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DECISIVE

A DECENTRALISED MANAGEMENT SCHEME FOR INNOVATIVE VALORISATION OF URBAN BIOWASTE

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A Decentralised Management Scheme for Innovative Valorisation of Urban Biowaste

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Abbreviations

a	Year
AD	Anaerobic digestion
BP	Bring point
BW	Biowaste
DtD	Door-to-door collection
CHP	Combined heat and power
d	Day
DST	Decision support tool
FW	Food waste
GW	Garden waste
HH	Household
Inh.	Inhabitant
mAD	Micro-scale anaerobic digestion
MSW	Municipal solid waste
RW	Residual waste
SE	Stirling engine
SSF	Solid-state fermentation
Mg	Megagramm (1 Mg = 1 t = 1000 kg)
UAB	Universitat Autònoma de Barcelona
w	Week
WEEE	Waste from Electrical and Electronic Equipment

Abstract

This report evaluates the waste collection performance of two demonstration sites and two case study sites within the DECISIVE project. It provides insight into quantitative and qualitative data gathered within the new DECISIVE-specific biowaste (BW) collection systems. It also introduces the original waste management of the local authorities and thus the transition to the DECISIVE decentralised BW management concept as proximity management approach. The assessment is carried out through waste characterisations in the ex-ante situation and during the transition for the different studies. In addition, a number of key parameters important for the assessment of the collection part itself is presented and data for each site is included if available.

The *Lyon urban farm* is a full implementation of DECISIVE's decentralised BW management concept. It includes the collection of food waste (FW) from surrounding restaurants, supermarkets and other food services, as well as the treatment at the farm where the micro-anaerobic digestion (mAD) plant is installed. The Lyon mAD demonstration plant has a capacity to treat 50 Mg a^{-1} of BW. In this report, the ex-ante situation and the situation after the start-up of the mAD were assessed by waste characterisations. The characterisations followed ongoing communication activities to raise awareness among waste generators about the upcoming separate collection of fFW. Although not commonly implemented in Lyon, a few of the waste generators had already established their own BW management system, mainly in the form of composting at the farm's premises. Due to COVID-19 restrictions, the mAD demonstration plant faced problems, which led to a temporal shut-down and a partial change of waste providers. However, the initial performance results are promising and the waste quantities from the selected waste generators are expected to be sufficient to run the plant at full capacity. However, some waste providers still need to improve the quality of source-separated BW. Impurities can reach between 3 - 5% which is too high for the manual pre-treatment.

Also, *Dolina town* has a full implementation of DECISIVE's decentralised BW management concept. It includes the valorisation of the municipality's FW from households and commercial activities in a mAD demonstration plant. The local waste management company A&T2000 already collected FW in a door-to-door system before the start of DECISIVE. As the original treatment plant is more than 100 km away, the company looked for alternatives to reduce the impact of transport and to explore local treatment options. The mAD demonstration plant has a capacity to treat 200 Mg a^{-1} of BW and is located in a designated BW collection area in Dolina called "biomass platform".
In this report, the ex-ante situation was assessed. Since no additional communication actions or changes in Dolina's collection system are planned, it is assumed that the qualities and quantities of source-separated BW will remain at the measured level. Dolina's source-separated BW consists mainly of FW. An additional stream of green waste (GW) will be treated on the designated demonstration site, too. The amount of source-separated BW already exceeds the capacity of the mAD. Including GW, separately delivered by the inhabitants, approximately 360 Mg a^{-1} are collected. Therefore, the establishment of an additional community composting site is planned. The quality of source-separated BW is high, with impurities below 1%. This excludes collection bags made of paper or biodegradable plastics since they are within the compliance requirements of A&T2000. It is necessary to evaluate whether these bags cause problems in the mAD plant, as it does not include intensive pre-treatment. Residual waste (RW) comprises only small amounts of FW, resulting in a source-separation efficiency of 77% - 92% of the FW generated.

The *Barcelona UAB campus* is a case study where a full implementation of the DECISIVE BW management concept was originally planned but eventually abandoned. However, the potential BW streams for the potential demonstration site were studied. The mainly targeted generators were the three largest restaurants of the campus. Furthermore, BW of the student village and the town of Cerdanyola del Vallès,

in which the campus is situated, was characterised. The restaurants showed good BW sorting performances. The FW source-separation efficiency was estimated with 85 – 90%. Impurities ranged between 4 – 5% which leaves potentials for improvements. In the BW of the student village and town, a higher share of impurities was found, between 7 – 13%. Therefore, these were not considered as potential waste providers. Communication activities were carried out to improve FW separation behaviour. The focus was directed towards the staff, but also with customers of the restaurants (Guerrero et al. 2019). Further communication actions could involve the student village.
Furthermore, a concept was to homogenise the collection equipment was developed, as most of the equipment did not follow a comprehensible concept across the campus

The *Lübeck neighbourhoods* is a case study that aimed to test an alternative FW collection system in two socio-economically different areas in the city of Lübeck, with a focus on multi-family houses. As is common in Germany, FW is mostly collected as a co-mingled fraction with GW in a biobin. In most cases, the efficiency of FW source-separation is rather low, averaging around 35%. The largest share of FW is collected in the RW bin. Collection of GW works efficiently with source-separation efficiencies above 70%. GW often accounts for far above 50% of comingled collected BW.
The tested system aimed at improving the efficiency of FW source-separation and simultaneous reduction of impurities. The system set-up included a single-stream collection of FW. Important elements were the provision of small collection buckets, a high collection frequency of source-separated FW, and intensive communication activities with residents. In result, it was found that in both areas, impurities were reduced to less than 1% from up to 5%. This is all the more impressive given the usual dilution effect of GW, which reduced below 4%. FW had a share of around 95% in source-separated BW in both areas during the test. Source-separation efficiency of FW increased from initially 6% and 17% in areas A and B to 62% and 66%, respectively. The long-term effects were tested on the reintroduced original BW collection system. Results were promising, with shares of FW higher than 50% and source-separation efficiencies between 35 and 50%. Also, impurities remained below 1%.

1. Introduction

The DECISIVE project investigates the development of decentralised biowaste management concepts, in particular for food waste (FW) as part of biowaste (BW). BW often includes also green waste (GW). In existing BW collection systems, FW is collected either as single-stream (e.g. in Catalonia or Italy) or co-mingled stream (e.g. in Germany). Some countries or regions have not yet enrolled a comprehensive BW collection system (e.g. France). The main pillars on which the DECISIVE project is based are (i) concept development including influencing factors, (ii) technology development, (iii) decision support tool (DST) development and (iv) proof of concept with demonstration sites and case studies.

The concept (i) aims at valorisation of BW including FW by closing the loop towards an urban circular economy model at a local level. It involves stakeholders within the circular economy cycle from cradle to cradle. Stakeholders in the loop include local waste management companies, local authorities, farmers and FW generators, such as households or food processing companies like restaurants, canteens or retail. Local valorisation increases the resilience of cities by reducing environmental impacts, including through shorter transport distances, reduced losses in the valorisation chain and increased visibility for the population. The latter can also support communication tools and incentive measures to motivate waste generators to improve their wasting and sorting habits.

The main technological pathway (ii) within the DECISIVE project is biogas production using micro-scale anaerobic digesters (mAD) that can treat between 50 and 200 Mg a^{-1} of BW. The biogas produced is then used in a Stirling engine (SE) as a combined heat and power (CHP) unit. The digestate has multiple uses, such as use on land, but will also be used in solid-state fermentation (SSF) to produce solid fertilisers and bio-based pesticides. The DST (iii) will help local stakeholders to implement or improve their current waste management system by comparing different options, such as centralised versus decentralised systems.

The demonstration sites and case studies will serve as proof of the DECISIVE concept. The DECISIVE project has 2 demonstration sites (iv), one in Lyon, France, another in Dolina, Italy. In addition, there are two case studies, one on the campus of the Universitat Autònoma de Barcelona (UAB) in Spain and the other in two multi-family building neighbourhoods in the city of Lübeck, Germany. The location of the sites is shown in Figure 1. While the demonstration sites have a full implementation of the DECISIVE concept, the case study sites investigate specific parts of the system in detail. The focus is on improvements in waste sorting and collection at the waste generator level.

Figure 1: DECISIVE demonstration and case study sites

The following gives a short introduction of the demonstration sites and case studies:

- *Lyon urban farm*: The demonstration site is located in a local peri-urban farm, the "Ferme de l'Abbé Rozier", and BW for mAD treatment is collected from various food services, schools and supermarkets. The treatment capacity is 50 Mg a^{-1}.
- *Dolina town*: The demonstration site in Dolina is situated in a public space in town. The mAD plant has a capacity of 200 Mg a^{-1} and will treat waste from the town's households and food services. As a rough estimate, 360 Mg a^{-1} of separated BW is already collected either door-to-door (DtD) or as delivered GW at the recycling centre. Since treatment capacity of the mAD is lower, an additional community composting facility is planned to treat the remaining part.
- *Barcelona UAB campus*: The case study at the Barcelona UAB campus was planned with a fully enrolled DECISIVE concept, but various circumstances led to a failure of the implementation (discussed in WP 7, Deliverable 7.3). The focus was adjusted on improving FW collection in the campus restaurants by awareness raising supported by various campaigns.
- *Lübeck neighbourhoods*: The case study in Lübeck focused on the improvement of FW collection including a test involving citizen engagement to achieve better sorting efficiency and lower macro-impurities in source-separated FW.

In the following, the connection of this report with other working packages of the DECISIVE project is highlighted.
This report focuses on FW collection investigations at the demonstration and case study sites.
In the project's agreement, it is entitled "*Deliverable 6.6: Report on collection set-up performance - Mass balance and characterisation of collected waste"*. It goes hand in hand with the achievement of milestone "*MS15: Collection systems in place"*. The underlying work package (WP) on which this report is based is "*WP 6.2: Collection and pilot(s) implementation"*:

"WP6.2. will be dedicated to the implementation of the decentralised valorization system on two real demonstration sites: one at the urban farm in Lyon (LYON – case France) and one in Italy (DOLINA case). This implementation work will be coordinated by INRAE, but technical work will be mainly performed by demonstration sites responsible (reFARMERS / CFPH (INRAE's in kind contributor) and A&T 2000) and by private partners in charge of processes development, installation, commissioning and exploitation (AERIS, ITS and SE). Moreover, TUHH and ENT will contribute to advice collection system and incentives implementation."

WP 6.2 is further divided into specific activities, of which "*Activity 3: Collection system set-up for decentralised treatment"* is the one to which this report belongs:

"According to the results given by the decision support tool for collection, developed in WP3.2, feasible collection procedures will be chosen for the both demonstration territories. Switching from the existing collection system to the one associated to the decentralised valorisation system will be gradual and implemented in synergy with the information campaigns developed in Activity 1 and the advancement of the prototypes installation (Activity 2). A special attention will be paid to the quality of the biowaste collected."

As mentioned in the description, *Activity 3* is linked to "*Activity 1: Preparation of demonstration sites for stakeholder's involvement"* and "*Activity 2: Building-up of demonstration prototypes"* of the same WP.
The report is linked to the parts of the results of "*WP 3.2: Collection chains for decentralised biowaste management"* provided in "*D3.7: Scenarios for decentralised biowaste collection chains with a waste collection database for representative situations"* (Walk et al. 2020). The report is also linked to the results of "*WP5.1: Elaboration of a methodology for planning and reporting a decentralised system"*, provided in "*D5.1: Methodology for planning a decentralised biowaste management"* (Martinez Sanchez et al. 2018). In addition, the results of "*WP 6.1: Selection of sites and associated incentives for the implementation of the demonstration"* are considered, in particular deliverables "*D6.2: State of the art of communication materials and incentive methods and proposal for communication materials and incentives"* (Bel 2018) and "*D6.5: Report on implemented communication activities and incentives"* (Guerrero et al. 2019). This report also links to work packages still in progress, such as "*WP 7.1: Evaluation of the waste prevention effect provided by the new decentralised valorisation system*," and with future work packages such as "*D7.1: Report on waste management behaviour in demonstration areas"* and "*D7.2: Prevention effect provided by decentralised management*: *recommendations"*.
Figure 2 illustrates the circular approach of the DECISIVE project. It also shows the focus of this report. In the chapters of the detailed descriptions of each demonstration site and case study, the degree of implementation is assigned according to a scheme.

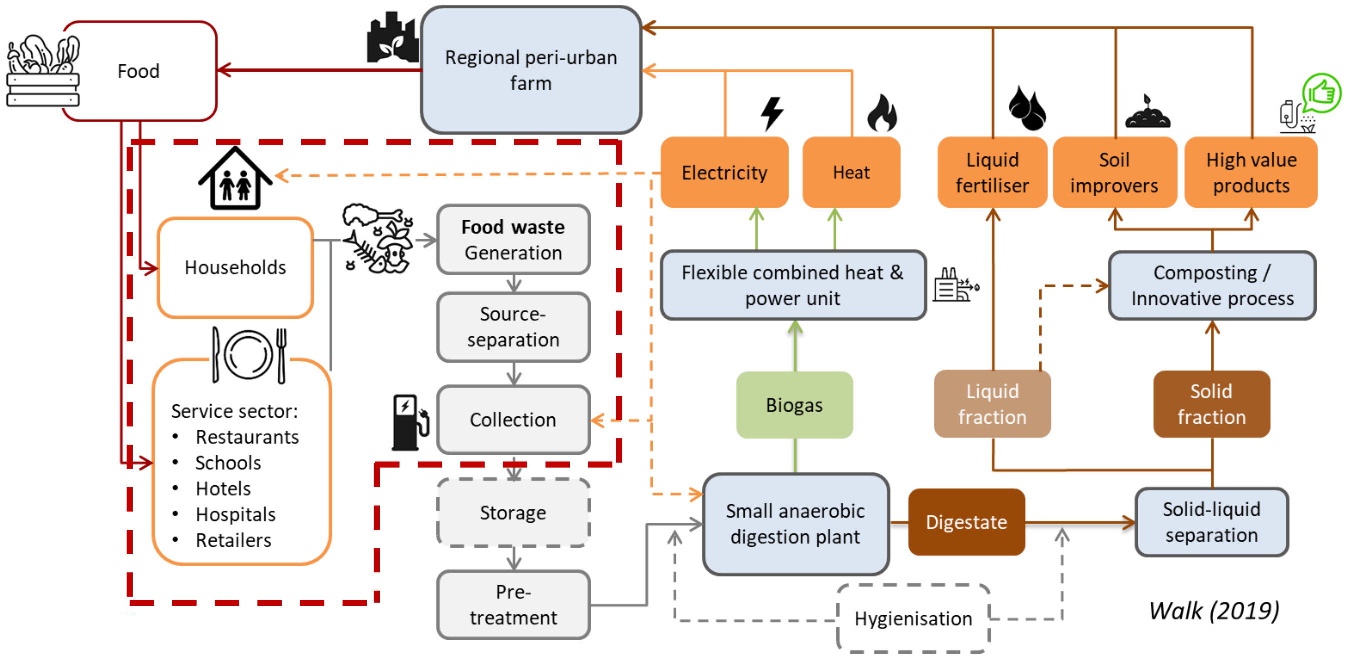


Figure 2: The overall DECISIVE technical concept including the focus of Deliverable 6.6 (red dashed box)

The aim and scope of this report are to provide

- a description of the original FW collection system and comparison with the newly implemented system,
- information on measures implemented at demonstration and case study sites to improve FW collection,
- results of alternative FW collection system in terms of quality and quantity improvements,
- a set of parameters to describe the transition of the original FW collection to the DECISIVE concept.

2. Methodology

The assessment of the performance of the implemented FW collection systems at the demonstration and case study sites consists of four main steps:

(i) Description of FW collection system prior the implementation of the DECISIVE concept,
(ii) Description of new FW collection system including the measures implemented at the demonstration and case study sites,
(iii) Evaluation of the performance of the new FW collection systems or the measures implemented compared to the previous FW collection system through mass balances and characterisation of source-separated BW and residual waste (RW), and
(iv) description of the collection-related parameters and results describing the changes to the newly implemented system.

The core of the assessment is formed by waste composition analyses and mass balances. This includes the estimation of qualities and quantities of collected FW. The comparison between the ex-ante situation and the situation when the newly introduced system allows an assessment of the changes that the DECISIVE concept may bring. The collection-related parameters highlight the potential shifts and savings that may result from the changed collection system.

Some of these parameters were introduced in D3.7 (Walk et al. 2018) and D5.1 (Martinez Sanchez et al. 2018). The baseline scenario was characterised in D6.1 (Chifari et al. 2018), but for the total cities' area, referred to as the study area in D6.1, rather than specific to the demonstration sites.

In chapters 2.1 and 2.2, parameters related to FW generators and include the description of the waste characterisation and quantification approach are described. In chapter 2.3, the assessment of parameters related to the waste collection is described, starting at the interface with the FW generators, over the roadside waste disposal containers, up to the transport of the FW to the treatment facility.

2.1 System descriptions

The system descriptions contain information on the identification and selection of waste generators to be implemented in the demonstration and case study sites. For the *Barcelona UAB campus*, the *Lyon urban farm* and the *Lübeck neighbourhoods*, a description of the identification of the target waste generators can be found in D6.5 (Guerrero et al. 2019). In the same report, there is a detailed description of the communication activities carried out at the *Barcelona UAB campus*, as well as brief descriptions for the *Lyon urban farm* and the *Lübeck neighbourhoods*. The demonstration site of *Dolina town* was not yet included in report D6.5, as A&T2000 joined the project only after its publication. The system descriptions also contain information on the original waste collection and treatment at the generator sites. It includes the existing equipment and means of collection, followed by a description of the changes made towards the new system. Finally, pictographic flowcharts are used to illustrate the degree of implementation of the DECISIVE concept at each demonstration site and case study site.

2.1.1 Lyon urban farm

Lyon metropole, also called Greater Lyon (GL), is the second-largest urban area in France, while Lyon is the third-largest city. It is located at the confluence of the Rhône and Saône rivers, about 470 km southeast of Paris and 320 km north of Marseille. Together with its suburbs and outskirts GL, contains a mixture of large urban areas, peri-urban and rural areas with agricultural activities. The agricultural area covers about 10,000 ha, representing 20% of the GL area (agreste 2021) . Most of the usual agricultural sectors are represented: cereal farming, livestock keeping, arboriculture, horticulture and vegetable farming. GL is a territorial entity comprising 59 communes around Lyon, located in the Rhône department and in the Auvergne-Rhône-Alpes region (Figure 3). GL covers an area of 534 km² and had a population (GrandLyon 2018) of 1,381,249 in 2018, corresponding to about 600,000 households. The population density in GL is 2,383 inhabitants $(km^2)^{-1}$, with the central city of Lyon having a density of 10,583 inhabitants $(km^2)^{-1}$.

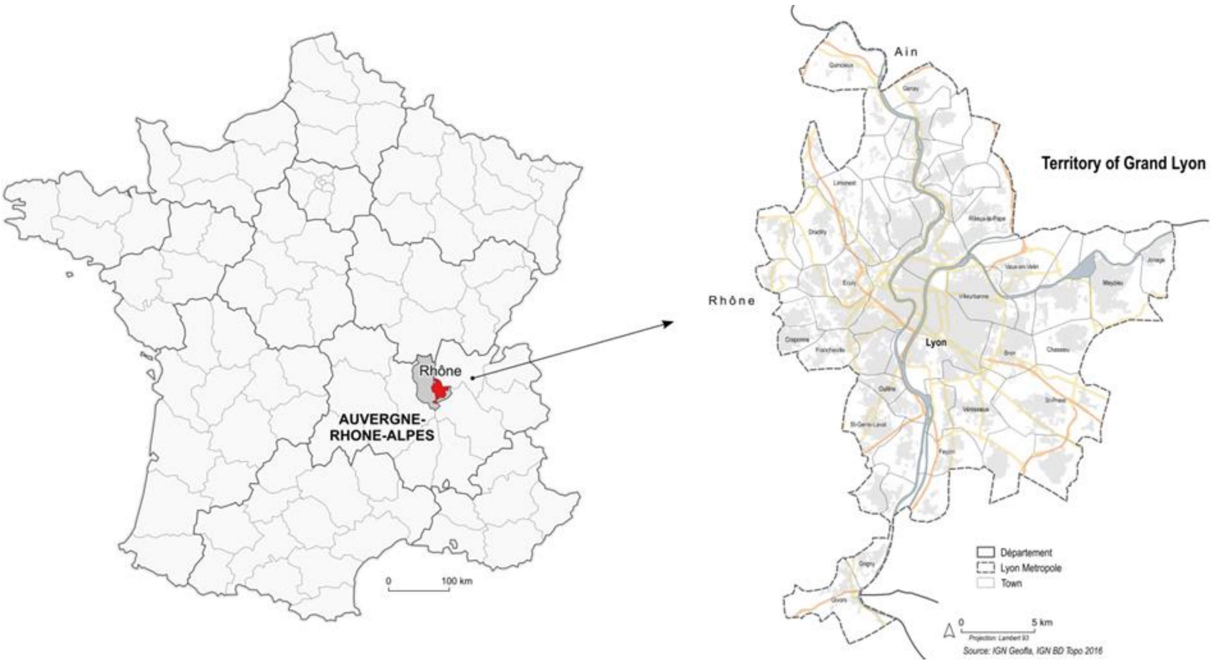
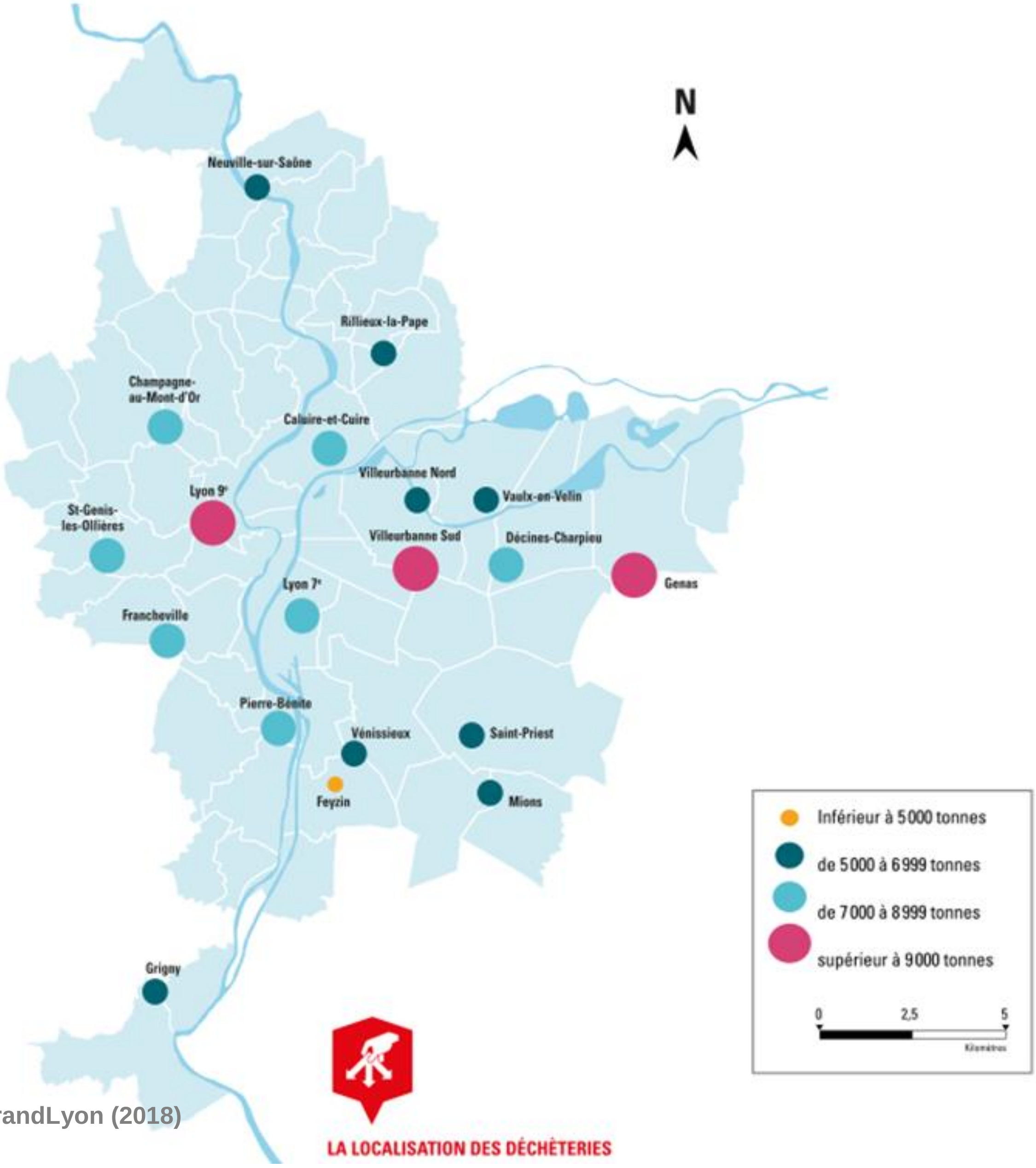


Figure 3: Location of Grand Lyon in France

2.1.1.1 Initial biowaste collection and management

In GL, recyclables (paper, cardboard, plastics, glass), bulky waste and hazardous waste are collected separately from households. The remaining waste is collected as RW in containers for each household or building. BW is not collected separately and is disposed of in the RW bin. In addition to waste from households, waste is also collected from private companies and public organisations that produce waste similar to households regarding type and quantity.

