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Report on the simulation of the implementation of the methodology in different types of locations

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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

D6.4 - Report on the simulation of the implementation of the methodology in different types of locations

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ABSTRACT

This document reports on the results of the use of the planning methodology (the Decision Support Tool - DST) in different locations to verify its capacity and flexibility to compare the performance of urban biowaste management systems currently in place with theoretical implementation of decentralised solutions such as those proposed in the DECISIVE project. Results obtained from the tool are used to derive a set of considerations suggesting which "ideal" profiles could typically be better served by the DECISIVE technological package and that can be used in the future to choose appropriate locations where this alternative biowaste management system can be implemented successfully.

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Abbreviations and acronyms

ABP	Animal-by- Product
AD	Anaerobic Digestion
ARC	Agència de Residus de Catalunya
Bt	Bacillus thuringiensis
BW	Biowaste
CAPEX	Capital Expenses
CFPH	Centre de Formation et de Promotion Horticole
DECISIVE	**DEC**entral**I**sed management **S**cheme for **I**nnovative **V**alorisation of urban biowast**E**
DtD	Door to Door
DST	Decision Support Tool
EBL	Lübeck waste management
ENT	Fundació ENT
EWC	European Waste Code
GA	Grant Agreement
GHG	Greenhouse Gas Emissions
GL	Grand Lyon
GW	Green Waste
HORECA	Hotel/Restaurant/Café
IMMB	Institut Municipal de Mercats de Barcelona
mAD	micro-Anaerobic Digestion
MBT	Mechanical Biological Treatment
MSW	Municipal Solid Waste
OPEX	Operational Expenses
RDF	Residue Derived Fuel
RM	Rennes Métropole
RW	Residual Waste
SSBW	Source Separated BioWaste
SSF	Solid State Fermentation
SS RW	Source Separated RW
tonne	ton
TS	Total Solid
UAB	Universitat Autònoma de Barcelona
WEEE	Waste Electrical and Electronic Equipment
WMZ	Waste Management Zones
WtE	Waste to Energy
WW	Woody Waste

Table of content

Preface

This report is the last deliverable foreseen in work package 6.1 “selection of locations and associated incentives for the demonstration implementation of the DECISIVE system” of the DECISIVE project. The scope of this work package was characterising the demonstration sites and simulating the application of the DECISIVE system in other theoretical sites by using the DECISIVE Decision Support Tool (DST) developed in the previous deliverables D5.1, D5.2 and D5.3. The present document is meant to present the results of this simulation first to check the usability of the DECISIVE DST as a planning methodology and second to derive a set of criteria that can be used in the future to choose appropriate locations where a decentralized biowaste management scheme could be implemented successfully.

As matter of fact, thanks to the evaluation obtained from the DST by using specific indicators, a first assessment of the decentralized system for a valorisation of municipal biowaste proposed by DECISIVE in comparison with other treatment options in urban areas is provided.

The “theoretical”, “simulation” or “tested” sites, as they were named in the GA (Grant Agreement), have been decided in this report, based on the potential list of locations obtained by applying the selection criteria defined in a previous deliverable (D6.3).

The final set of theoretical locations together with the two demonstration sites (Lyon Pilot and Dolina Pilot) are used to test the DST and its capacity to characterize impacts and opportunities of different waste management schemes.

Executive Summary

Overall, the objective of this deliverable is to carry out a simulation of the application of the DECISIVE technology-package in both theoretical (the sites selected to test the DST) and demonstration sites (Lyon Pilot and Dolina Pilot) by using the DECISIVE DST (Decision Support Tool). This simulation will help compare the performance of business as usual and alternative scenarios to identify the pros and cons when implementing the DECISIVE technology-package in different EU contexts. This exercise helped: (1) evaluating the usability of the DST as a planning methodology to assess benefits and drawbacks of biowaste management options; and (2) identifying possible improvements to be included in the DECISIVE DST. From the potential list of improvements only a few were implemented in the second version of the DECISIVE DST. This improved version of the DST was used to obtain the results of the simulations presented in this deliverable.

The methodology developed to achieve the main objective of the deliverable is based on the following steps: 1) selection of the theoretical sites, 2) gathering of the data needed to generate the waste processes representing the biowaste management in the selected sites, 3) introduction of data in the waste process libraries of the DECISIVE DST, 4) construction of baseline and alternative scenarios for each site, and 5) comparison between the results obtained from the DST for the baseline and those of alternative scenarios, for each site.

The conclusions concerning the suitability of the DECISIVE system implementation in the selected sites are based on a specific set of performance indicators and on the available data. Conclusions could be different with different indicators. While interpreting the results, it was also possible to identify limits of the indicators used in the tool and improvements that might be included in future versions.

The lack of standardised datasets that properly describe biowaste management systems at local scale has been identified as an important limitation encountered when gathering the data. Indeed, due to the large amount of data required to build waste processes libraries, data availability was the main criteria adopted for the selection of the locations to test the DST.

1. Introduction

DECISIVE has developed a technology-package, including a micro-scale anaerobic digestion treatment process (mAD), a solid-state fermentation (SSF) as well as a Stirling Engine, and a Decision Support Tool (DST) for the planning and reporting of decentralised systems for biowaste management.

The main objective of this deliverable is to simulate the implementation of the DECISIVE technological-package in different types of sites using the DST to understand: 1) benefits and drawbacks of the DECISIVE technology-package in different EU contexts and 2) usability of the DST to assess benefits and drawbacks of biowaste management options.

While performing the analysis, it was possible to identify potential improvements to be included in the first version of the DECISIVE DST. Some of the identified improvements were introduced in a second version of the DECISIVE DST that has been used to obtain the results presented in this deliverable for demonstration and simulation sites.

2. Methodology

To achieve the main objective of the deliverable described in the introduction, different steps were carried out. First, the simulation sites were selected. Second, the data needed to generate the waste processes representing the biowaste management in the selected sites were gathered. Third, the data were inserted to compile the waste process libraries of the DECISIVE DST; in a such a way, for each site both baseline and alternative scenarios were built. The results related to the baseline and alternative scenarios for each site were compared.

From the results obtained in the different sites, it was possible to draw some conclusions regarding the suitability of the DECISIVE technological scheme in different types of sites. The validity of the assessment and the conclusions depend on the indicators used in the DST and on data availability.

In the following subsections the details of each step of the methodology are described.

2.1 SELECTION OF THE SIMULATION SITES

The provisional list of 18 locations (Table 1) that could serve as simulation sites listed in Deliverable D6.3 was used as starting point to select the final theoretical sites. The 18 preliminary locations were selected for representing the broad diversity existing in the EU (with reference to biowaste generation and management systems, but also for the scale of analysis, geographical and economic diversity, etc.). See D6.3 for further details.

Table 1 - List of provisional theoretical sites to test the DST (Source: D6.3).

	Name	Country	Type of location	Nature of location	Type of biowaste source
1	Municipality of Argentona	ES	City	URBAN	HOUSEHOLD
2	Planta de Grupo Soteras	ES	Area	INDUSTRIAL	RESTAURANT
3	Market Ninot	ES	Area	URBAN	MARKET
4	Hospital (Vall d'Hebron)	ES	Area	SERVICE	HOSPITAL
5	Catalonia Region	ES	Region	URBAN	MIXED
6	Lübeck-Flintenbreite ecovillage settlement	DE	Village	URBAN	HOUSEHOLD
7	Lübeck City	DE	City (NUT3)	URBAN	HOUSEHOLD
8	Hamburg	DE	City	URBAN	HOUSEHOLD
9	Bargstedt	DE	Region	RURAL	HOUSEHOLD
10	Aarhus City	DK	City	URBAN	HOUSEHOLD
11	North of Zealand	DK	Country	URBAN	MIXED
12	Grand Lyon	FR	City	URBAN	MIXED
13	Rennes Métropole	FR	City	URBAN	MIXED
14	Brussels Region	BE	City	URBAN	MIXED
15	San Dorligo della Valle (Dolina)	IT	Village	MIXED	MIXED
16	Gemona del Friuli	IT	City	MIXED	MIXED
17	Taipana	IT	Village	RURAL	HOUSEHOLD
18	Dogna Municipality	IT	Village	RURAL	HOUSEHOLD

To select the theoretical sites for the conclusive analysis, a participatory process was carried out within the DECISIVE Consortium. DECISIVE partners participated in different meetings to propose the sites and the related responsible person for data gathering. Finally, it was decided that due to the large amount of data needed to build waste processes libraries in the DST, data availability was the main criteria to select the final theoretical sites. Table 2 provides details of the two demonstration and nine simulation sites modelled in the DST and assessed in this deliverable.

Table 2 - List of the 11 sites (2 demo and 9 theoretical) assessed in this Deliverable.

Name		Country	Type of biowaste source
Site 1	Bellaterra University Campus	ES	UNIVERSITY
Site 2	Guineueta Market	ES	MARKET
Site 3	Lübeck City	DE	HOUSEHOLD
Site 4	Dogna Municipality	IT	HOUSEHOLD
Site 5	Rennes Métropole	FR	MIXED
Site 6	Vall d'Hebron Hospital	ES	HOSPITAL
Site 7	Zagreb City	HR	MIXED
Site 8	Brussels Region	BE	MIXED
Site 9	Gran Lyon	FR	MIXED
Demo Site1	Lyon pilot	FR	RESTAURANT
Demo site 2	Dolina pilot	IT	HOUSEHOLD

2.2 DATA GATHERING PROCESS

For each site, a partner of the consortium was defined as responsible for the data collection. ENT, as a coordinator of the deliverable, provided a template to be filled in by the person responsible with the data needed to model each site in the DST. The templates were organised in Excel sheets, providing examples to be used as a guide for each step of the waste management scheme. For each site, the partner in charge of data collection was responsible for retrieving the required information and providing them in the required format.

Monitoring of the gathered data was realised in a centralised manner by ENT to ensure that the data provided by site responsible partners were sufficient and correct to be used in the DST. When specific data values were not available, assumptions were made based on the values provided for similar sites.

The data collected was used to elaborate (1) a general description of the site, (2) the biowaste mass balance of the baseline scenario and (3) the waste process libraries needed to model the site in the DST.

Data needed to analyse and characterise the waste management systems currently in place in the theoretical and demonstration sites were collected in a specific format required to build the waste process libraries to feed the DST.

Apart from business-as-usual waste processes libraries, data inventories related to the decentralised DECISIVE system implemented in the Lyon and Dolina pilots have been built, introducing the available data from demo sites and the characteristics of DECISIVE technology-package (WP6.2).

Waste processes libraries have been reported in Excel tables available online. Data sources, assumptions and calculations have been also made available.

During the data gathering process, it was possible to identify easily available data fields and information that was difficult to retrieve, in order provide a more comprehensive overview about data requirements for future versions of the tool.

Simulations for the Hospital Vall d’Hebron, Brussels region and Zagreb city were not carried out because for those cases there was not sufficient information to be inserted in the DST.

