 – 10/05/2023.

The main conclusions obtained in these pilot tests are listed below:

- In reference to gas production, it was detected that the amount of gas generated in the pilot plant was somewhat less than theoretically expected, but as reflected in the following graph, this deviation remains similar throughout the test period, with an average registerd production (0.36 $Nm^3$ gas/Kg COD)

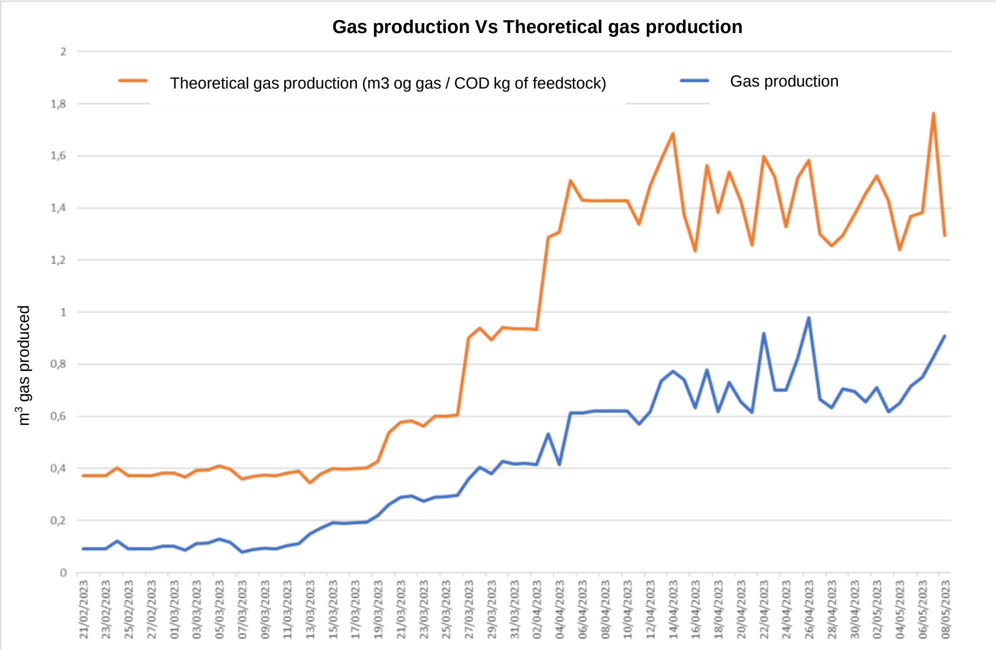



*Figure 36. Gas production Vs Theoretical gas production. In orange: Theoretical gas production (m3 og gas / COD kg of feedstock). In blue: Gas production registered in the pilot plan.*

- It was verified in the tests carried out that the higher the proportion of bio-waste, the greater the amount of gas generated per kg of COD of the feedstock.

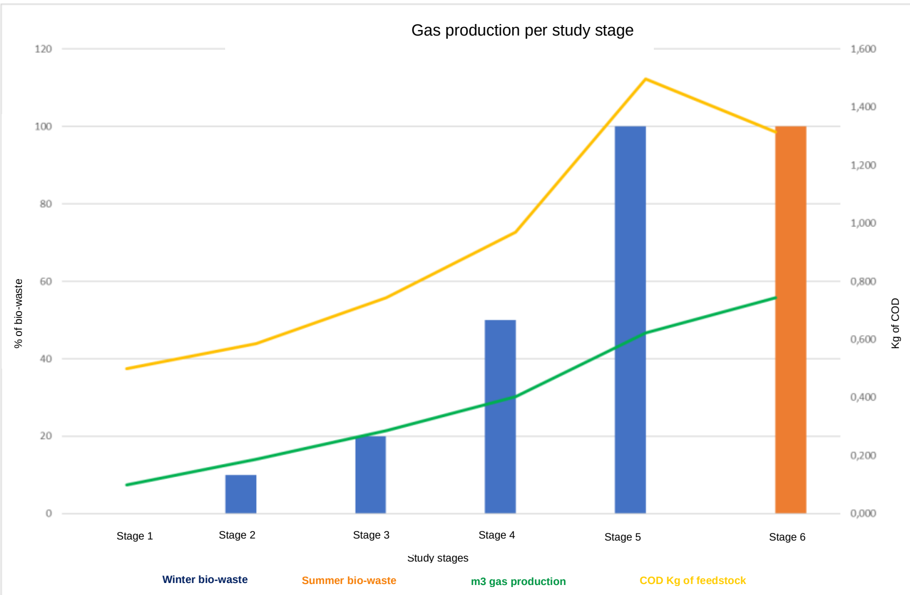



*Figure 37. Gas production in pilot plan for work period. 2 the left to right, Period 1 to Period 6. Columns in blue: Bio-waste of winter season. Columns in orange: Bio-waste of summer season. Green Line: Gas production. Yellow line: COD Kg of feedstock.*

- The digestion process was not affected by the addition of bio-waste, and the control values such as pH and acidity-alkalinity ratio of the digestate remained stable.

- As regards the quality of the biogas generated, at all times it remained within the normal range for biogas generated in this type of facility. In addition to the controls carried out in the pilot plant, a sample was sent to an external laboratory for complete analysis, including determination of the Lower Calorific Value (LHV) and other parameters, all of which were within normal limits.

### 3.2.6 Activity 6: Revision of the results obtained. Analysing how to design a pre-treatment system or the process strategies for managing the anaerobic digestion of the WWTP using BW.

The analysis of the results from the pilot (quantity and quality of biogas, parameters of CODs and sludge produced, operational parameters of the digestor, quality of the bio-waste obtained, etc.) has helped to set the basis for decision making process for the near future regards to bio-waste treatment in the City of Seville

Several meetings have been held, between June 2022 and May 2023, where, in addition to the initial planning and subsequent monitoring of the test, the evaluation of the findings and partial results obtained has been carried out, mainly between LIPASAM and EMASESA technicians, with profiles dedicated to planning, innovation, wastewater treatment and environmental management.

The main conclusions reached by this working group are listed below, after the tests carried out

- It is necessary to establish an adequate pretreatment of bio-waste in order to avoid problems in the equipment used for grinding. The adaptation made for these tests (manual sieving) is not valid for industrial scaling, so it would be necessary to purchase pretreatment equipment for said scale.
- The trituration to be carried out must be adequate to achieve a particle size that generates a correct fluidization of the bio-waste, in order to avoid problems of clogging in pumps and recirculation pipes.
- It has be corroborated with the appropriate biomethanation tests that the digestion of bio-waste in the EMASESA WWTP is technically feasible, either alone or jointly with sludge, since in both situations the digestion control parameters remain within the appropriate limits for the proper functioning of the process.
- The gas produced has presented a correct composition and adequate characteristics

The work team, in view of the results obtained, has agreed to carry out a feasibility study in the short-medium term, whose objective is the use of EMASESA digesters for the industrial treatment of the bio-waste generated in the city of Seville. In the long term, it has also been considered interesting to evaluate the use of the biogas produced, as as fuel for the fleet of municipal vehicles, urban buses and heavy-duty vehicles for waste collection, among others.

### 3.2.7 Activity 7: Economic and environmental benchmarking analysis between base scenario and demonstration action.

As a final part of the review of the results of the tests carried out, the work group made up of technicians from LIPASAM and EMASESA carried out a first preliminar comparative analysis between the management of bio-waste, as it is currently carried out (composting in a treatment plant) and a possible management scenario of bio-waste in EMASESA's WWTP plant, in economic and environmental terms.

This analysis was carried out through telematic, in-person and telephone meetings.

In the current scenario, bio-waste is collected and transported to the Montemarta-Cónica mechanical-biological treatment plant, located about 37 km from Seville, for composting. The entrance fee for this waste to the plant is around €20/tonne, with the transport cost being around €50 per travel (round trip) and the landfill tax cost for material that was not recovered at €30/tonne.

The hypothetical scenario would be collecting the bio-waste and transport it directly to EMASESA facilities, which are in Seville, with a entrance fee for this waste around €10/tonne. To do this would be necessary invest in a bio-waste pretreatment plant for the screening and preparation of the bio-waste collected before its treatment through anaerobic digestion, and also adjustments in Emasesa facilities. The comparison has been made taking into consideration a hypothetical collection of 25,000 tonnes of biowaste per year.

The main conclusions reached are detailed below, after comparing the current scenario with a hypothetical future scenario, if it were decided to scale up the demonstration action carried out:

From an environmental point of view, the fact that this bio-waste was managed through Emasesa would have the following consequences:

- Produce biogas (renewable energy) for the city, (around 1.463 $m^3$ gas/day in a first calculation).
- Savings in terms of traveling fewer kilometers for treatment, and therefore lower fuel consumption and lower $CO_2$ emissions, since currently the bio-waste collected in Seville is transported to the mechanical-biological treatment plant in Montemarta-Cónica, located about 37 km away, whereas the EMASESA plants are around 10 km

away (in a first calcutation: 120,000€ and 30,000 litres of fuel in transport could be saved).

- Modification of the environmental authorization (environmental prevention and control instrument) applicable to the EMASESA facility. Therefore, time is required (around 1-2 years according to Spanish legislation) to obtain authorization, before the start of the construction project of the necessary facilities).
- After anaerobic digestion, the expected final destination of the digestate cannot be other than composting according to current legislation. Therefore, a nearby composting facility is necessary. In this case, EMASESA is working on the construction of a facility of this type, so this weakness would be easily overcome.

In economic terms, managing the bio-waste generated in Seville through EMASESA would have the following conclusions:

- The investment in a bio-waste pretreatment plant is completely necessary for the screening and preparation of the bio-waste collected before its treatment through anaerobic digestion. After preliminary consultations with providers of this technology, the necessary investment would be between €3 -4 M, in addition to recurring expenses (€300K – €400K/year).
- Co-digestion also has other associated costs, such as the input fee for digestate sludge to the composting plant at EMASESA facilities, estimated at €10/tonne.
- Economic savings in fuel due to the lower mileage to travel.
- Considering as an annual benefit the annual savings derived from not carrying out the transfer of the bio-waste to the Montemarta Cónica Complex, the investment in the pretreatment plant for the digestion of the bio-waste could be amortized, in a first approximation in about 10 years, in the hypothetical scenario of separately collecting some 25,000 tons/year of bio-waste. This extreme must be corroborated in a detailed feasibility study, that has been agreed to be carried out in the short-medium term.

After Cityloops experience, the conclusions reached have been:

- The treatment of bio-waste collected separately in the city of Seville at the EMASESA facilities seems technically feasible.
- This treatment option would entail benefits in environmental, economic and circular terms for the city, compared to the current treatment, which are:
    - Savings in terms of traveling fewer kilometers for treatment, and therefore lower fuel consumption, lower $CO_2$ emissions and lower costs in transport.
    - Improvement in the management of bio-waste: through obtaining, for one side: energy (biogas) from the waste generated in the city of Seville, which would be returned to the city's own facilities, and for other side, a product, digestate, that can be valorised as compost.

- Move towards a more circular city, taking advantage of the value of the bio-waste generated therein, being treated and valued within its own administrative limits.

- In order to carry out this alternative, it should work in 3 lines, which would be:
  - Develop a detailed feasibility study to analyze this alternative in detail.
  - The implementation of the pertinent legal processing (environmental authorizations, etc.) to materialize the project.
  - The seek for funds, whether local, national or European, that largely covers the necessary investment costs, this being one of the main barriers.