The current BW management system includes material recovery such as composting. 29,428 Mg a^{-1} were collected (GrandLyon 2018). This only refers to BW delivered to existing municipal drop-off centres and only includes GW. A list and locations of drop-off centres, including their annual waste reception capacity, is shown in Figure 4. BW collected as mixed RW is mainly destined for incineration with energy recovery or landfilling. The GL region has two incinerators with a capacity to treat up to 400,000 Mg RW a^{-1}. In fact, 314,677 Mg a^{-1} of RW from households and commercial activities are collected. They are mainly incinerated for energy recovery (62%), followed by material recovery (29%), landfilling (7%) and material recovery excluding recycling (2%) (GrandLyon 2018).



GrandLyon (2018)

Figure 4: Drop-off centres in Grand Lyon indicating the annual amount of total waste that is received

2.1.1.2 Implementation of separate collection of food waste within the DECISIVE concept

The public school of agriculture (CFPH) owns a farm with more than ten hectares of land in an urban setting where they carry out agricultural activities, including two hectares of organic vegetable production. Originally located in a peri-urban and quite rural area 150 years ago, the farm is now fully integrated into the metropolitan area of Lyon and surrounded by various facilities (convention centre, business park) and numerous villas.

The school was willing to host the DECISIVE demonstration facility next to the reFARMERS vertical farming demonstration greenhouse.

In order to provide FW to the DECISIVE demonstration facility, several restaurants, public caterers, a brewery and an organic supermarket were contacted and asked if these establishments would join the project by providing FW (Figure 5). Unlike the other demonstration and case study sites, the FW providers of the Lyon urban farm case were not selected according to a specific area, but according to their willingness to participate in the project. The nearby company restaurant *RIE*, the *Valpré* Hotel and *Paul Bocuse* cooking school were approached first because of their proximity. However, they did not join the project, also because of COVID-19. These institutions could have provided enough FW to use the full capacity of mAD. Besides these potential institutions, those who joined the project are marked in Figure 5. The timing of joining the project was very different for each establishment. Some joined from the beginning, some later, some left the project again due to COVID-19 closure (chapter 3.1). In addition, the farm itself acts as a provider of waste from its agricultural activities.

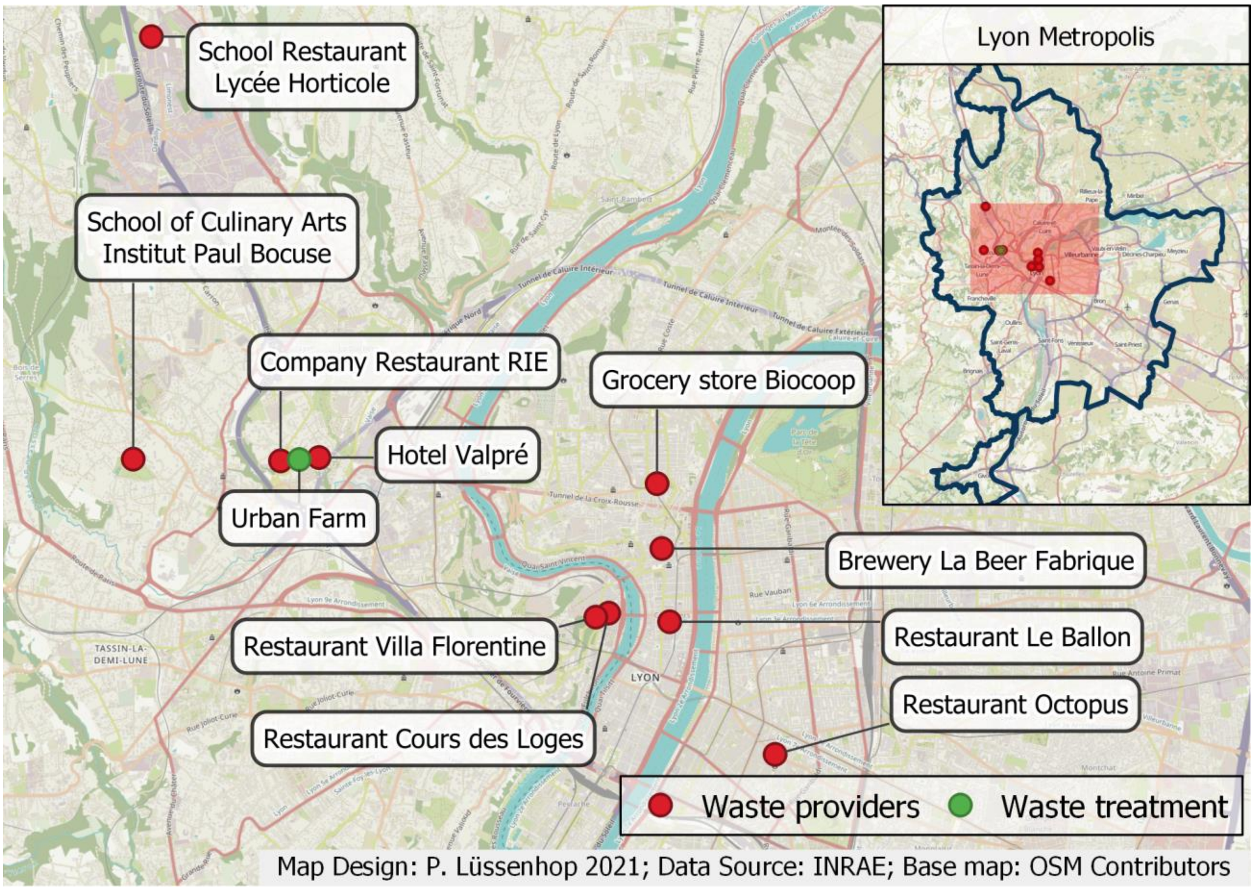


Figure 5: Location of the demonstration site, as well as potential and current providers of biowaste in the Lyon urban farm case

In contrast to the common practice in GL, some of the commercial waste providers had organised their own separated BW management. While the BW from the farm was already composted on-site, vegetable FW from the preparation leftovers of the hotel restaurants Cour des Loges, Villa Florentine and the supermarket Biocoop were collected and brought to the farm. In addition, FW from the Lycée Horticole school restaurant was collected for anaerobic treatment and taken to the town of Anthon. However, this FW was still collected in the RW.

2.1.1.3 Degree of implementation of DECISIVE concept

Figure 6 highlights the parts of the DECISIVE concept that were integrated at the *Lyon urban farm* demonstration site. Communication and incentive measures were described in D6.5 (Guerrero et al. 2019). Existing storage facilities of FW providers that already had separate BW collection continued to be used.

Storage units were provided for those providers who did not have an existing FW collection system. Various vehicles are used for collection, but without an optimised routing system. Finally, a mAD facility with a capacity to treat 50 Mg a^{-1} of BW was implemented at the farm (Figure 7). Its ramp-up phase started in October 2019. It was placed next to a greenhouse that was mainly used by project partner reFARMERS.

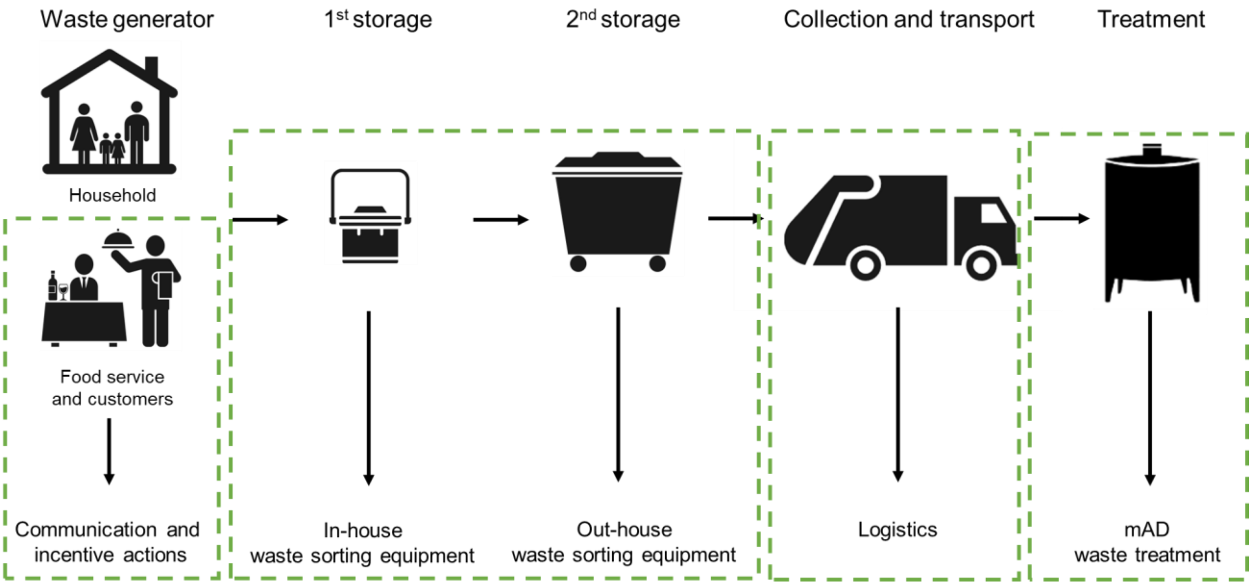


Figure 6: Degree of implementation of the DECISIVE concept within Lyon urban farm demonstration site

Figure 7: mAD unit of the Lyon demonstration site including FW storage devices

2.1.2 Dolina town

The municipality of San Dorligo della Valle - Dolina has about 5,700 inhabitants and about 390 commercial activities and is located on the border between Italy and Slovenia. The area is characterised by a heterogeneous territory that hosts a protected cross-border natural area where the cultivation of olive trees and vineyards are the main agricultural activities. In addition, the area of Dolina hosts the facilities of the free port of Trieste and also the most important ship engine factory in the northeast of Italy. Figure 8 shows the location of Dolina in the south-eastern corner of the Italian region of Friuli Venezia Giulia.

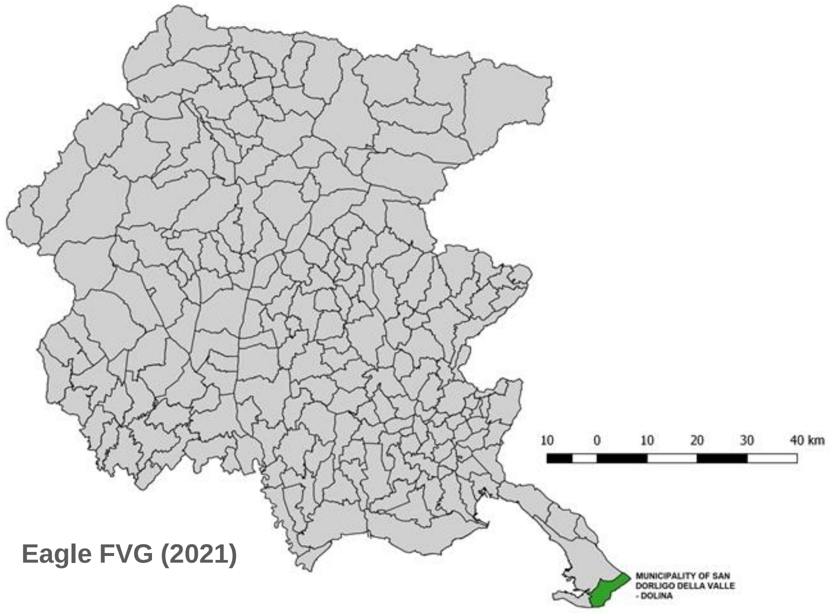


Figure 8: Location of Dolina/San Dorligo della Valle within the Italian region of Friuli Venezia Giulia

2.1.2.1 Initial biowaste collection and management

In Dolina, separate DtD waste collection is carried out for all waste streams (Table 1). A&T2000, Dolina's waste management company, provides each household or business with bins or bags of different colours depending on the type of waste (Table 1). A&T2000 also provides each user with a calendar describing the collection days for each waste fraction. The highest collection frequency is for BW, followed by RW. The three different recyclable material streams are collected fortnightly. Waste is collected on the same day for both households and commercial enterprises. BW includes a single-stream FW collection, while GW has to be delivered to the recycling centre.

Table 1: Types of container used for separate collection in Dolina

Type of waste	Bin/Bag	Colour	Collection frequency	Typical bin sizes ($L\ bin^{-1}$)
Biowaste	Bag + Bin	Brown	2/week	25[a] 240[b]
Paper waste	Bin	Yellow	Fortnightly	40[a] 240[b]
Glass waste	Bin	Green	Fortnightly	35[a] 240[b]
Plastic plus can waste	Bag	Blue	Fortnightly	90[a] 90[b]
Residual waste	Bag	Pink	1/week	70[a] 120[b]

[a]Households, [b]Commercial activities

The choice of using bags or bins for the different types of waste is based on the Municipal Ordinance, which regulates how a municipality has to manage its municipal waste collection service. In particular, the choice of using bags for plastic waste was introduced after a cost-benefit analysis. The operator can visually and easily check the compliance of the material and put it in the collection truck while the time for waste collection is reduced. To enable quick waste collection while reducing hygiene issues, BW must be delivered in bags to the bin. To facilitate treatment, A&T2000 only allows the use of paper bags or certified biodegradable plastic bags.

Figure 9: Organic waste bin (left) and plastic bags used for plastic plus metal cans packaging (right) for door-to-door collection

When A&T2000 took over waste management in Dolina in 2017, the company focused its activity on communicating the importance of proper waste separation. For this reason, A&T2000 organised several public meetings with residents and other users of the system to describe their DtD waste collection system and explain the different fractions that need to be sorted and taken to a collection centre.

To promote the correct segregation of BW, A&T2000 required their waste collectors to label incorrectly segregated material with a sticker describing the mistake made by the user and all the information to contact the municipality. If the material is not sorted correctly, the whole bag or bin will not be collected.

Furthermore, it is the responsibility of the person generating the waste to separate the components correctly so that they will be collected. Collectors are also not allowed to collect the waste within the RW collection cycle e.g. if the waste is not yet sorted correctly. An incorrectly filled bin or bag can only be collected as *abandoned* waste in exceptional cases and on behalf of the municipalities. The collection is then at the municipality's expense, which is added to the general waste fee.

With the aim of reducing their waste fee, households or commercial activities may decide to manage their FW through home-composting. In this case, no bin is provided for BW, and the user has the responsibility to follow all the steps to produce their own compost.

In addition to the DtD collection system, there is a recycling centre to which residents and commercial activities must deliver any waste that is not collected under the system, such as metals, WEEE or GW.

Another option for bulky GW such as branches, tree pruning material and logs was created by A&T2000 for Dolina. The so-called biomass platform (Figure 12) allows residents to deliver these materials there. In the future, it is planned to pre-treat this waste with a solar-powered dryer for chopped biomass and further treat it in another experimental plant for energy recovery.

The destination of the FW and GW was Codroipo, about 100 km away, before the DECISIVE demonstration started (Figure 10). There, all FW and GW collected in the catchment area of A&T2000, but also in the whole Friuli Venezia Giulia region, is treated in a combined anaerobic and aerobic plant with direct energy recovery through biogas combustion and compost production.

Due to the long distance between Dolina and the treatment plant, the BW collection was separated into two phases. First, BW from households and commercial activities was collected by a small truck that is suitable to drive through the narrow streets of the municipality. Secondly, once the collection circuit was completed, the waste was immediately transferred to a trailer and transported to its treatment plant in Codroipo.

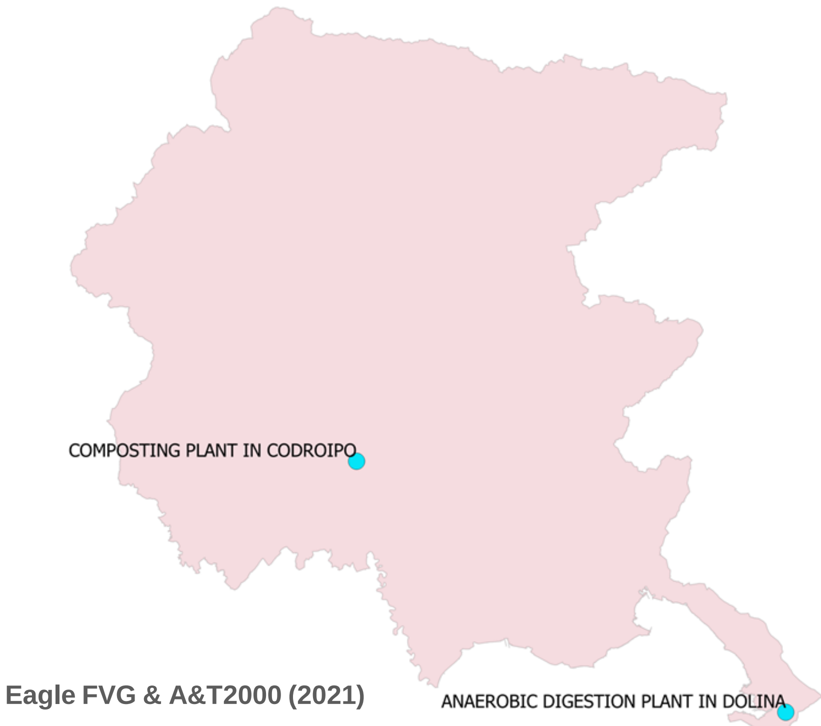


Figure 10: Location of original biowaste treatment plant in Codroipo and new mAD in Dolina

2.1.2.2 Implementation of separate collection of FW within the DECISIVE concept

As described earlier, the FW collection in Dolina was already in place before A&T2000 entered the DECISIVE project and the implementation of the mAD demonstration site. Figure 11 shows the location where the mAD is installed and is referred to as the biomass platform. A picture of this platform can be seen in Figure 12. Originally, the FW was collected and brought to the recycling centre where it was transferred into a larger truck. This recycling centre is also meant for other wastes that are collected either by the municipality or delivered by the inhabitants. Figure 11 also shows the BW catchment area, which is the town of Dolina.

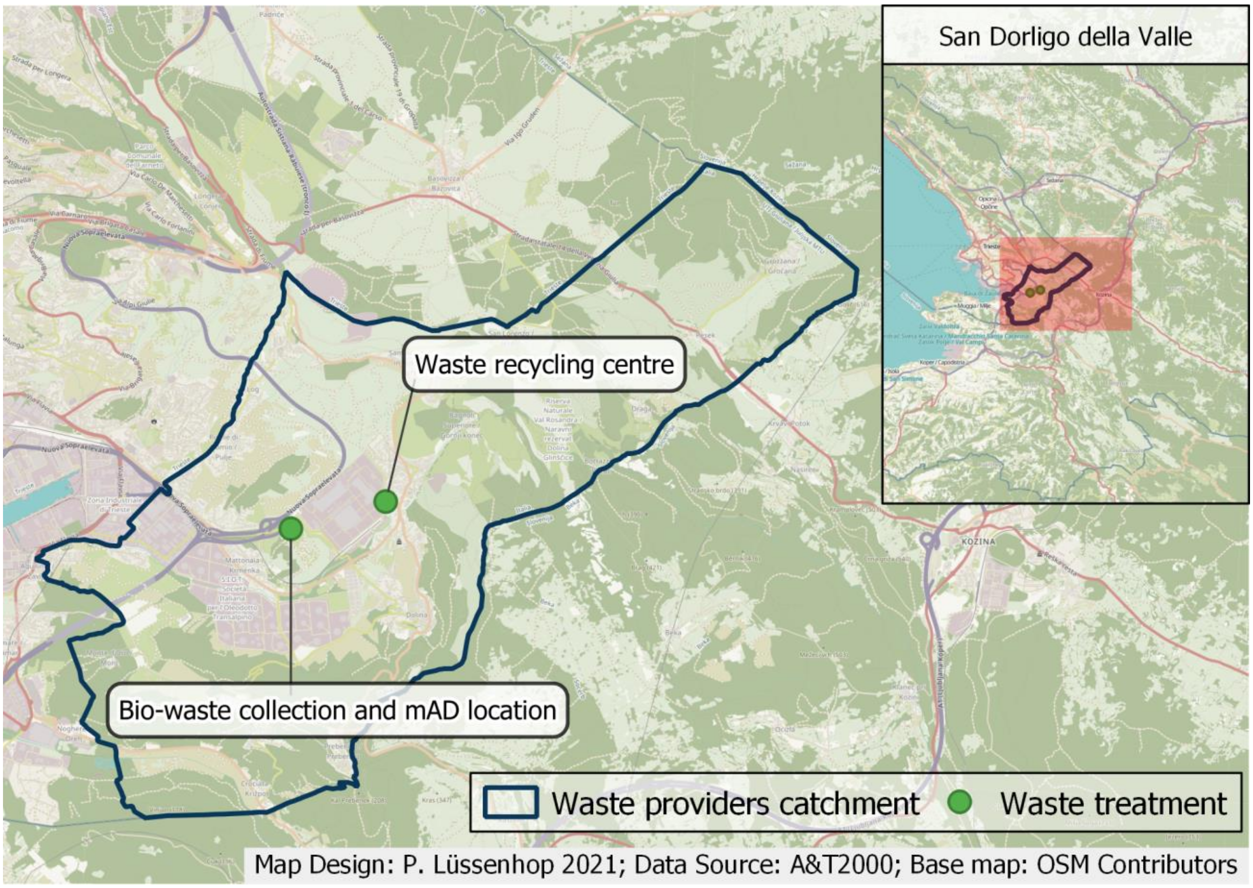


Figure 11: Location of the mAD, the original waste recycling and collection centre and the catchment total area of Dolina

The mAD plant was installed in October 2020. It consists of four containers: the BW receiving unit, the control unit, the digester unit and the gas storage. In February 2021, another container was placed, which will allow the integration of the Stirling engine into the system as a CHP unit (Figure 13).

Figure 12: Area of the installation of the mAD plant and current biomass platform

It is planned to treat all separately collected BW from Dolina, which mainly consists of FW. This includes all waste provided by households and commercial activities. Therefore, all households plus commercial activities will serve as BW providers. The commercial activities can be included due to the Italian legislation that considers BW generated by commercial activities similar to household BW and therefore can be assigned to the public waste management service.

Figure 13: Micro-anaerobic digestion plant in Dolina. In process order from right to left: Biowaste reception unit, control unit, digester unit with gas storage unit on top, CHP unit (blue, Stirling engine) for energy generation

The plant has a capacity to treat 200 Mg a^{-1} of BW and produces two main products: biogas and a liquid, the digestate. The latter is dewatered for further processes. The biogas will be combusted and generate energy for the system. Due to temporary permit restrictions, the digestate will be transported to the composting plant in Codroipo in the meantime. This allows for an additional maturing time and can then be used as fertiliser. The aim is to keep the maturation process close to the mAD treatment. Therefore, A&T2000 will investigate digestate properties and process parameters for its treatment to create a suitable maturation process on-site. Subsequently, it is planned to use the nutrient-rich digestate as fertiliser in Dolina's public areas. For excess quantities of BW, an additional aerobic treatment is planned in form of a community composting unit.

2.1.2.3 Degree of implementation of DECISIVE concept

By treating all of Dolina's FW, a small closed-loop system will be introduced that recycles all organic matter collected as part of the separate BW collection system. It is used as a resource to meet local energy and soil nutrient needs. The BW treatment process has not been started by the time of report submission (July 2021). When the process starts, also logistics will be adjusted towards the DECISIVE concept. Therefore, the Dolina town case can be considered as full integration of the DECISIVE concept in terms of FW management since all previous steps are already in place (Figure 14). The measures on the waste generator level will not change compared to the original BW collection system.