2.3 MODELLING OF THE SELECTED SITES

The data gathered by the consortium and revised by ENT was introduced in the DECISIVE DST in the form of waste process libraries and projects. The data inserted in the tool are based on interviews, literature review and own calculations) in the years of data generation, i.e., 2018-2020. Each site was modelled as a project and within each project there were two scenarios. One scenario representing the current biowaste management in the site (i.e., Baseline) and an alternative scenario where the potential biowaste management using the DECISIVE technology-package substituted totally or partially the current waste management.

For the alternative scenarios, there were two types of cases. For the small-scale sites (e.g., Bellaterra, Guineueta market, Dogna), it was assumed that all the source-separated biowaste could be handled with the DECISIVE technological package. For cities and regions (e.g., Lübeck, Grand Lyon), it was assumed that only a small percentage of the biowaste source separated was handled with the DECISIVE technology-package and the rest remained as in the baseline scenario.

While modelling the different sites, it was possible to identify the potential improvements of the tool to facilitate the simulation of biowaste management systems. For example, it was realised that the radar included in the first version of DST provided results not clearly displayed since the scale of the indicators was not normalised. During the testing of the DST, the impossibility of comparing the performance assessment results of two different scenarios in a same diagram was a clear limitation to visually check the differences. Moreover, the absence of an error management system was a further barrier to understand why the DST was not running correctly.

2.4 RESULTS INTERPRETATION

For each site, a first assessment was dedicated to check that the results provided by the tool were reliable. This step was followed by the evaluation of the benefits and constraints of the implementation of DECISIVE technology-package.

For each scenario, the DST provides the results in two forms: (1) radar diagram with the total impact for each indicator and (2) Excel file with the contribution of each part of the scenario to the overall impact. The tool can compare the results of two scenarios within the same project. The results of such a comparison are shown in a radar figure that integrates the total impacts of both scenarios.

The performance of the different biowaste management systems is assessed using a set of indicators (assessment criteria) classified into three categories: 1) environmental assessment (climate change, transport intensity index) 2) economic assessment (economic costs), 3) social assessment (labour, space requirement, time use for sorting waste)

- **Climate change** - it assesses the kg of CO_2 equivalent due to direct emissions and consumptions of background processes for each waste process involved in each scenario.
- **Labour** - it includes the amount of person*hour needed to handle waste in all involved waste processes of a specific scenario.
- **Space requirement** – it includes three types of areas: A) private space of the biowaste generator for source-separation activities, B) urban area needed for the management of the biowaste, C) non-urban area needed for the management of the biowaste
- **Time** - it measures the hours dedicated from the biowaste generator for the sorting waste at the place of generation, as well as bringing the biowaste to the storage place (e.g., bring-points) where it is picked up by the collection operator.
- **Energy recovery indexes (Thermal Ratio** and **Electric Ratio) -** they quantify the capacity of the biowaste management system to convert waste into energy. It is a dimensionless index calculated as the ratio between the energy produced in the biowaste management system (e.g., incineration

and anaerobic digestion plants) and the sum of the energy consumed by the system and the energy production.

- **Economic costs** - it includes Capital Expenses - CAPEX (investment costs for all the waste processes involved); the Operational Expenses - OPEX (labour costs, maintenance costs and costs associated with the background processes consumed, e.g., electricity) and revenues of all the waste processes involved in the analysed scenario.
- **Transport Intensity Index** - it assesses how intensive the system is in terms of transport based on the distances travelled by the biowaste generated in the study area during its management.

In Figure 1 an example of such a radar diagram where the set of the mentioned indicators is displayed can be seen.

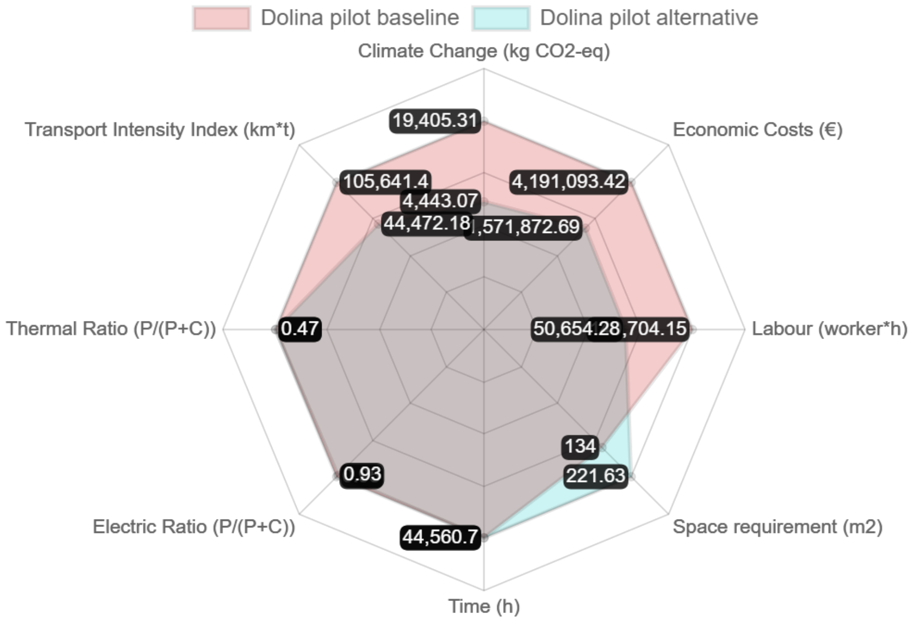


Figure 1. Results of baseline vs alternative scenarios – Dolina Pilot.

More details about assessment indicators used in the DST and related methodology are available in the D.5.1.

The results reported for each site are shown using the radars exported from the tool. However, for the interpretation of the results, the authors of this document have used the results presented in the Excel files downloaded from the tool.

The first phase of the results interpretation aimed at verifying that the calculations done by the tool were correct and that the data inserted in the tool provided plausible outcomes. While executing this preliminary analysis for the Bellaterra site, some calculation errors were identified in the tool and fixed by the software developers, following the indications provided by ENT. In addition, while modelling the different sites it was also possible to refine some data values that provided odd results. This operation consisted of checking the contribution to each indicator provided by the radar diagram by using the Excel file generated by the assessment for each scenario. For the climate change indicator, for example, the alert of potential errors in data inputs was identified when the main contribution was not coming from incinerator's emissions or diesel production but from or the production of waste plastic bags and containers. Carbon dioxide emissions related to incinerators operations or diesel production normally have a higher impact compared to the production of plastic bags or containers needed for waste collection. This checking procedure was applied to each of the indicators reported in the radar diagram.

The second phase of the results interpretation aimed at assessing the current biowaste management system in the different sites and comparing them with the alternative management proposed by DECISIVE.

The study was performed for different EU contexts to identify the situations in which the decentralisation using the DECISIVE technology package could be beneficial.

During the results interpretation, it was also possible (1) to identify the limits of the indicators used in the tool and (2) to suggest improvements that could be included in future versions of the tool. For example, the surface indicator was reformulated to account only for the space needed by the waste generator instead of including different types of areas (agricultural land, sorting and waste plants) because the addition of different types of areas did not provide relevant information. A limitation of the representation of indicators in the radar diagram is linked to the fact that the radar displays the sum of extensive values coming from the different stages of the waste management system. This means that, to understand the contribution of each indicator items to the total value or to identify from where the main impact is coming, the users will need to check the Excel file generated by the tool and downloadable for each site.

3. Analysis of the theoretical sites

In this section the selected theoretical sites are analysed in detail and the information is reported in four different sections. The first part reports a general description and the main characteristics of the current waste management systems for each selected theoretical site. In the second section, gathered data are used to develop the flow diagram for business-as-usual scenarios and build the related waste processes libraries to insert into the DST. The third section describes the reason behind the potential suitability/unsuitability of the DECISIVE system in the specific site. In the final section, current and alternative scenarios are defined and built in the DECISIVE DST in order to obtain the results of the performance assessments and the comparisons between scenarios that is reported in chapter 5.

3.1 SITE 1 - BELLATERRA UNIVERSITY CAMPUS

Description of the site

The Campus of the Universitat Autònoma de Barcelona (UAB) is in the municipality of Cerdanyola del Vallès (Barcelona), 20 km to the North-West of Barcelona, in the Metropolitan Area of Barcelona. Cerdanyola del Vallès is the municipality, with a population of 57,543 spread over an area of 30.56 km^2, that includes the UAB Campus (called also Bellaterra Campus).

The campus of the UAB has a total of 260 ha, of which 90 ha are built and 60% are forest and agricultural land. It is constituted by more than 30 buildings including faculties, research centres, residential buildings (Vila Universitaria and Sert Area) and 10 restaurants (three large restaurants, four medium restaurants and three cafeterias) Figure 2. The Sert area includes private housing of the Bellaterra village within the campus limits. The Campus hosts more than 35,000 people between students and staff (teachers, researchers, administrative and general services). Also, the Vila Universitaria accommodates over 1,200 people nearly all year long. For the scope of the case study, the Vila Universitaria residence and the 10 restaurants were considered.

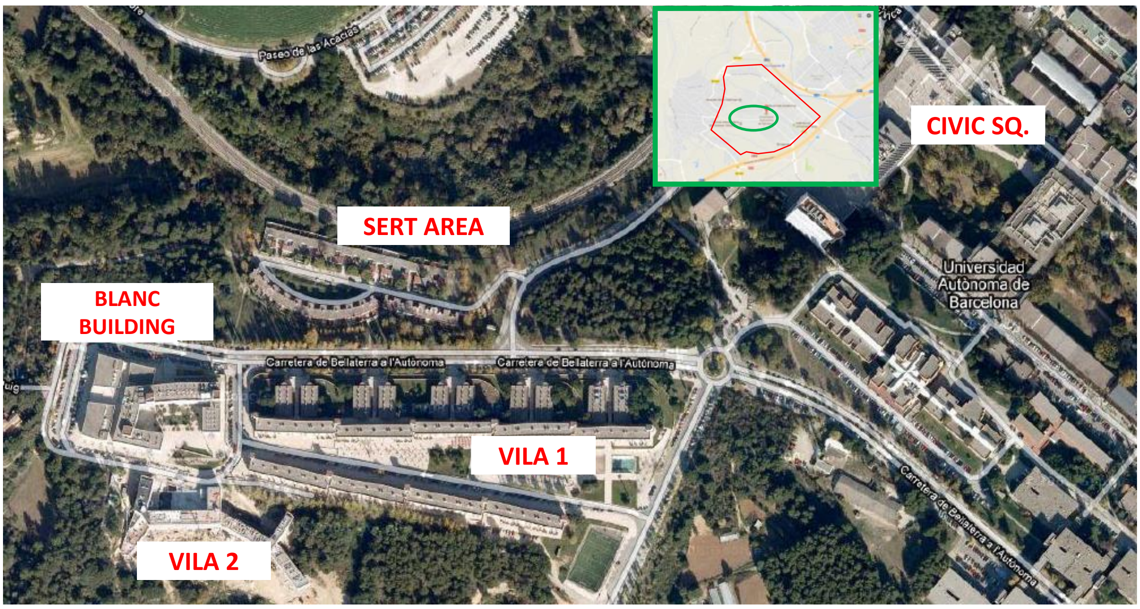


Figure 2 - Detail of the components modelled in the Campus of the Universitat Autònoma de Barcelona (Vila and private buildings) (Source: Google Maps and UAB).