# 4. Results

## 4.1 Summary

The Cityloops demonstration actions in Seville have helped to promote the separate collection of bio-waste, to test other ways of using the resources contained therein and to optimise the available municipal collection systems. The impacts of the two demonstration actions are shown below. In all this process the involvement and commitment of different stakeholders, such as private and public entities and citizens has been crutial.

Last but not least, Cityloops has served for exchanging knowledge and learning with our European counterparts on how to best address these challenges.

## 4.2 Impacts - Evaluation

The objective of the CityLoops evaluation work is to ensure a comprehensive Evaluation framework is established for all demonstration actions to assess their impact on sustainability and to assess the progress towards a more Circular Economy (CE).

Evaluation plan was prepared in co-operation with NRI and ICLEI according to the CityLoops Deliverable 6.1 Circular City Indicator Set (Vangelsten et al. 2021). Expected outcomes were phrased and indicators were selected to be in accordance with city-specific goals given in the Grant Agreement of the CityLoops –project.

Final version of the evaluation plan was submitted in February 2022.

Baseline for the evaluation is typically data from year 2020. Main data sources were statistics from:

- LIPASAM. Waste management company of the City of Seville.
- EMASESA. Integral Water Cycle management company of the City of Seville.
- ABORGASE.Operator Treatment Plant.
- City Council of Seville.

Interim evaluation data was collected by the end of July 2022 according to the Evaluation plan. Final evaluation data will be reported in the Final Evaluation report. For more detail, please, see 0 Annex II.

## 4.3 Economic Analysis

### 4.3.1 Economic assessment of demonstration

**Demo action 1**

The relative costs of Demo action 1 are shown below, mainly focused on its execution.

The costs have been structured into three different categories:

- Investment costs: those consigned to fundamentally acquire goods necessary to carry out the demonstration action, such as containers, electronic locks, cards for opening containers, and the route recommendation platform itself developed by IDENER. The investment cost has been € 138,750.00.
- Recurring costs: are those costs that occur recurringly over time, to continue with the demonstration action (staff involved, vehicles, maintenance, etc. It is estimated that the recurring cost during the duration of the demonstration action has been € 62,172.23.
- Finally, in other costs, there are costs of services necessary to start the demonstration action (installation of containers on public roads, communication campaigns, etc. The estimated amount is € 74,353.50.

*Table 13. Demo action 1 Costs.*

| Demo 1 | € |
|---|---|
| **Recurrent Costs (per year)** | **62,172.23 €** |
| Personnel | 42,906.97 € |
| Amortizacion truck | 3,011.25 € |
| Cleaning Interior Container Cost | 2,554.24 € |
| Cleaning Exterior Container Cost | 3,387.28 € |
| Maintenance of containers | 3,529.17 € |
| Maintenance electronic locks | 6,783.33 € |

| Investment | 138,750.00 € |
|---|---|
| Containers (100 units) | 67,500.00 € |
| Smart locks (100 units) | 31,000.00 € |
| Cards for Citizens to open smart locks (20.000 units ) | 5,250.00 € |
| OMSW flow optimisation tool | 35,000.00 € |

| Other costs | 74,353.50 € |
|---|---|
| Installation of containers | 3,000.00 € |
| Citizens Kits (kitchen bucket, compostable bags for bio-waste, and raffia bags for other selective waste fractions). | 31,403.50 € |
| Neighbourhood communication campaign on the separated collection system: | 27,350.00 € |
| Citywide communication campaign on reducing food waste. | 12,600.00 € |

| Total Demo 1 | 272,275.73 € |
|---|---|

In total, it is estimated that the total cost of demonstration action 1 has been € 272,275.73.

**Demo action 2**

For demonstration action two, the fundamental external expenses have been:

- Physical characterizations (5 characterizations): € 1,125.00
- Laboratory analysis: € 15,000.00

That is, a total of € 16,125.00. Likewise, there have also been personnel costs involved in the follow-up and monitoring of the biomethanation tests carried out, there costs were covered internally by EMASESA.

### 4.3.2 Business case

This work has been implemented through studies of literature, meetings and the organisation of events such as workshops and webinars. The business cases have also been drawn from the discussions within the stakeholder activities and regular meetings with the tecnichal staff that have participated in the project belonged to LIPASAM, IDENER, EMASESA and the City Council of Seville.

The business cases discussed have been:

For demo action 1:

- Economic and environmental savings in terms of collecting bio-waste separately, instead of mixing it with other fractions, since the cost of composting is less than that of biological mechanical treatment and landfill disposal.
- Savings in terms of fuel, due to the optimisation of transport logistics using the recommendations made by the IT software flow optimsation tool.
- Savings in terms of collection services by optimising consumption in commercial establishments, through the campaign to minimize food waste.

For demo action 2, the business case that has been discussed is the possible savings of managing the bio-waste collected through EMASESA digesters instead of through the composting plant in Montemarta Cónica, due to the reduction in kilometers to be covered. With the results obtained, as reflected in section 3.2.7, it seems that it would be technically feasible, as long as a pre-treatment technology is invested in.

Some of the benefits of betting on scaling this alternative to a city scale would be:

- The use of the biogas produced as electricity in the plant itself, to ensure that the facilities could become energy self-sufficient, including being able to analyze the possibility of deriving part of the biogas for use in vehicles.
- The use of digestate, as compost, once sanitized. Currently, the compost produced in MonteMarta cónica is destined for agriculture and soil restoration.

To materialize the scaling up of the demo would be necessary:

- Seek funding for the project, to cover its investment costs, mainly the bio-waste pre-treatment unit and adjustments in the currect facility of EMASESA.
- The legal authorization by the Enviromental body of Andalusia to able to treat bio-waste on a large scale in the current EMASESA facilities.
- Keeping the scalinp up of the bio-waste collection in the city, besides keep working in the sensibilization of the citizens and commercial establishment in order to keep as less as possible the pollutans of the bio-waste fraction collected.

# 5. Conclusions

## 5.1 Lessons learned

In general, during the demonstrations, the following conclusions were the most remarkable:

- Bio-waste management needs to be a key factor in urban planning and political decission making now and in the coming years, defining and testing differents instruments (technological, organisational, legal, relationship with citizens, etc.) in order to meet the European objectives of quantity and purity of this flow of material.
- Political commitment is fundamental to reinforme the importance of Bio-waste management as well as to promote opportunities for circular economy in the city.
- The commitment and the engagement of the Procurement departments and managers is crutial to succeed in the implementation of these circular procurement practices.
- Awareness campaigns are fundamental for the change, both the initial campaigns, as well as regular reminders. Additionally, the inspection and sanction of those establishments and citizens that do not comply with municipal ordinances, and particularly the separation of bio-waste, are crucial.
- The participation and engagement are key to the success of the project. The project has taught us that the interested parties appreciate and get more involved if you evolve from informative actions to participatory actions.
- In the business cases it was learned that there are rapid changes in the EU directives, laws, subsidies and in technology, related to transportation, energy and fuels. Information about these changes is greatly needed. Since it might not be in the interest of the local companies that sell and market the products to give out this information considering all aspects, a neutral actor could preferably take this role. These changes should also be followed by the city and taken into accordance in the city procurement actions and environmental- and other city strategies.

## Demonstration 1

We concluded:

- **Good specifications at tender stage.** It is important to indicate in the tender document that the mechanical part of the lock must be as robust as possible and be able to absorb certain "deformations" that occur during the lifting and unloading of containers by trucks. It is better to use metal locks than other materials such as plastics, which are rigid and more prone to breakage.
- **Involve people in the process.** Before the implementation of the system, it is important to inform and involve the neighborhood associations and merchants in the area, in order to explain the project, receive comments, etc.
- **Taking advantage of communication campaigns**. Distribute to the public tools that facilitate their participation in the project such as compostable bags, kitchen buckets, containers for leftover food, information brochures, etc.to maximise the results.
- The **visualization and usability of digital tools** are key for their consultation and exploitation by user personnel (both citizens and managers).
- **Good response of the market in the tender of containers**, where the requirement to use recycled plastic during the manufacturing of the containers was valued positevily. It was presented by all bidders.

*Opportunities for improvement:*

- Request/associate the electronic cards that open the locks to a name of citizen or business respectively. This issue has not been addressed in the case of Seville and we believe that it may be one of the factors that has led to the results obtained in terms of residue purity. Associating the name with the card causes a feeling of responsability in the user, so they feel more controlled and possibly more interested in participating in the system correctly. For this matter it is important to be well advised regarding personal data management policy.
- Integrate from the beginning the provider's platform or webapp with the organisation's ERP system, this will avoid having to consult several “places” at the same time.
- Adequate budget should be allocated for the maintenance of the locks. This maintenance must go beyond simply repairing and supporting them when they fail. It should also involve monitoring of their operation, such as identifying common failure patterns, tracking the number of openings, and analyzing openings by card. That is, it must be plan an integrated maintenance service. To ensure the maintenance is effective from the outset, it is advisable to propose metrics and performance indicators to be controlled and monitored, along with their frequency.
- In general, it seems that many lock manufacturers underestimate the complexity and factors involved in the collection process and that affect the integrity of the locks, as well as the handling and management of the data. This often results in frustration during the contract execution. Therefore, it is crucial to communicate these complexities to the manufacturers. In our opinion, there is still significant room for improvement in the product to better meet the needs of waste management companies and public entities.
- Current bio-waste campaigns have always focused on the collection stage, without paying attention to previous or subsequent stages (reminders, prevention, self-

composting, etc.). It is highly recommended to include these approaches for future campaigns.
- The IT software tool for flow optimisation gives several functionalities for managers such as optimisation of the collection routes, data analysis for future scenarios, and collection frequency collection estimation. Those functionalities provide useful recommendations in the decision-making process. Additionally, good room for improvement is identified such as considering factors such as traffic, changes in the itinerary due to works in the city, changes in the direction of the streets, etc.

**Demonstration 2**

We concluded:

- Carrying out both physical and chemical characterizations of the waste gives a lot of information about its potential uses, as well as strategies and instruments to be implemented to materialize said uses.
- The physical characterizations have been good tools to evaluate the purity of bio-waste obtained throughout the experience.
- Carrying out prior laboratory analysis generates useful information for testing in a pilot plant digester.
- The trituration to be carried out must be adequate to achieve a particle size that generates a correct fluidization of the bio-waste, in order to avoid problems of clogging in pumps and recirculation pipes.
- It has been corroborated with the appropriate biomethanation tests that the digestion of bio-waste in the EMASESA WWTP is technically feasible, either alone or jointly with sludge, since in both situations the digestion control parameters remain within the appropriate limits for the proper functioning of the process.
- The gas produced has presented a correct composition and adequate characteristics.

*Oportunities for improvement:*

- It is necessary to establish an adequate pretreatment of bio-waste in order to avoid problems in the equipment used for trituration and digestion. The adaptation made for these tests (manual sieving) is not valid for industrial scaling, so it would be necessary to purchase pretreatment equipment for said scale.

### 5.1.1 Stakeholder engagement

During the planning phase of both demonstration actions (1 and 2) of the project, an exhaustive analysis was carried out, focused on the bio-waste value chain in the city of Seville, trying to include groups and entities from each of the stages (production, manufacturing, retail, consumption and waste management). The list of stakeholders, as well as the list of activities in which they have been involved, as well as their importance, can be found in 0 Annex III.