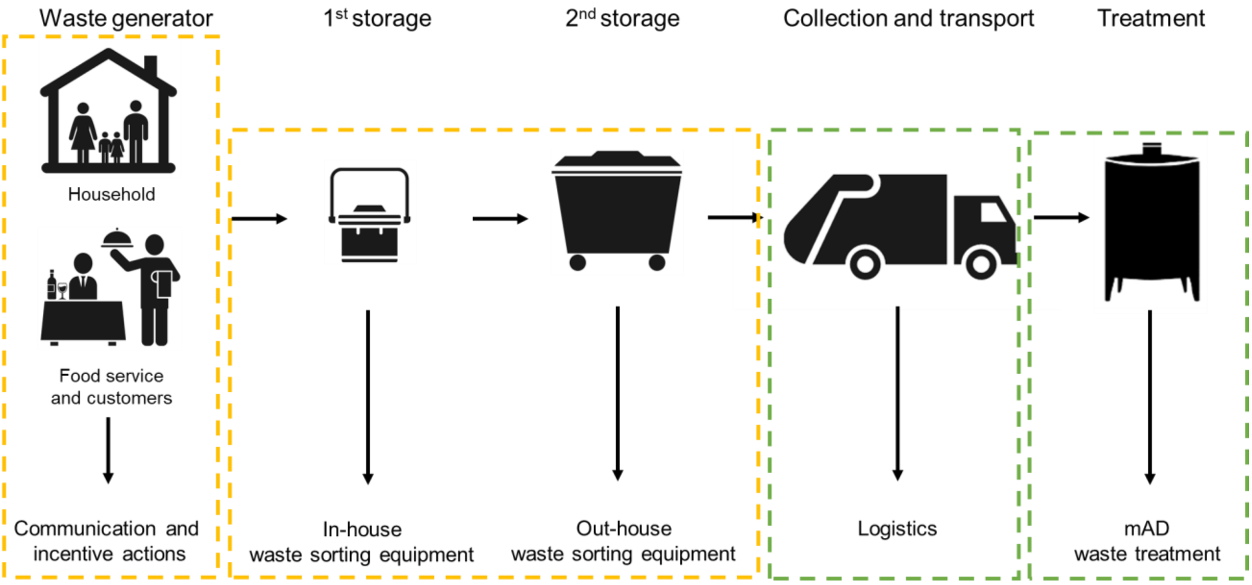


Figure 14: Degree of implementation of the DECISIVE concept within Dolina town demonstration site

2.1.3 *Barcelona UAB campus*

The campus of the Universitat Autònoma de Barcelona (UAB) is located north of the Barcelona metropolitan region in the municipality of Cerdanyola del Vallès, as shown on the mini-map in Figure 19. More than 50,000 people move around the campus, including students and staff. About 2,000 of them live in a student village called *Vila Universitaria*. More information on the campus can be found in D6.5 (Guerrero et al. 2019).

2.1.3.1 Initial biowaste collection and management

On the UAB campus, there are about 35 areas with bring-point (BP) containers for BW, glass, packaging, paper and cardboard and mixed RW (Figure 15, left). The waste fractions deposited in these containers are collected by CESPA on behalf of the municipality of Cerdanyola del Vallès and transported to centralised treatment plants. For BW, this is Ecoparc 2, which is located 7 km from the campus. Also, the UAB has a very active recycling point (Space R) for useful materials (e.g. electronics, furniture and books). In addition to the municipal collection circuits, there are several systems for separating and collecting waste on the terraces and inside the bars and restaurants on campus (Figure 15, right). They are emptied into the kerbside containers by the cleaning services staff. However, the collection systems are not uniform on the campus, but mostly inconsistently provided. There are different types of bins and the colour coding is inconsistent (Figure 16). The collection devices were implemented in different campaigns initiated by various stakeholders.

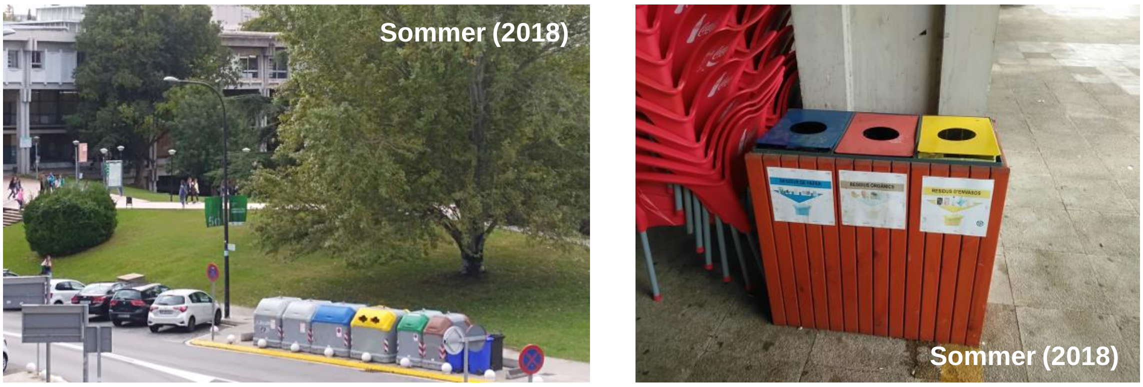


Figure 15: Collection areas in kerbside containers (left) and in the restaurant terraces (right).

Figure 16: Collection areas inside the buildings: common area for staff (left) and collection for refuse and packaging in restaurants (right)

So far, the deployment of containers for waste separation at source in the restaurants and on the terraces has not been too successful. It was observed that waste of all kinds is deposited in the containers with a high percentage of misthrow. One reason could be due to the lack of awareness of the students, which manifests itself in the substantial amounts of food and packaging waste left on the tables and removed by the restaurant staff. It is also possible that the inconsistency of colour coding and the large variety of collection bins play an important role in the poor performance (Figure 17). The student village has several areas designated for the deployment of BPs for separate collection and is part of the collection circuits of the municipality of Cerdanyola del Vallès (Figure 18). Recent environmental policies, including an improvement in waste source separation, developed at the UAB campus to improve source-separation are described in D6.5.

Figure 17: Cafeteria, interior and terrace

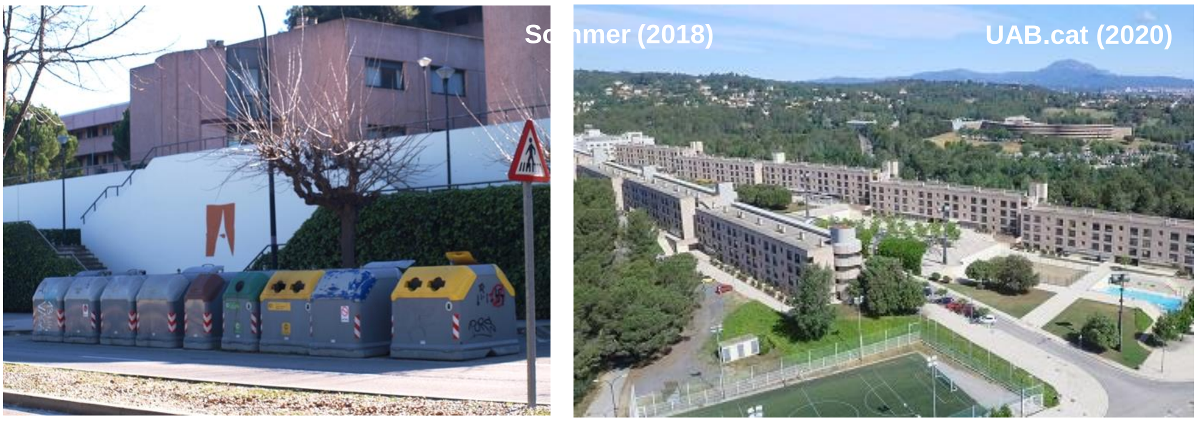


Figure 18: Student village at *Barcelona UAB campus* and bring banks

The waste that is disposed of at the BPs is collected by specific companies to treat it appropriately. Recyclables such as paper and cardboard (blue container), glass (green container) and packaging (yellow container) are transported to recycling companies and authorised centres of Ecoembes and Ecovidrio to be transformed into new raw materials. Depending on the quality, which is determined by the content of impurities, the recycling rate can vary and generate a large amount of refuse. This refuse is transported to landfills or incineration. RW (grey container) and BW (brown container) are transported to Ecoparc 2 in Montcada i Reixac in a common collection circuit with the municipality of Cerdanyola del Vallès. Once at the plant, both materials undergo mechanical pre-treatment, which is more intensive for RW. The separated materials can also be recycled if the quality is as good as for separately collected waste. The organic material separated from the RW is aerobically stabilised to reduce the organic matter content. The BW is treated anaerobically by wet fermentation to produce biogas after mechanical separation of impurities. The solid fraction of the digestate is mixed with GW to produce compost.

2.1.3.2 Implementation of separate collection of food waste within the DECISIVE concept

The *Barcelona UAB campus* case study was originally planned as a fully implemented demonstration site, but various reasons led to abandoning this plan, as explained in D7.3.

For the theoretical case of full implementation, the main campus restaurants were selected as the main FW providers due to quantity, ease of collection and logistics. In addition, the campus hotel and student village were selected to act as potential additional providers (Guerrero et al. 2019). In addition, the study included the FW generated in the nearby town of Cerdanyola del Vallès, where the UAB campus is located. It was analysed due to the fact that waste collection in Catalonia is organised in specific circuits, and the UAB campus is included in the common collection circuit of the municipality. However, it only served as a comparison of the quality between the FW on campus and the town. It was not planned to be a FW supplier.

The three main campus restaurants are located at the Faculty of Arts and Humanities (382 seats inside and 60 outside), operated by Soteras, at the Faculty of Biosciences (980 seats inside and 60 outside), operated by Clece and at Plaça Civica (650 seats inside and 200 outside), operated by Aramark. Including the other campus restaurants, more than 2,000 meals can be served daily on campus.

As these restaurants also supply the smaller cafeterias with cooked and prepared food, they are the main sources of FW generation on campus and suppliers of the largest share of FW for potential treatment. Therefore, the assessment focused on them in the first phase. The restaurants are open most of the year, but the waste generation is related to the university activity. The second largest FW generator is the student village. It is residence for students and visiting lecturers, with a capacity for about 2,000 people. During holidays (e.g. summer, Christmas), there are almost no students, although research activities continue.

More detailed information on the selected waste generators can be found in D6.5 (Guerrero et al. 2019).

Figure 19 shows the three main campus restaurants that were intended to be the main providers for the mAD demonstrator. The location for the latter was planned in “Space R". The student village including a hotel is located to the west of the main campus.

Despite the abandonment of the plan to implement a mAD plant, work continued to improve FW collection in the three campus restaurants and surrounding areas. Various communication activities and incentive programmes were implemented. Furthermore, the in-house collection system, which refers to collection up to the second storage (see D3.7, Walk et al. 2018), was improved. This relates firstly to the kitchens, which received new collection equipment and training, and secondly to waste collection in the restaurants, which also received new equipment and a change in procedure. The latter includes a change in the sorting system in the restaurant. Customers were asked to remove paper and packaging from their plates, but to leave FW and glass, which would be disposed of by the kitchen staff. In addition, for those who bring their own lunch box, special bins for FW will be installed in the restaurant premises.

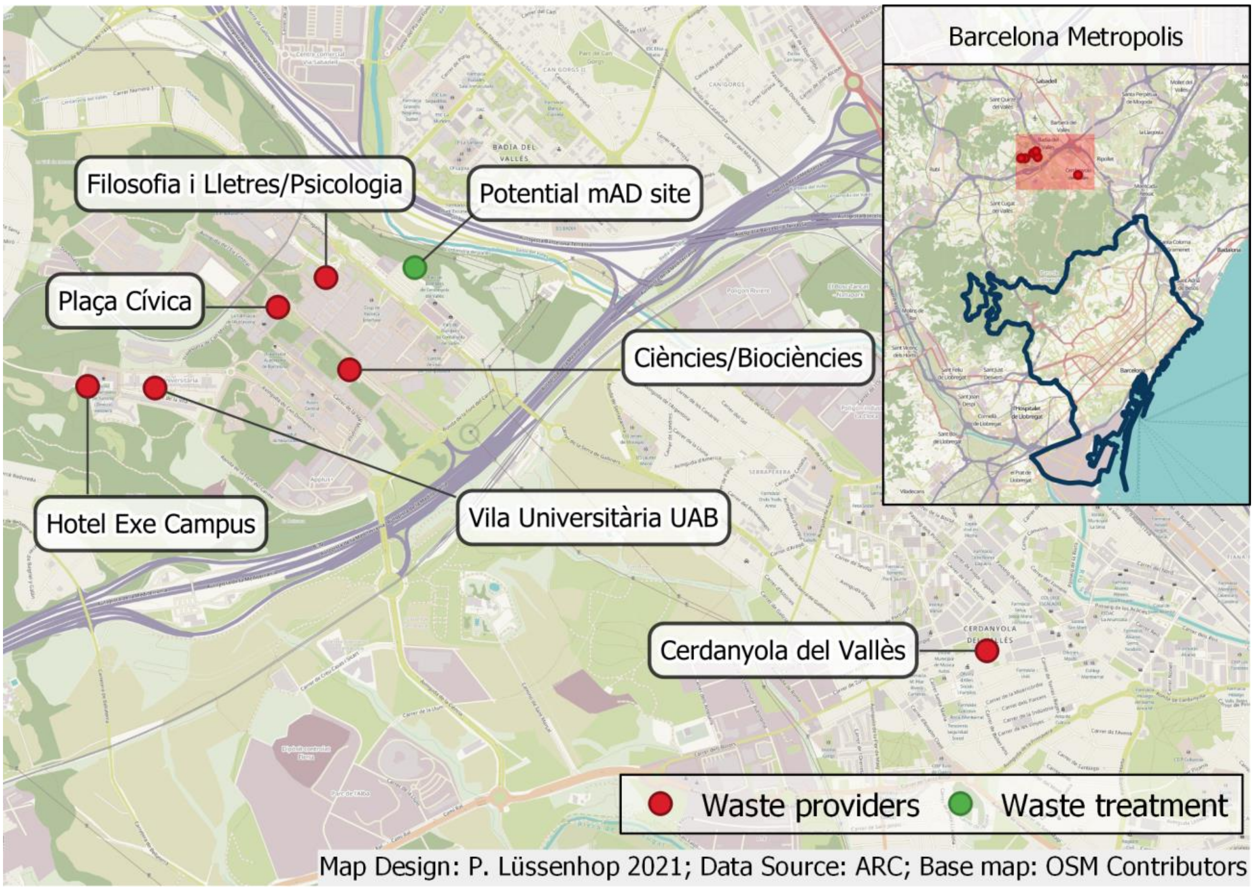


Figure 19: *Barcelona UAB campus* including restaurants and the initially foreseen space "R" for the mAD unit

2.1.3.3 Degree of implementation of DECISIVE concept

Figure 20 shows a pictographic flowchart illustrating the degree of implementation of the new means of FW collection initiated during the DECISIVE project. The green dashed box contains the newly implemented means and the yellow dashed box contains the means that are partially implemented or still planned to be implemented in the future. On the other hand, the red dashed box contains the abandoned plans. They will remain the same as in the original waste collection system.

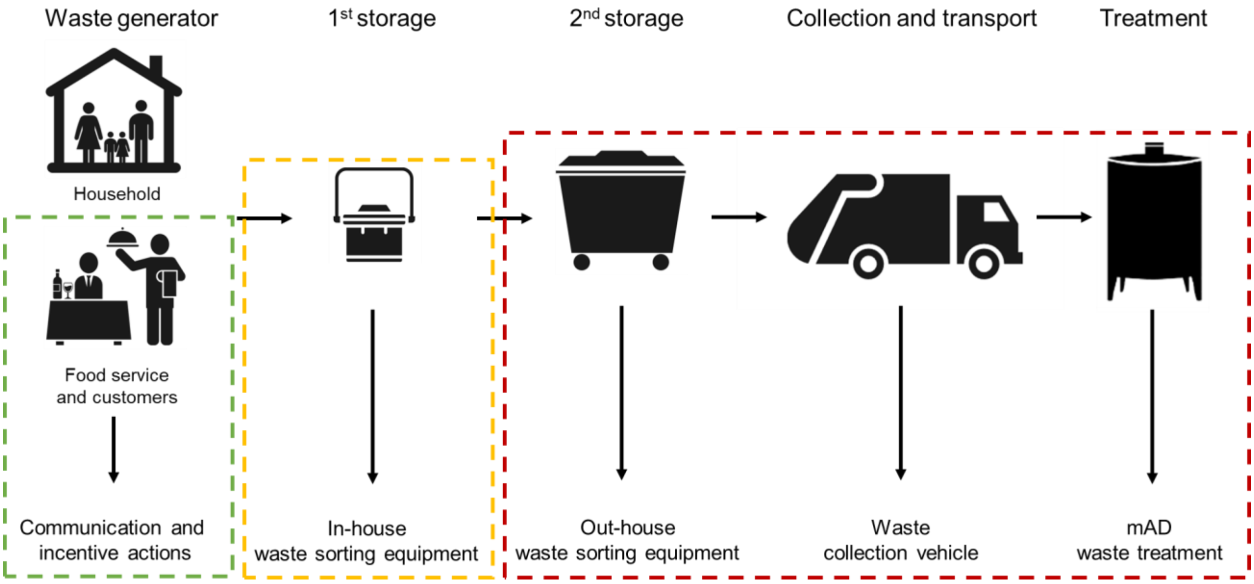


Figure 20: Degree of implementation of the DECISIVE concept within *Barcelona UAB campus* case study

2.1.4 Lübeck neighbourhoods

The city of Lübeck is located in the northern German state of Schleswig-Holstein and has 219,645 inhabitants (2020).

2.1.4.1 Initial biowaste collection and management

In Lübeck, waste management is organised by the municipality and carried out by Entsorgungsbetriebe Lübeck (EBL). BW, RW, paper and dry recyclables are collected in a DtD scheme, as is mostly applied in Germany. BW and RW are mostly collected fortnightly in Lübeck, with exceptions for weekly collection. The choice of bin size lies within the responsibility of the homeowner who can choose between 80 - 240 L for BW and 120 - 240 L for RW for single family houses. For multi-family houses, the bin sizes can increase to 1100 L for both waste types. For the latter, it is common in Germany, and therefore also Lübeck, for multi-family complexes with one or more houses to have a community collection point at the second storage. This can be defined as private BPs within a DtD scheme (in contrast to the public BP system, as it is common e.g. in Catalonia). These places are either locked, e.g. in the basement or a cage and only accessible to residents. In some cases, they are placed outside without locking. The latter would theoretically be accessible to the public. Private BPs are more anonymous which may lead to a higher level of waste contamination and collection point pollution. This can demotivate other residents to sort their waste accordingly.

All bins are colour-coded as shown in Figure 21; paper (blue), RW (green), dry recyclables (yellow) and BW (brown). BW is collected as a co-mingled fraction consisting of FW and GW. In addition, GW can be handed in by residents and commercial activities at the recycling centres. Generally, BW has the smallest total bin volume of all waste types collected.

Further basic information on Lübeck's waste management can be found in D3.6 (Schermuly et al. 2018).

Figure 21: Door-to-door waste collection point (second storage) of at multi-family houses

2.1.4.2 Implementation of separate collection of food waste within the DECISIVE concept

The Lübeck case study focused on improving household FW collection. It was planned to investigate, the residential structures that usually have the biggest problems in terms of waste separation, namely multi-family houses. Furthermore, two areas were chosen to represent socio-economic differences.

The map of Lübeck (Figure 22) shows the two study areas and also the location of the central BW treatment plant. Area A is defined as socio-economically low, and area B as socio-economically moderate based on the rent that residents have to pay. The flats in Area A are publicly subsidised, and the rent is well below Lübeck's average, while the flats in Area B are not publicly subsidised, and the rent is slightly above average. Area A consists of three multi-family houses with a total of 37 households and an average of 1.6 residents per household. Two houses have 9, one has 19 households. Area B consists of 5 houses with a total of 46 households and an average of 1.7 residents per household. Four houses have 9, one house has 10 households. The Lübeck average is 2.0 residents per household, but including further types of housing.

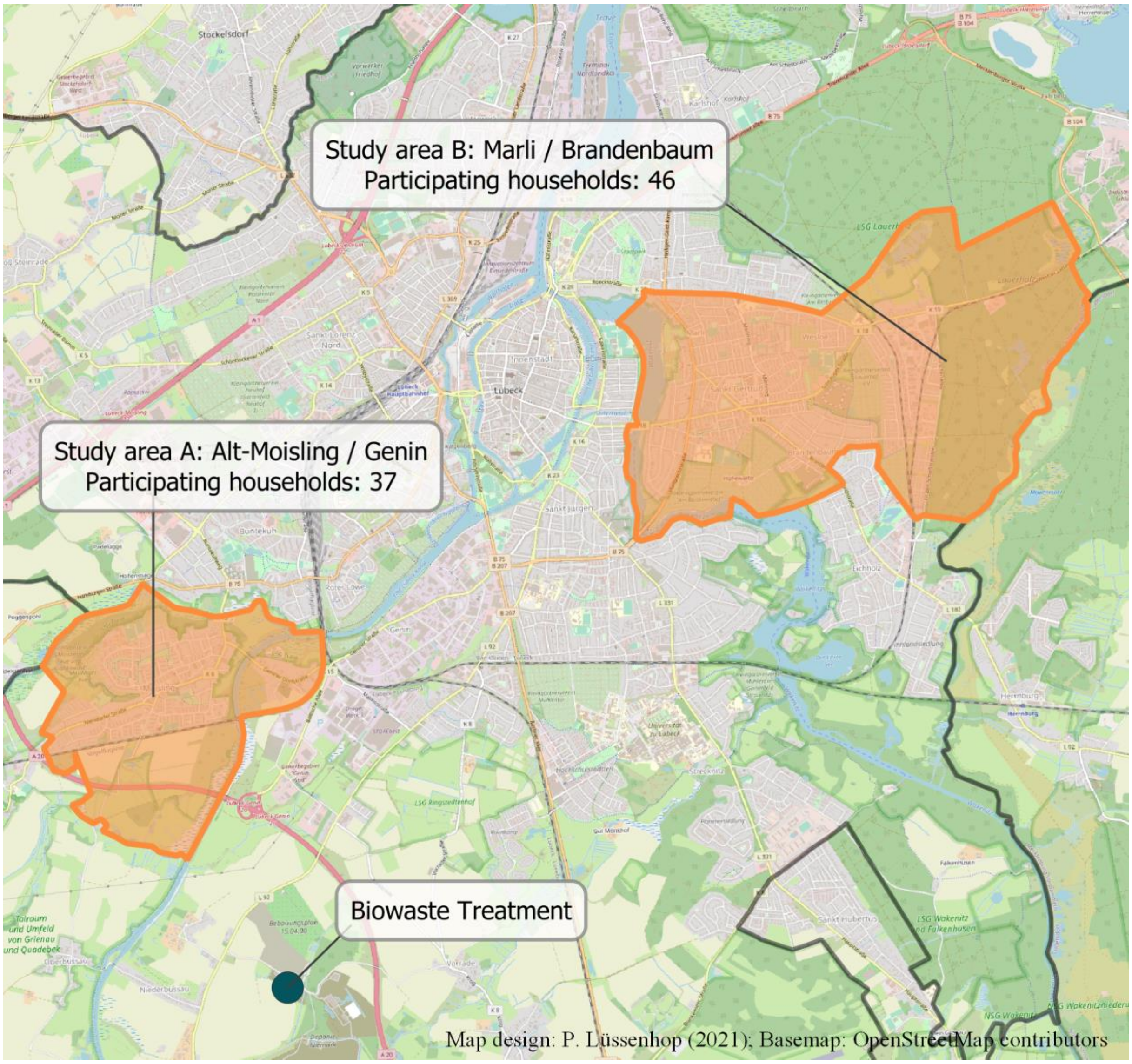


Figure 22: City districts where the case study neighbourhoods are located

Before implementing the new collection system, both areas studied had an existing BW collection system as described in chapter 2.1.4.1. It included bin sizes of 120 L and 660 L for both, BW and RW in area A. Each of the three houses had an own set of bins, which were not locked. In area B, all five houses were connected to the same collection point, which was locked. The total bin volume was 480 L (4 x 120 L) for BW and 3300 L (3 x 1100L) for RW. BW was collected fortnightly in areas A and area B. RW was collected weekly in area A but fortnightly in area B.

The new collection system aimed to increase convenience for collecting FW in the kitchen, but also for transport and secondary storage. Figure 23 highlights the important parts of the system. Prior to the trial, the residents were informed about the collection tests by leaflets. Additionally, an event was organised for area A to introduce the system. A few days before the start, residents were provided with further information such as sorting guidelines and FW collection buckets (Figure 23). The sorting guidelines provided and important information for residents are shown in Figure 24. Equipment for the secondary storage was also set up a few days before the launch (Figure 25). The original BW bins were removed on the day of the test start. The collection frequency was increased to three times a week. The collection days were Mondays, Wednesdays and Fridays. As waste is often taken out of the home when people leave it for another reason,

it is important to provide an option that eliminates the need for people to return to their flat again to return the bucket. Therefore, residents were asked to put their filled buckets in the secondary storage unit. The buckets were replaced with clean ones on the collection days to be picked-up by the residents.
Each household was anonymously assigned a number. Residents were asked to put a provided sticker with their number on their buckets to enable tracking of source-separated FW quality and quantity per household. This also reduced the risk of a household taking more buckets than was allocated for them. After collection, the waste was weighed and characterised as described in chapter 2.2.
The duration of the test of the new FW collection was 5 weeks. Afterwards, the original collection system was reintroduced starting from the secondary storage. However, residents were allowed to keep the collection buckets. The end of the test of the collection system was the starting point of the long-term evaluation of the effects of the tested system as well as the permanent provision of the collection buckets. However, the whole study lasted about one year, including the evaluation of the ex-ante situation immediately before the test and the long-term effects, six and 12 months after the test.