In the UAB campus there is a great variety of activities generating different types of waste, from municipal solid waste to specific wastes derived from research activities such as hazardous and non-hazardous laboratory waste. The biowaste in the area is generated by different sources. Restaurants and cafeterias on campus are the main producers of kitchen- and food-waste. The area of the Vila is residential with a significant generation of food waste. This case study includes source-separated biowaste and residual waste (still containing about 40% of biowaste) generated from restaurants and Vila buildings

The collection system on the campus consists of 49 bring bank points for the five main fractions of municipal waste (biowaste, paper and cardboard, packaging, glass and residual waste). The containers are distributed all over the campus but those for biowaste are only present near restaurants. Biowaste is source-separated in the restaurants in 120 L bins and afterwards emptied into the biowaste containers (1,800 L) located in the street outside the buildings. The biowaste containers are freely accessible and not of exclusive use for the restaurants. This condition has a negative impact on the quality of the biowaste, which has a high impurity content.

The residual waste and the source-separated biowaste collected in the UAB Campus are sent to the Ecoparc2 facility located 7.7 km from the campus centre. The first fraction goes to the mechanical biological treatment line while the second is treated by the anaerobic digestion line. The digestate produced in the biowaste line is composted along with green waste.

Figure 3 shows the mass flow of the current generation and management of the biowaste from 10 restaurants and the university residence in Bellaterra Campus.

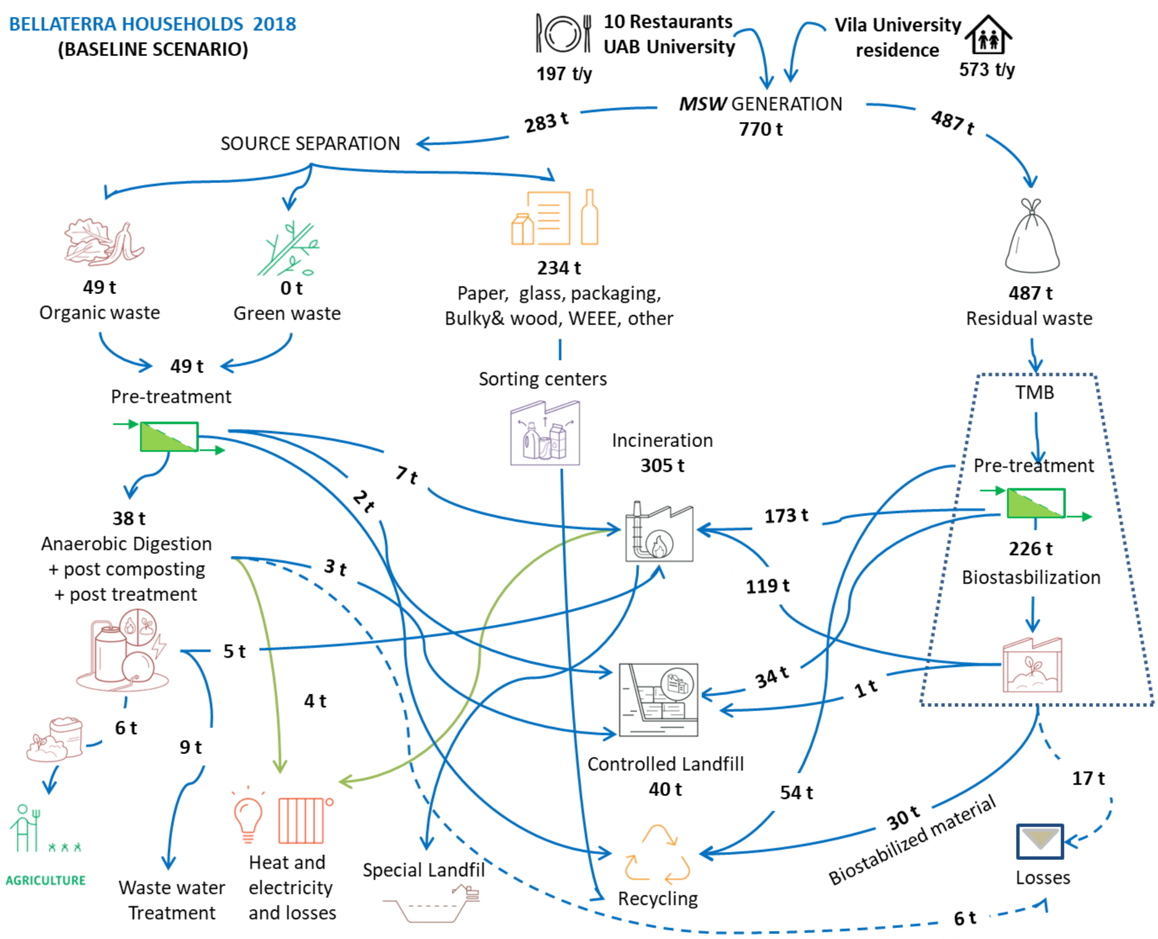


Figure 3 – Flow diagram representing the current waste management system in Bellaterra UAB campus (data 2018).

Waste process libraries of current waste management system

Data collected for building the waste processes libraries related to the current waste management inventories in Bellaterra Campus were gathered from meetings and interviews organized with the UAB environmental department of the UAB. An important source of information for this site was the deliverable

D6.1 since Bellaterra campus was selected at the beginning of the project as one of the DECISIVE demo pilots. In addition, web pages of the campus and university residence's managers provided complementary information.

Data concerning the restaurants characteristics and biowaste generation came from internal communication with the UAB maintenance department and campus restaurants managers and were gathered for the content of Deliverables D6.5 and D6.6. Also, a comparison with data related to biowaste generation was obtained from available publications related to other Catalan universities.

Data related to waste pre-treatment, treatment and disposal plants were gathered from annual waste declarations of the plants, internal database and reports provided by ARC.

Tables with the inventories of the waste management system related to the baseline scenario for the Bellaterra University Campus can be found at the following link: Bellaterra University Baseline inventories.xls.

Analysis of the suitability of the DECISIVE system

The potential application of the DECISIVE system was studied in detail since Bellaterra Campus was in the early stage of the project planned as the demonstration site to implement the DECISIVE system. Bellaterra University was considered as a suitable site for the implementation of the DECISIVE system for a variety of reasons. First, the biowaste generation from restaurants was consistent in terms of quantity for the mAD operation. Secondly, the quality of biowaste required for mAD should be easily achieved by sensitising all the community and particularly kitchen staff, who are experienced in separating waste while clearing the plates. This is a relevant favourable point since the quality of biowaste is critical for the proper functioning of the mAD. Secondly, the existence of a hotel, restaurants, and students' residences on the Campus assures the quantity of biowaste but attention may be paid to differences in quality. Even though currently only around 49 ton/year (15% of the generated biowaste) is selectively collected from the 10 restaurants (30.9 ton/year) and the student residence (18t/year)[1], there is a commitment from the managers of the catering companies so that the selective collection of biowaste can reach at least 100 ton in one year. Even if the mAD could start treating only biowaste from restaurants, there is the possibility of introducing household biowaste from the students' residence, which could be potentially a further input to the system especially after the organization of awareness campaigns in the campus. Indeed, communication activities could probably lead to a high impact on biowaste generation and the sorting behaviour of resident and non-resident students and staff. Thirdly, the digestate produced by the mAD could be potentially spread on the agricultural areas for research activities by the Faculty of Veterinary Medicine. Technical staff are available on site and could be involved in the operation and management stages of the mAD.

The relevant stakeholders to study the feasibility of the implementation of a DECISIVE system in the UAB were identified. Among the most important actors to be approached there were the Vice-Rector for Innovation and Strategic projects, the Vice-Rector for Economics and the Waste Manager of the UAB. Other important actors were the heads of each of the three companies that manage the restaurants and the person responsible for the student residences. The previous stakeholders were interviewed to get information about the potential areas to place the mAD, the waste collection system currently in place in the campus and the characteristics of restaurants and the students' residence. ARC was also an important stakeholder to gather relevant information about the biowaste collection circuit used in the campus. The Municipality of Cerdanyola del Valles, in charge of current waste collection in the campus, was identified also as a relevant actor to be involved in the decision process. In fact, in the case of implementing a DECISIVE system, the current biowaste collection scheme of the campus needs to be substituted by one ad-hoc compatible decentralised scheme.

[1] Table 25 of D6.1.

Despite the initial green light for the mAD in Bellaterra, in August 2019 Consortium partners realised that the implementation of the demonstration in Bellaterra campus was practically impossible due the conjunction of different issues so, a new demonstration site (Dolina Municipality) was proposed as a substitute.

Although it was decided that the UAB Bellaterra campus would not be the second pilot of the DECISIVE project, it was considered as an interesting case to study because of its features, which makes it suitable for decentralisation (as other university campus with similar characteristics).

Definition of scenarios

For the **baseline scenario**, BW generated in the 10 restaurants and university residence is respectively 66 ton/year and 251 ton/year while 31 ton/year (for restaurants) and 18 ton/year (for the university residence) are source separated and wastes are collected in road containers of 2,200 L. BW source separated in Bellaterra is sent to the Ecoparc2 biowaste line and the residual waste is sent to the Ecoparc2 residual line. Ecoparc2 is around 7.7 km away from the Bellaterra Campus. From Ecoparc2 outputs are sent to Tersa incineration (22.8km away), Tivissa landfill (174 km away), to recycling centres (estimated 3km away) and Montcada i Reixac wastewater treatment plant (15 km away). Compost obtained from the Ecoparc2 biowaste line is considered to be used as a soil amendment. For collection it is assumed that trucks have a capacity of 22 m^3 and for the rest of transports trucks with a capacity of 14 ton and average speed of 59 km/h are considered.

For the **alternative scenario**, the current centralized waste management system would be substituted with two decentralized DECISIVE units. So, source separation would go from 15% (baseline) to 38% (alternative) of the generated biowaste; 38% of generated biowaste (122 ton/year) should be separately collected and the rest would remain in the residual bin. It is assumed that there would be an improvement in the collection system. In fact, the bring scheme for both the SSBW (Source Separated BioWaste) and the RW would be substituted by a DtD (Door to Door) system. Containers of 2200L would be substituted with 1000L ones. It is assumed that this change also could lead to an improvement in the quality source – separated biowaste, and also because of the implementation of a communication campaign. An e-vehicle would be used to move the BW to the DECISIVE system while a 22-m^3 truck would be used to send the RW to the current treatment plant: the residual line of Ecoparc2. The two mADs are considered located on average 0.2 km away from biowaste generation points. It was assumed that the source separated biowaste would be sent to the decentralization by using an electric vehicle of 0.65 ton of capacity. The amount of source-separated biowaste that would be sent to the decentralised system is around 100 ton/year. Since the mAD DECISIVE system such as the one deployed in Lyon can annually treat 50 ton of source separated biowaste, this means that it is foreseen to virtually introduce 2 units (or 1 DECISIVE unit treating 100 ton) in the campus area. The solid digestate generated would be used as compost in the fields of the Bellaterra campus, in the agricultural land of the Faculty of Veterinary Medicine, while the liquid fraction would be sent to Montcada i Reixac wastewater treatment plant as in the baseline scenario. Part of the solid digestate could be used to produce organic amendments and biopesticides that can substitute fossil pesticide use.