Likewise, in the execution of both demonstration actions, the main stakeholders, whose have had a direct impact on the results of the project, have been the citizenship and the commercial establishments (consumer stage). During all the project, CityLoops Seville cluster have tried to find out their concerns and motivations throughout the demostrantion actions developed. For instance, further the planification stage, these colectives have been involved in activities like the installation of containers (meetings were held with neighbourhood associations and merchants from the demo area), and communication campaigns that were carried out through various channels and media (social networks, in-person meetings, information points in schools, institutes and other places with a special influx of people).

### 5.1.2 Procurement

The most important purchase action in the demonstration actions has been the purchase of containers for the selective collection of bio-waste, and the associated electronic locks for controlling access to said containers. In the tender of containers, it was included as an evaluable clause that they were manufactured with recyclable materials. The market responded better than expected to this clause, presenting all the offers received a significant percentage of recycled material (around 50%).

On the other hand, the search for suppliers of electronic locks adaptable to containers has been complex. Despite the fact that it is a product that in the last 5 years is usually very recurrent in the news of the sector, in terms of innovation and digitization, it is a product that is scarcely tried and tested. Although there are a significant number of suppliers of this technology, its actual application is discreet, with important aspects still to be resolved and improved, such as the integrity and robustness of the mechanical part of the lock in the face of load cycles. unloading of the collection trucks, or the management of the data that it emits. Prior to the bidding for these elements, meetings were held with different suppliers at the national level. It was decided to purchase locks and containers separately, with the former having a maintenance service and sending data for several years. It could be interesting, in the future, to analyze the profitability of betting on a leasing contract instead of an acquisition.

*Table 14. Procurement tenders and cost associated to containers of Demonstration action 1.*

| Tender | Cost | Link |
|---|---|---|
| 100 containers for the selective collection of bio-waste | 67,500 € | Link |
| Tender of 100 smart locks for containers | 31,000€<br>Recurrent cost ( Communication + reparation+maintenance during 2 years): 14,800€ | Link |
| A 20,000 Electronic cards | 5,250 € | Minor tender |

The communication actions had a lower external cost, but their execution is very important to guarantee the participation of citizens and other stakeholders.

*Table 15. Procurement tenders and cost associated to communication campaings of Demonstration action 1.*

| Tender | Cost | Link |
| --- | --- | --- |
| Communication actions related to installation of containers (mailing, posters and information points). | 27,350€ | Two minor tenders. |
| Communication campaign avoid food wast | 12,600€ | Minor tender |

### 5.1.3 Organisational changes

The implementation of a new route has resulted in an increase in personnel, with a driver profile to attend to the collection of said bio-waste route. Likewise, the exploitation of data that comes from the locks and their management has been assigned to a technician of the organisation, who periodically controls and monitors that they are in an optimal state as well as reporting warnings as soon as any problems are detected.

### 5.1.4 Data collection and monitoring

Evaluation work of the project has been labour intensive. Choosing and modifying the correct indicators was a difficult task that required deep insight and collaboration of all project workers.

Some of the difficulties founded have been:

- Data from smart locks. For the future it is important to commit larger budget items in the maintenance of electronic locks. During demonstration action 1, failures in the electronic locks have been detected, and the response time given by the contracted company could be improved. This situation has somewhat compromised the quality of data collection on locks, such as the number of openings or the number of times the containers are used per household.
- The data from the locks are exploited through a webapp. Also, this webapp has the functionality of being automatically configured to report some types of warnings. For the future, it is considered desirable that this web app be integrated into the organisation's ERP system.
- In terms of waste treatment was difficult to have the data, due to the daily operative of the treatment plant, besides, since the beginning of the project, the operator has been treated as an importans stakeholder for the Cityloops Seville cluster.

However, thanks of the different tools and guide provided by the project partners (ICLEI, NRI etc.) and consistent work on data collection and understanding of the data needed for all indicators has produced a coherent evaluation of the project and the demonstration actions, which can be found in Annex II.

## 5.2 Future perspectives

It is imperative to continue advancing in compliance with the objectives in terms of recycling and landfill disposal established by the European Union. For this, the best management of bio-waste, both in terms of collection and treatment, is fundamental, as well as posing an environmental, social and economic challenge for cities.

In the short-medium term, the implementation of the separate collection of this fraction will mean an increase in operating costs for the cities.

Since the experience of both Seville in this project, as well as other cities, the participation in the first months and years by citizens and commercial establishments is small, so there is no significant transfer of waste from the rest fraction stream (organic matter + others) to bio-waste selective stream. In order to achieve a significant mass of selective bio-waste and true savings from route substitution (theoretically, the greater the selective capture of bio-waste, the flow of mixed rest waste must decrease, and therefore its need for collection) time and a lot of effort are needed in terms of communication and awareness.

At the same time, waste management optimisation tools, such as those developed in the project by IDENER, are emerging, which are desirable to rationalize operating costs as much as possible.

The separate collection of bio-waste will be completed in Seville during 2023 – 2024, estimating an implantation of 15 routes for the separate collection of bio-waste. A production of 25,000 tons/year once all the routes have been consolidated is estimated.

Part of these routes are going yo pilot different systems for accessing the containers, for which exhaustive and periodic monitoring will be carried out, using physical characterizations, to compare different systems.

From the point of view of the recycling of bio-waste, in the short-medium term, there is a commitment to continue exploring the biomethanation treatment of the bio-waste collected in Seville from citizens and large generators, so it is desirable to advance in more tests and the preparation of a more in-depth feasibility study, beyond the analysis or first approximation carried out within the framework of the CityLoops project.

The results of CityLoops demonstrations have been disseminated in the Seville and Andalusia region and other cities and dissemination of the results continue until the end of the project. Discussion will be continued with stakeholders on how bio-waste recycling can be promoted in Seville after CityLoops.

## 5.3 Assessment of replicability / recommendations

In the case of bio-waste, all European cities must achieve the European recycling targets of 55% of municipal waste by 2025, being this fraction fundamental to accomplish this goal. All European cities must achieve this objective, so the models piloted in Demonstration action 1 and Demonstration action 2 of Seville could be replicable and adaptade to the specific context of each city.

Participatory workshops, as well as the realisation of "on-site" visits are an appropriate methodology to share and identify potential barriers, problems and also opportunities. Lessons learned from demonstration actions are crucial to their replication.

Below are a series of recommendations at a general level, obtained during the Seville experience in the two demonstration actions carried out, to be taken into account for replicability:

- Each city has its own characteristics and particularities, it is important to carry out a preliminary diagnosis to establish the baseline. This can be done through available statistics, previous studies and analyses, talks with experts, etc.
- To develop this preliminary diagnosis, it is important to involve key stakeholders, who may have information and knowledge in the field of both city waste, as well as "upstream" of the material value chain (extraction, manufacturing, retail, consumption, etc.). Communication with stakeholders can be done in different ways, depending on the profile of said stakeholder, the most appropriate must be selected.
- It is recommended, before implementing any methodology or solution, to carry out small pilots, in order to be able to evaluate the experience, as well as possible errors that are commented during the implementation of the test itself. In the case of Seville, both pilot actions have fulfilled this purpose.
- Before the execution itself, consider which indicators and metrics will be used to evaluate the results and impact of the demonstration actions.
- Coordination is very important in projects or actions that involve the participation of various entities. In the case of Seville, weekly follow-up meetings have been held for both demonstration actions.

More particularly, focused on the methodologies and technologies used during the project, it is recommended:

*For technologies applicable to waste collection:*

- Integrate the solution to use from the beginning the provider's platform or webapp with the organization/City's ERP system, this will avoid having to consult several “places” at the same time.

- Have a life cycle perspective. The maintenance stage is crucial. Maintenance must be as comprehensive as possible, establishing from the first moment with the service operator, the metrics, indicators, monitoring frequency and admissible response times for possible failures or deviations in the acquired technology.
- If container opening control systems are chosen, it is interesting for the city to review its personal data management policies. In other experiences, it seems that this aspect is key to achieving a better quality or purity of the deposited waste.
- If it is an immature technology, or if your city or organization has little experience, it would be advisable, before the tendering process, to establish a preliminary dialogue with the market.

*For communication campaigns focused on participation in selective waste collection:*

- In most cases, only an initial campaign is carried out. This produces a "call" effect due to the novelty, reaching significant levels of participation at the beginning, but this is diluted as the months go by. It is important to carry out reminder campaigns, events, informative talks, etc. on a recurring basis, so that the message to be conveyed has a more sustained effect over time, until the habit is created.

*For the applicability and treatment of waste.*

- It is important to determine from the beginning what you intend to do with the collected waste. Depending on its expected applicability (composting, biomethanization, biofertilizers, etc.), different strategies and solutions must be invested and implemented to obtain a purity of the waste at source, according to the requirements of said application, even in previous stages (pre-collection and collection).

# 6. Annexes.

## Annex I. Tecnology used in the development of the IT-tool, requirements, funcionalities and list of componentes.

***Technology -based.***

Machine learning and Data-Driven Applications have been gaining popularity in recent years. However, the final deployment requires a combination of different mathematical, programming and web development skills (or creation of graphical applications using frameworks such as Qt5 or GTK+).

Django is a very popular framework for web development with a very smooth learning curve, allowing the full development of web applications from initial concepts to final user products very quickly taking into consideration the most important aspects of security. These advantages overcome some limitations of other frameworks such as verbosity and complexity or steeper learning curves. Besides those limitations related to the development of the software platform, the use of Django as a framework also helps to improve the performance of the applications developed with other popular web frameworks. Dynamic applications did not always perform well, and complex single-page applications may have a significant lag, making them inconvenient to use due to their size.

Even if Django is an easy-to-learn framework for web development, it has been used in developing professional sites and platforms such as Instagram, Spotify, YouTube, BitBucket, DropBox, The Washington Post, Mozilla, Pinterest and even websites of NASA or National Geographic. The other additional advantage consists in using a single web framework other Python module without using communication protocols or separated containers with the back-end operations.

For the back-end part of the application, the data analysis and machine learning have also been powered by Python libraries. Communication between data sources has also been managed with Python when needed.

The initial developments have been provided to the managers for testing in containers or virtual machines to facilitate direct deployment in any computer. Virtual Machines allow preparing a complete operating system with the pre-installed CityLoops platform in a single file which can be directly executed by the user using Virtual Box, KVM, VMware or Hyper-V. Similarly, Docker containers allow running virtual servers to deploy web applications very quickly, even not booting an OS with the main advantage of allowing continuous integration. However, if an application is designed to run in a Docker container on Windows, then it cannot run on Linux or vice versa.

A GitHub repository has been created with a clean Django project to serve as a template to implement the initial features of the CityLoops platform. Once the main functionalities and widgets have been developed and tested, they have been all integrated on a single common application panel (e.g., like a dashboard), and interactions between them have been implemented and tested. This corresponds to Stage 1 of the development. Stage 2 has been the full development of one of the CityLoops platforms (i.e., OW flow optimisation tool) without taking into consideration aesthetics or final product aspects, only a basic front-end and main functionality. Stage 3, has been reproducing this development in all the remaining applications, obtaining as a result an initial version fully functional of all the CityLoops applications. Finally, Stage 4, will consist of adding the aesthetics and improving UX and GUI, together with the deployment of citizens' web pages for visualization and services.