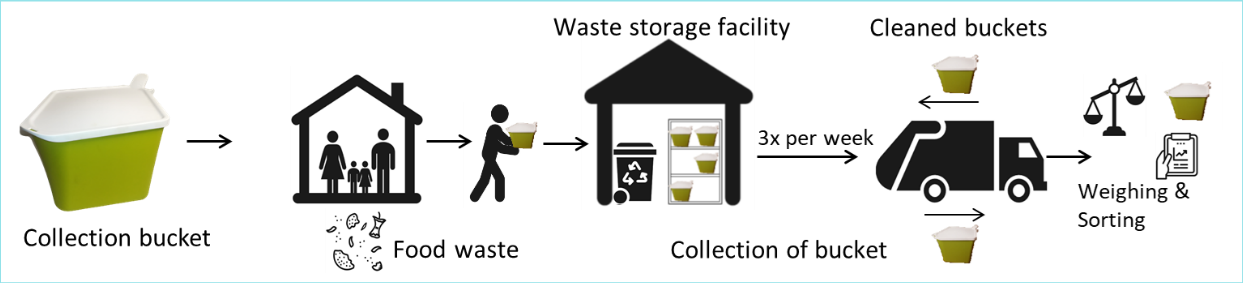


Figure 23: Scheme of the tested collection system in both areas

With the new system, the collection of FW and GW was decoupled. While small plants were allowed in the collection buckets, twigs and branches had to be disposed of with the RW for organisational reasons during the test. Ideally, the GW would have its own collection system including equipment that allows for a demand-based collection.
The reorganisation of the FW collection space is shown in Figure 25. Due to local constraints, different solutions were chosen: for area A, a box to hide the small collection buckets and in area B, an open shelf was placed. The solution with a shelf is more space-saving than the box solution. However, both solutions fit well in the available space for waste collection and use only slightly more (area A) or less (area B) space than the original BW bins. Certainly, further improvements and customised equipment can lead to more space savings, especially when lockable shelves are used.

Figure 24: Waste sorting guidelines for the testing phase of the new food waste collection system

Figure 25: Second storage of tested food waste collection system in area A and B

2.1.4.3 Degree of implementation of DECISIVE concept

Figure 26 highlights the degree of implementation of the case study. Intensive communication activities were carried out before and during the test. This included face-to-face interviews with some residents in both areas, asking them about their knowledge of waste separation and their problems with it. The collection was different from the original one. In the test, FW was collected by the university group and not by the regular waste collection vehicle. The means of transport and treatment were not investigated in this study.

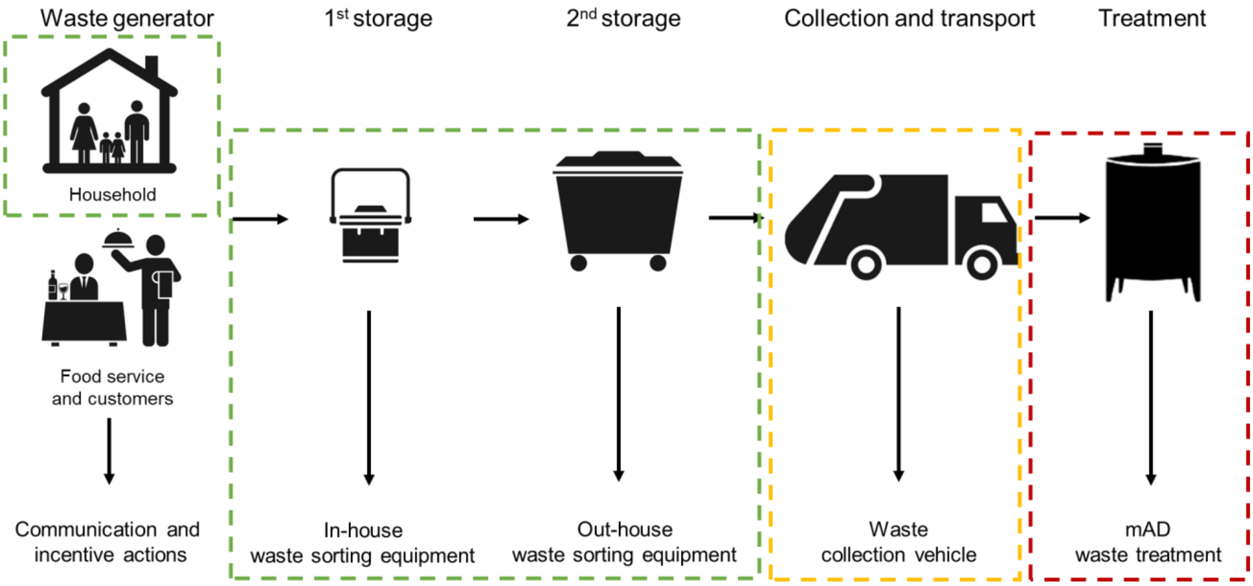


Figure 26: Degree of implementation of the DECISIVE concept within the Lübeck neighbourhoods case study

2.2 Waste qualities and quantities

A standard methodology for waste characterisation has been established for all sites, but it includes a certain degree of freedom for each specific site due to local differences. The estimation of the amount of source-separated FW is important for decisions on the capacity of a mAD plant on collection equipment needed. The means for the assessment are presented in the chapters for the specificities of each site (2.2.3 - 2.2.6).

2.2.1 Method for waste characterisation

Analysing the waste composition of source-separated FW is important to identify impurities and the share of biodegradable waste that can be used for further treatment. For RW, it provides information on the share of FW that is not source-separated. This amount is seen as potential to be shifted to the BW bin. In addition, information on further recyclables such as glass, paper, plastics and metals can be received. These could also be shifted from both the RW bin and the BW bin to the respective collection bin. Ideally, the BW bin should contain 100% biodegradable waste and the RW bin 0%. The latter should only contain materials that are difficult or impossible to recycle.

Waste quality is measured using a waste composition analysis. The waste characterisation protocol developed for DECISIVE is based on the Catalan (Agència de Residus de Catalunya (ARC) 2018), French (Wavrer et al. 2010) and German (Intecus GmbH 2015) waste characterisation methodologies. The summarised protocol, used for this report can be seen in Table 2. Slightly different characterisation protocols were used at each site. Particularly, the naming of fractions, or further sub-fractions were used at each site. The fractions have been standardised for this report and are given in Table 2. The sub-fractions presented are a summary of a larger number of originally characterised sub-fractions of FW. The complete

site-specific waste characterisation protocols can be found in Appendix 1 (UAB campus), Appendix 2 (Lyon and Dolina) and Appendix 3 (Lübeck).
The waste to be analysed was collected by different means at each site. A description of the means can be found in the chapters for the specifics of each site (chapters 2.2.3 - 2.2.6).

Table 2: Summarised waste characterisation protocol

Fractions	Sub-fraction	Explanation	Biodegradability
Food waste	Unavoidable	Fraction that is considered not to be edible	Biodegradable
	Avoidable	Fraction that is considered to be edible	
Garden waste	-	Leaves, lawn, twigs, trunks	
Paper & cardboard	-	Non-food organic waste from kitchen, e.g. kitchen tissues, newspapers and other paper	Biodegradable with exceptions[1]
Non-biodegradable	-	All that is not accountable for the above described	Non-biodegradable

[1]Paper and cardboard will be accounted separately since it is biodegradable with some restrictions but is usually accounted for an impurity in source-separated BW or FW.

For this report, FW is mainly differentiated into avoidable and non-avoidable fractions. Avoidable is the fraction of FW, that is generally edible when fresh. For the Lübeck neighbourhoods case study, a further distinction was made between partly avoidable FW, which includes edible parts that are usually cut off. GW is the sum of woody and green waste originating from the garden. Paper is reported separately as it is not necessarily an impurity but biodegradable with restrictions. Furthermore, plastics, glass, metals and others are grouped into macro-impurities in source-separated BW and others in RW.

2.2.2 Method for waste quantification

Collecting information on the available waste quantities in combination with waste characterisation enables an in-depth analysis of the waste collection performance. Information on waste quantities is important for the design of the mAD plant, but also for the selection of the collection equipment. Therefore, quantities of source-separated BW and RW were investigated.
The quantification method differs between the demonstration sites and case studies as described in chapters 2.2.3 - 2.2.6.

2.2.3 Specifics at Lyon urban farm

Prior to the start of the demonstration mAD, FW quantities from restaurants and other suppliers were not determined. However, when the mAD operation started, the weight of each FW delivery from almost each supplier was measured at the facility. As indicated in chapter 2.1.1.2, only some of the selected FW suppliers had an existing separate collection. Therefore, only their separately collected FW and RW was characterised prior to the start of the new system. For all other suppliers, RW was collected to characterise the share of FW and total generation. After the start of the demonstration mAD, also source-separated FW was characterised. Furthermore, there were some exceptions:

- The waste composition of the restaurants *Octopus* and *Le ballon* and the brewery *Beer fabrique*, which joined the project after the two ex-ante characterisation campaigns, as well as the farm, was not characterised until the publication of the report. However, in particular the waste from the farm and the brewery were assumed to be of high quality.

- The hotel *Valpré*, the canteen *RIE* and the cooking school *Institute Paul Bocuse* were initially characterised for their waste composition, but withdrew from the project and are therefore not included in the results section. A short summary for the reasons for the withdrawal is given in Appendix 6.

The characterisations were conducted at the demonstration site. BW and RW were collected from each potential provider at the end of the day to obtain the complete daily waste amount. In addition, the characterisation process considered differences in waste composition resulting from the restaurants' menus for breakfast, lunch and dinner. The characterisation also included a chemical analysis, the parameters of which are attached as a table in Appendix 4.

In total, three waste characterisation campaigns were organised, two before and one after the ramp-up of the demonstration mAD. Table 3 indicates the activities that have been carried out as part of the DECISIVE project.

Table 3: Waste assessment at *Lyon urban farm* before DECISIVE concept implementation

Waste generator	Characterisation campaign	Waste quantity estimation		Waste characterisation	
		Source-separated biowaste (*)	Residual waste	Source-separated biowaste	Residual waste
Hotel restaurant *Cour des Loges*	April 19	🟢	🔴	🟢	🔴
	October 19			🟢	🟢
	June 2021			🟢	🔴
Hotel restaurant *Villa Florentine*	April 19	🟢	🔴	🔴	🔴
	October 19			🟢	🟢
Restaurant *Octopus*	April 19	🟢	🔴	🔴	🔴
	October 19			🔴	🔴
Restaurant *Le ballon*	April 19	🟢	🔴	🔴	🔴
	October 19			🔴	🔴
High school *Lycée Horticole*[a]	April 19	🟢	🔴	🔴	🟢
	October 19			🟢	🟢
	June 2021			🟢	🟢
Grocery store Biocoop	April 19	🟢	🔴	🟢	🔴
	October 19			🔴	🔴
	June 2021			🟢	🔴
Farm *Abbé Rozier*	April 19	🟢	🔴	🔴	🔴
	October 19			🔴	🔴
Brewery *Beer Fabrique*	April 19	🟢	🔴	🔴	🔴
	October 19			🔴	🔴

[a] Originally, no source-separation of BW in place, * BW quantity estimation was based on the weight received at the mAD plant. And not only measured during characterisation events.

🔴 No specific event for quantity estimation. No waste characterisation.

🟢 BW was weighted for each provider at each day of reception. A waste characterisation was conducted.

2.2.4 Specifics at Dolina town

Total waste quantities per year are frequently measured by A&T2000. Therefore, there was no need to do this as a specific task within the DECISIVE project. Future quantities are estimated based on FW collection data from 2015 to 2020. Furthermore, a first waste characterisation was carried out in 2018, before A&T2000 joined the DECISIVE project. A further specific characterisation of the composition of BW and RW was planned within the DECISIVE project for households and commercial activities in order to assess potential quality differences. However, an estimation of quantities for each generator was not performed. The characterisations conducted before the start-up of the mAD system in 2018 and May 2021 are included in this report (Table 4). Another one is planned after the system implementation in September 2021.

Table 4: Waste assessment at *Dolina town* before DECISIVE concept implementation

Waste generator	Characterisation campaign	Waste quantity estimation		Waste characterisation	
		Source-separated biowaste	Residual waste	Source-separated biowaste	Residual waste
Households	2018 May 2021	🟠	🟠	🟢	🟢
Commercial activities	2018 May 2021	🟠	🟠	🟢	🟢

🟠 No specific quantity estimation but official data was available from A&T2000. However, only for both providers combined.
🟢 A waste characterisation was conducted. In 2018, only for both providers combined.

BW was collected on one of the two official collection days (Tuesday) and therefore represents half a week's waste quantity. Composition was assumed to be similar in the other half of the week. RW was collected on its only official weekly collection day on Saturday and therefore represents one week's waste quantity and composition. The characterisation was done according to the procedure defined in chapter 2.2.1. Due to COVID-19 restrictions, reduced staff and in order to reduce workload, less than the commonly suggested 250 kg per waste stream and characterisation were characterised. 100 kg of source-separated BW was characterised for each, households and commercial activities. 123 kg and 108 kg RW were characterised, respectively. The characterised amounts cannot serve for the separate determination of waste quantities originating from either households or commercial activities. Before weighting, waste was reduced to the aforementioned quantities. The organic fraction of each sample was analysed for chemical composition as indicated in Appendix 4.

2.2.5 Specifics at *Barcelona UAB campus*

Table 5 indicates the activities carried out in restaurants and in the student village plus hotel. A waste quantification was only carried out in the three main campus restaurants, Faculty of Arts and Humanities, operated by Soteras, Faculty of Life Sciences, operated by Clece and Plaça Civica, operated by Aramark. In the following, these restaurants are referred to by their operating company names. May and October were considered the most representative for waste generation, according to the academic activity and also confirmed by the restaurant managers. For this reason, the waste quantity estimation was carried out for

one week in May 2018 and October 2019. The FW separated and collected in the kitchens of the three main restaurants was weighed every day (Monday to Friday) before being introduced into the BP container. The FW found in the bins of the dining halls was not weighted. In addition, the quantities of BW and RW were measured during the waste characterisation events (Table 5).
For the student village, the amount of waste was measured only at the waste characterisation events. The amount of waste from the municipality of Cerdanyola del Vallès was measured once during ARC's regular waste characterisation event. However, the waste quantities and qualities of the municipality are regularly monitored by ARC and recorded in the official waste monitoring platform (GenCat 2021). FW and RW characterisation for the different waste origins was carried out in September 2018 and October 2019.

Table 5: Waste assessment at *Barcelona UAB campus* for baseline and future scenario

Waste generator	Characterisation campaign	Waste quantity estimation		Waste characterisation	
		Source-separated biowaste	Residual waste	Source-separated biowaste	Residual waste
Cerdanyola del Vallès	September 2018	🟠	🟠	🟢	🟢
	October 2019				
Student village+Hotel	September 2018	🔴	🔴	🟢	🟢
	October 2019				
Restaurant *Clece*[a]	May 2018	🟢	🔴	🔴	🔴
	September 2018	🔴		🟢	🟢
	October 2019	🟢			
Restaurant *Aramark*[a]	May 2018	🟢	🔴	🔴	🔴
	September 2018	🔴		🟢	🟢
	October 2019	🟢			
Restaurant *Soteras*[a]	May 2018	🟢	🔴	🔴	🔴
	September 2018	🔴		🟢	🟢
	October 2019	🟢			

[a]For the waste characterisation, waste was collected together for all three restaurants.
🔴 No specific event for quantity estimation. Only measured at waste characterisation. No waste characterisation.
🟠 No specific event for quantity estimation but data was available in ARCs waste monitoring platform.
🟢 A specific event for quantity estimation was carried out. A waste characterisation was carried out.

The characterisation followed the procedure set out in chapter 2.2.1. The original waste composition protocol normally used by ARC can be found in Appendix 1. For this report, it was compiled into the fractions shown in Table 2.
Figure 27 shows the procedure for assessing the composition of the waste collected in the BW and RW bins. First, the total mass of each delivery was determined, and then the mass of each component in the respective waste was determined. In addition, the chemical composition of the organic fraction was analysed (will be presented in DECISIVE WP7, D7.1). using the protocol for the chemical analysis shown in Appendix 4.

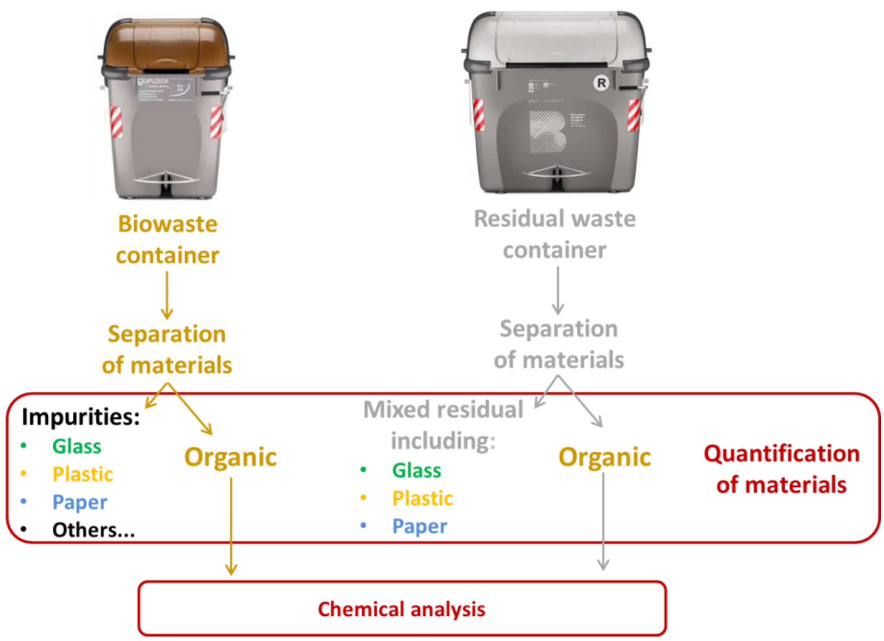


Figure 27: Proceeding for characterisation and chemical analysis of samples at Barcelona UAB campus

A cooperation with the collection company was made and a special collection was commissioned. At the *UAB, campus* BW is currently collected on Mondays, Wednesdays and Fridays, while RW is collected daily together with the municipal waste from Cerdanyola del Vallès. The characterisations required a change in the current circuit to avoid waste from different origins. This change was agreed with the collection company for both BW and RW to only collect waste from restaurants, from the student village plus hotel and the municipality of Cerdanyola del Vallès. The latter was only collected and characterised to be compared with the intended waste sources on campus. The collection of BW and RW for characterisation was carried out on Monday and Wednesday, corresponding to the days with higher generation amounts in the restaurants. The truck transported the waste to the waste treatment facility, Ecoparc 2, which serves as the reference facility. It released the waste into a special area where it was reduced to the amount to be characterised. The procedure involved quartering to obtain a sample quantity of about 250 kg to be characterised according to the fractions described in Table 2. This amount was not always reached because the collected amount was below this threshold. In this case, the total waste received was characterised.
The collected mixed RW in Catalonia generally still contains large amounts of biodegradable material. The material not separated at source is, therefore, more difficult to recycle than separately collected material due to the high share of non-biodegradable fractions. For these reasons, it was considered to characterise BW and mixed RW from the three origins to assess their material composition before the campaign and afterwards.

2.2.6 Specifics at Lübeck neighbourhoods

As introduced in chapter 2.1.4, the test was divided into four different phases. The ex-ante situation, the situation during the test and the long-term impacts, which were assessed after six and 12 months respectively. During all these phases, source-separated BW or FW, and RW were collected. For the ex-ante situation, a two weeks' amount of waste was collected for both areas. During the test, all separately collected FW was collected for characterisation, and RW with the amount of one week in the last week of the test. However, it was weighed on each FW collection day. For the evaluation six and 12 months after the test, a two weeks' amount of waste was collected each time for both areas. A total of about 1177 kg BW and 3240 kg RW were weighed. Of these, 96.5% and 62%, respectively, were characterised. Table 6 shows a summary of the analyses carried out.

Table 6: Waste assessment of waste generators at *Lübeck neighbourhoods* for baseline and future scenario

Waste generator	Characterisation campaign	Waste quantity estimation		Waste characterisation	
		Source-separated biowaste	Residual waste	Source-separated biowaste	Residual waste
Area A (socio-economically low)	Before (October 2018)	●	●	●	●
	During (November – December 2018)				
	After (June + November 2019)				
Area B (socio-economically moderate)	Before (October 2018)	●	●	●	●
	During (November – December 2018)				
	After (June + November 2019)				

● A specific event was carried out.

2.3 Transition of the food waste collection system at different sites

In order to assess the impact of the transition from the current to the new decentralised management system, several collection-related parameters are important. These parameters relate to the original collection system and the changes associated with the new system. Two general situations were identified:

- Introduction of separate collection of BW.
- Transition of existing separate collection of BW.

Both situations can be included in a decentralised management system but also a centralised one while adapting the collection part of the system.

In the first situation, a major change is introduced and the BW is diverted from the RW to be managed separately (*Lyon urban farm* case). In the second situation, the BW is already collected separately, but a change in the current management is introduced (case of *Dolina town*, *Barcelona UAB campus* and *Lübeck neighbourhoods* as scenario).

A comparison between before and after implementation can help to assess the suitability and constraints of changing or implementing separate collection. The parameters to be considered are related to distance, time, labour and cost of collection. They are highlighted in Table 7, and are important to assess the performance, transition and potential benefits from a common centralised waste management approach to proximity and decentralisation. They are provided to show the need for their assessment. Those that were assessed for the report already are included in the results section for each site.

Table 7: Key collection-related parameters to evaluate the transition towards a new biowaste management system by comparing the situation before and after

Parameter	Unit	Note
Collection frequency	d w^{-1}	Times of collection per time interval
Vehicle loading capacity	Mg $vehicle^{-1}$ m^3 $vehicle^{-1}$	Maximum loading of vehicle
Vehicle energy consumption	kWh Mg^{-1} km^{-1}	How much energy is consumed specifically per Mg of waste collected and km driven
Total distance	km	Distance of one collection circuit
Waste amount	Mg collection $circuit^{-1}$	collected per collection circuit
Payload distance	Mg*km	Capacity or actual average collected waste quantity of a vehicle to transport it within the defined distance (collection circuit)
Time	h	needed for collection circuit
Size of bucket / bin at generator space	L m^2	Volume and floor space at 1st storage
Size of bucket / bin at kerbside	L m^2	Volume and floor space at 2nd storage
Labour	Person*hours	For one collection circuit
Maximum distance for vehicle	km	Distance possible with one tank / battery charge
Time for sorting	h Mg^{-1}	Time a generator needs to sort the waste correctly at 1st storage into the respective bin.
Original collection cost	€ a^{-1}	Cost of BW and RW collection within a centralised management system.
New collection cost	€ a^{-1}	Cost of RW collection within a centralised management system without BW collection plus cost of BW collection in a decentralised system

The data obtained for the collections can be used and inserted into the DECISIVE DST (Martinez Sanchez et al. 2019). It can help evaluate the scenario with the current FW management practice.

3. Results

The results are presented for all sites at least for the situation before the implementation of parts or the entire DECISIVE concept. For *Dolina town*, quantity data was taken from 2015 until 2020 from the official statistics, while waste characterisations were included from 2018 and May 2021. The latter is part of the DECISIVE project. For *Lyon urban farm*, the waste characterisation results only represent the situation before the implementation of the DECISIVE concept and was carried out in April 2019 and September 2019. Another characterisation was carried out in June 2021 but not included in this report. For the *Barcelona UAB campus* case, two characterisation events were carried out in September 2018 and October 2019 and an estimate of BW quantities of the main restaurants are presented. For the case of the *Lübeck neighbourhoods,* waste quantities and qualities were assessed at all phases of the study in 2018 and 2019.

3.1 Lyon urban farm

3.1.1 Waste quantities

Although they are the potential suppliers closest to the demonstration sites, *Hotel Valpré*, canteen *RIE* and the *Institute Paul Bocuse* have never participated in the project. One reason is the COVID-19 outbreak, the other legal constraints. All other BW generators listed in Figure 5 provided their FW to the demonstration site. The total waste quantities collected per FW generator are shown in Table 8. The table includes two phases, the first from January to June 2020 and the second from September 2020 to April 2021. In between these phases, there was a summer plus maintenance break. Hotel restaurant *Villa Florentine*, the one with the lowest amount delivered, stopped its waste provision after June 2020 due to the closure of COVID-19. In contrast, the restaurants *Octopus*, *Le ballon* and the brewery *Beer Fabrique* joined. The providers with the highest share of FW deliveries were the farm *Abbé Rozier*, supermarket *Biocoop*, the high school *Lycée Horticole* and brewery *Beer Fabrique*.