The multicriteria assessment of the DECISIVE scenario in Bellaterra University campus was carried out and compared with the performance assessment of the current waste management system by using the DST. The results are shown in chapter 5.

3.2 SITE 2 - THE GUINEUETA MARKET

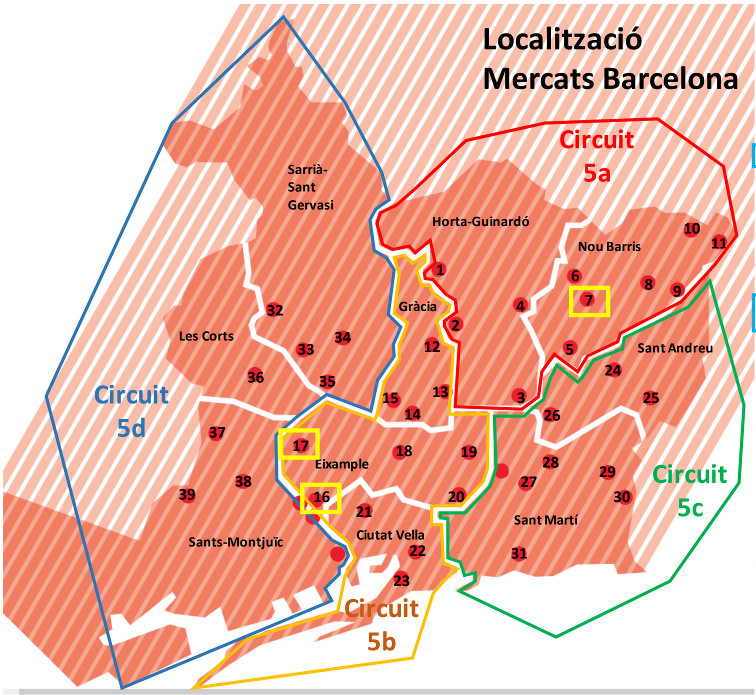
Description of the site

Municipal markets in Barcelona are the main suppliers of fresh food for the citizens, particularly for meat, fish, and vegetables (MMBB, 2009). The main commerce is for food but also some stalls sell clothes, hardware, kitchenware, etc. In the 10 districts of Barcelona, there are 39 municipal markets spread over the territory and located in buildings (Figure 4) (Mercats de Barcelona, 2021). Some of the markets, such as la Boqueria, are emblematic because of their location in the inner city and the variety of food that can be found. Municipal markets cover nearly all areas and there is one in each district except Les Corts, where at least three markets exist. The location, size and architecture are very different among all of them, and partly attributed to the age of the buildings (Mercats, l'experiència de Barcelona, 2021). Some of them were built over ancient open markets (La Boqueria - 13th century) and other are recent, from the latest of the past century (Mercat de Canyelles - 1987) to provide fresh food in districts of new housing (Els mercats de la Mediterrània, 2016). Because of this, there are different types of facilities.

The waste management of the public markets of Barcelona is managed by the Municipal Department for City Cleaning and Waste Management. This organism provides by means of several contractors the collection of wastes generated at the market. For several years the separate collection of biowaste was implemented in the public markets and is organised in specific collection circuits, most of them exclusive for each market, and with the biowaste shipped to biological treatment facilities in the Metropolitan Area of Barcelona.

Three public markets (Figure 4) were pre-selected as theoretical sites of D6.3 (Guineueta, Ninot (Mercat del Ninot, 2021) and Sant Antoni) but only the Guineueta market has been included in the final selection sites, mainly due to data availability.

The waste collection of markets is divided in different areas of Barcelona, which correspond to different circuits (Figure 4) that are managed by separate contracts with private companies. These differences depend on the separate collection requirements set on the public procurement process. Collection of biowaste generated in the markets of Barcelona is organized in four circuits (5a, 5b, 5c, 5d) that only collect waste from markets and transport it to public treatment plants (Figure 4).



	Districte	Circuit	Nom mercat
1	HORTA/GUINARDÓ	5a	Mercat de Vall d'Hebron - Teixonera
2	HORTA/GUINARDÓ	5a	Mercat del Carmel
3	HORTA/GUINARDÓ	5a	Mercat del Guinardó
4	HORTA/GUINARDÓ	5a	Mercat d'Horta
5	NOU BARRIS	5a	Mercat de la Mercè
6	NOU BARRIS	5a	Mercat de Canyelles
7	NOU BARRIS	5a	Mercat de la Guineueta
8	NOU BARRIS	5a	Mercat de Montserrat
9	NOU BARRIS	5a	Mercat de la Trinitat
10	NOU BARRIS	5a	Mercat de Núria
11	NOU BARRIS	5a	Mercat de Ciutat Meridiana
12	GRÀCIA	5b	Mercat de Lesseps
13	GRÀCIA	5b	Mercat de l'Estrella
14	GRÀCIA	5b	Mercat de l'Abaceria Central
15	GRÀCIA	5b	Mercat de la Llibertat
16	EIXAMPLE	5b	Mercat de Sant Antoni
17	EIXAMPLE	5b	Mercat del Ninot
18	EIXAMPLE	5b	Mercat de la Concepció
19	EIXAMPLE	5b	Mercat de la Sagrada Familia
20	EIXAMPLE	5b	Mercat de Fort Pienc
21	CIUTAT VELLA	5b	Mercat de la Boqueria
22	CIUTAT VELLA	5b	Mercat de Santa Caterina
23	CIUTAT VELLA	5b	Mercat de la Barceloneta
24	SANT ANDREU	5C	Mercat de Sant Andreu
25	SANT ANDREU	5C	Mercat del Bon Pastor
26	SANT ANDREU	5C	Mercat de Felip II
27	SANT MARTÍ	5C	Mercat del Clot
28	SANT MARTÍ	5C	Mercat de Provençals
29	SANT MARTÍ	5C	Mercat de Sant Martí
30	SANT MARTÍ	5C	Mercat del Besòs
31	SANT MARTÍ	5C	Mercat de Poblenou
32	SARRIÀ/SANT GERVASI	5D	Mercat de Sarrià
33	SARRIÀ/SANT GERVASI	5D	Mercat de Les Tres Torres
34	SARRIÀ/SANT GERVASI	5D	Mercat de Sant Gervasi
35	SARRIÀ/SANT GERVASI	5D	Mercat de Galvany
36	LES CORTS	5d	Mercat de Les Corts
37	SANTS/MONTJUIC	5D	Mercat de Sants
38	SANTS/MONTJUIC	5D	Mercat d'Hostafrancs
39	SANTS/MONTJUIC	5D	Mercat de la Marina

Figure 4 - Location of the municipal markets of Barcelona and collection circuits of biowaste. The three pre-selected markets are highlighted but only Guineueta market (7) was selected for the present study.

In Mercat de la Guineueta (Mercat de la Guineueta, 2021) the stallholders separate waste inside the stall and transport it to an intermediate collection point nearby. From there, market assistants (contracted by the Stallholders Association of the market) do the transport of waste from stalls to containers. Meat waste is collected in a particular circuit to be returned to the central distributor (Mercabarna) to be transformed into animal feed.

Biowaste collected from the market of Guineueta is transported to Ecoparc 2, located 14 km away in

Montcada i Reixac. The truck also collects biowaste from the other markets of circuit number 5a, which includes the districts of Horta-Guinardó and Nou Barris. Solid refuse from Ecoparc2 is finally disposed of at the energetic valorisation plant in Sant Adrià de Besòs (18 km away from Ecoparc2) and at Tivissa landfill (174 km away from Ecoparc2). Figure 5 shows the location of the pre-selected markets for the study in a map and the respective biological treatment plants where biowaste is transported.

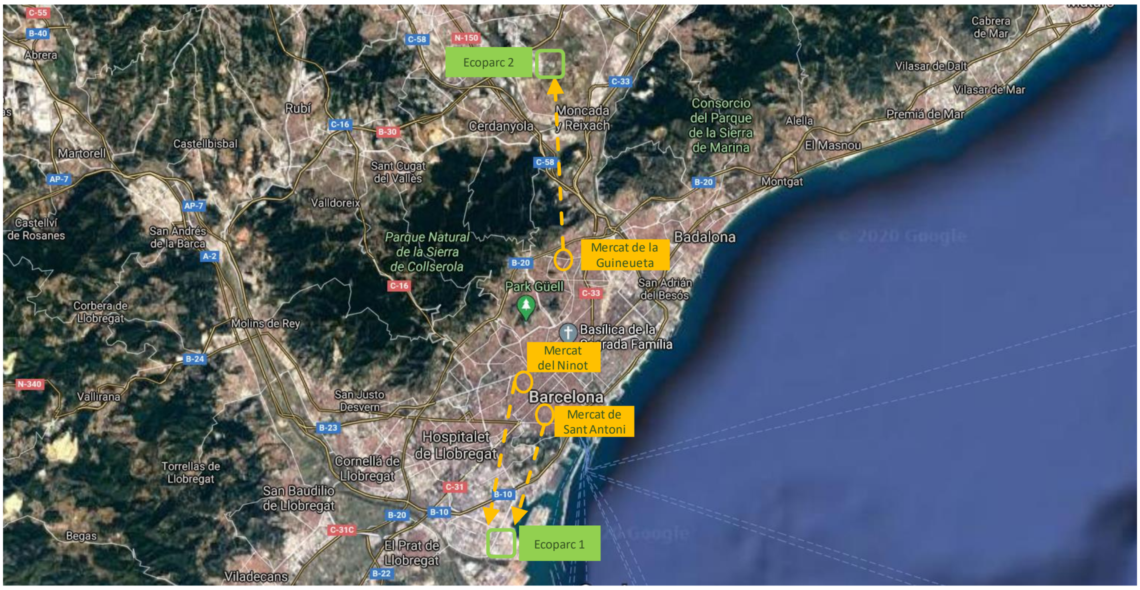


Figure 5 - Location of Guineueta, Ninot and Sant Antoni markets and the respective biowaste treatment plants Ecoparc 1 (Barcelona) and Ecoparc 2 (Montcada i Reixac). Source: Google Maps.

The individual generation of biowaste in each market is not available and is difficult to assess. The available data is the quantity collected in each circuit, which includes several markets. The amount collected is recorded when the trucks arrive at the treatment plants. The biowaste quantities collected by circuits were 525 ton and 2,040 ton for 5a and 5b, respectively, in 2018, and 359 ton and 1,326 ton, in 2019. Therefore, 33-48 ton/year are produced per each market in circuit 5a and 110-170 ton/year per each market in circuit 5b. These values clearly indicate the differences between circuits, due to the number and size of markets in each circuit.