Requeriments.

This section lists specific functions and object-oriented designs linked to functionalities of the Cityloops platform.

- ORM/SQL database management (included already using Django)
- Machine Learning functionalities: regression, clustering.
- GIS / OpenStreetMap data management.
- Web Apps, Widgets and data visualization.
- Data collection and data analysis.
- PostgreSQL 12.6
- Django 3.2
- OSGeo4W
- Leaflet
- Gdal: (required modules installation: wheel; pipwin; numpy; pandas; shapely; gdal; fiona; pyproj; six; rtree; geopandas)
- Pgrounting (PostgreSQL extension)
- Psycopgr module

***Functionalities***

Functionalities of OW platform for citizens

- Forms for query: The citizen will provide data about its location. The OW CityLoops platform for citizens will show the closer OW route and the location of OW bins.

- Dropdown list: The citizen could select a district. The OW CityLoops platform for citizens will show the OW route (if exist) or the closer OW route and the location of OW bins.
- Map showing OW routes implemented: A widget with a map (using OpenStreet Maps) will be presented to the citizens showing current OW routes and location of OW bins, and after the results of the query or the selection of the dropdown list, the closer one will be highlighted.
- Dashboard showing the current data on OW waste collection: The dashboard will show the data on the amount and quality of collected OW and the timestamp of the presented data.
- Control panel: A set of buttons will be included in the application to clean the forms, do the query and export information. Logos of the involved partners (Emasesa, Lipasam, Municipality of Sevilla, CityLoops project) will be included providing additional information.

Functionalities of OW platform for managers.

- District representation of Seville Data: The city of Seville will be divided into a discrete representation of districts and overlapped over a real map of the city, including streets´ direction for the road traffic.
- Data request of each district: Each district will be represented by different social and economic aspects, Lipasam´s infrastructure and the waste generation and collection will be described (i.e., amounts, types of waste, quality, involved equipment, etc.).
- Evolution of the waste collection: Data about the evolution of the waste collection systems, both quantitative and qualitative, will be represented in a time-lapse showing in the last frame the success estimation of the OW collection in the districts in which it is not already implemented, regarding both quantitative and qualitative data according to the data provided by the manager through the platform.
- Optimisation of new OW collection routes: Using the data provided by the managers and the results from the resolution of the Travelling Salesman Problem, the platform will present the optimised OW collection route in compliance with the LIPASAM criteria.
- Optimisation implemented OW collection routes: Using the data provided by the managers and the results from the resolution of the Travelling Salesman Problem, the platform will present the optimised OW collection route in compliance with the LIPASAM criteria.
- Location of new OW bins: Using the data provided by the managers and the results from the optimisation of the OW collection routes, the platform will present the location where the new OW bins could be placed in the new OW collection route in compliance with the LIPASAM criteria.

***List of Components of WebApp for Organic Waste (OW)***

| | |
|---|---|
| OW_APP001 | Web Form for Query and Data Collection |

| | |
|---|---|
| Platform version | Basic User or Citizen |
| Description | This component of the Cityloops platform for OW is a web form where the citizen or basic user will introduce the parameters of a query to find the closest OW bin to dump organic waste. Some fields of these data include postal code, district, street name, etc.<br><br>Once all the fields of the form are completed, and the button "Search" is pressed, two actions occur. Database of OW generation by districts is updated, and the query is sent to the back-end function, which will provide as answer the "closest OW bins and OW route collection according to the location of the user" |
| Input Data and Widgets | Text Edit (Postal Code), Comboboxes (District), Push Button (Search, create the query) |
| Output / Results | The database of OW by the district will be updated (all the queries will be incorporated in a dedicated database). Once the button is clicked, the closest OW bins will be highlighted on a map and the information on the collection route |

| | |
|---|---|
| OW_APP002 | Web Form for Query |
| Platform version | Basic User or Citizen |
| Description | This component of the Cityloops platform for OW is a web form where the citizen or basic user will introduce the parameters of a query to see the implemented OW collection routes. The user will select a district among those in which the OW route collection is implemented.<br><br>Once the district is selected, and the button "Show" is pressed, two actions occur. Database of OW generation is updated, and the query is |

| | |
|---|---|
| | sent to the back-end function, which will provide as answer the "OW route collection according to the user´s selection". |
| Input Data and Widgets | Comboboxes (District), Push Button (Show, create the query) |
| Output / Results | The database of OW by the district will be updated (all the queries will be incorporated in a dedicated database). Once the button is clicked, the OW collection route will be highlighted on a map and the information of the OW collection. |

| | |
|---|---|
| OW_APP003 | OpenStreet Map showing districts highlighted and OW bins & routes collection |
| Platform version | Basic User or Citizen / Manager or Admin |
| Description | Widget imported from OpenStreetMaps showing a map of Seville City, including some additional layers, such as polygons representing the districts of Seville in terms of administrative divisions and waste generation.<br><br>Locations of current OW collection routes will be marked in the initial map.<br><br>Once the query is done and the result of checking the "closest OW bins" is obtained, these bins will be highlighted in the map as well as the district of the origin of OW. |
| Input Data and Widgets | Map imported from OpenStreetMap library. Additional layers added, including district representation and OW bins position. |

| | |
|---|---|
| Output / Results | Points and polygons highlighted on the map. |

| | |
|---|---|
| OW_APP004 | OpenStreet Map showing districts highlighted and OW routes collection |
| Platform version | Basic User or Citizen / Manager or Admin |
| Description | Widget imported from OpenStreetMaps showing a map of Seville City, including some additional layers, such as polygons representing the districts of Seville in terms of administrative divisions and waste generation.<br><br>Locations of current OW collection routes will be marked in the initial map.<br><br>Once the query is done and the result of checking the selected district is obtained, the OW collection route will be highlighted in the map as well as the district. |
| Input Data and Widgets | Map imported from OpenStreetMap library. Additional layers added, including district representation and OW collection route |
| Output / Results | Lines and polygons highlighted on the map. |

| | |
|---|---|
| OW_APP005 | Visualisation of OW collection routes Status |
| Platform version | Basic User or Citizen / Manager or Admin |

| | |
|---|---|
| Description | This part of the platform for OW will present the status and the expected evolution (according to previous data) of the waste amount collected and quality in each collection route.<br><br>Once the OW bin or district are selected in the menu, the corresponding collection route will be highlighted in the map of OW_APP002 / OW_APP003, and the status of waste collection will be presented in the panel. |
| Input Data and Widgets | ComboBox containing the list of bins and routes to select.<br><br>Panel with several plots showing the status of the collection routes and the projection based on past data. |
| Output / Results | Bar Plots with the evolution of the containers and line plots with the projected evolution. |

| | |
|---|---|
| OW_APP006 | Updating data of the OW collection routes |
| Platform version | Manager or Admin |
| Description | The responsible for the management of this app will collect the information about the status of the OW collection routes and will update the corresponding XLSX or CSV file, which will be loaded into the platform.<br><br>The information about the status of the OW collection routes will be part of the inputs for the decision-making process when recommending a new district to implement future OW collection routes. |
| Input Data and Widgets | The input of this data may be done in two possible ways: 1) a table widget within the OW platform or by an external CSV file which will be loaded into the OW platform. |

| | |
|---|---|
| Output / Results | Once the data is loaded (or updated) into the system, the visualisation panel OW_APP5 of the OW collection routes will be refreshed, showing the updated data and a corrected projection for the next 2-3 days. |

| | |
|---|---|
| OW_APP007 | Loading data for new OW collection routes & bins locations |
| Platform version | Manager or Admin |
| Description | Classify & prioritize districts to implement new OW collection routes. Other criteria will be included (e.g., socio-economic data, data from the current waste collection system). |
| Input Data and Widgets | Data will be loaded in one or several CSV files to the platform. Widget: Load File Dialog Window for each one of the input files. |
| Output / Results | According to the results obtained by the back-end calculations, the prioritized districts for new OW collection routes will be highlighted in the OpenStreet Map of the OW_APP003 (or perhaps a new one).<br><br>Current and Expected tons of OW will be presented on the map over the corresponding polygon of the district. |

| | |
|---|---|
| OW_APP008 | Manually loading data of OW generation by district |
| Platform version | Manager or Admin |
| Description | CityLoops Platform for OW will collect the data (stored in Ayto. Sevilla, or Lipasam servers) from the users. This data will include the district name, the amount of OW and quality. However, it may be necessary to |

| | |
|---|---|
| | complete this data with additional data introduced manually (or corrected). |
| Input Data and Widgets | Loading CSV or XLSX file or modifying the data directly in the OW platform (this must be decided). |
| Output / Results | Updated data about OW generated in each district of Seville city. |

Citizen platform

The OW citizen platform presents a form where the user introduces the district and zip code. Just below said form, there are several checkboxes where the user can mark the type of container they need. At the end of the form, there are two buttons: one to submit the form ("Search") and the other to reset all inputs.

Next to the form, there is a map with all the city districts highlighted in various colours.

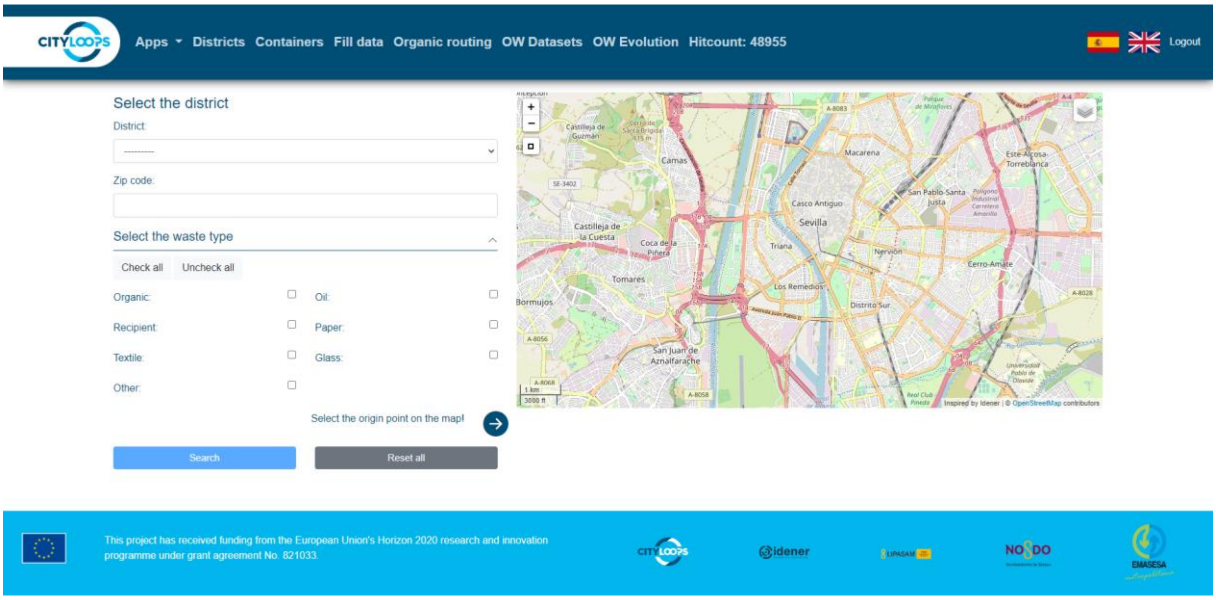



*Figure 38. OW platform main page.*

When the user has filled in every text field and selected the containers, they can click the button "Search" to submit the form. The application then shows the number of containers by type that is in the selected district in a new column located between the original form and the map. In the map, there will be markings indicating where are each of the containers in the selected district. Each of these markers will be coloured after the colour of the real container (organic: brown, oil: orange, packaging: yellow, paper: blue, textile: pink, glass: green and other: grey). In addition, there may be some organic containers that are not available for public use. These containers will be represented by a red marker on the map.