It is noticeable, that even within these periods, not all waste was collected from the various generators. The two main reasons are i) the global COVID-19 pandemic, which resulted in either a full or partial shutdown of the waste generators facilities and the demonstration site, and ii) the temporary full or partial shutdown of the demonstration site due to maintenance. In order to estimate the full potential of FW to be collected from each waste generator for the situation without the COVID-19 pandemic, different considerations were made:

1. In the period between September 2020 and April 2021, for the generators farm Abbé Rozier, supermarket Biocoop, high school Lycée Horticole, brewery Beer fabrique and hotel restaurant Cour des Loges, some weeks with frequent waste collection were used to estimate their maximum annual potential FW generation quantities. Only weeks with comprehensive collection data were considered. These periods were not at the same time for the mentioned generators.
2. For the restaurant's FW generation quantities, only the quantities measured during waste characterisation campaigns in 2019 were considered, thus representing only one day's waste generation. However, this data originates from the situation without global crisis. This data is available for the hotel restaurants Cour des loges and Villa Florentine. Due to the low representativeness of the quantity collected on one day, it cannot be used to make proper estimates for annual potential FW generation quantities.

Table 8: Total waste quantities of source-separated biowaste delivered to the Lyon urban farm site

Waste generator	Period		
Type and name	**01/2020 - 06/2020 [kg period^{-1}]**	**09/2020 - 04/2021 [kg period^{-1}]**	**Total [kg period^{-1}]**
Farm Abbé Rozier	572.2	857.5	1429.7
Supermarket Biocoop	1493.4	1850.0	3343.4
Hotel restaurant Cour des Loges	593.1	331.7	924.8
Hotel restaurant Villa Florentine	75.8	-	75.8
High School Lycée Horticole	162.3	2810.0	2972.3
Restaurant Octopus	-	452.0	452.0
Restaurant Le ballon	-	264.8	264.8
Brewery Beer Fabrique	-	1930.0	1930.0
Total	2896.8	8496.0	11392.8

Figure 28 shows the actual quantities collected per week for both periods together, which result from the quantities indicated in Table 8. It also shows the potential amounts to be collected from the waste generators that supplied most of the FW. The largest quantities are expected from the hotel restaurant Cour des Loges, the supermarket *Biocoop*, and the brewery *Beer fabrique*.

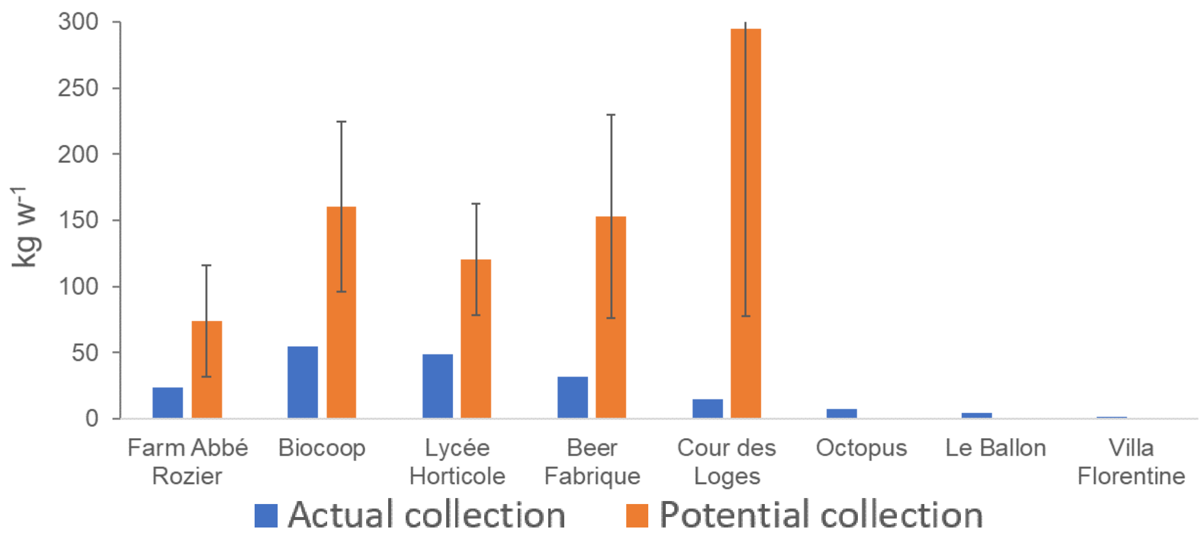
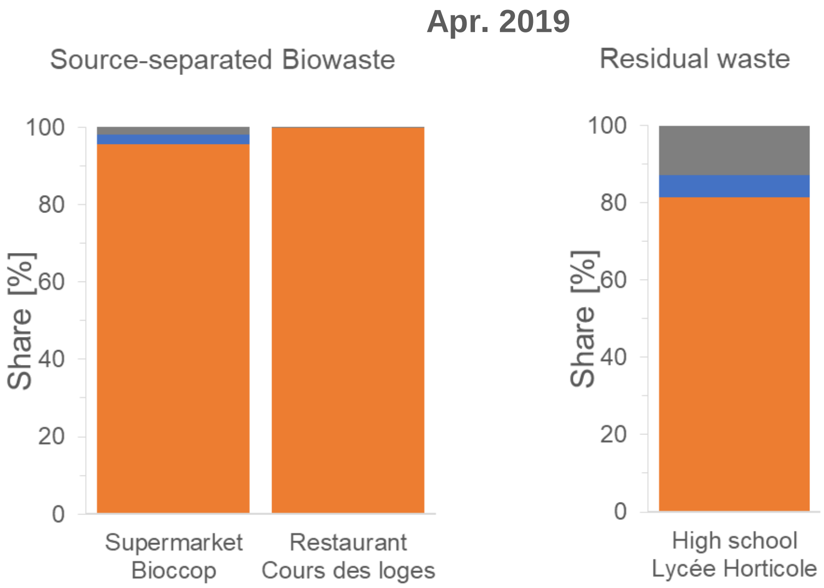


Figure 28: Actual collection and estimated maximum quantities of FW for the Lyon urban farm case

The potential FW quantities of the providers for which it was possible to calculate an estimate, add up to about 40.8 (± 22.7) Mg a^{-1}, indicating that under regular conditions, about 80% of the maximum capacity of the mAD plant could be reached with these five waste providers. However, the weekly deviations are high. With the inclusion of the restaurants, it is assumed that enough FW is collected to reach full capacity.

3.1.2 Waste characterisation

In the first characterisation event, only the BW of the supermarket *Biocoop* and the hotel restaurant *Cour des loges* and the RW from the high school *Lycée horticole* were characterised. In the second, the BW of the supermarket was no longer characterised due to its high quality. Instead, the BW and RW from the high school *Lycée horticole* and the hotel restaurants *Cour des loges* and *Villa Florentine* were characterised. In June 2021, a third characterisation campaign was conducted for the BW and RW from the high school *Lycée horticole* and the BW from the supermarket *Biocoop* and the restaurant *Cours des loges*.
The composition of the waste found in each stream is shown in Figure 29. In each site and characterisation event, FW was the most abundant, followed by paper, which was only substantial in RW. GW quantities are negligible. The waste characterisation showed a high quality of the source-separated BW with a share of non-biodegradable substances of less than 3% in all measured cases. Furthermore, the RW consisted mainly of biodegradable waste with a share of at least 76%.



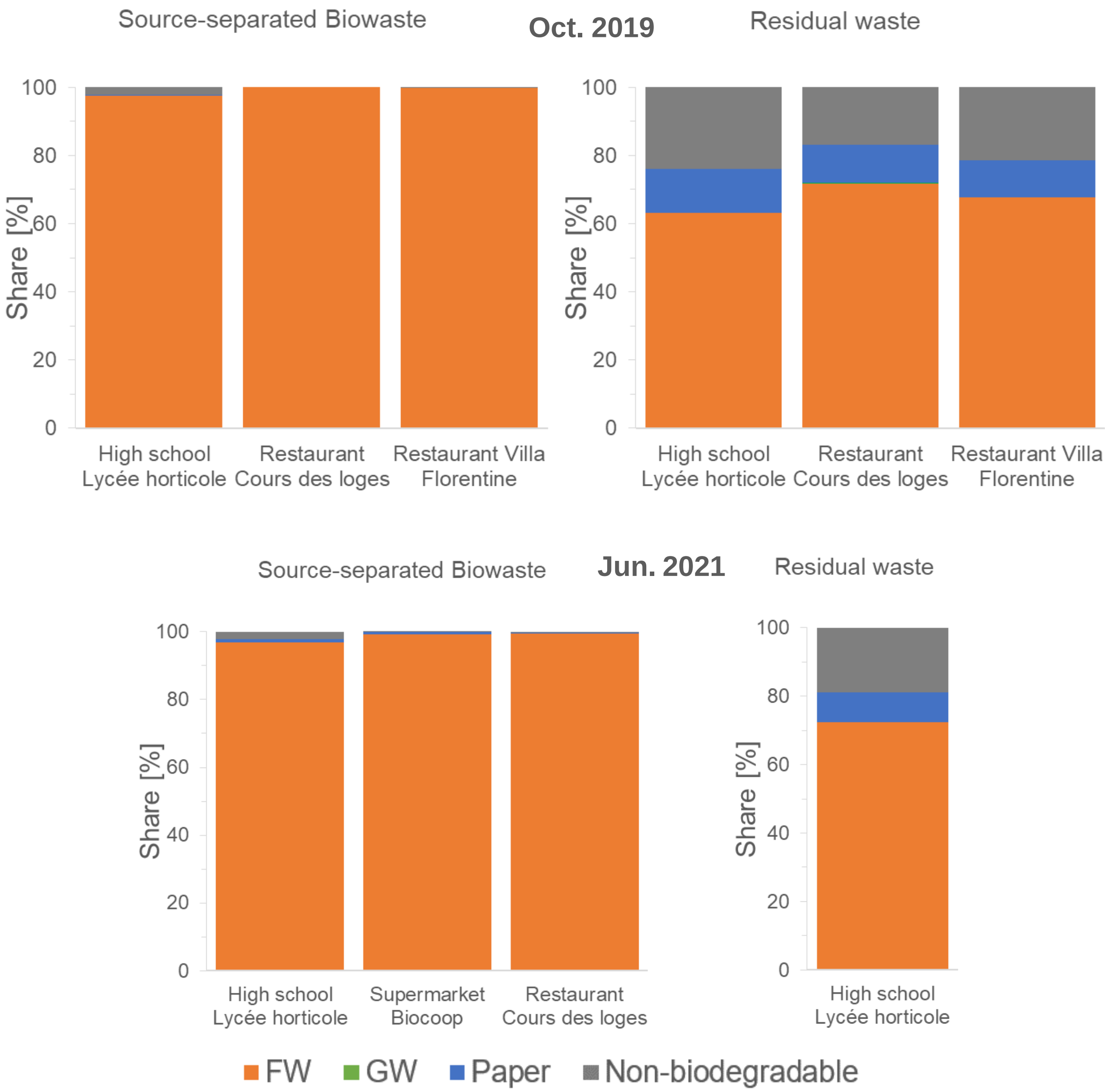


Figure 29: Waste composition of source-separated biowaste and residual waste in Lyon in April 2018, October 2019 and June 2021

For the providers with both, source-separated BW and RW characterised, the source separation efficiency of FW is shown in Figure 30. It shows a high efficiency for the high school, which separates more than 60% of its FW. However, the source-separation efficiency measured in the June 2021 campaign decreased to about 25%. Also the two restaurants still have a large potential for improvement, as only about 20% and 25%, are sorted correctly. In any case, these results can only serve as a general trend. They cannot be considered as generally representative. However, it must also be taken into account that hotel restaurant *Villa Florentine* no longer supplies the mAD with FW. For the other current waste providers listed in Table 8, it is not possible to estimate their separation efficiency, either due to a lack of waste characterisation or the fact that only source-separated BW, but not RW, was characterised.

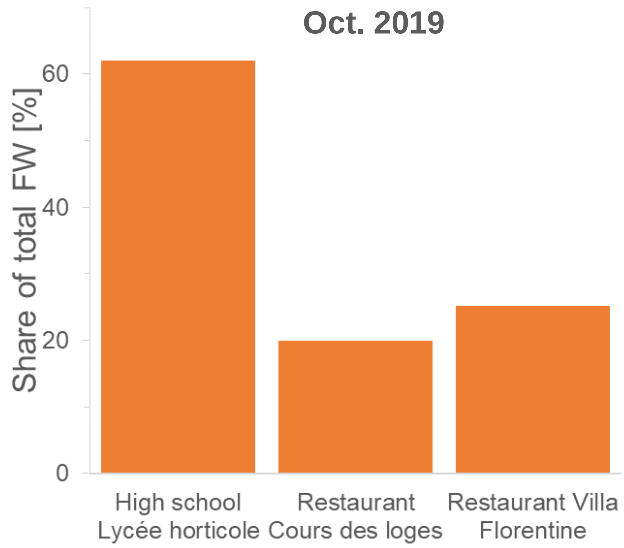


Figure 30: Food waste source-separation efficiency for some waste providers at the Lyon urban farm case

Linking the potential collection quantities shown in Figure 28 with the waste composition analyses shown in Figure 29, a more precise estimate of the actually collectable FW quantities can be made. Since the quality is high and the share of putrescible material other than FW is low, the quantities estimated in Figure 28 can be transferred almost 1:1 to the potential of FW. With a contamination level of 3%, approx. 51.5 Mg a^{-1} of source-separated BW would have to be collected by all selected providers to achieve the maximum annual mAD treatment capacity of 50 Mg a^{-1} of pure FW. However, it must be considered that the sites may have a longer summer break, especially the high school and restaurants for which an adequate substitute must be found for the period of break.

3.1.3 Food waste collection

The FW collection of the Lyon demonstration site has potential for improvements. Waste from various generators is still delivered by different means, being different collection routes and vehicles. This leads to a fragmented and heterogeneous setting, which adds high complexity to a potential collection system assessment. Furthermore, information on the parameters of the original collection system of source-separated FW, where existing, is missing. The collection frequency for the various waste generators varies between daily and weekly. An ideal collection circuit, connecting all waste generators, has a length of around 25 km. It was calculated by connecting all waste providers and the mAD site with the shortest circular route.

3.2 Dolina town

3.2.1 Waste quantities

Figure 31 shows the quantities of BW, RW and GW collected in Dolina from 2015 until 2020. In average for 2019 and 2020, 361 Mg a^{-1}, 63 kg inh.$^{-1}$ a^{-1}, of BW was collected in Dolina town. Thereof, 266 Mg a^{-1}, 47 kg inh^{-1}. a^{-1}, was collected DtD as source-separated BW, which mainly targets FW. This is the target BW to be treated in the mAD, while the remaining part is GW delivered to the recycling centre by citizens.

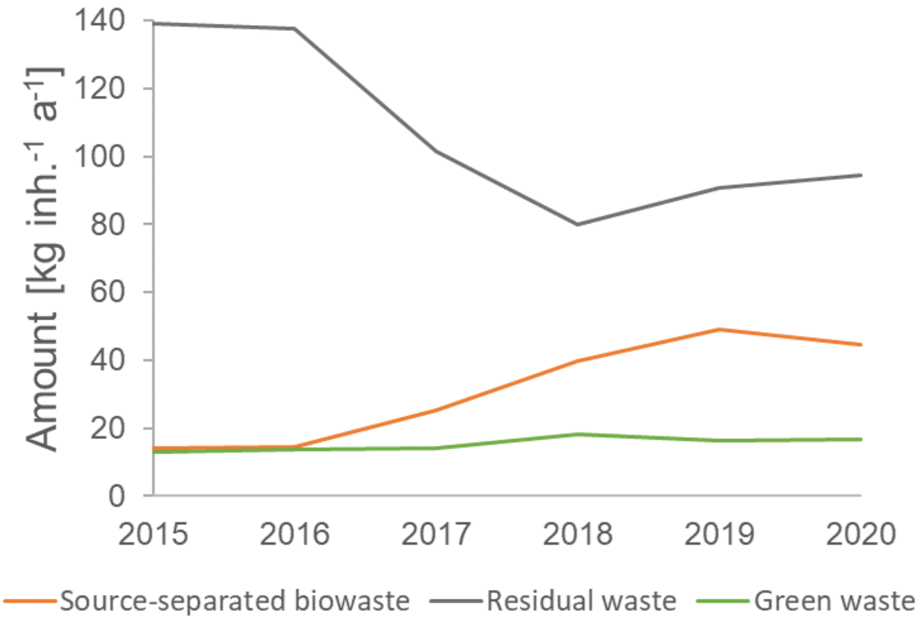


Figure 31: Quantities of source-separated biowaste, green waste and residual waste in Dolina

Figure 31 highlights the strong changes in BW separation behaviour from 2017 onwards since A&T2000 took over waste management in Dolina. RW quantities decreased to 529 Mg a^{-1}, 93 kg inh.$^{-1}$ a^{-1} on average in 2019 and 2020, while source-separated BW increased steadily except in 2020. The decrease in BW and the simultaneous increase in RW is a result of COVID-19 waste collection restrictions. One of the regulatory measures to reduce the spread of COVID-19, implemented by the Italian Ministry of Health, required that people who tested positive for the virus should not sort their waste and dispose of all waste as RW.
In general, these quantities refer to households and commercial activities in the town. A separate estimation of waste quantities was not planned.

Not all source-separated BW collected can be treated in the mAD as its capacity is limited to 200 Mg a^{-1}. The general goal is to treat all BW in Dolina to drastically reduce transport costs. Therefore, A&T2000 plans an additional aerobic treatment in a community composting unit. The legal regulations in Italy allow this possibility if the waste providers are residents or commercial activities of the town.

3.2.2 Waste characterisation

The waste characterisation data provides insight into the composition of the collected BW and RW. In 2018, Dolina's source-separated BW and RW were characterised in terms of composition outside the DECISIVE project. Figure 32 shows that in 2018 85.6% of the BW consisted of FW and 2.8% of GW, while 10% were impurities. The majority of the impurities, 8.3%, consisted of plastic bags and films, most of which were assumed to be biodegradable bags, leaving a further 1.7% of impurities. Biodegradable bags comply with

the FW collection requirements of A&T2000, who encourage collection with these bags. It was found that the share of FW in RW was only 3.9% and GW 6.1%.
The DECISIVE characterisation campaign in May 2021 distinguished between household and commercial waste. Since quantities were not estimated separately, the total waste composition is shown as an unweighted average. However, this allows for a comparison with the 2018 characterisation. Notably, the proportions of FW in source-separated BW are similar, at 87.7% in households and 88.1% in commercial activities. While the waste of commercial activities does not contain GW, its share in households is 3.7%. The main difference is paper, which accounts for 1.8% in household BW and 8.1% in commercial activities BW. The share of biodegradable bags is almost twice as high in households (6.3%) as in commercial activities (3.2%). One reason for this could be the use of larger bags in the commercial sector and thus a higher BW to bag ratio. Non-biodegradable impurities are low in both BW origins, amounting to 0.6% in households and 0.7% in commercial activities. This indicates a decrease in contamination of about 1% from 2018 to 2021.

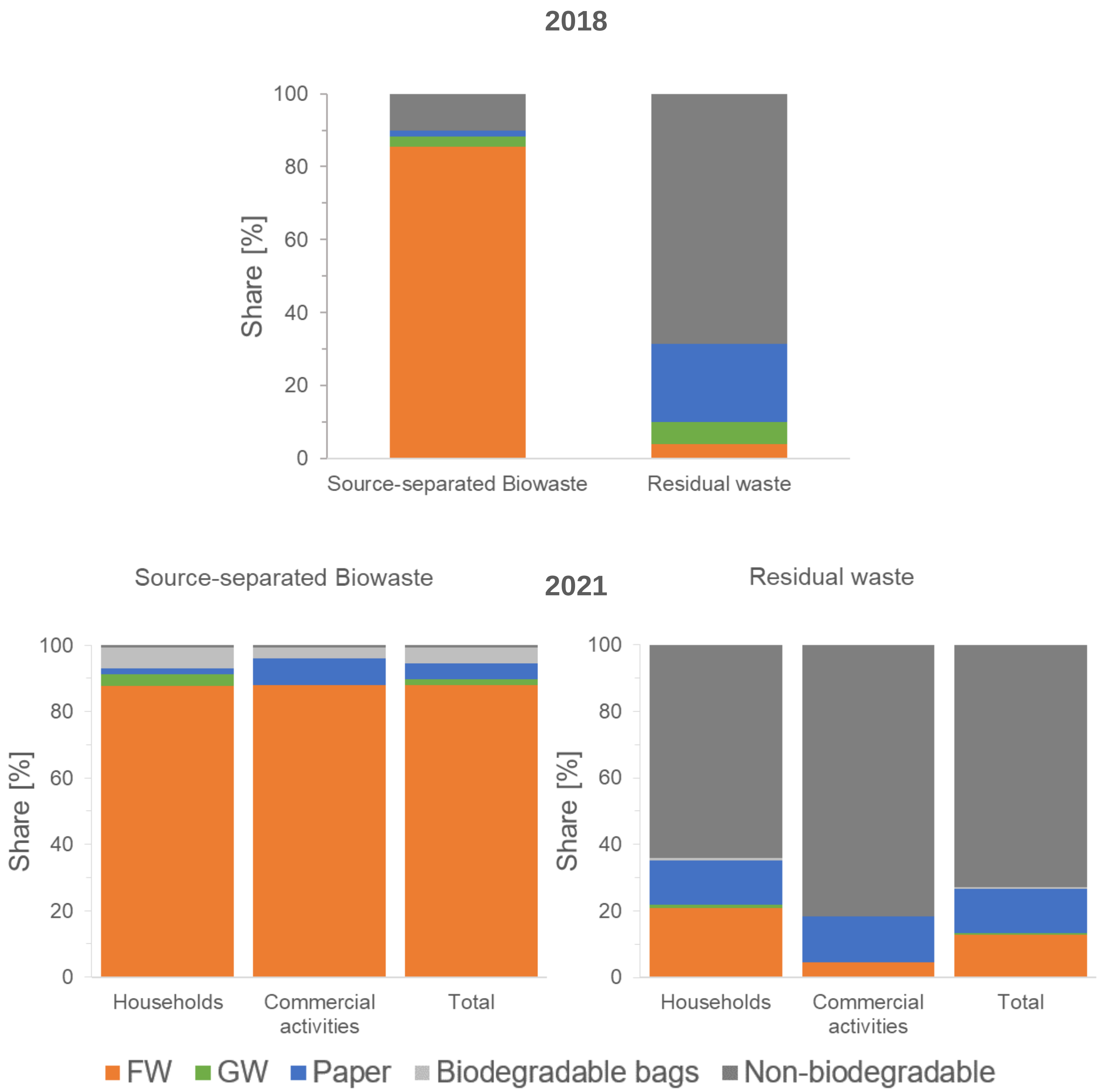


Figure 32: Waste composition of source-separated biowaste and residual waste in Dolina 2018 and 2021

In 2021, the RW of households comprises 20.8% FW and that of commercial activities only 4.7%. The shares of GW are negligible as they only account for 1% in the RW of households and are not present in the RW of commercial activities.

In 2018, 91.6% of FW was correctly sorted, indicating a very high separation efficiency. Combining the average data of 2019 and 2020 with the results of the waste characterisation of May 2021, only 77.7% were sorted correctly.
As indicated in chapter 2.2.4, the quantities to be characterised within the 2021 campaign were reduced due to COVID-19 restrictions. They amounted to about 100 kg for each waste stream. This fact needs to be taken into account when discussing the representativeness of the sample size, as it was also below 250 kg per waste stream, which is recommended by the waste characterisation protocols used for the DECISIVE characterisation events (Wavrer et al. 2010; Intecus GmbH 2015; ARC 2018).
As shown in Table 9, this becomes evident when comparing the total potential FW and biodegradables generated in 2018 and 2019/2020.

Table 9: Potential annual food waste and biodegradables amounts

	Source-separated		**Total generated**	
Year	FW **[Mg a^{-1}]**	Biodegradables* **[Mg a^{-1}]**	FW **[Mg a^{-1}]**	Biodegradables* **[Mg a^{-1}]**
2018	197	207	215	253
2019/2020	234	252	352	444

*Biodegradables include: FW, GW and paper only from source-separated BW

An increase in total FW quantities of about 75% can be questioned, while the quantities of source-separated FW and biodegradables are still in a narrower range. In terms of FW, the increase in source-separated FW would be from 34.1 kg $inh.^{-1}$ a^{-1} to 41.0 kg $inh.^{-1}$ a^{-1}, which could be a justifiable increase from a global COVID-19 pandemic perspective. Furthermore, the inaccuracy in waste characterisation due to the low quantities analysed can have an impact on differences in waste quantities.
The share of avoidable FW was only measured in the 2021 campaign and only for source-separated BW. For households, it was 16.8% and for commercial activities 4.3%. Considering the low shares of FW in RW, and the low share of avoidable FW, a very good FW separation and avoidance performance for Dolina can be indicated.