The quality of the biowaste collected by circuits is assessed by regular characterisations in the treatment plants, according to the protocol established by ARC (3-4 samples per year). Figure 6 shows the impurities content in circuits 5a and 5b during 2018, 2019 and 2020.

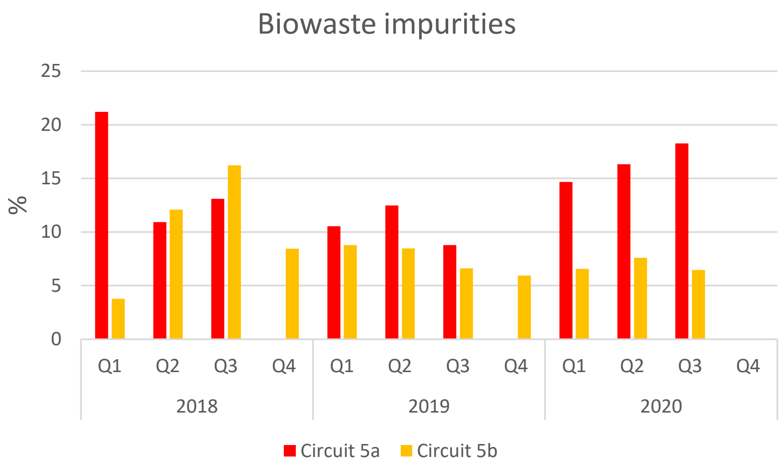


Figure 6 - Content of impurities in biowaste in the collection circuits 5a (Mercat Guineueta) and 5b (Mercat Ninot and Mercat Sant Antoni).

The residual waste generated at the Guineueta Market (mixed residual waste European Waste Catalogue (EWC) code 200301) is collected by a contractor authorised for collection and transfer of waste. The waste is passed on to another waste management company, which stores mixed residual wastes from many commercial origins and performs some sorting. The output from storage and sorting, classified as non-valorisable waste (EWC code 191212), is destined to another company outside Catalonia for the preparation of Residue Derived Fuel (RDF). It is not possible to assign the residual waste from the market to either landfill or waste incineration. It has also to be kept in mind that the residual waste from the market consists mostly of wood, plastic and cardboard.

Figure 7 shows the mass flow diagram of the biowaste generation and management of the food waste generated in the Guineueta market.

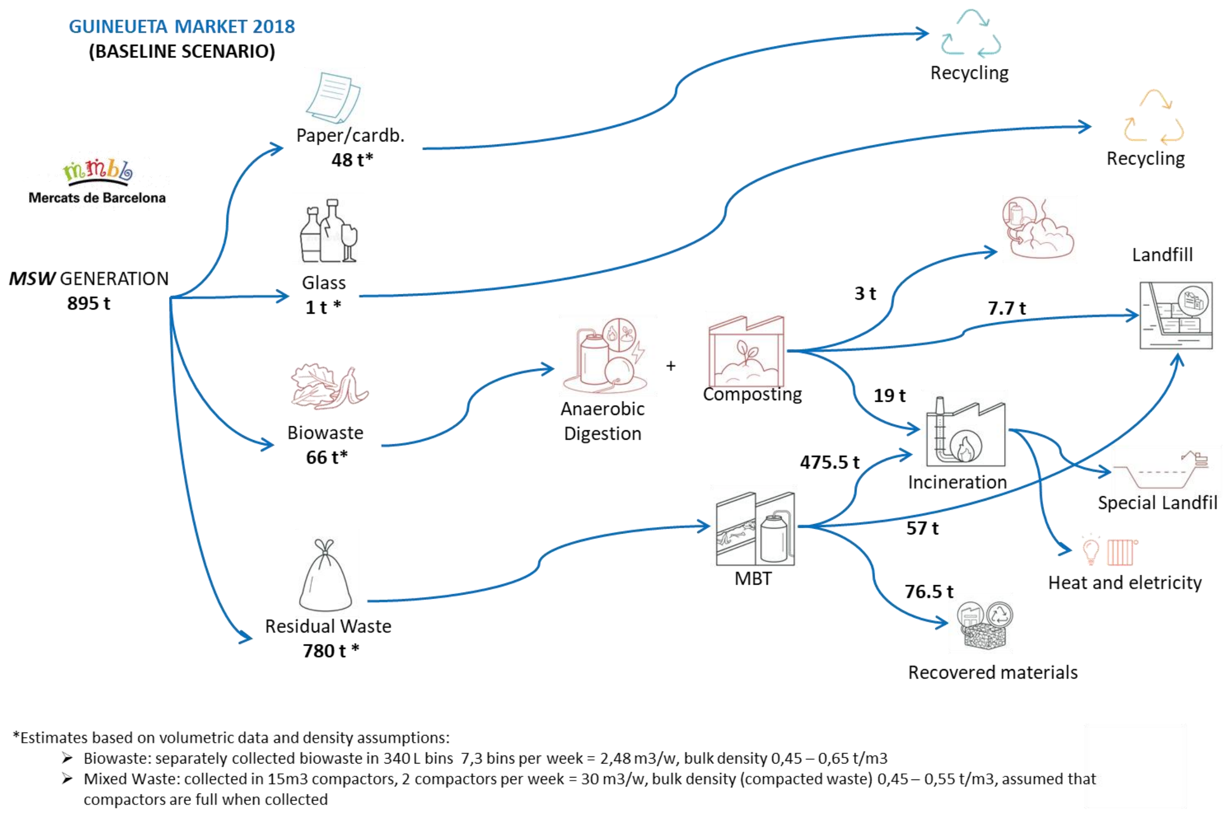


Figure 7 - Flow diagram representing the current waste management system in the Guineueta Market (2018 data).

Waste process libraries of current waste management system

General information about markets was collected from the Institut Municipal de Mercats de Barcelona (Barcelona Municipal Markets Institute) hereinafter referred to as IMMB. Specific information about the visited markets was also collected from the interviews with their respective directors and the visual observation during the visits. In addition, webpages of the markets and of the IMMB provided complementary information.

The information gathered from IMMB about the markets included: number and distribution of the municipal markets; size of the selected markets (total surface, number and type of stalls, size of each stall); and distribution of waste containers (type, size and location) for different waste fractions separated inside the visited markets (Mercats de Barcelona, 2021).

ARC, as the regional competent authority for waste management, holds in its database statistical information on municipal waste generation, biowaste collection circuits and destination plants for the treatment of biowaste generated in the selected markets. These data, however, are in general organised at municipal level. For biowaste, the data are also available at the level of collection circuits. Nevertheless, for a big city as Barcelona, this does not provide sufficient detail to assess the situation of a specific market as the circuits cover several commercial activities.

To retrieve more information, a meeting was held in the autumn of 2019 with the heads of the IMMB and the Department for City Cleaning and Waste Management. This meeting helped to find out which data and information regarding waste generation and organisation of the separation and collection (trucks, containers, energy and water consumption) was available. An effective collaboration was established and general information on the administrational organisation and operation of the markets was provided by IMMB. It was agreed that in a first step ARC identified the most relevant collection circuit for the markets and then IMMB facilitated visits to the markets of interest for the DECISIVE system implementation. Due to data availability, Guineueta market was selected as the theoretical site to investigate.

Tables with the inventories of the waste management system related to the baseline scenario for the Guineueta Market can be found at the following link: The Guineueta market Baseline inventories.xls.

Analysis of the suitability of the DECISIVE system

The quantification of biowaste is a key factor to assess the suitability of the implementation of a DECISIVE system in a food market. In the case of Barcelona municipal markets, the existence of a centralised collection and treatment could make the implementation of a decentralised system such as DECISIVE difficult. In this case, potential benefits must be clearly demonstrated considering the current biowaste management systems. As previously shown, an average of 40 ton/year and 130 ton/year per market can be expected respectively in circuits 5a and 5b. In these cases, it could be considered appropriate to implement individually the DECISIVE system for the largest markets (as Sant Antoni-circuit 5b) and a collective system for smaller and close markets (as Guineueta-circuit 5a). In fact, the size of small markets and the available space in their premises could be a limiting factor for the implementation of the DECISIVE system. A potential solution could be collecting biowaste from several markets and treating it in the premises of a bigger market. This would keep the circuit of the biowaste from markets vs. the biowaste from households separate.

In other cases, different from Barcelona, if one or two markets exist in a municipality, the implementation of the DECISIVE system can be more attractive. This is because the costs of transport and treatment of biowaste to centralised plants could be compensated.

Public municipal markets suggested themselves as suitable potential sites for the implementation of the DECISIVE system for a variety of reasons. First, their characteristics of biowaste generation is expected to be consistent in terms of quantity and quality, which is essential for the operation of a mAD. Secondly, the products (biogas and digestate) of the mAD could be consumed onsite or in close circuits. Common service facilities on the market premises may be potential consumers of energy obtained from the biogas. Local suppliers of fruit and vegetables could use digestate and SSF products. Thirdly, the public projection and social function of markets make them a great platform for communication. Awareness campaigns about markets reach citizens directly at the very beginning of the household biowaste chain. The beneficial impacts of a DECISIVE approach and the idea of biowaste as a resource would be conveyed effectively both to vendors and customers.

To study the feasibility of the implementation of a DECISIVE system in public markets in the municipality of Barcelona, relevant stakeholders were identified as the first step. One of the most important actors and the first to be approached in the search for information was the IMMB, the official municipal organism responsible for the administration of the public markets in Barcelona. Its main tasks are improving infrastructures and services and promoting the commercial activity in the markets. The IMMB also carries out dissemination and communication activities related to social aspects of the commercial activity of food retail. Another important stakeholder is the Barcelona City Hall, which is responsible for waste management of municipal markets. The third main actor was ARC that helped getting relevant information about biowaste collection circuit for markets and the quality of collected biowaste.

Definition of scenarios

For the **baseline scenario**, BW generated by a market of 378 m^2 is 69 ton/year while 65.5 ton/year is source separated. The unit of generation selected for this case study is “m^2 of stall in the market”. The simulation has been made considering this unit of generation even if it is not among the units of generation listed in the DST. Waste collection is carried out by using street containers with a capacity of 360 L for source-separated waste fractions and one compaction container of 15 m^3 for residual waste. BW source separated is sent to the Ecoparc2 biowaste line and the residual waste is sent to the Ecoparc2 residual line. Ecoparc2 is around 17 km away from the market. From Ecoparc2, the outputs are sent to Tersa incineration (22.8km away), Tivissa landfill (174 km away), to recycling centres (estimated 3 km away) and Montcada i Reixac wastewater treatment plant (15 km away). For collection, it is assumed to use trucks with capacity 18 m^3 and for the rest of transportation, it was assumed to use a truck with capacity 14 ton and average velocity of 59 km/h. Compost obtained from the Ecoparc2 biowaste line is supposed to be used as a soil amendment.