If the user selected "Organic" in the container filter checkboxes and the selected district does not have any organic containers, the application warns the user with a message below the map that reads "There are no organic waste containers in your district. Below we show you the nearest containers for your district.". Below the warning, a table will be displayed with up to three organic containers nearest to the selected district.

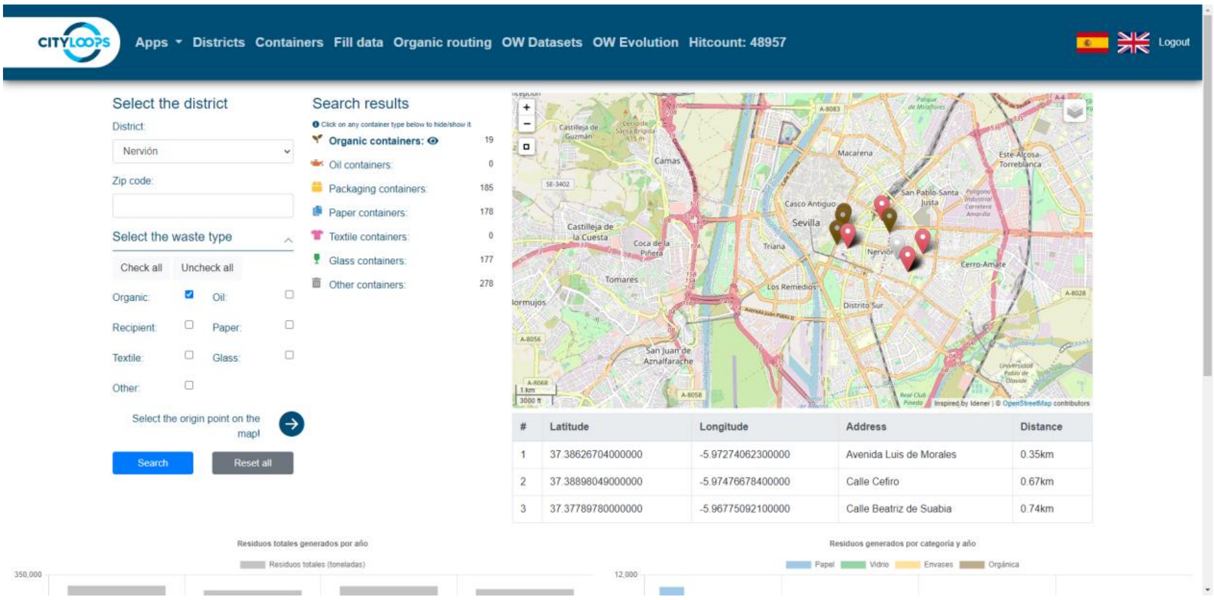



*Figure 39. OW platform showing results.*

Manager platform

The manager platform has several pages to perform actions related to the management of the application and its resources.

To access the manager platform, the user must click the "Login" link at the top right corner of the page. This will lead them to the login page, in which they can enter their username and password to access the manager platform.

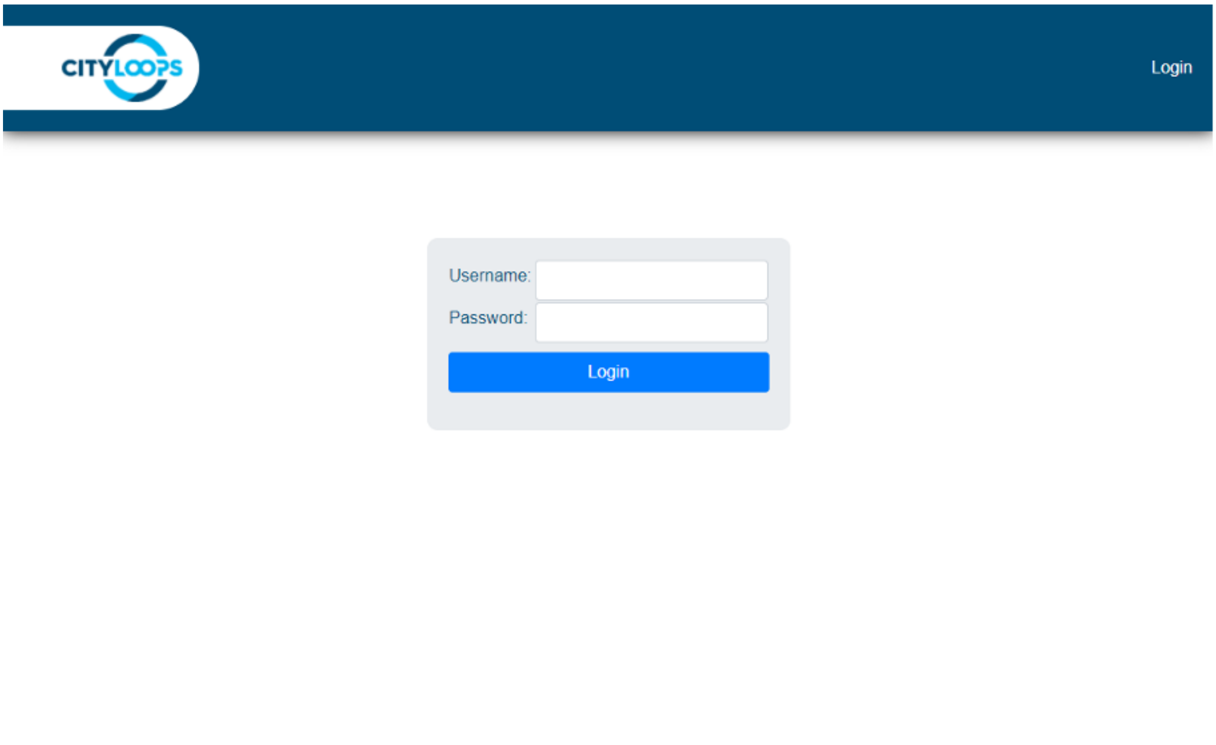



*Figure 40. Login screen.*

Once the user has logged in to the application, they will be able to access the pages to manage the entities of the application (containers, clean points, and districts). Each of the buttons located at the top bar of the page regarding these entities leads to the list of said entity. Through this list, the user can see the different attributes of each entity created. They can also create a new entity by clicking on the + sign located at the top right of the table, or edit any of the already created ones, by clicking the pencil icon at the end of each row.

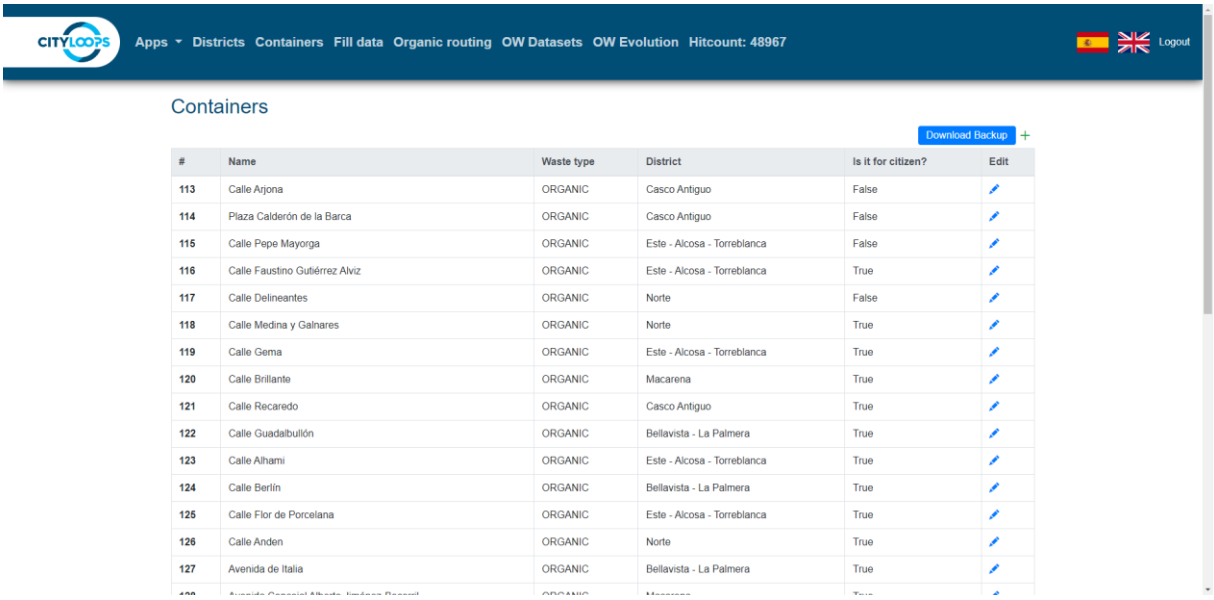



*Figure 41. Container list page.*

The user can also download a backup of the containers saved in the database clicking the “Download backup” button located on the top-right corner of the container list table.

When entering the page to create a new entity, the user will be supplied with two ways to create a new entity: to create it manually entering the data in several inputs or uploading a file that contains the pertaining data. Note that the file uploaded must be in the correct format and contain the needed data to create a new entity.

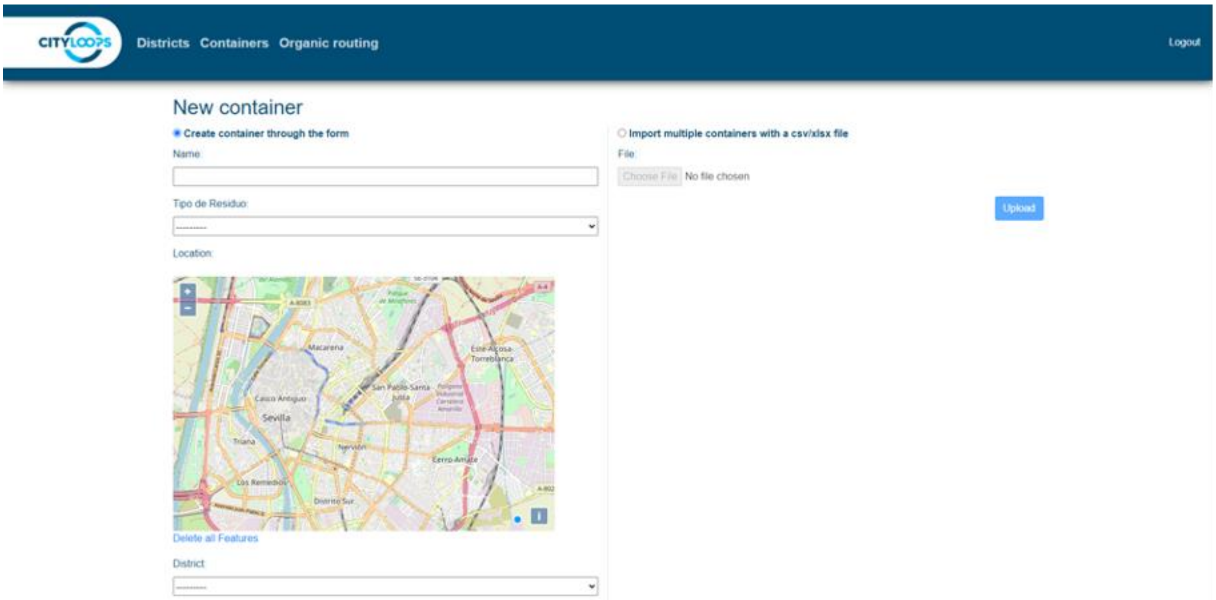



*Figure 42. Container creation page. On the left, the form to create the container manually. On the right, the input to upload a file with the containers data to create.*

Apart from managing the different entities of the application, the user can access the organic routing page, where they can optimise the waste collection route.