3.2.3 Food waste collection

As indicated in chapter 2.1.2, it is not intended to change the existing collection system in the Dolina demonstration site. The major change applied is that FW is no longer transported to Codroipo for treatment but to the mAD site. Quantities that cannot be treated in the mAD plant, will be treated in a community composting unit next to the mAD site. This allows for a reduction of the collection distance by 95 km one-way distance. The collection circuit within *Dolina town* is between 20 and 25 km. This circuit will only have a minor change as the waste will be delivered to the mAD location instead of the waste recycling centre as indicated in Figure 11.

3.3 Barcelona UAB campus

FW is generally collected separately in the restaurants' kitchens in plastic bags with 80 L capacity. For the estimation of quantities, several bags of different weights were collected in each restaurant. The characterisation of FW and RW was carried out at their original treatment site, Ecoparc 2 in Montcada i Reixac.

3.3.1 Waste quantities

Table 10 shows the collected and characterised quantities of the various waste generators for both characterisation campaigns. Only the waste from the restaurants represented quantities of daily generation. The amounts collected from the UAB student village and municipality of Cerdanyola del Vallès represented the quantity collected during regular collection frequency, which is three times per week for BW and daily for RW.

Table 10: Amounts of collected and characterised waste during the characterisation campaigns

Waste generator		Campaigns			
	Waste stream	2018 [kg]		2019 [kg]	
		Collected	Characterised	Collected	Characterised
Restaurants	BW	200	117.7	200	179.4
Restaurants	RW	100	42.8	55	54.6
Student village + Hotel	BW	60	55.9	137	137.2
Student village + Hotel	RW	940	244.5	1,650	253.3
Cerdanyola + general campus	BW	252	251.6	5,554	505.5
Cerdanyola + general campus	RW	6,620	250.7	11,940	417.03

A DECISIVE specific waste quantification for a longer period was done for source-separated BW from the UAB restaurants[1]. It was monitored in a time frame of one week in May 2018 and October 2019. In both periods, Clece restaurant was the restaurant that generated the most waste. This restaurant also produces food for other restaurants on campus. The total amounts are lower in 2019 than in 2018, but the sampling period in 2019 coincided with a strike that completely shut down activities at the university on Friday. The amount of source-separated BW sampled in 2018 was 117.3 (± 17.5) kg d^{-1} at Clece Restaurant, 45.6 (± 8.2) kg d^{-1} at Aramark and 54.7 (± 11.5) kg d^{-1} at Soteras. In 2019, the amount of source-separated BW was 94.2 (± 14.2) kg d^{-1} at Clece Restaurant, 37.6 (± 9.0) kg d^{-1} at Aramark and 50.5 (± 7.3) kg d^{-1} at Soteras. Figure 33 summarises the BW collected in both periods and indicates the quantities collected per day.

[1] The quantities of the full Cerdanyola del Vallès collection circuit is frequently updated on ARC's monitoring platform.

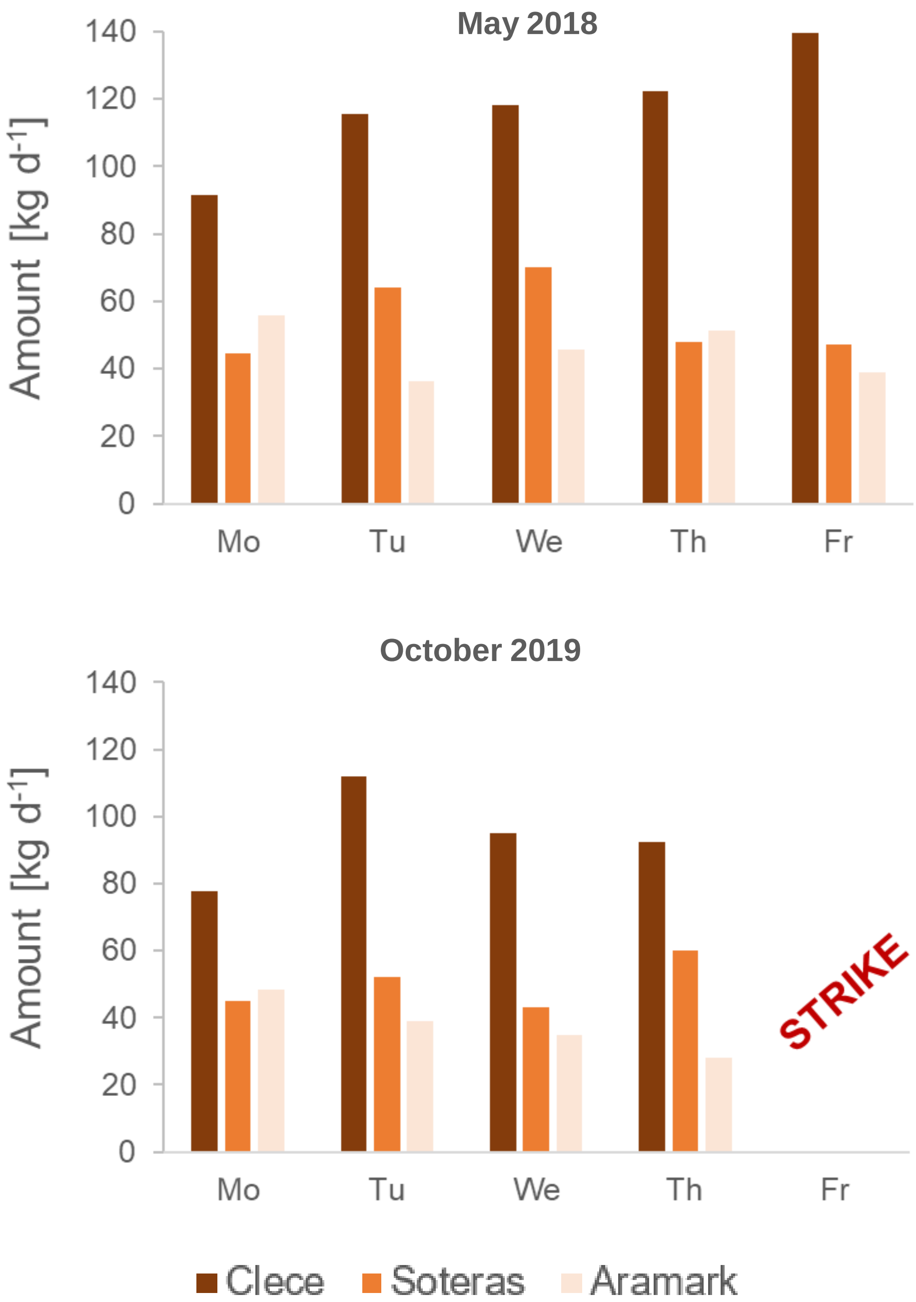


Figure 33: Source-separated food waste at each restaurant in 2018 and 2019

In addition to the total BW quantities, the number of bags and their weight, as well as the total amount of BW generated were examined (Table 11). The number of bags was higher in the Clece restaurant, where the most waste is generated, while Soteras and Aramark have rather similar values. The heaviest bags were also found in Clece, where 25% of them weighed more than 13 kg, the heaviest around 30 kg. In Aramark and Soteras 25% of the bags weighted more than 9 kg and 6 kg respectively. These values indicate that in Clece, the bags tend to be filled with more waste than in the other restaurants. 38% of the bags were over 10 kg. This can pose a labour risk to staff who have to lift and carry them. For the estimation of the annual amount of source-separated BW, an operating time of 30 weeks is assumed for all restaurants.

Table 11: Quantity of collected food waste from UAB restaurants in 2018 and 2019

Restaurant	Bags	Avg. bag weight	min. bag weight	max. bag weight	Daily generation	Specific generation	Weekly generation	Annual generation
Unit	Bags d^{-1}	kg bag^{-1}	kg bag^{-1}	kg bag^{-1}	kg d^{-1}	g $seat^{-1}$ d^{-1}	kg w^{-1}	Mg a^{-1}
Clece 2018	12.0±1.9	9.8±4.5	2.8	21.0	117.3±17.5	117.3±17.5	586.6	17.6
Clece 2019	9.5±2.4	10.0±6.2	0.4	30.0	94.2±14.2	94.2±14.2	472.3*	14.2
Aramark 2018	8.6±1.5	5.3±3.2	1.3	21.5	45.6±8.2	70.1±12.6	227.9	6.8
Aramark 2019	7.8±1.3	4.9±2.7	1.0	11.3	37.6±9.0	57.9±13.9	188.1*	5.6
Soteras 2018	7.0±1.7	7.8±3.2	1.7	15.3	54.7±11.5	136.7±28.8	273.4	8.2
Soteras 2019	7.0±0.8	7.2±2.3	2.8	13.3	50.5±7.3	126.3±18.3	252.6*	7.6
Total 2018	24.3±2.9	7.7±2.0	1.3	21.5	217.6±15.7	108.0±34.7	1087.8	32.6
Total 2019	27.6±3.0	7.5±4.8	0.4	30.0	182.7±12.6	92.9±32.4	913.4	27.4

No. of seats (capacity): Clece 1000, Aramark 650, Soteras 400, Total 2050
*Since only 4 days of BW generation were monitored in 2019, weekly generation was calculated by summing the generation of the 4 days and adding the average of these 4 days to get a proxy for Friday.

The restaurant that produces the largest amount of source-separated FW is Clece. It has the highest number of seats (1000) compared to Aramark (650 seats) and Soteras (400 seats). The amount of waste produced by Aramark and Soteras is lower than Clece but in a similar range, although Aramark's service capacity of 650 seats is higher than Soteras' 400 seats. The actual number of meals served in the observed period was not available, but the number of seats can be used to approximate generation per person. As Table 11 shows, FW generation per seat for both periods is lower at Aramark, between 57.9 - 70.1 g $seat^{-1}$ d^{-1} and higher at Soteras, between 126.3 - 136.7 g $seat^{-1}$ d^{-1}. The difference can be attributed to the discrepancy between available seats and actual meals served. Soteras and Clece are located in a building in contact with the faculties, while Aramark is located in a square in the middle of the campus. This could indicate that customers spend more time eating lunch at Aramark (about twice as much) than at Soteras and Clece. These figures for FW generation per seat are consistent with data from other similar studies (Lladó und Pujol 2013; Lopez et al. 2012). There is no pattern for the days with maximum or minimum generation among the restaurants.

Considering these values obtained during a representative week in two periods, it can be calculated that the three restaurants together produce about 1000 kg FW w^{-1}. The working period in the university throughout the year is assumed to be 210 days (30 weeks), which means that total FW generation of about 30 Mg a^{-1} can be expected. This value can provide guidance on the dimensioning of the equipment and facilities required to treat the generated FW.

3.3.2 Waste characterisation

Figure 34 shows the composition of source-separated BW and RW during the characterisation campaigns in 2018 and 2019. The organic fraction in the characterised BW is over 85% in the three areas considered (UAB restaurants, UAB student village plus hotel and Cerdanyola plus general UAB campus without restaurants). The highest share was found in the restaurants with a value of 96% in 2018 and 95.1% in 2019 in organic material.

In RW, biodegradable waste has a share of at least 44.6% in the three sites. It was particularly high in the waste collected together with the RW from the restaurants and from Cerdanyola del Vallés in 2019, where the shares exceed 55%. The results of the characterisation of the RW from the three origins confirm that substantial amounts of BW still end up in the RW. In summary, these results indicate that there is still work to be done to raise awareness among the population, but also among restaurant staff, to improve separate collection at source.

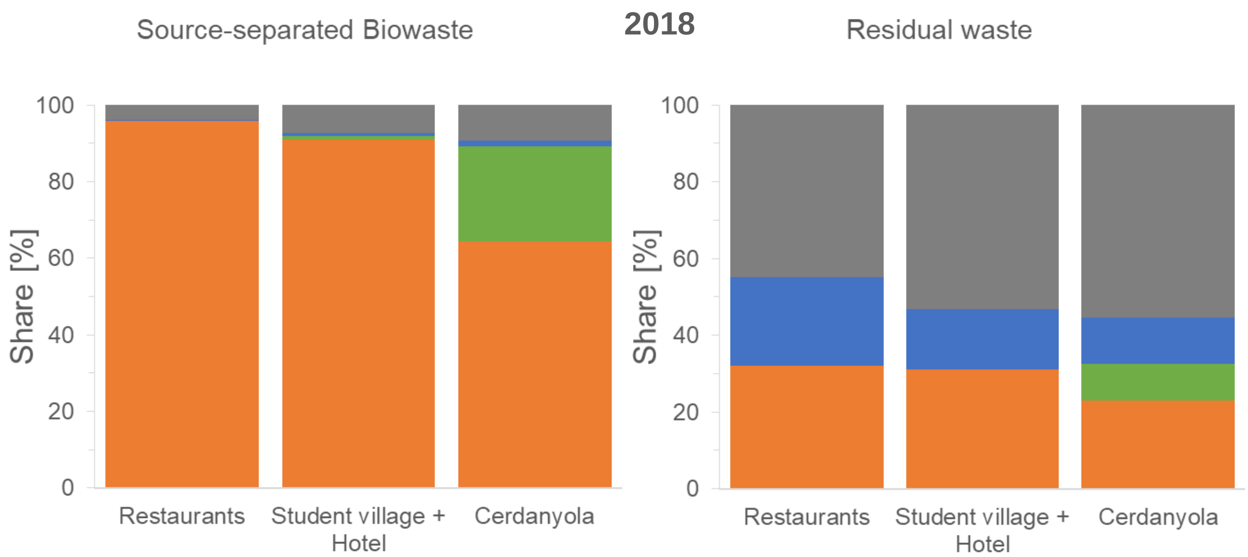
The biodegradable fraction of source-separated BW and RW is further differentiated into FW, GW and paper, as indicated in the protocol in Table 2. FW includes packaged and unpackaged as well as avoidable and unavoidable shares.

Comparing the 2018 and 2019 campaigns of the restaurants, the average FW share found in source-separated BW decreased from 95.9% to 90.4%, while average paper share increased from 0.1% to 4.7% (Figure 34). Furthermore, the average non-biodegradable waste share in source-separated BW increased slightly from 4.0% to 4.9%. The largest fraction of macro-impurities found in the source-separated BW is plastics, with the lowest share found in the restaurants and the highest in Cerdanyola.

FW found in RW slightly decreased from 32% to 31%. In the student village, the FW fraction in source-separated BW decreased from 90.9% to 80.8%, while the GW fraction increased from 1.1% to 10.4%. The non-biodegradable fraction also increased slightly from 7.2% to 7.6%. The FW found in the RW decreased from 31.1% to 30.4%.

In Cerdanyola del Vallès, the FW fraction in the source-separated BW increased from 64.3% to 81.6%, while the GW fraction decreased from 24.9% to 2.6%. Non-biodegradable substances increased from 9.3% to 13.5%. FW found in RW increased from 23.0% to 37.7%.

In all cases, paper accounted for a significant proportion of RW in 2018 and 2019, with the highest proportion of RW in restaurants at over 23.1%.



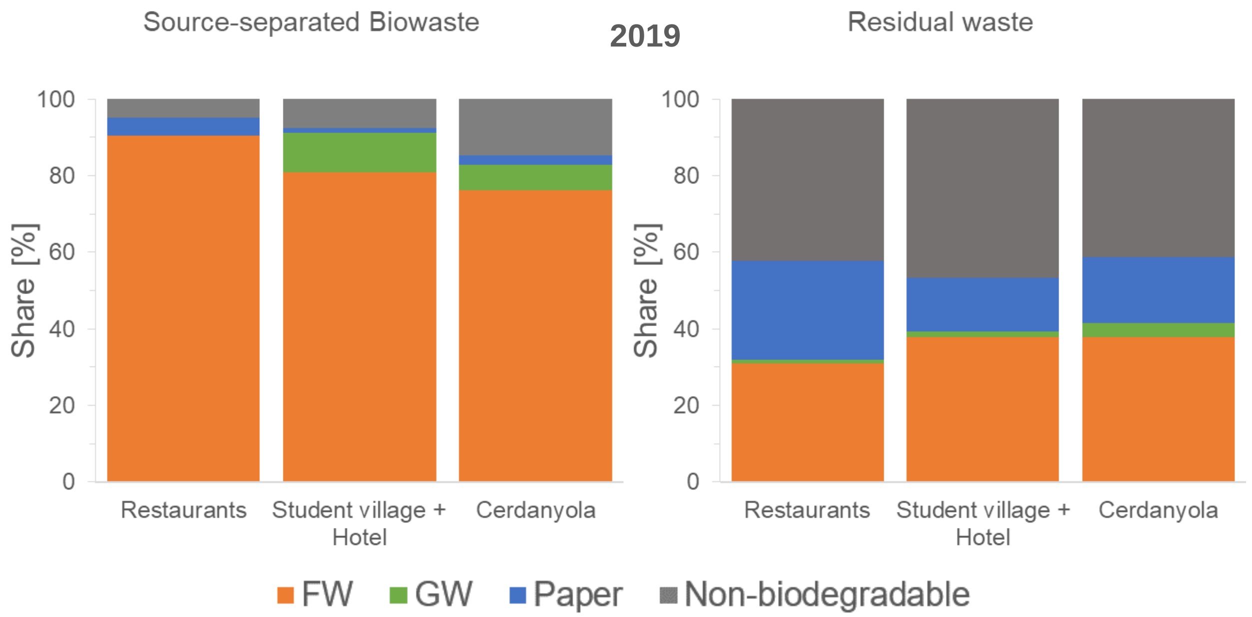


Figure 34: Waste fractions in source-separated biowaste (left) and residual waste (right) in 2018 and 2019

A rough estimate of the source-separation efficiency of FW was only made for the restaurants since these formed the core of the case study. Restaurants were the favoured FW providers for a potential mAD demonstration site. In 2018, the combined source-separation efficiency of the restaurants ranged from 85.7% to 89.3%. In 2019, it was 90.5%. The data indicates that FW source-separation efficiency is very good. Hence, the focus must be laid on communication activities to reduce impurities in source-separated FW.

The share of avoidable FW in the total FW of the different waste sources is shown in Table 12. In the source-separated BW, FW has the largest share, adding up to 96% (restaurants) and 91% (student village plus hotel). The source-separated BW of the Cerdanyola collection circuit contains a large share of GW, which reduces the share of FW to about 64%. The share of FW found in the RW bin is similar for that of the restaurants (32%) and the student village plus hotel (31%). The share of FW found in RW of the Cerdanyola circuit is lower (23%). However, as the total amount of waste found in the RW of the Cerdanyola circuit is assumed to be higher, it can also be assumed that the total amount of FW and GW found in the RW bin is higher than for the RW of the UAB restaurants and the student village plus hotel.

Table 12: Share of avoidable food waste of total food waste in the various waste origins

Waste generator	**Waste stream**	Avoidable FW [% of total FW]	
		2018	2019
Restaurants	BW	38.9	40.7
Restaurants	RW	29.2	35.8
Student village + Hotel	BW	51.7	27.9
Student village + Hotel	RW	28.0	34.5
Cerdanyola + general campus	BW	6.9	9.8
Cerdanyola + general campus	RW	14.6	10.5

A relevant share of FW found in the source-separated FW fraction in restaurants and student village plus hotel was classified as avoidable FW (Table 12). The high value of student village plus hotel may be due to the higher tendency of the residents to waste edible food compared to the restaurant, where the staff is more used to sorting and food managing similarly to the restaurants.
Comparatively, the share of avoidable FW in the separately collected stream of the Cerdanyola + general campus collection circuit is very low at only 6.9% and 9.8% and in the RW at 14.6% and 10.5%.
This highlights the need for actions on waste avoidance especially in the student village while the general Cerdanyola residents appear to have a good FW avoidance performance.

Overall, the changes between the two characterisation periods are not considered significant due to the short time span of the events. The reasons for the differences are assumed to be individual events rather than a general change of habits since waste streams can be very heterogeneous in their short-term qualities and quantities.
Nevertheless, the data shows a very good source-separation efficiency of FW in the UAB restaurants. There is still a potential for improvement to separate even more FW since 30% of RW comprises FW. The main issue remains the share of macro-impurities, which is seen at the upper limit for an implementation of a mAD plant with little mechanical pre-treatment. This is also true for a potential inclusion of the student village with even higher shares of impurities.

3.3.3 Food waste collection

This chapter describes the performance of the original FW collection of *Barcelona UAB campus* waste management. It is compared to a new FW collection scenario including the potential location for mAD treatment. The latter is called Space "R", the university's recycling centre
As described in section 2.1.3, the current collection of BW generated and source-separated on campus is carried out by the same company that collects waste in the nearby municipality of Cerdanyola del Vallès in a common collection circuit. Treatment is also carried out in the same facility in Ecoparc 2. If the UAB campus had become a demonstration site with a mAD plant, the campus would have been excluded from the regular BW collection cycle.
To evaluate alternative collection system options, the aspects considered were: i) the distance from generation to treatment, ii) the internal collection cycle on campus, iii) the responsible of the collection and treatment (current contractor or alternative), iv) collection equipment and maintenance such as cleaning.

Figure 35 shows the campus including a potential route for the collection of the restaurant's FW and Space "R" ("Deixalleria Campus"), the potential treatment site.
The distances between the restaurants and "Space R" are between 0.5 km and 2.8 km. The terrain is hilly with some considerable slopes. The collection route that includes the three restaurants has a total distance of 4.2 km (Figure 35) and includes slopes between 8% and 11%.

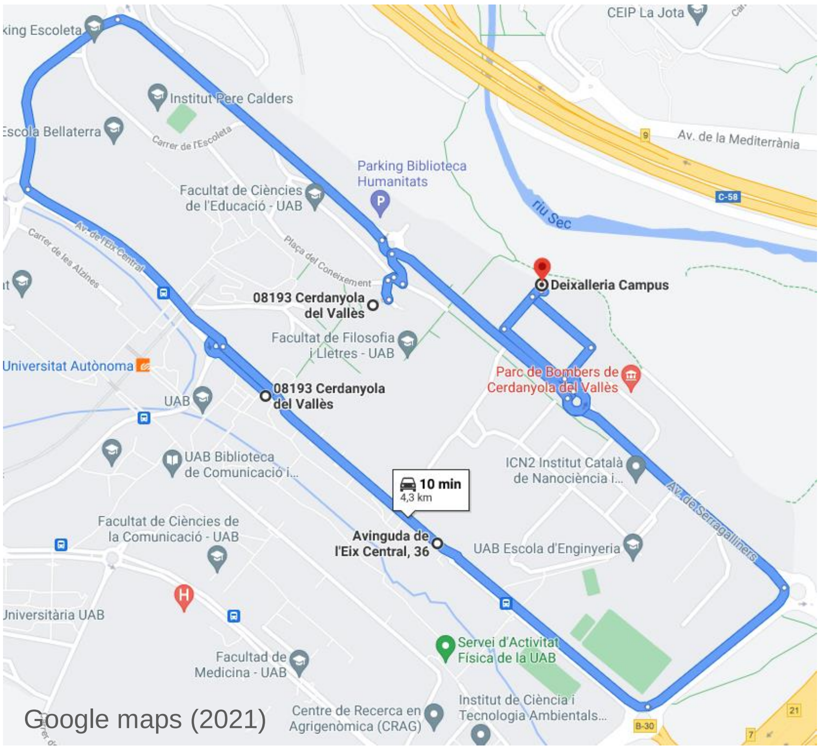


Figure 35: Scenario 2 for collection of food waste of the three main restaurants on the UAB campus

The main scenarios identified for the collection of FW are the following:

- Scenario 1: Collection of FW only from the restaurant closest to Space "R" (Filosofia Psicologia operated by the Soteras company). In this case, it was envisioned to use a small trolley or handcart for the transport of about 50 kg FW d^{-1} in one or two standard 120 L waste containers. The total collection circuit is about 800 m with only minor slopes and only on asphalted roads. Management could have been provided by UAB staff for both transport and feeding of the treatment unit.
- Scenario 2: Collection of FW generated in the three main restaurants (operated by Soteras, Clece and Aramark). For this case (Figure 35), an external company could be contracted to organise the collection and feed the mAD unit. A small truck would be needed for the collection. The entire collection circuit has a length of about 4.3 km. Lockable containers are needed to ensure the quality of the collected FW. Furthermore, it is considered inevitable to collect FW only in bags in the bin, due to hygienic reasons and reduce the cleaning effort for the bin.
- Scenario 3: Collection of FW from the student village and hotel in addition to the one from the restaurants (scenario 2). The organisation of the collection is similar to that envisioned in scenario 2. The total circuit would have a length of 5.8 km. However, this addition would require intensive training and communication efforts, also due to quality issues.