For the **alternative scenario**, the current waste management system would be substituted with one unit of DECISIVE system (50t/year) that would be located 0.5 km away from the market. It was assumed that the source separated biowaste (53 ton/year) would be sent by using an electric vehicle of 0.65t of capacity to the decentralized unit. It is assumed that the RW would be sent to the current residual line of the mechanical and biological treatment plant (Ecoparc2). The current source separation and collection system would remain unvaried as bring scheme. The outputs from the DECISIVE package such as solid digestate would be used as fertiliser according to regulation and considering that during the process will pass through hygienisation while the liquid fraction would be sent to Montcada i Reixac wastewater treatment plant as in the baseline scenario. Part of solid digestate would be used to produce organic amendment and biopesticide that can substitute fossil pesticide use.

The multicriteria assessment of the DECISIVE system compared to the current waste management system in the Guineueta market was carried out using the DST and the results are shown in section 5.

3.3 SITE 3 - LÜBECK CITY

Description of the site

Lübeck is a northern German city of around 216,500 inhabitants (2019) and therefore the second largest city in the federal state of Schleswig-Holstein. It has a high population density in the city centre, however with lower density suburbs, reaching the Baltic Sea. On average, the population density is 1,000 inhabitants per km^2. The north-eastern to south-western extension measures 29.5 km. Lübeck is one of the three German cities originally part of the “Hanseatic League”, besides Hamburg and Bremen. Therefore, the central old town has many buildings with Hanseatic origin and is visited by many tourists, whose presence can impact waste generation throughout the year. It is located on a river island, surrounded by the river Trave. The city can be seen as an average large size (>100,000 inhabitants) city in Germany. Commercial activities focus on trade with Lübeck’s harbour being among Germany’s largest ones in the Baltic Sea. Another relevant area is health technology, also due to a strong medical faculty at Lübeck’s university.

Biowaste management is fully developed in Lübeck. According to the municipal waste management, source separation of biowaste is largely practiced by households. Biowaste in Germany, and therefore also in Lübeck, is commonly collected as a mixed fraction of garden waste and food waste in DtD collection. The bin sizes range from 80 L to more than 1,000 L, depending on the building structure. The collection frequency varies between weekly and fortnightly. There is no information about the capacity of additional home composting. There is also still a substantial amount of biowaste collected with the residual waste, especially food waste. Around 66 kg/(inhabitant*year) of biowaste is collected in Lübeck. The waste composition was investigated in a 2020 study. It mostly comprises of garden waste, 64.3%, followed by food waste, 33.4%. Paper, considered to be an unwanted fraction but not an impurity, is present at 1.2%, while 1.1% of the waste consists of macro-impurities.

Lübeck waste treatment system is uncommon in Germany since both source-separated biowaste, and residual waste are sent to the MBT plant in Niemark where they are treated in two separated lines. The common approach in Germany is still the incineration of residual waste. After post-treatment, bio-waste and residual waste undergo, in their respective line, the anaerobic digestion treatment. The Niemark MBT plant is in the southern part of the city, around 8 km from the city centre (old town). The non-biodegradable but energy-rich light fraction originating from the pre-treatment of bio-waste and residual waste lines is transferred to the waste incineration plant in Neumünster, around 74 km from Lübeck's MBT plant.

Figure 8 shows the three main parts of bio-waste and residual waste treatment in Lübeck (from D3.6). Its treatment capacity is around 120,000 ton. Around 100,000 ton of source-separated bio-waste and residual waste are currently treated per year. Around 50% of the treated waste is source-separated bio-waste. The bio-waste originates from Lübeck city and different counties in the federal state of Schleswig-Holstein while the residual waste mostly originates only from the Lübeck city. The treatment of residual waste is special for its kind since, after a pre-treatment and removal of major impurities, it also comprises an anaerobic treatment followed by stabilisation (aerobic treatment of the digestate). The stabilised digestate is being landfilled. In both lines, the impure fractions are sorted in the mechanical pre-treatment and further sorted to be recycled or incinerated. The treatment of bio-waste consists of a mechanical pre-treatment followed by anaerobic digestions to produce biogas and a composting of the digestate with green waste. The mass flow of the bio-waste generated in Lübeck City is summarized in Figure 9.

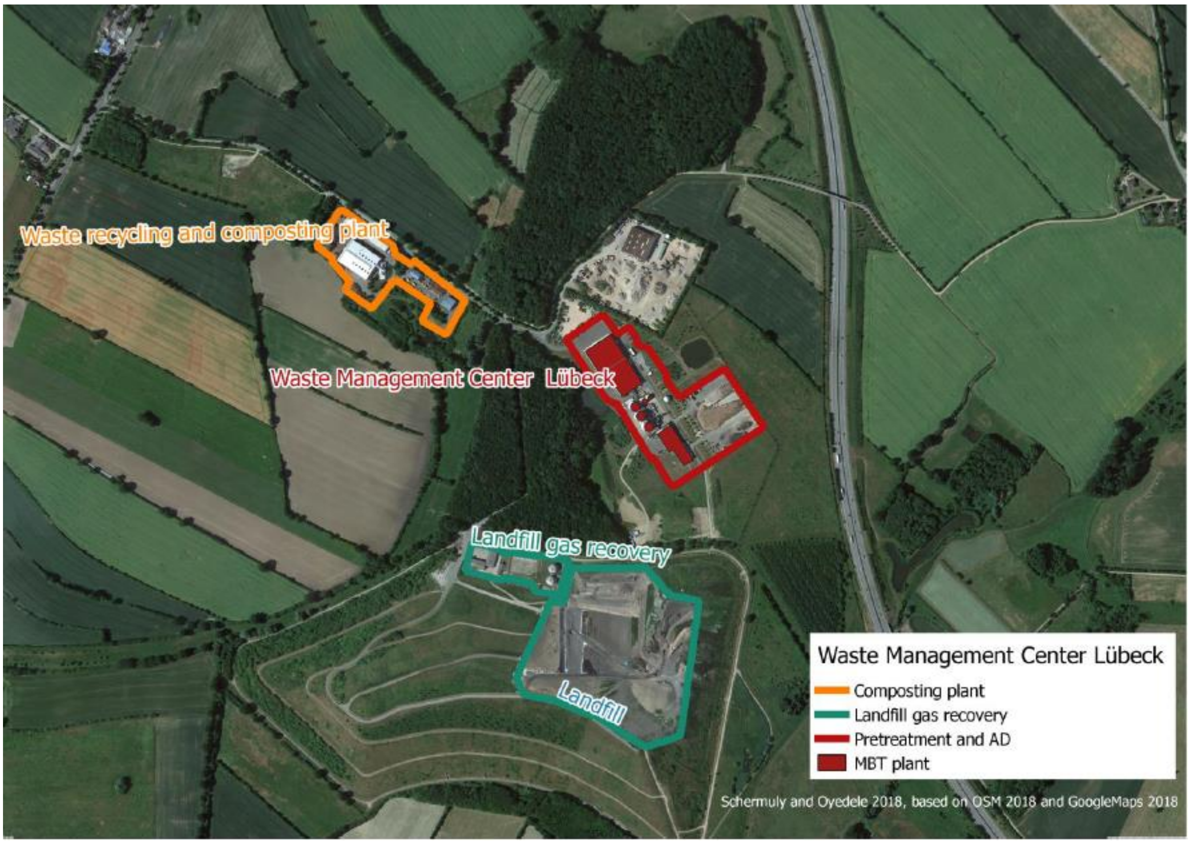


Figure 8 - Overview of the waste-management centre of the city of Lübeck.

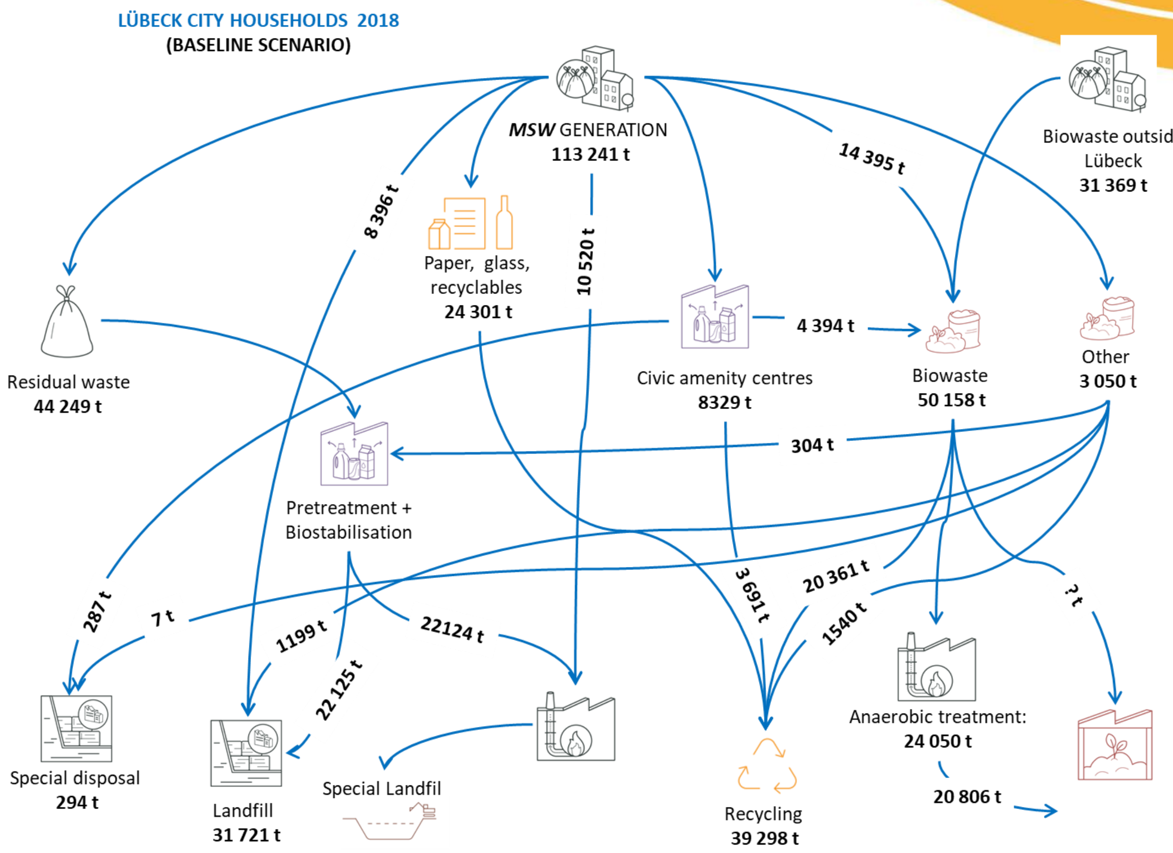


Figure 9 - Flow diagram representing the current waste management system in Lübeck City (2018 data).