On this page, the user can select the containers they want to include in the route by selecting the corresponding checkboxes. At the right of the container list, there is a map showing every container location. Whenever the user selects a container, the corresponding marker in the map will change from blue to red, indicating that that container will be included in the route.

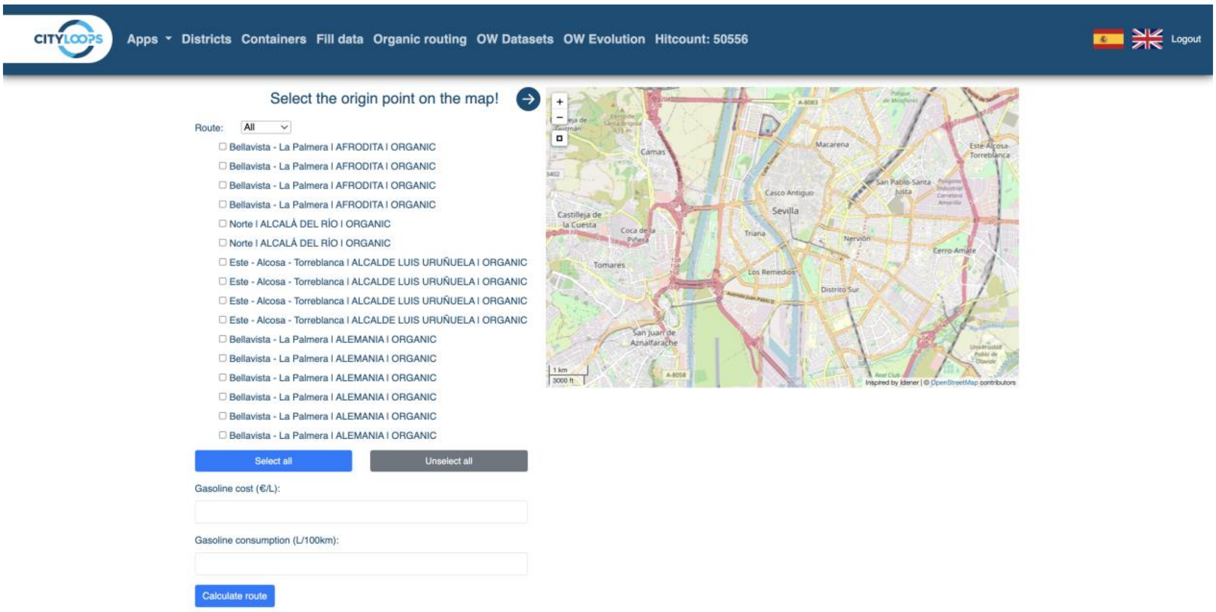



*Figure 43. Waste collection route optimiser page.*

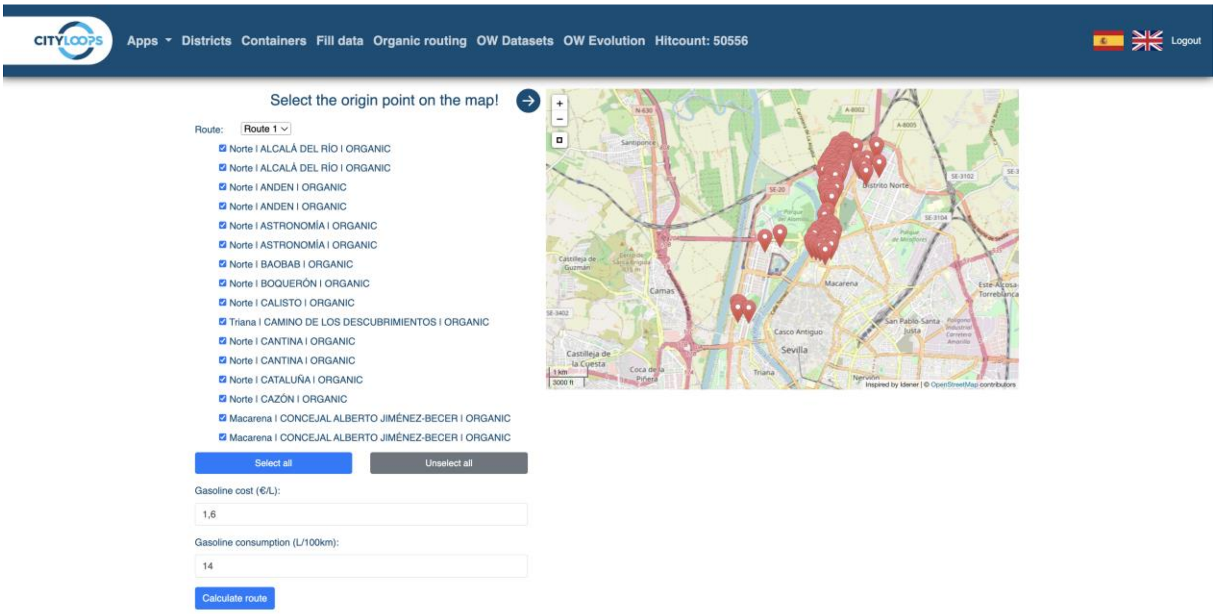



*Figure 44. Waste collection optimiser page with some of the containers selected.*

When the user clicks on the “Calculate route” button, the application shows the optimised route on the map at the right of the page, including the directions of the route.

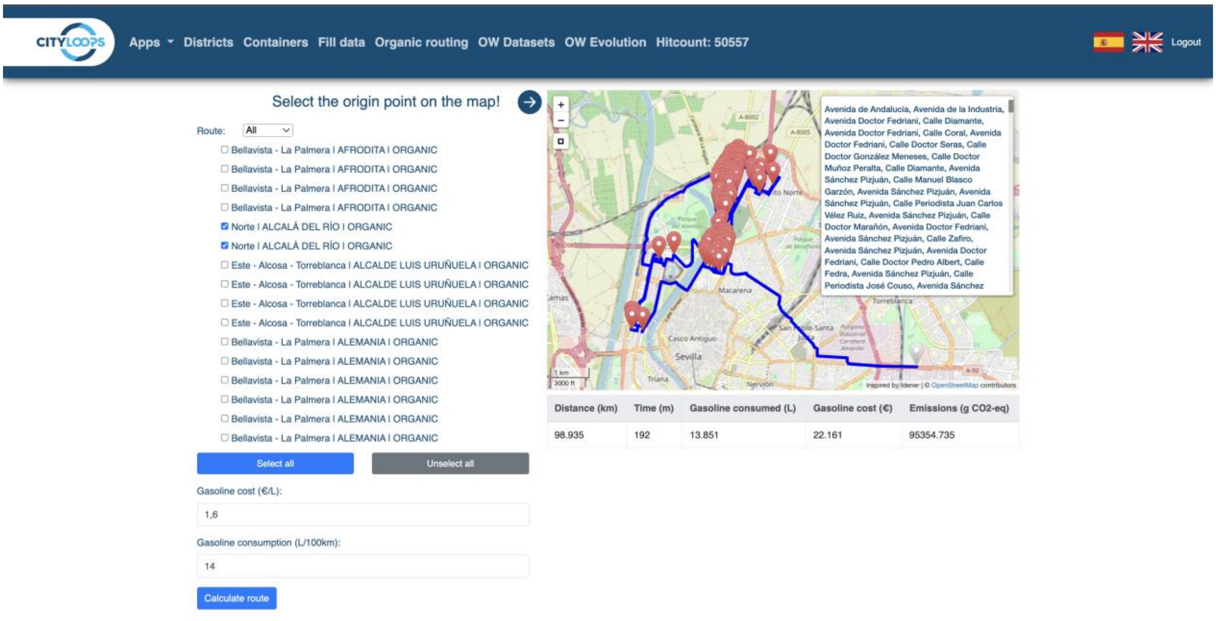
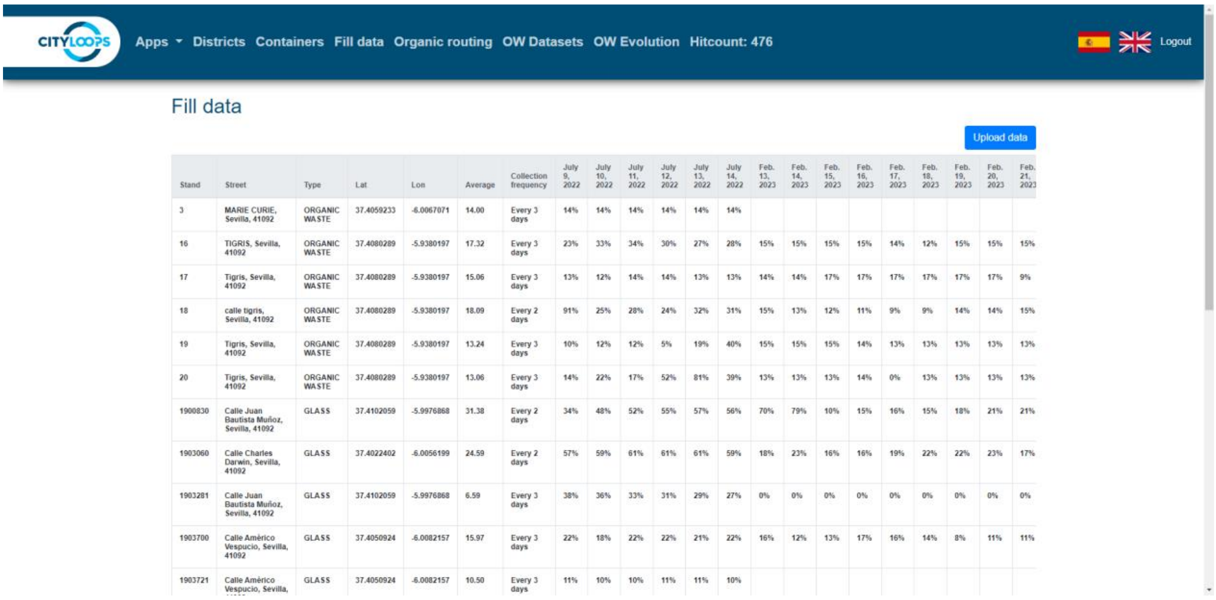



*Figure 45. Waste collection optimiser page showing the results.*

The manager can also upload and view organic container fill data. In the list view, the manager can see a collection recommendation that displays the waste collection frequency.