Table 13 presents a comparison of the collection-relevant parameters of the regular collection circuit and the previously introduced scenario 2, where the waste is collected from the three main restaurants. Scenario 2 was envisioned most realistic, since all restaurants could potentially provide sufficient waste for the planned mAD plant but also showed the best performance in terms of quality of feedstock.

Table 13: Performance of the collection system of biowaste in the *Barcelona UAB campus* case and scenario

Parameter	Unit	Before	Scenario 2	Note
Collection frequency	Days week^{-1}	3	5	Weekend neither generation nor collection
Loading capacity/vehicle	Mg vehicle^{-1} m^3 vehicle^{-1}	6 11-21	0.5 1	Bulk density assumed to be 0.5 kg^{-1}.
Total distance	km	>6.6	4.3	of collection circuit
Waste collected	Mg (collection circuit)$^{-1}$	0.6	0.2	Assumed average amounts of Table 11
Payload distance	Mg*km	39.6	2.15	-
Time for collection	min	90	20	Assumed 2x driving time in scenario 2
Size and number of bucket/bin at generator space (1st storage)	Volume (L) Space (m^2)	0 – 4*60 1	0 – 4*60 1	One restaurant currently has no storage bin
Size and number of bucket/bin at kerbside (2nd storage)	Volume (L) Space (m^2)	3*1300 4	6*240 3	-
Labour	Person*hours	2*1.5	1*0.33	For one collection
Private generator time for waste sorting	h Mg^{-1}	10	10	-

3.4 Lübeck neighbourhoods

As described in section 2.1.4 the test was divided into four phases, ex-ante, during, post 1 after six months and post 2 after 12 months. The ex-ante situation represents the situation without any specific treatment and can therefore be directly compared to the current overall situation in Lübeck. The results for Lübeck start with a general overview of the waste quantities in the entire city. It follows the description of waste quantities found in the different study phases in the investigated areas A and B. These quantities are furthermore compared to the average ones from 2015 until 2020 in the entire city of Lübeck. Afterwards, the waste composition in the different study phases as well as the separation performance is described.

3.4.1 Waste quantities

The trend of BW, RW and GW collected annually in Lübeck is shown in Figure 36. It shows that the amounts of source-separated BW are very stable, with an average of 71.2 ±1.6 kg inh.$^{-1}$ a^{-1}. Average RW amounts to 197.6 ± 3.3 kg inh.$^{-1}$ a^{-1}, but quantities were slightly decreasing, from 202.2 kg inh.$^{-1}$ a^{-1} in 2015 to 192.6 kg inh.$^{-1}$ a^{-1} in 2019. The slight increase to 199.2 kg inh.$^{-1}$ a^{-1} in 2020 might be caused by the COVID-19 pandemic. The amounts of GW, collected from gardens and parks in recycling centres, are mostly influenced by annual weather conditions. Furthermore, it has to be considered, that substantial amounts of GW are present in the BW bin due to the co-mingled collection system.GW ranges from 13.4 kg inh.$^{-1}$ a^{-1} in 2015 to 29.1 kg inh.$^{-1}$ a^{-1} in 2020 with an average of 19.1 ± 5.3 kg inh.$^{-1}$ a^{-1}.

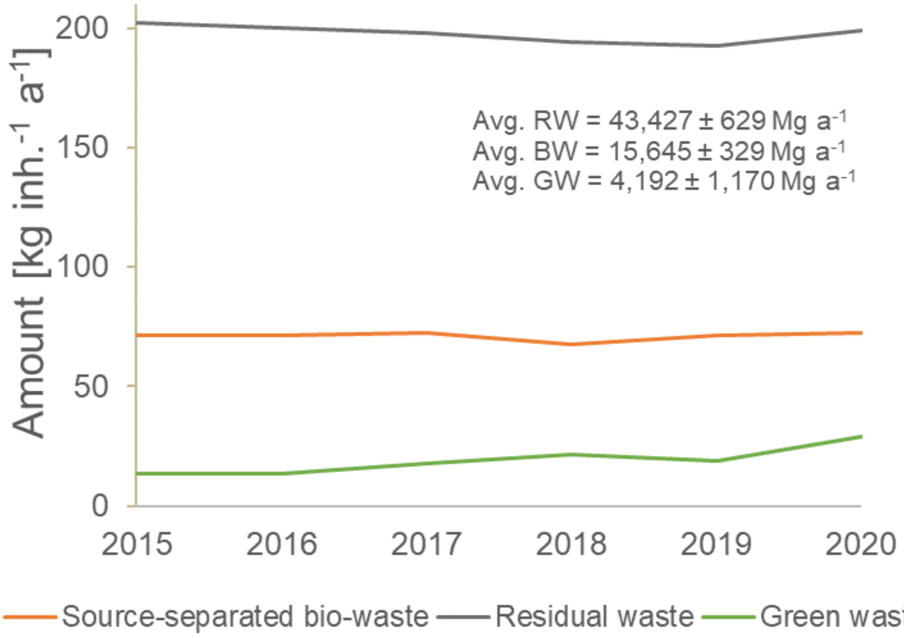


Figure 36: Quantities of source-separated biowaste, green waste and residual waste in Lübeck

Figure 37 shows the total average weekly quantities collected in all phases of the study in the selected areas in Lübeck. The ex-ante situation represents the average generation without specific activities undertaken to improve FW collection.
It can be seen that the total amount of waste collected in area B is more stable compared to area A but steadily increasing. However, this may also be due to seasonal changes in waste generation. In area A, a significantly higher RW quantity was observed especially after six months (post-phase 1). The reasons for this short-term increase was not identified but mainly related to non-biodegradable waste. On average for source-separated BW and RW together, 223.7 kg w^{-1} and 232.0 kg w^{-1} were generated in areas A and B, respectively.

The amounts of waste per inhabitant and week are shown in Figure 38. It can be observed that residents in area B generated less total waste compared to area A. On average, area A generated 3.8 kg $inh.^{-1}$ w^{-1} and area B generated 3.0 kg $inh.^{-1}$ w^{-1}. In terms of total weekly waste generation, area B was more stable in comparison to area A.

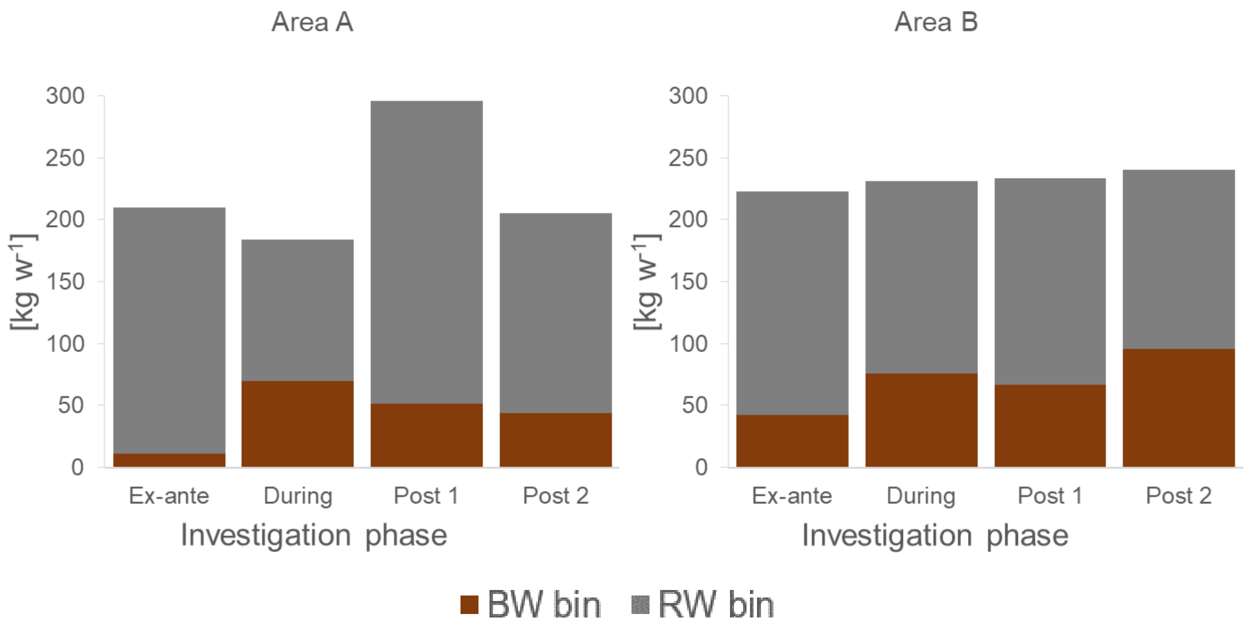


Figure 37: Average weekly quantities of collected source-separated biowaste and residual waste per investigation phase

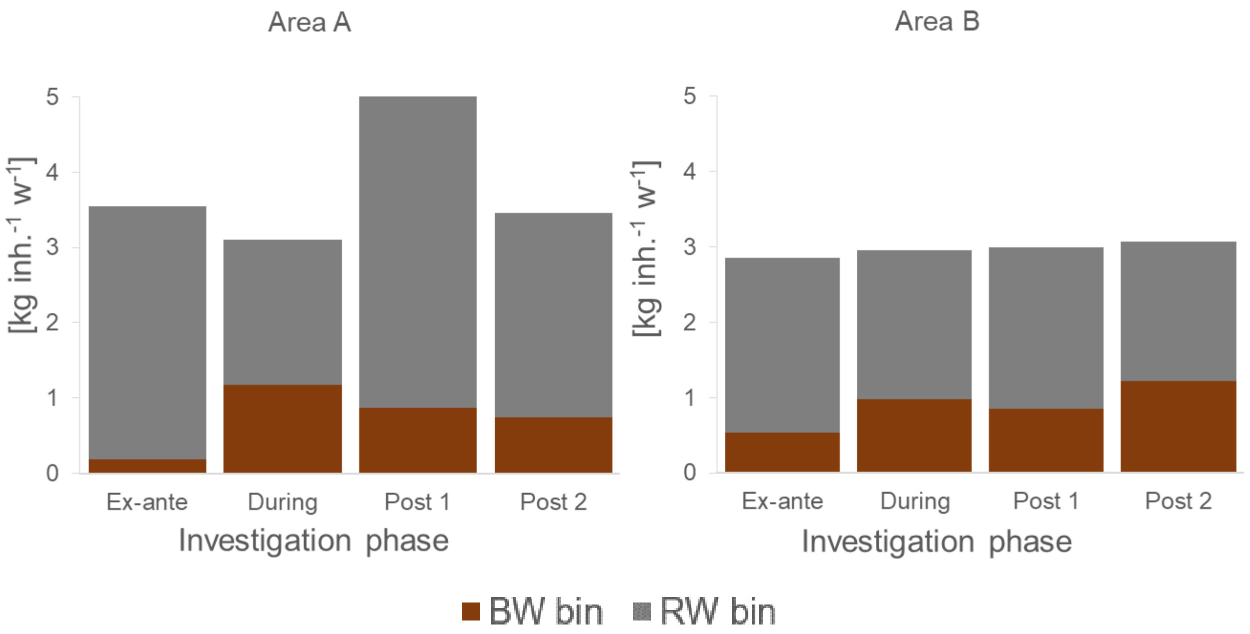


Figure 38: Average weekly quantities of collected source-separated biowaste and residual waste per inhabitant and investigation phase

The general Lübeck waste quantities and the data generated in the individual phases of the study were compared based on a weekly generation per inhabitant (Table 14).

Table 14: Comparison of general Lübeck and case study specific waste quantities (SD in parenthesis)

Study phase	Area	Source-separated biowaste [kg inh.$^{-1}$ w^{-1}]	Residual waste [kg inh.$^{-1}$ w^{-1}]	Total waste[2] [kg inh.$^{-1}$ w^{-1}]	Share of source-separated biowaste in total waste [%]
General Lübeck[a]	Entire city	1.37 (0.03)	3.79 (0.06)	5.16 (0.08)	26.48 (0.43)
Ex-ante phase (2018)	Area A	0.19 (0.05)	3.35 (0.60)	3.54 (0.55)	5.35 (2.37)
	Area B	0.54 (0.01)	2.31 (0.03)	2.85 (0.04)	18.91 (0.07)
During-phase (2018)	Area A	1.18 (0.16)	1.93 (0.18)	3.11 (0.17)	37.87 (4.54)
	Area B	0.97 (0.06)	1.98 (0.09)	2.96 (0.07)	32.88 (2.16)
Post-phase 1 (2019)	Area A	0.87 (0.08)	4.13 (0.56)	5.00 (0.48)	17.49 (3.29)
	Area B	0.85 (0.06)	2.13 (0.01)	2.99 (0.05)	28.58 (1.53)
Post-phase 2 (2019)	Area A	0.74 (0.20)	2.72 (0.02)	3.46 (0.17)	21.41 (4.60)
	Area B	1.22 (0.00)	1.84 (0.03)	3.07 (0.03)	39.87 (0.39)

[a]Average from 2015 -2020

Table 14 shows that the quantities of BW collected were lower than the general Lübeck quantities in all study phases. This can be argued with the type of areas studied. Both, area A and B comprise multi-family houses without gardens, which generates less GW than the Lübeck average. Furthermore, the amounts of RW were also lower except in post-phase 1 in area A. Total waste was lower than the Lübeck average in all study phases. The share of source-separated BW in the total waste was in average 26.5% in general Lübeck. In both studied areas, this share was below average in the ex-ante phase. Especially in area A, source-separation performance was very low. In both studied areas, the shares increased manifold in the during-phase due to the implemented collection system and communication activities. During the post-phases, the source-separation performance remained higher compared to the ex-ante phase in both areas with area B showing better performance. While area A exceeded the Lübeck average only in the during-phase, it remained above it in area B in all subsequent phases. Comparing both studied areas, area B shows lower deviations in total waste generation than area A.

3.4.2 Waste characterisation

BW and RW were characterised in each of the study phases. Figure 39 shows the composition of source-separated BW and RW based on FW, GW, waste paper and macro-impurities (BW), respectively others (RW). In the ex-ante phase before the test of the new collection system, source-separated BW amounts were either low (area A) or FW had only a small proportion in it (area B). In addition, impurities were high, 6.0% in area A and 13.6% in area B. However, if waste paper is not considered an impurity, area B only had 0.5% impurities. Wastepaper mainly comprised newspapers and paper bags, which are permitted for

[2] Total waste as the sum of source-separated BW (without GW delivered to recycling centres) and RW.

BW collection. During the test, FW was the fraction with by far the highest percentage of about 95% in both areas. Macro-impurities without paper decreased to 0.3% in area A and remained constant at 0.5% in area B. Simultaneously, there was a decrease of FW in RW in both areas. GW increased in RW due to the collection instructions to place large GW in the RW bin. These were considered problematic for a potential mAD operation. Even six and 12 months after the test, when the original BW bin system was reintroduced, FW remained the main fraction in source-separated BW. However, FW in RW further decreased in area A while it increased again in area B. This can partly be explained with different shares of GW and other waste and is therefore not only caused by a lower source-separation performance.

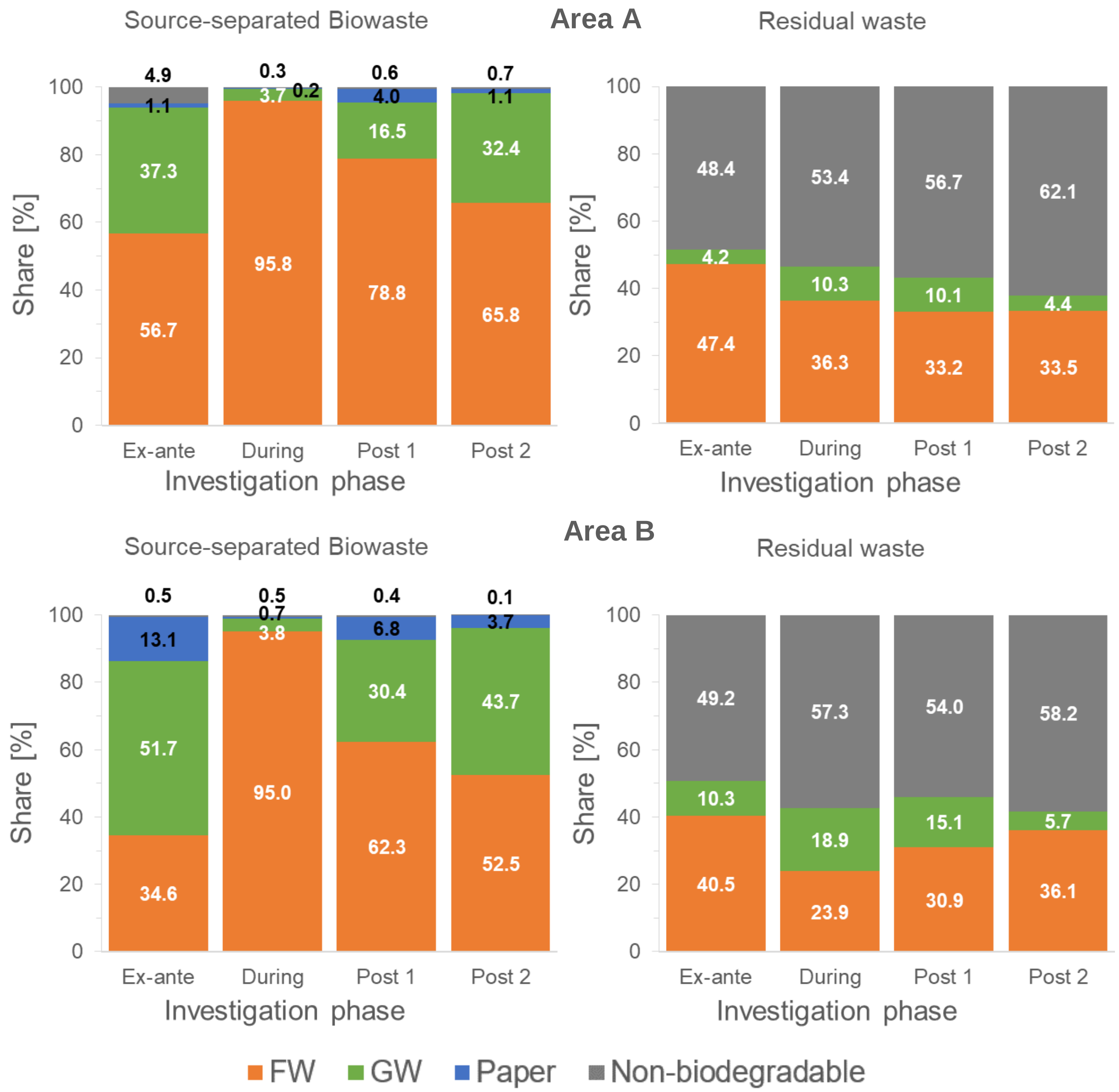


Figure 39: Waste composition of biowaste and residual waste of both areas in all investigation phases

With the results of the waste characterisation and the measured total quantities, it was possible to estimate the amounts of FW found in the respective bins, as shown in Figure 40. The higher quantities found source-separated BW in the during-phase of the test are directly related to the measures implemented. Fluctuations in total quantities in between all phases might have occurred due to rather short intervals of the phases and the rather small study sizes of 37 and 46 households. Due to the study size, specific individual behaviour of a few households might have a large impact on the overall results. As an example, they can be caused by the individual wasting behaviour, e.g. some prefer to dispose of their waste in shorter, some others in longer intervals. However, FW generation in area B is rather stable while the one in area B shows wider deviations. Another reason could be found in seasonal effects. Overall, area A generated more FW than area B. On average, area A generated 1.8 kg inh.$^{-1}$ w^{-1} and area B generates 1.3 kg inh.$^{-1}$ w^{-1}.

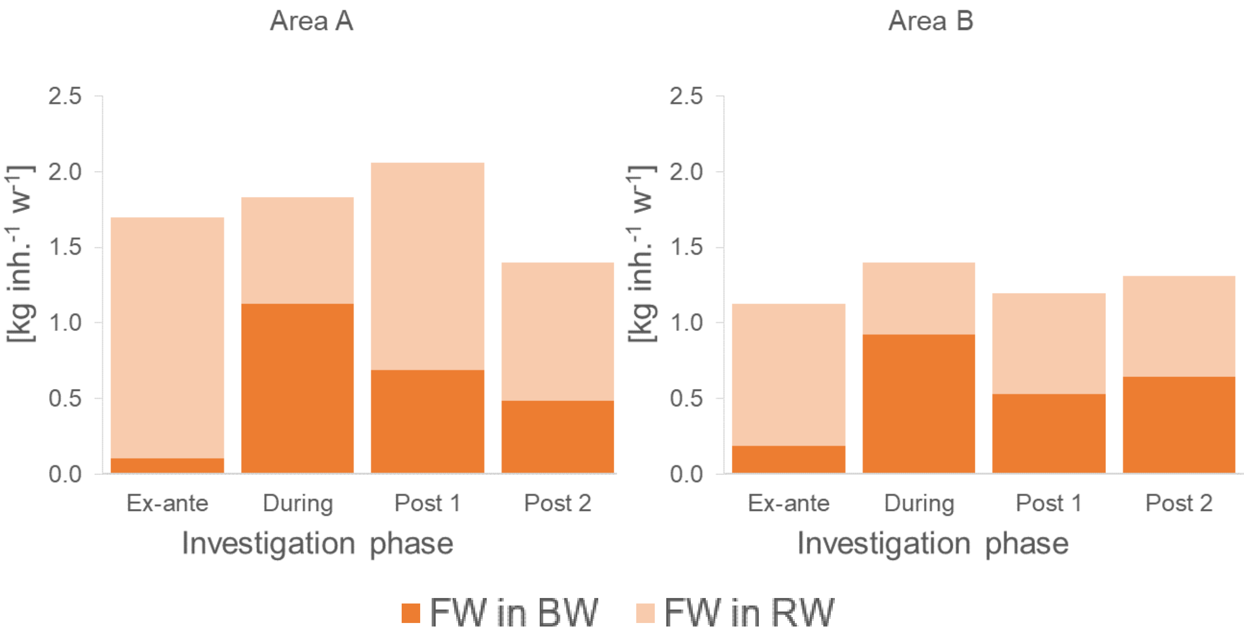
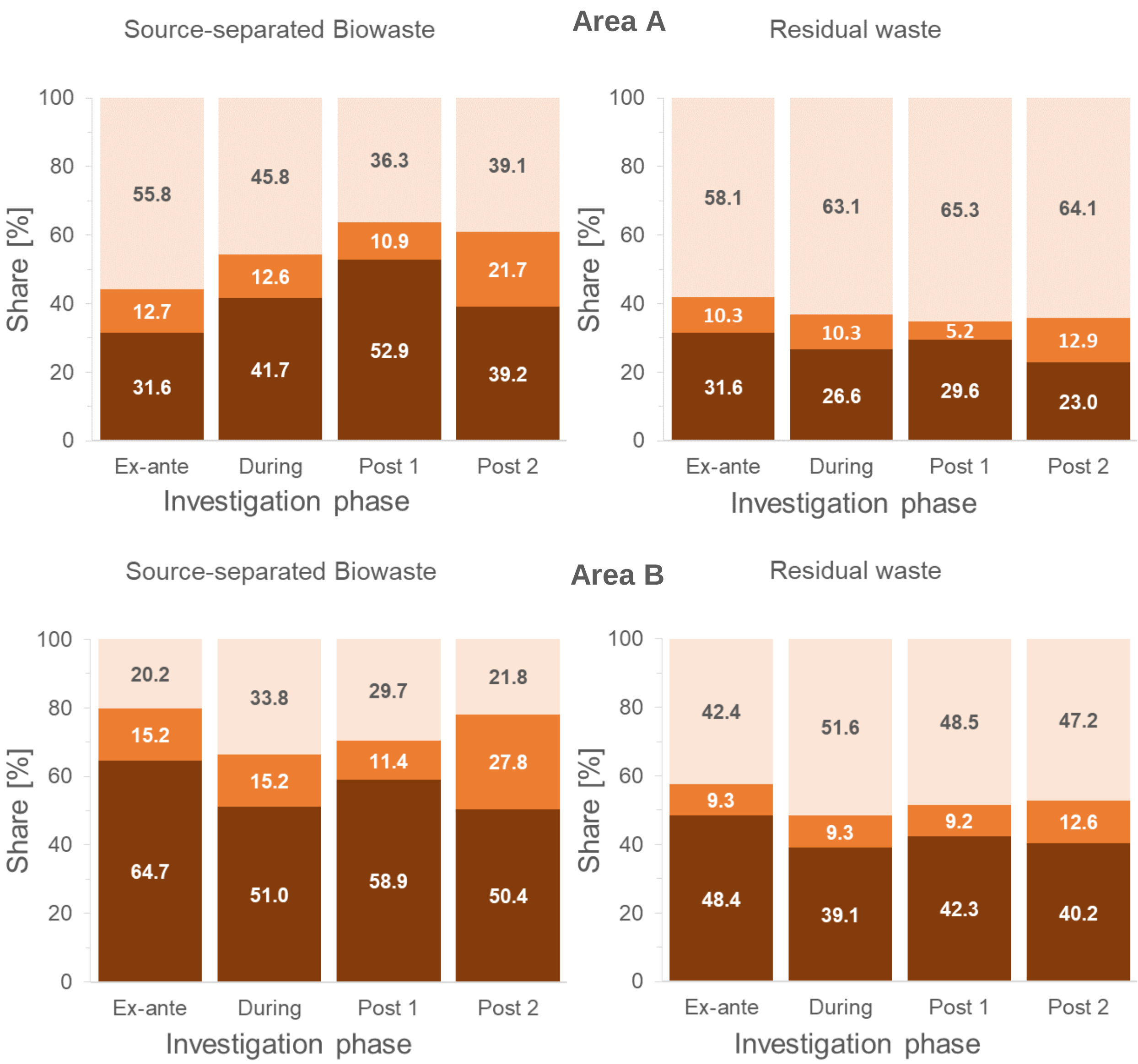


Figure 40: Average weekly quantities of collected food waste in the biowaste and residual waste bin per household and investigation phase

A more detailed characterisation of the total FW generated is shown in Figure 41 presenting the shares of avoidable, partly avoidable and unavoidable FW and the generated amounts as average of all study phases. While for both areas the unavoidable and partly avoidable FW are similar, especially the avoidable FW in the RW in area A is much higher than that in area B. This also explains the difference in the total FW generated. The section of Figure 41 showing the amounts as kg inh.$^{-1}$ w^{-1} give a clear view of the main cause for differences in FW between both studied areas. Both areas generate a similar amount of unavoidable FW, 0.6 kg inh.$^{-1}$ w^{-1} and partly avoidable FW, 0.2 kg inh.$^{-1}$ w^{-1}, but area A generates twice as much avoidable FW, 1.0 kg inh.$^{-1}$ w^{-1}, compared to area B. The higher amount of avoidable FW in area A might be explained by the difference in socio-economic status. Wasting more FW in the socio-economically low area (A) might be explained by more careless shopping habits and not by wealth.
Adding to that, unavoidable and partly avoidable FW is sorted better than avoidable FW. The latter also includes packaged FW that was only disposed of in the RW bin.