Waste process libraries of current waste management system

The data collected cover the whole city area of Lübeck and additional areas in the federal state of Schleswig-Holstein where biowaste is coming from to be treated in Lübeck's waste treatment plan. Those are amongst others Kiel and Steinburg. For the treatment, the municipal waste management of Lübeck (Entsorgungsbetriebe Lübeck, EBL) also receives biowaste from surrounding municipalities. The data originate directly from EBL or were requested to INFA, a waste management consultancy company (https://infa.de/), e.g., for waste composition analysis. The data include source-separated biowaste and residual waste. Paper waste is not included but is also collected by EBL. The recyclable waste of Lübeck is collected by a private company (VEOLIA).

The annual data includes the different streams entering and leaving the treatment plant while the specific analysis includes the fractions contained in the waste streams, being food waste, garden and park waste etc. The waste collected by EBL originates from households and small companies. In Germany larger companies can choose whether they want their waste treated by a private or public company.

Tables with the inventories of the waste management system related to the baseline scenario for the Lübeck city can be found at the following link: Lübeck City Baseline inventories.xls.

Analysis of the suitability of the DECISIVE system

The potential application of the DECISIVE system is mainly linked to the key stakeholder EBL (Entsorgungsbetriebe Lübeck), which is in charge of Lübeck's biowaste management. Waste management in Lübeck is mostly centralised and there are plans to even expand the plants' size to include more biowaste from other surrounding municipalities. However, there is still a large potential, especially for food waste, in the residual waste stream. In order to shift these amounts to biowaste, new and innovative solutions have to be found. Multi-family houses are amongst those housing types with the worst sorting performance. One reason is the anonymity and the use of one bin by many residents, which can be a demotivational issue for good sorting if only one resident is not following the sorting rules. Furthermore, impurities are still an issue in Lübeck, especially for the marketing of compost. Sorting technology at the plant is very modern but also cost and energy intense. Therefore, the DECISIVE system, at least for one site, could be seen as an educational building block that would be incorporated into Lübeck's centralised waste management.

Other stakeholders, such as city planners and regional politics show interest in climate friendly solutions. New city districts are planned with the aim of being self-sufficient from the energetic point of view, however biowaste treatment was not yet included.

To study the feasibility of the implementation of a DECISIVE system in Lübeck city, the most relevant stakeholders were identified:

- Lübeck waste management (EBL): main player in local waste management. In the example of Lübeck, this is EBL. They are not only responsible for collection but also treatment and product marketing. There is less interest from EBL in implementing decentralised systems such as a DECISIVE package or just limiting the implementation in one site for educational purposes.
- Regional public authorities: it describes local politics/government or city administration and urban planning. This can be political parties, ministries and the associated policy objectives. Public authorities seemed to be very interested in the DECISIVE system, mainly to include it for planning new "climate neutral" city neighbourhoods.
- Architects: a branch of industry that deals with the design of materials that are included in the concepts. Architects focus on the design of kitchens and waste collection areas.
- Interest groups including NGOs: it refers to organised interest groups in the field of biowaste management such as ECN or "Wir für Bio". They are concerned, for example, with policy making or communication strategies.
- Education/training centres and schools: schools that train in waste management professions, but also general schools.
- Farmers: they are the main users of the products of biowaste management.
- Local food suppliers: they are selling farmers' products.
- Property management: housing association/cooperative or property management. They manage or rent apartments/houses, to either third-party or private entities. They can have educational tasks but also organise waste collection
- Facility management: it takes care of any facility, cleaning, organisation etc.
- Waste generators: those who need to be willing to enter a new system. Education for waste related matters is key.

Definition of scenarios

For the **baseline scenario,** BW generated by households is around 35,751 ton/year while 17,037 ton/year is source separated in a DtD system in bin of 120L for BW and 240L for RW. BW source separated and residual waste are collected in trucks of 18 m^3 of capacity and sent to the MBT plant in Niemark respectively to the biowaste line and the residual line of this installation. Niemark is about 8 km away from Lübeck. An internal excavator of 2 ton of capacity transports for 0.2 km the pre-treated BW to the wet continuous AD plant in Niemark. The solid refuse outputs of the MBT plant are sent to Neumünster incineration (74 km away), the landfill of Lübeck waste management centre (1 km away), to recycling centres (estimated 3 km away) and the wastewater of Lübeck waste management centre (1 km away). Compost obtained from the Niemark MBT biowaste line is used as a soil amendment. For the rest of transportation, it is assumed that trucks with a capacity of 14 ton and average speed of 59 km/h are used.

For the **alternative scenario**, the current waste management system would be combined with the alternative one. It was assumed that around 2% (849 ton/year) of the total generated biowaste (35,751 ton/year) would be source separated and sent to decisive systems. The collection system would remain unvaried since in Lübeck City the DtD system is already correctly implemented. Since the mAD DECISIVE system can annually treat 50 ton of source separated biowaste, this means that 17 units would be needed around the Municipality of Lübeck in a radius of 0.5 km from the biowaste generation places. It was assumed that the source separated biowaste would be sent to the decentralisation by using an electric vehicle of 0.65t of capacity. The solid digestate produced by the DECISIVE system would be then used as compost since it would have been exposed to hygienisation during the process while the liquid fraction would be sent to a wastewater treatment plant (on average 1 km away from the decentralised systems). Part of the solid digestate would be used to produce organic amendments and biopesticides that can substitute fossil pesticide use.

The multicriteria assessment implementing the DECISIVE system in the Lübeck City was compared to the performance assessment of the current waste management system by using the DST, and the results are shown in section 5.

3.4 SITE 4 - DOGNA MUNICIPALITY

Description of the site

Dogna is a small Italian municipality of 165 inhabitants placed in the north-east of Friuli Venezia Giulia region (Figure 10). Its territory (area = 69.18 km^2) is mostly mountainous and attracts hikers and bikers as well as history lovers (these areas were border territories during the WWI).

Figure 10 - Dogna location in Friuli Venezia Giulia Region (source: A&T2000).

Dogna is characterised by a low inhabitant density (2.29 inhabitant/km^2), due to its mountainous territory. Almost the entire village is located not far from the Fella's and Dogna's riverbed. Due to hostile territory and the low number of inhabitants, Dogna's municipality has no industries but there are, as main commercial activities, holiday farms managed by the local population.

In Dogna, municipal waste is separately collected in road containers differentiated by fraction (biowaste, glass, paper, plastic plus can-packaging and residual waste). The different types of waste are collected based on a specific calendar: organic and residual waste are collected once a week while glass, paper, plastic plus can-packaging waste are collected once every two weeks.

Paper, glass, plastic plus can-packaging are sent to a selection platform before going to recovery facilities while the residual waste is directly sent to a waste-to-energy plant located in Trieste, 140 km away from the municipality.

Before 2020, the biowaste produced in Dogna was transported to an anaerobic digester plant that is almost 90 km away. The composting plant treats about 31,000 ton of biowaste per year. The plant operation is based on “biocells” technology. First stages of waste treatment (anaerobic biodegradation and aerobic bio-oxidation) take place in separate confined environments (biocells), which prevent the emission of odours into the surrounding environment. In the first phase named “anaerobic digestion (dry technology)”, the organic fraction is treated to generate biogas which will be used to produce electricity through motors. During the second stage, the aerobic treatment, a quality compost is produced to be placed on the market. Now, the compost is given for free to locals as a form of compensation for the presence of the plant on municipal territory.

Since December 2020, the biowaste produced by household and commercial activities has been collected in composters placed at specific points in the village not far from the other waste bins. Periodically, the biowaste deposited in the composters is collected and transported in a dedicated municipal area where it is mixed with green organic material that, over the months, will turn the entire material into compost.

Even before the implementation of community composters, households and commercial activities were required to not use plastic bags to deliver the biowaste or only use paper or biocompostable bags. Indeed, whilst plastic bags are not easily removed from the biowaste during the composting process, paper and certified biocompostable bags are preferable for their compostable characteristics since they do not interfere with the composing process.

In both cases, A&T2000 asked the households and commercial activities not to use plastic bags to deliver the biowaste or only use paper or biocompostable bags. This choice is because bags and biowaste are not divided during the composting process.

During 2018, in Dogna municipality 70 ton of MSW were generated: 25 ton of residual waste, 32 ton of source-separated waste in road containers (14 ton represents biowaste) and 13 ton of separated waste collected in civic amenity sites. Figure 11 shows the mass flow of the MSW in Dogna municipality.

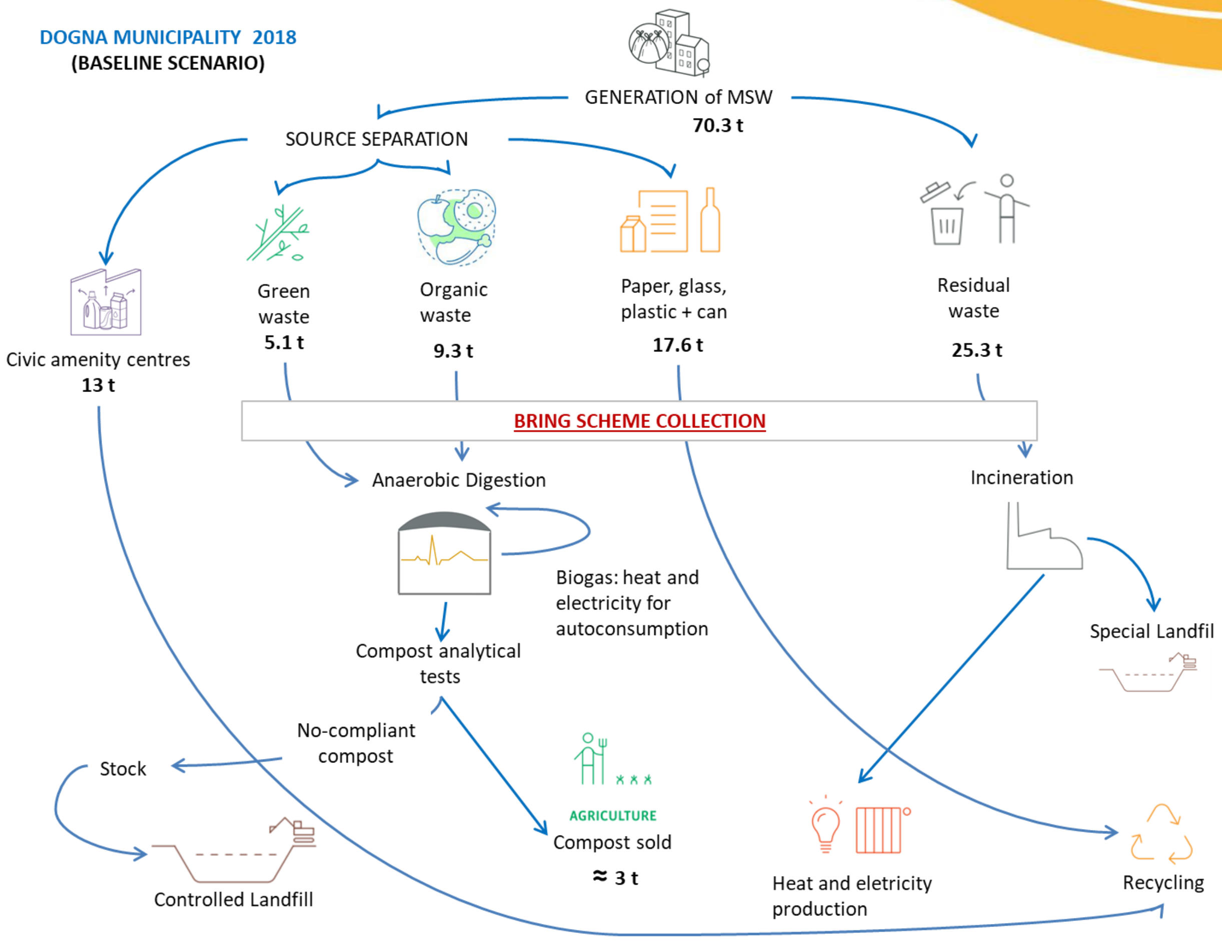


Figure 11 - Flow diagram representing the current waste management system in Dogna Municipality (2018 data).