| Stand | Street | Type | Lat | Lon | Average | Collection frequency | July 9, 2022 | July 10, 2022 | July 11, 2022 | July 12, 2022 | July 13, 2022 | July 14, 2022 | Feb. 13, 2023 | Feb. 14, 2023 | Feb. 15, 2023 | Feb. 16, 2023 | Feb. 17, 2023 | Feb. 18, 2023 | Feb. 19, 2023 | Feb. 20, 2023 | Feb. 21, 2023 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | MARIE CURIE, Sevilla, 41092 | ORGANIC WASTE | 37.4059233 | -6.0067071 | 14.00 | Every 3 days | 14% | 14% | 14% | 14% | 14% | 14% | | | | | | | | | |
| 16 | TIGRIS, Sevilla, 41092 | ORGANIC WASTE | 37.4080289 | -5.9380197 | 17.32 | Every 3 days | 23% | 33% | 34% | 30% | 27% | 28% | 15% | 15% | 15% | 15% | 14% | 12% | 15% | 15% | 15% |
| 17 | Tigris, Sevilla, 41092 | ORGANIC WASTE | 37.4080289 | -5.9380197 | 15.06 | Every 3 days | 13% | 12% | 14% | 14% | 13% | 13% | 14% | 14% | 17% | 17% | 17% | 17% | 17% | 17% | 9% |
| 18 | calle tigris, Sevilla, 41092 | ORGANIC WASTE | 37.4080289 | -5.9380197 | 18.09 | Every 2 days | 91% | 25% | 28% | 24% | 32% | 31% | 15% | 13% | 12% | 11% | 9% | 9% | 14% | 14% | 15% |
| 19 | Tigris, Sevilla, 41092 | ORGANIC WASTE | 37.4080289 | -5.9380197 | 13.24 | Every 3 days | 10% | 12% | 12% | 5% | 19% | 40% | 15% | 15% | 15% | 14% | 13% | 13% | 13% | 13% | 13% |
| 20 | Tigris, Sevilla, 41092 | ORGANIC WASTE | 37.4080289 | -5.9380197 | 13.06 | Every 3 days | 14% | 22% | 17% | 52% | 81% | 39% | 13% | 13% | 13% | 14% | 0% | 13% | 13% | 13% | 13% |
| 1900830 | Calle Juan Bautista Muñoz, Sevilla, 41092 | GLASS | 37.4102059 | -5.9976868 | 31.38 | Every 2 days | 34% | 48% | 52% | 55% | 57% | 56% | 70% | 79% | 10% | 15% | 16% | 15% | 18% | 21% | 21% |
| 1903060 | Calle Charles Darwin, Sevilla, 41092 | GLASS | 37.4022402 | -6.0056199 | 24.59 | Every 2 days | 57% | 59% | 61% | 61% | 61% | 59% | 18% | 23% | 16% | 16% | 19% | 22% | 22% | 23% | 17% |
| 1903281 | Calle Juan Bautista Muñoz, Sevilla, 41092 | GLASS | 37.4102059 | -5.9976868 | 6.59 | Every 3 days | 38% | 36% | 33% | 31% | 29% | 27% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| 1903700 | Calle Américo Vespucio, Sevilla, 41092 | GLASS | 37.4050924 | -6.0082157 | 15.97 | Every 3 days | 22% | 18% | 22% | 22% | 21% | 22% | 16% | 12% | 13% | 17% | 16% | 14% | 8% | 11% | 11% |
| 1903721 | Calle Américo Vespucio, Sevilla, | GLASS | 37.4050924 | -6.0082157 | 10.50 | Every 3 days | 11% | 10% | 10% | 11% | 11% | 10% | | | | | | | | | |

*Figure 46. Frequency collection waste estimations page showing the results..*

Lastly, the manager can access the OW evolution page, where they can calculate district similarities via machine learning.

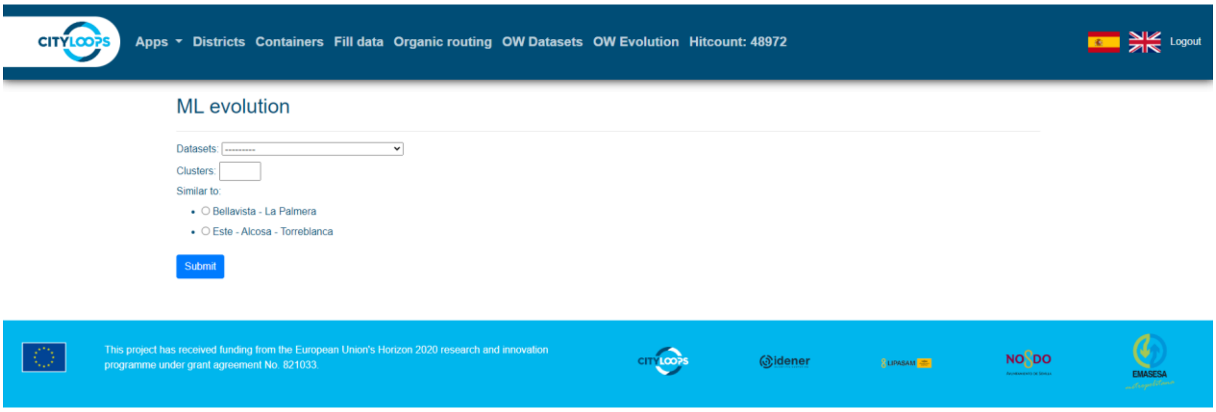



*Figure 47. Waste collection disctrits' comparison by ML*

When the user submits the form, the application will show graphs with results of the evolution calculations.

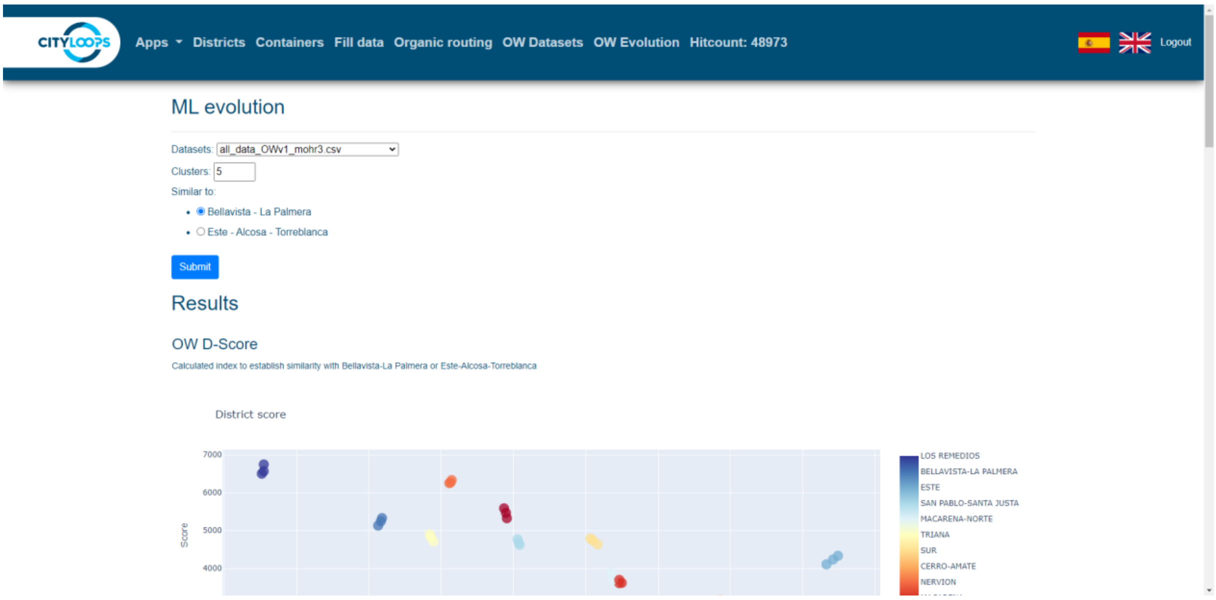



*Figure 48. Waste collection disctrits' comparison by ML showing scoring districts*

# Annex II. Impacts and evaluations

*Table 16. Planned outcome 1: Strengthened alliances with relevant local and regional actors in the field of bio-waste circularity.*

| Indicator | Baseline result | Final result |
|---|---|---|
| 6. Circularity-related stakeholder activities | 0 | - Worshops: 10<br>- Personalized emailing explaining project and purpose of the workshop. No. of people reached: 30.<br>- Individual phone calls and snowball sampling: No. of people reached: 50.<br>- No. of people reached: 70. |

**Outcome review:**

The outcome has been reached. Several workshop with good participations of differents stakeholders and actors has been helded:

- 3 Wokshops in Febuary 2020 in order to prepare the planification of the Demonstration actions and Evaluation.
- 3 workshops related to Circular Procurement along the project (2020, 2022 and 2023).
- 3 CLN meetings helded.
- 1 twin visit helded an organised by LIPASAM for Murcia.

These meetings have led to the realization of more initiatives and conversations, in the field of circular economy among the participants.

*Table 17. Planned outcome 2: Raised awareness among citizens about the collection and segregation at source of bio-waste, as well as its benefits.*

| Indicator | Baseline result | Final result |
|---|---|---|
| 4. CE-related knowledge building campaigns: Qualitative description | 0 | Actions:<br>#1 Meeting with the municipal district body affected and neighborhood and commercial associations, explanining them the project.<br>#2 Mailing and posters in buildings with information about the project (information on the new containers installed, forms of use, accepted waste, advantages associated with selective collection).<br>#3 Information points in schools, municipal markets and other venues of special affluence. This information action has been carried out for students of the schools of the both area and it was contemplated the distribution of "kitchen bin for bio-waste", a roll of compostable bags and a pack of 3 raffia bags for each participant.<br>#4 Digital campaing focused in the piloted area. |
| 5. CE-related knowledge building campaigns: Impact | 0 | 10,728 households have been impacted with mailing and posters.<br>199 commercial establishments have been impacted with mailing and posters.<br>26 schools have been impacted with information points, what has meant the participation of 8,675 participantes.<br>8,675 "Bio-waste kits" has been distributed. |
| **Outcome review:** | | |

| |
|---|
| The outcome has been reached.<br><br>A large part of the population and commercial establishments in the pilot area have been reached. Similarly, during the campaign, a good response was perceived from the target groups. |

*Table 18. Planned outcome 3: Raised awareness among large bio-waste generators, mainly in the HORECA sector (hotels, restaurants, and catering), about minimizing food waste.*

| Indicator | Baseline result | Final result |
|---|---|---|
| 11. Communication measures on circular transformations and waste prevention | 0 | 30 commercial establishments have been impacted. |
| The outcome has been reached. The actions were developed in the catering establishments (HORECA) of the main shopping centers of the city: Before communication action in establishments, the management bodies of each one of the shopping centers were informed about the communication action through in-person meetings. It was well received. For instance, the “Lagoh” Shopping Center commented in during this meetings that this action was aligned with his Sustainability Plan | | |

*Table 19. Planned outcome 4: More sustainable street furniture deployed in the city as a result of the inclusion of circular specifications in tender documents and contracts.*

| Indicator | Baseline result | Intermediate result |
|---|---|---|
| 15. Procurement with circularity requirements beyond existing levels: Impact | 0 | ● Type of procurement action: Containers supply contract. Framework contract |

| | | |
|---|---|---|
| | | ● Value of procurement: 2,280,275 €.<br>● Time period: 11/2021 - 11/2024<br>● Number of procurement contracts: 1 |
| Outcome review:<br>Outcome reached. Containers procured have been manufactured with a 50% of recycled material. | | |