Area A
Source-separated Biowaste
Residual waste
Share [%]
100
80
60
40
20
0
55.8
12.7
31.6
45.8
12.6
41.7
36.3
10.9
52.9
39.1
21.7
39.2
58.1
10.3
31.6
63.1
10.3
26.6
65.3
5.2
29.6
64.1
12.9
23.0
Ex-ante
During
Post 1
Post 2
Investigation phase
Area B
Source-separated Biowaste
Residual waste
20.2
15.2
64.7
33.8
15.2
51.0
29.7
11.4
58.9
21.8
27.8
50.4
42.4
9.3
48.4
51.6
9.3
39.1
48.5
9.2
42.3
47.2
12.6
40.2

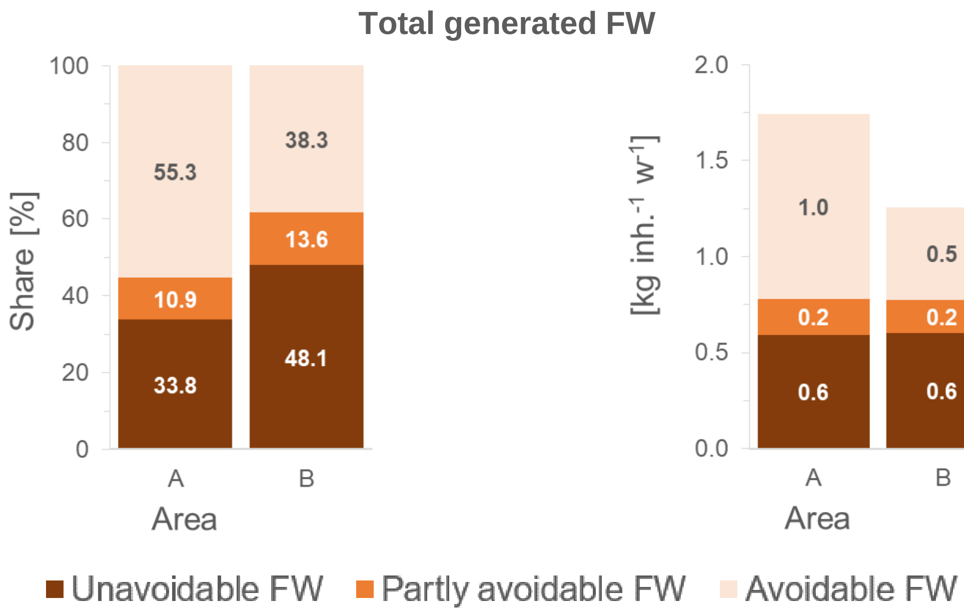


Figure 41: Composition of food waste in the respective waste stream in area A, area B and total generated

To illustrate the source-separation efficiency of the FW in relation to the different investigation phases, Figure 42 shows the share that was correctly sorted. In the ex-ante phase of the study, only 6.3% and 16.6% were sorted correctly in areas A and B, respectively.

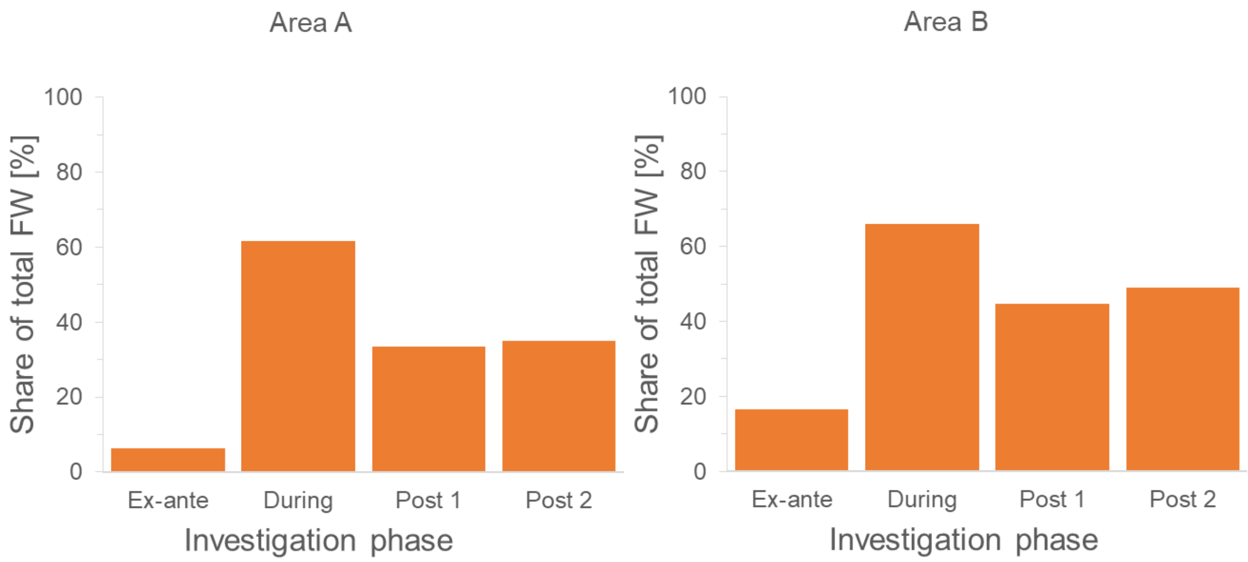


Figure 42: Food waste source-separation efficiency in all investigation phases

In the during-phase, FW source-separation efficiency increased to 61.7% and 66.1% in areas A and B, respectively. This also explains the decrease in FW in RW and underlines the success of the measures implemented regardless of socio-economic differences. The small differences in the during-phase are not significant. However, the source-separation efficiency decreased after the test but remained several times higher compared to the ex-ante situation. In the post-phase 2 after 12 months, it was 34.9% and 49.1% in areas A and B, respectively. However, this indicates that the effects of the communication measures and the provision of the collection buckets lasted better in area B than in area A. In addition, the drop in

performance is due to the less convenient regular collection system. The service of direct bucket collection three times per week including specific bucket storage and bucket cleaning was no longer provided.
From the results of the waste characterisation and further observations in the post phases 1 and 2, it was suspected that some people completely stopped sorting FW again, while others continued as in the during-phase. The results also suggest that continued incentives and action are needed, especially in areas where waste management is poorly addressed by residents.

3.4.3 Food waste collection

Two main scenarios for FW collection can be derived from the results of the tested system including its several measures described in section 2.1.4.2.

1. Provision of free sorting buckets which can be used for FW collection in the kitchen. However, as in the after-phases, the content of the buckets has to be disposed of in the regular BW bin. The regular collection system remains the same as currently practiced with common waste collection trucks and low collection frequency, i.e. fortnightly. Furthermore, the campaign is accompanied by an intense short-term communication activity, which is repeated with certain frequency, e.g. annually. This would potentially lead to the performance as observed in the after-phases when source-separation efficiency was better than in the ex-ante phase but lower than in the during-phase. Furthermore, impurity level might be low.
2. A full introduction of a separate collection system for FW and an additional system for GW collection in selected areas in Lübeck. This involves the provision of technical equipment such as FW collection buckets and storage facilities. Furthermore, the system comprises increased collection frequency and service. For GW, collection frequency will be demand-based. A specific storage facility for FW collection buckets could result in less demand for space than for the regular BW collection system as in the ex-ante phase. Also, a specifically developed collection for FW from storage to treatment will be in place. This system focusses on neighbourhood-based approaches with small collection vehicles. Overall, these measures would potentially lead to the source-separation efficiency and low macro-impurity content experienced in the during-phase. In the long-term, source-separation behaviour can even be increased by the implementation of frequent review measures as well as financial incentives. While the revision of waste quality can be used to apply specific awareness-raising measures in order to keep macro-impurity levels low, a fee system such as the PAYT-system can give financial incentives to residents to sort BW correctly, meaning FW in the FW collection bucket and GW in the GW bin and as little of both as possible in the RW bin. The financial system will be designed that residents save money by doing so.

The scenarios will be evaluated regarding their techno-economic potential in D7.8.

4. Discussion and outlook

All demonstration sites and case studies have shown different angles of FW collection. The collection system at each site has shown its advantages and disadvantages.

The *Lyon urban farm* demonstration site shows that even with existing proximity treatment, intense communication is the key to high-quality BW. Nevertheless, impurities are present, which is very time-consuming in manual sorting at the mAD unit. In addition, a substantial amount of BW is still present in the RW. In addition, the demonstration site showed that flexibility in terms of BW providers is important, especially during an exceptional event such as the COVID-19 pandemic with restaurants, schools, etc. closed for long periods. However, a stable group of providers is inevitable to reduce the workload in the waste-organisation. Further improvements need to be made in the waste collection as the current system is not yet as efficient as would be appropriate for small-scale local BW management. Furthermore, the surrounding households could be approached to provide their FW. However, involving the households increases the need for intensive communication. The first step could be a voluntary delivery of FW by the households themselves, e.g. in return for quality compost or fertiliser.

The demonstration site of *Dolina town* performs very well in terms of low impurities in source-separated BW with high shares of FW. Moreover, the FW separation efficiency is very high, exceeding 77% in both characterisation campaigns. However, the results of the specific DECISIVE characterisation campaign have to be considered with caution regarding their representativeness. It is suggested to implement a controlling system with frequent waste characterisations in order to identify specific issues.
In addition, the amount of generated FW and biodegradables is higher than the capacity of the implemented mAD plant. For this case, a community composting site is planned, in which residents can participate. For upcoming projects, it is recommended to plan the mAD plant in accordance with the expected FW quantities or in addition enrol a regional concept including the interaction of several mAD plants.

The *Barcelona UAB campus* showed good results for the three main restaurants in terms of quality of separately collected BW. Therefore, it would be an appropriate input material for a mAD plant. The inclusion of the campus hotel or even the student village would require further communication measures to improve the efficiency of BW sorting. Although, various reasons led to the abandonment of plans to implement alternative BW management on the campus (see D7.3), improved source-separation efficiency of FW is still useful for the current waste management. In terms of a collection scenario if a decentralised BW management is implemented at the campus in the future, the most viable scenario appears to be the collection of bagged BW by an external provider using small containers for transport. However, existing contractual obligations of the university may stand in the way of an improvement of the collection system and should therefore be thoroughly examined in advance to check the feasibility of the proposed changes.

The example of the *Lübeck neighbourhoods* case shows that household FW collection can be improved substantially with the right measures. Switching to the single-stream collection of FW instead of co-mingled collection with GW, provision of small collection buckets, high FW collection frequency, and intensive interaction with residents can bring about significant improvements in the short-term. However, long-term evaluation of the tested system, when the original system was being reintroduced showed a decline of collection performance in terms of source-separation rate. It indicates the need for frequent awareness raising activities by providing incentives for better sorting. The data does not show it clearly, but it can be assumed that some households have maintained their good performance, while others have returned to no separate collection of FW. Comparing the performance six and twelve months after the test suggests a stabilisation of sorting performance since results are very similar.

The improved option of system implementation would be a long-term enrolment. However, a cost-benefit analysis will be necessary to assess the expenditure incurred and the return in terms of high quality and quantity FW for further treatment. In addition, a separate collection system for GW will also need to be established, which was not explored in detail in the case study.

Appendix

Appendix 1: Waste characterisation protocol applied for the case study of Barcelona UAB campus

Fraction	Global fraction
Biowaste (except avoidable food waste and garden waste) easy biodegradable	
Biowaste (except food wastage and garden waste) difficult decomposition	
Biowaste garden waste (except food wastage and garden waste) difficult decomposition	
Avoidable food waste	
Garden waste (small sized non-woody plant waste)	
Garden waste (not bulky)	
Garden waste (bulky)	
Glass	Total impurities
Paper and cardboard	
Mixed plastics and film	
Plastic bags	
Ferric metals	
Non-ferric metals	
Textile	
Sanitary textiles	
Electronic waste and hazardous waste	
Bulky waste	
Other avoidable food wastage: packaged FW incl. packaging	
Other waste	

Appendix 2: Waste characterisation protocol applied in Lyon urban farm and Dolina town case

Categories	Subcategories
Avoidable foodwaste	Packaged foodwaste
	Unpackaged foodwaste
Non avoidable foodwaste	Organic part
	non organic part
Green waste (small sized non-woody plantwaste similar to FORM)	Green waste
Other putrescible waste	
Garden waste (woody waste)	
Other wood waste	
Glass	
Paper and cardboard	
Mixed Packaged	
Plastics bags (compostable)	
Plastics bags (non-compostable)	
Ferric metals	
Non ferric metals	
Textile	
Sanitary textiles	
Electronic waste	
Hazardous waste	
Other wastes	

Appendix 3: Waste characterisation protocol applied in Lübeck neighbourhoods case

Date: **Type of waste:** **Origin of waste:**

m tot. sample [kg]: **m prep. sample [kg]:**
m charact. sample [kg]:

Fractions	Sub-fraction	Example
Unavoidable Food waste	Plant-based	Inedible parts from food preparation or: shells, bones
	Animal-based	
Avoidable Food waste (unpackaged)	Plant-based	leftover food, unprepared food - unpacked
	Animal-based	
Avoidable Food waste (packaged)	Plant-based	leftover food, unprepared food - packed
	Animal-based	
Partly avoidale	Plant-based	Peels, leaves
	Animal-based	Meat mixed with fat/bones
Other organic kitchen waste	-	Kitchen tissues
Garden waste	-	Grass, Leaves, branches
Woody waste	-	Bigger branches
Other garden waste		e.g. Soil
Paper and cardboard	P&C	
	Paper bags	
Plastic	Plastic	
	Plastic bags	
	Biodeg. Plastic	
Glass	-	
Metals	-	Cans
Textiles	-	
Sanitary Textiles	-	Diapers, sponges, sanitary tissues
Bulky waste	Wood waste	
	others	
Electric waste	-	
Special waste (hazardous)	-	Drugs, chemicals, batteries
Other waste	-	Not identifiable or multi-fractions

Appendix 4: Protocol of chemical analysis for the waste samples of the case study of Barcelona UAB campus

For biodegradable waste found in source-separated FW and mixed RW, the organic –biodegradable- part was sent to a laboratory to be analysed for chemical and physico-chemical parameters, including heavy metals. Table 15 presents the parameters considered and the analysis methodology.

Table 15: Parameters analysed in the organic fraction separated from the biowaste and the residual waste and methodology

Parameter	Methodology
Dry matter	Indirect Gravimetry – 105ºC
pH	Potenciometry in the extract 1:5 H_2O
Electric conductivity	Conductimetry in the extract 1:5 H_2O – 25ºC
Organic matter	Gravimetry
Total nitrogen (tN)	Kjeldahl and volumetric titration
Organic nitrogen (oN)	Calculation (tN-aN)
Ammonium (aN)	Volumetric titration
C/N ratio	Calculation
Phosphorus (P)	ICP Spectrometry in acid extract
Potassium (K)	ICP Spectrometry in acid extract
Calcium (Ca)	ICP Spectrometry in acid extract
Magnesium (Mg)	ICP Spectrometry in acid extract
Iron (Fe)	ICP Spectrometry in acid extract
Cadmium (Cd)	ICP Spectrometry in acid extract
Copper (Cu)	ICP Spectrometry in acid extract
Chromium (Cr)	ICP Spectrometry in acid extract
Mercury (Hg)	ICP Spectrometry in acid extract
Nickel (Ni)	ICP Spectrometry in acid extract
Lead (Pb)	ICP Spectrometry in acid extract
Zinc (Zn)	ICP Spectrometry in acid extract
Sulphur (S)	ICP Spectrometry in acid extract

Appendix 5: Results of the chemical composition analysis of the samples of the *Barcelona UAB campus* case

The chamical characteristics of the BW, both from source-separated BW and RW collection is shown in the table below. The analysis corresponds to the BW after having removed manually the impurities of the sample, consequently, no plastics or metals are included in the analysis.

Comparison of quality can be done between origin (Restaurant or student village plus hotel) and between type of waste (BW or RW). No statistical analysis was conducted because only one sample was taken for each case. Also, these results indicate the composition of waste in that moment and do not pretend to be exhaustive of its quality.

The analysis indicates that samples are wet, particularly those from restaurants, and rich in organic matter and nitrogen, mainly BW. However, the content in nitrogen of sample from RW of student village plus hotel is significantly lower than the other materials. Considering the use of these materials for and AD treatment, the high values of nitrogen should be considered in order to avoid risks for microbiota

The separate collection of BW produces a material particularly rich in nitrogen, while other properties are not so different. This does not mean that quality of biodegradable fraction is the same both in separate collection than RW; far from this, the content in impurities that comes along with the biodegradable material in the RW would difficult the biological process, and pollute both raw materials and, consequently, the final product. Furthermore, the low quantity of biodegradable material in RW makes it unsuitable for biological treatment to produce a quality product. Finally, the contact of the biodegradable material with impurities in this case has been very short, which can reduce the migration of components from impurities to biodegradable fraction in acidic conditions that takes place in a regular collection of waste.

Parameter	Restaurant BW	Restaurant Residual	Student village + Hotel, BW	Student village + Hotel, RW
Dry matter (% wm)	18,90	14,04	22,9	34,7
pH	4,09	4,24	4,17	4,16
Electric conductivity (dS/m)	3,10	2,86	3,41	3,06
Organic matter (% dm)	89,20	85,2	86,6	90,7
Total nitrogen (% dm)	>10,00	4,22	7,26	0,75
Organic nitrogen (% dm)	9,65	3,24	6,25	0,51
Ammonium (% dm)	0,51	0,98	1,01	0,24
C/N ratio	4,62	13,60	6,92	89,10
Phosphorus (% dm)	0,57	0,68	0,39	0,29
Potassium (% dm)	1,22	1,83	1,23	0,73
Calcium (% dm)	0,62	0,87	0,60	0,44
Magnesium (% dm)	0,107	0,134	0,130	0,108
Iron (% dm)	<0,100	0,129	<0,100	<0,100
Cadmium (mg/kg dm)	<0,50	<0,50	<0,50	<0,50
Copper (mg/kg dm)	<20,0	<20,0	<20,0	<20,0
Chromium (mg/kg dm)	<10,0	<10,0	<10,0	<10,0
Mercury (mg/kg dm)	<0,40	<0,40	<0,40	<0,40
Nickel (mg/kg dm)	<5,0	<5,0	<5,0	5,0
Lead (mg/kg dm)	<5,0	5,0	<5,0	<5,0
Zinc (mg/kg dm)	42	61	39	38
Sulphur (% dm)	0,33	0,59	n.d.	n.d.

n.d.: not determined

Appendix 6: Log-file of the impact of the COVID-19 pandemics on the Lyon urban farm case

Initially planned to process a various mix of organic wastes from restaurants only, the Lyon urban farm demonstration site had to adapt due to two main reasons:

- Legal requirements
- COVID-19 pandemics

Indeed, in the first month of operation the demo received the official agreement to process vegetal waste only. The focus was therefore laid on vegetal preparation wastes and on-farm wastes.

We then received the agreement to process all range of BW including the animal-based ones and could accept various organic wastes from restaurants including all their preparation wastes and even the leftovers returning from plates.

Then the COVID crisis seriously affected restaurants and canteen as follow:

1st French total lockdown: From 17th of March till 10th of May 2020:

- All restaurants: closed
- Bocuse Institute restaurants: closed
- All school and their canteen: closed.
- Microbrewery: closed
- Organic Grocery Shop: open.
- Farm: closed for 2 weeks then slow and partial reopening of sales and waste production.
- ➔ **French Pilot operations stopped during 2 months.**

From 10th of May till 30th of June 2020:

- All restaurants: closed
- Bocuse Institute restaurants: closed
- Primary school reopened but not high school. Very limited canteen operation from May in June (2 weeks).
- Microbrewery: closed
- Organic grocery Shop: open
- Farm: open
- ➔ **Very limited operation level for 1 month and half.**

From 1st of July till 30th of August 2020:

- All restaurants: closed
- Bocuse Institute restaurants: closed
- Schools and canteen: closed
- Microbrewery: closed
- Organic Grocery Shop: open at limited level (fewer sales during summer)
- Farm: open at limited level (fewer sales during summer)
- ➔ **Not enough waste for a reasonable operation. Stops during 2 months.**

From 31st of August till 29th of October 2020:

- All restaurants: closed
- Bocuse Institute restaurants: closed
- Schools and their canteen: open
- Microbrewery: open at very limited level
- Organic Grocery Shop: open
- Farm: open
- ➔ **Limited operation of pilot for 2 months**

From 30rd of October 2020 till 20th of January 2021:

- All restaurants: closed
- Bocuse Institute restaurants: closed
- School and their canteen: open but at half level for high school with half student at school

- Microbrewery: open at very limited level
- Organic Grocery Shop: open
- Farm: open
- ➔ **Limited operation of pilot for 3 months.**

From 20th of January 2021:

- All restaurants: closed
- School and canteen: open
- Bocuse Institute canteen and restaurants: unknown
- Microbrewery: open at limited level
- Organic grocery shop: open
- Farm: open
- ➔ **Limited operation of pilot. Looking for more waste from other canteen.**

For the demonstration site at CFPH, different types of restaurants and caterings have been chosen in first time in order to provide BW but due to the delayed start-up and the COVID crisis changed over-time.

Waste generator	Type of generator	Previous state before Demo	Notes
Cour des Loges	Five-star hotel's restaurant	Only vegetal BW from preparation were collected for composting.	Initially planned. Closed during COVID Crisis.
Villa Florentine	Five-star hotel's restaurant	Only vegetal BW from preparation were collected for composting.	Initially planned. Closed during COVID Crisis.
Valpré	Congress center and hotel	No sorting	Initially planned "if necessary". Collection never started due to legal delay + COVID crisis
RIE	Companies shared canteen	No sorting, not even packaging.	Initially planned "if necessary". Collection never started due to legal delay + COVID crisis
Lycée Horticole Dardilly	High School canteen	BW collection by third party	Initially planned. Quantities and qualities have varied due to COVID
Institute Paul Bocuse	Culinary School	BW collection by third party	Collection never started due to legal delay + COVID crisis
Farm de l'Abbé Rozier	On-site organic vegetable farm	BW were composted on-site	Only vegetal wastes based on losses, trimming of vegetables and destruction of crop remains.
Biocoop	Organic grocery Shop	Vegetal BW were already collected for composting	No animal based organic wastes available as employees take away the losses instead of throwing it away.
Octopus	Restaurant	No sorting	Closed to COVID Crisis
Le Ballon	Restaurant	No sorting	Closed to COVID crisis
Beer Fabrique	Micro-Brewery	Only spend grains	

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Figures 6, 14, 20 and 26

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Figure 23

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