*Table 20. Planned outcome 5: Significant transport energy and cost savings in the waste management system, which will serve as the basis for assessing the potential expansion of the demonstration action to the rest of the city.*

| Indicator | Baseline result | Final result |
|---|---|---|
| 32. Reduced costs due to improved circularity | 0 | A reduction of 13.82 euros by route |
| 36. Total energy demand | 0 | A reduction of 12.59 L of Fuel by route |
| Outcome review:<br>Outcome reached. A reduction of 14.36 % in the cost and energy demand has been identified with the optimisation of the CityLoops route implemented in the implementation period in comparison with the current route. | | |

*Table 21. Planned outcome 6: 0.6% increase in the separate collection of bio-waste in the city compared to the amount collected in 2020.*

| Indicator | Baseline result | Final result |
|---|---|---|
| 52.1. Quantity of material collected for composting destination | 0 | 100,200 kg during DEMONSTRATION ACTION 1. |
| 52.2. Quantity of material collected per inhabitant | 0 | 2.9 kg of bio-waste per inhabitant |
| 61. Landfilling rate | City 2021:<br><br>From Bio-waste flow (brown container) the 86.73% went to landfill.<br><br>From mixed waste (grey container), 83.17% went to landfill, of which 28.58% was organic matter. | Last available data at City Level (2022):<br><br>From Bio-waste flow (brown container), 87% went to landfill.<br><br>From mixed waste (grey container), 89.67% went to landfill, of which 31.63% was organic matter. |
| Outcome review:<br><br>The objective has been achieved discreetly. Although the expectations in terms of quantities collected have been met, the purity obtained has not been significantly higher than the other routes deployed in the city. | | |

*Table 22. Planned outcome 7: Reduced food waste from HORECA entities.*

| Indicator | Baseline result | Final result |
|---|---|---|
| 52.3. Reduction in food waste | 0 | 11,200 units of leftover food packaging has been distributed.<br><br>30 commercial establishments has decided to participate voluntarily in this action. |
| **Outcome review:**<br><br>The objective has been reached. The establishments have had a very good response to the campaign carried out. | | |

*Table 23. Planned outcome 8: Increased quality of bio-waste collected compared to the quality of bio-waste collected at the start of the demonstration action.*

| Indicator | Baseline result | Final result |
|---|---|---|
| 58. End of Life Processing Rate | 0 | 50 – 57% |
| 58.1. Quantity of pure bio-waste mass collected | 0 | 55.000 kg (estimation) |

| **Outcome review:**<br><br>Outcome achieved very discreetly. Although it is true that in the piloted area, the collection of bio-waste was not yet implemented before, the purity results obtained have been variable, and not excessively improving those obtained in other bio-waste routes in other areas of the city, which are around 48 - 50% purity. |
| --- |

*Table 24. Planned outcome 9: Reduced carbon footprint from waste collection activities.*

| Indicator | Baseline result | Final result |
| --- | --- | --- |
| 85. GHG emissions per year | 0 | A 14.36% reduction of $CO_2$ eq |
| Outcome review:<br><br>Outcome reached. A reduction of 14.36 % in the GHG emissions per year has been identified with the optimisation of the CityLoops route implemented in the implementation period in comparison with the current route. | | |

*Table 25. Planned outcome 10: Increased amount of material recovered for biogas production purposes, and therefore reduced amount of material that is deposited in landfills.*

| Indicator | Baseline result | Final result |
| --- | --- | --- |
| 53.1. Quantity of material for anaerobic digestion | 0 | 250 |
| 58. End of Life Processing Rate | 0 | 100% |
| Outcome review:<br><br>Outcome reached. All the amount of bio-waste that has been used for the tests has been valorized. | | |

*Table 26. Planned outcome 11: Increased efficiency of production of biogas per facility/unit.*

| Indicator | Baseline result | Final result |
| --- | --- | --- |
| 53.3. Quantity of biogas produced | 0 | 266% gas produced compared to isolated sludge (641 -743 litres per day during the demo action 2. |
| Outcome review:<br><br>Outcome reached. This data is the most relevant from demo 2. The biomethanation potential of bio-waste is revealed. | | |

*Table 27. Planned outcome 12: Information generated that allows the evaluation of the potential for expanding the pilot to an industrial stage.*

| Indicator | Baseline result | Final result |
| --- | --- | --- |
| 53.2. Quantity of sludge produced after anaerobic digestion | 0 | 0,3 - 0,43 ton of Dry Matter /ton of Dry Matter used as feedstock. |
| Outcome review:<br><br>Outcome reached. The ratio in normal situation (only sludge digestion), is 0.55 tDM/t DM fed in the case of 100% sludge to 0.3 or 0.43, depending on whether it is bio-waste of summer or bio-waste of winter, then the sludge production ratio decreases compared to feeding with isolated sludge. So, the incorporation of bio-waste does not negatively affect the production of digestate (sludge after digestion). | | |

# Annex III. Relation of stakeholders that have participated during the project.

*Table 28. Local stakeholders network*

| ACTIVITIES IN THE PROJECT WHERE HAS BEEN INVOLVED | ORGANIZATION | ACTIVITY PROFILE | ACTIVITY | IMPORTANCE |
|---|---|---|---|---|
| Material Flow Mapping<br>Planification Demo 1<br>Planification Demo 2 | Consejería Medioambiente | Public Administrations | Environmental agency of Andalucia | This body is the one that regulates and promulgates regional laws and policies in the fields of environment, water, waste, sustainable development and territory, in coherence with national and European policies and strategies. They have participated in the planning of the demonstration actions and have shown interest throughout the project in the progress and results obtained. |
| OW Diagnosis and characterization.<br>Planification Demo 1<br>Planification Demo 2 | Universidad de Sevilla | Universities & Technology Centres | University institution. | This organization has helped us sharing knowledge, best practices, etc, to achieve a better performance in collection, and treatment, etc. |
| Material Flow Mapping<br>Planification Demo 1<br>Planification Demo 2 | Joint Research Centre | Universities & Technology Centres | The JRC site in Seville works closely with sister services of the European Commission to provide socio-economic and techno-economic support for the conception, development, | This organization has helped us sharing knowledge, best practices, etc, to achieve a better performance in collection, treatment, etc.. |

| | | | | |
|---|---|---|---|---|
| | | | implementation and monitoring of EU policies. | |
| Planification Demo 2<br>Execution Demo 2 (lab tests) | Instituto de la Grasa | Universities & Technology Centres | University institution. | They are experts in wastewater treatment, and have supported the project with their experience in the planning phase of Demo 2 and the performance of laboratory tests that have served as the basis for the tests at the pilot plant level carried out at the EMASESA facilities. |
| OW Diagnosis and characterization, Material Flow Mapping<br>Planification Demo 1<br>Planification Demo 2<br>Evaluation | ABORGASE | Treatment plant | Sorting, recycling and landfilling several kind of waste. Commercialisation of recycled materials. | The Company opérate the treatment and composting plant that currently the bio-waste collected in Seville goes. It has helped us during the planification and evaluation of both Demonstration actions. |
| OW Diagnosis and characterization<br>Material Flow Mapping<br>Planification Demo 1<br>Planification Demo 2 | AICIA | Universities & Technology Centres | Andalusian Industrial Research and Cooperation Association | This organization as helped us transfer knowledge, best practices, etc, to achieve a better performance in collection, treatment, etc. It can be positively affected by his involvement in the project, been an opportunity to show or advance in new lines of work. |
| Material Flow Mapping<br>Planification Demo 1<br>Planification Demo 2 | APROCOM | Merchants Associations / Small distribution. | Confederation of Commerce, Services and Autonomous of Seville | This organization, which represents part of the commercial fabric, with bio-waste being one of the main wastes generated by these businesses, may be affected by new local policies, regarding waste segregation, fees, etc. Likewise, as waste generators, they are a fundamental part of obtaining quality waste at source, which means that their |

| | | | | |
|---|---|---|---|---|
| | | | | commitment, participation and involvement in the system has helped us to plan the demo actions in order to improve the bio-waste management in Seville (more quantity and quality). |
| Material Flow Mapping<br>Planification Demo 1<br>Planification Demo 2 | Corporación Tecnológica de Andalucía (CTA) | Universities & Technology Centres | Organization that promotes the transfer of knowledge and promotes R & D & I projects between universities, companies, and public administrations. | CTA has knowledge, by its own activity, of the industrial sectors of Seville and the rest of Andalusia, so its involvement in the project has helped us to know who are the main actors that handle organic matter, as raw material, and how it runs along the value chain (extraction, manufacturing, use, etc.) |
| Material Flow Mapping<br>Planification Demo 1<br>Planification Demo 2 | Mercasevilla | Distribution | Central Supply Market of Seville | MercaSevilla supplies municipal markets, the HORECA channel, supermarket chains, etc. therefore, their involvement in the project has given us greater knowledge of an important flow of raw materials in the city. |
| OW Diagnosis and characterization<br>Material Flow Mapping | Parques y Jardines | Public Administrations | General and road gardening service which belongs to the city council of Seville. | Parques y Jardines could be positively affected in terms of exploring new ways of treating bio-waste, at the city level, since they also handle this type of waste (pruning, bitter oranges, etc.). |
| Material Flow Mapping<br>Planification Demo 1<br>Planification Demo 2 | Unión de Consumidores de Andalucía (UCO) | Social organisations | Consumers Union of Andalusia | This organization, which represents consumers, with bio-waste being one of the main wastes generated by these businesses, may be affected by new local policies, regarding waste segregation, fees, etc. Likewise, as waste generators, they are a fundamental part of obtaining quality |

| | | | | |
|---|---|---|---|---|
| | | | | waste at source, which means that their commitment, participation and involvement in the system has helped us to plan the demo actions in order to improve the bio-waste management in Seville (more quantity and quality). |
| Material Flow Mapping | Factor Circular | Suppliers | Circular Economy Consulting | Factor Circular has knowledge, by its own activity, of the industrial sectors of Seville and the rest of Andalusia, so its involvement in the project has helped us to know who are the main actors that handle organic matter, as raw material, and how it runs along the value chain (extraction, manufacturing, use, etc.) |
| Material Flow Mapping<br>Planification Demo 1<br>Planification Demo 2 | Feicase | Merchants Associations / Small distribution. | Representative body of Seville food companies | This organization, which represents companies of the food waste sector, with bio-waste being one of the main wastes generated by these businesses, may be affected by new local policies, regarding waste segregation, fees, etc. Likewise, as waste generators, they are a fundamental part of obtaining quality waste at source, which means that their commitment, participation and involvement in the system has helped us to plan the demo actions in order to improve the bio-waste management in Seville (more quantity and quality). |

CityLoops is an EU-funded project focusing on construction and demolition waste (CDW), including soil, and bio-waste, where seven European cities are piloting solutions to be more circular.

Høje-Taastrup and Roskilde (Denmark), Mikkeli (Finland), Apeldoorn (the Netherlands), Bodø (Norway), Porto (Portugal) and Seville (Spain) are the seven cities implementing a series of demonstration actions on CDW and soil, and bio-waste, and developing and testing over 30 new tools and processes.

Alongside these, a sector-wide circularity assessment and an urban circularity assessment are to be carried out in each of the cities. The former, to optimise the demonstration activities, whereas the latter to enable cities to effectively integrate circularity into planning and decision making. Another two key aspects of CityLoops are stakeholder engagement and circular procurement.

CityLoops started in October 2019 and will run until September 2023.

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