Waste process libraries of current waste management system

Data collected for building waste processes libraries cover Dogna municipality in 2018. Data refer to the urban biowaste (produced by households) and the biowaste assimilated in urban waste (e.g., canteens from schools, and companies). Part of the gathered data are based on A&T2000 S.p.A. database that is yearly updated to properly manage biowaste collection and treatment.

When real data were not available in A&T2000 database, they were obtained thanks to the collaboration of the company with the managers of anaerobic digestors plants present in Friuli Venezia Giulia Region. Data about waste treatments were obtained looking both at installations' database and the environmental authorisation of the plant of Bioman S.p.A. In case of data unavailability, inventories related to similar plants were used.

Tables with the inventories of the waste management system related to the baseline scenario for Dogna Municipality can be found at the following link: Dogna Municipality Baseline inventories.xls.

Analysis of the suitability of the DECISIVE system

To analyse the possible benefits in implementing DECISIVE system in Dogna, a performance analysis of the current biowaste management is required. In Dogna there is already a community composting, which consists of a decentralised biowaste management system where the food waste is treated on site to produce compost for inhabitants.

The most relevant stakeholders were identified in household and commercial activities in the municipality. This classification can represent a first step for the potential application of the DECISIVE system in the Municipality of Dogna.

Definition of scenarios

For the **baseline scenario**, BW generated by households and commercial activities is 28 ton/year while 16.8 ton/year is source separated and delivered in road containers of 2,200 L. BW source separated is collected in a truck of 18 m^3 and sent to an AD plant (82 km away) without any pre-treatment. The same types of truck collected RW that is directly sent to an incineration plant 149 km away. From the AD plant, the outputs are sent to landfill (5 km away) and to a wastewater treatment plant (80 km away). For all transports, it was assumed to use a truck with capacity 14 ton and average speed of 59 km/h. Compost obtained from the AD plant is used as a soil amendment.

For the **alternative scenario**, the current waste management system would be substituted with one unit of DECISIVE system (50t/year) that would be placed 1km away from Dogna Municipality. It was assumed that the source separated biowaste would be sent to the decentralisation by using an electric vehicle of 0.65t of capacity. It is assumed an improvement in the collection system. In fact, the bring scheme for both the SSBW and the RW would be substituted by DtD system. Containers of 2,200 L would be substituted with bins of 25 L using mater-bi bags for BW and 70 L bins for RW using bags of 70L. It is assumed that around 80% of generated biowaste (28 ton/year) would be source separated and sent to be treated to the decentralised alternative unit. It is assumed that the RW would be sent to the incineration plant as in the baseline scenario. The solid digestate output from DECISIVE, would be used as compost while the liquid fraction would be sent to a wastewater treatment plant (60 km away). Part of the solid digestate could be used to produce organic amendments and biopesticides that can substitute fossil pesticide use.

The multicriteria assessment implementing the DECISIVE system was carried out and compared with the performance assessment of the current waste management system in Dogna Municipality by using the DST. The results are in chapter 5.

3.5 SITE 5 - RENNES MÉTROPOLE

Description of the site

Located in the centre of the department of Ille-et-Vilaine, the intercommunity of Rennes Métropole (RM) brings together 43 municipalities (Figure 12). According to INSEE, France's National Statistics Institute, the metropolis covers 70,494 hectares (19% of the territory in 2004) and reached 443,192 inhabitants in 2018. The RM ranks 4th among metropolises behind Montpellier, Bordeaux, Nantes and ahead of Toulouse and Lyon. The poverty rate in Rennes Métropole is 11.3% against 15.15% on average for all French metropolises. After Toulouse, it is the metropolis with the youngest population in France.

Capital of one of the most dynamic regions in France, with an economic area that concentrates 300,000 jobs and has an unemployment rate 2 points lower than the national average. Open to the world, Rennes is the leading (RM Annual Report Summary, 2018) higher education centre in the West, with 63,000 students. The city is renowned for its quality of life, the richness of its cultural program, the diversity of its heritage, its offer around contemporary art and the effervescence of its student life.

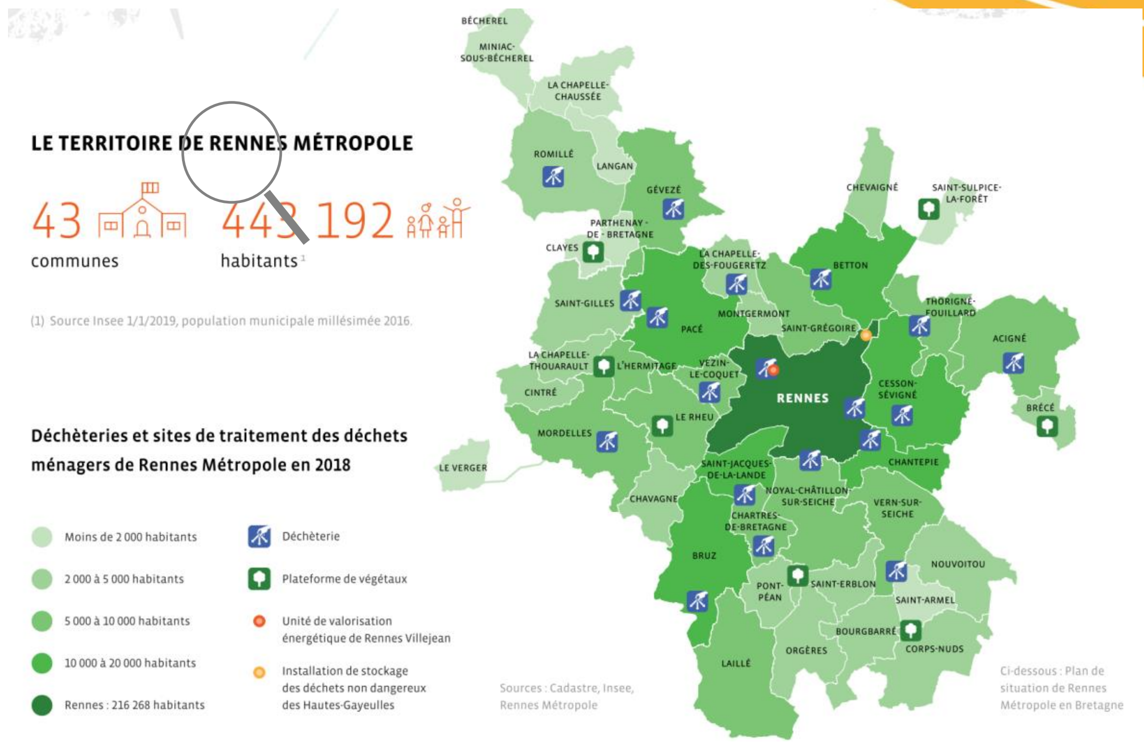


Figure 12 - Location of the RM, population density (green gradient), drop-off sites (blue points), composting sites (green points), incinerator (red point) (RM Annual Report, 2019).

For many years, RM has had an active communication policy to reduce the production of waste and increase the recovery of wastes that cannot be avoided.

In July 2018, 44 new household waste collection trucks running on natural gas were put into operation. This strong political choice reduces the environmental impact of collection (-95% fine particles, -80% nitrogen oxides) and contributes to developing a network of natural gas stations for vehicles in the metropolitan area.

Biowaste is collected with municipal solid waste (i.e., there isn't a biowaste source separation); 81% of people use containers to collect residual waste while 19% use voluntary drop-off points (near buildings or in residential areas). The minimum volume of a container is 140 L (range from 140 L to 770 L).

In 2018, 45% of the MSW carried out energy valorisation, 14% carried out mainly composting, 23% material valorisation (e.g., source separated waste fractions sent to recycling) and 18% was landfilled (RM Annual Report, 2018).

The operation of the Rennes Villejean incinerator, around 3.5 km away from the centre of RM and around 25 km from the farthest area of the RM, has been entrusted since 2018 to the company ValoReizh under a public service concession. Equipped with three ovens operating 24/7, in 2018 the incinerator treated wastes from Rennes Métropole, neighbouring communities and private companies. The waste quantity from household origin attained 90,602 ton in 2018. The energy recovered from the combustion of waste is used in two forms: heat and electricity (principle known as cogeneration). The districts of "Villejean and Beauregard" and the hospital centre of "Pontchaillou" are thus covered by the heating network (district heating and domestic hot water) for an amount equivalent to 20,000 housing units.

The residents usually have free access to the Civic amenity centres (Figure 12) since 2012. SMEs such as garden maintenance companies (production of green wastes) and construction companies (production of rubble) for instance are allowed to deposit their wastes paying a financial contribution.

A complementary DtD green waste collection is a service offered in the urban centre due to a lower density of collection equipment in this sector and 2,250 ton were collected in 2018. This amount of green waste is sent to 7 composting plants located between 10 and 15 km away from city centre.

In addition, the collection of recyclable waste at voluntary drop-off points serves 35,540 households and 650 professionals. Started in 2005, the installation of underground containers continues. The installation of these facilities is more expensive than conventional containers but more acceptable from the aesthetic point of view, easier to reach and to use and have a longer lifespan. Material recovery from civic amenity centres increased by 2.9% in 2018.

In RM, home composting is encouraged for a long time. Individual composting has been incentivised since the end of 2015 by free provision of composters (2,005 composters were distributed in 2018). Collective composting at the bottom of buildings and in subdivisions is also fostered as demonstrated by the installation of 37 new composting areas in 2018 (altogether, RM counts a total of 479 community composting areas). RM has also been collecting food waste from professionals since 2016. Commercial restaurants, school canteens, markets, retirement homes and food shops are targeted and five new areas of composting in collective catering were added in 2018 (57 in total). It was initially a question of allowing these large producers (more than 10 ton per year) to meet their obligation of source sorting and recovery. The involvements of participants, the feedback to them and, ultimately, the quality of the sorting, have led to the implantation of source collection of biowaste since mid-2017. Unfortunately, no sufficient data are available about the quantities or qualities of biowaste sent to home composting and the characteristics of the system.

The flow diagram in Figure 13 represents the current waste management system in place in Rennes Métropole.

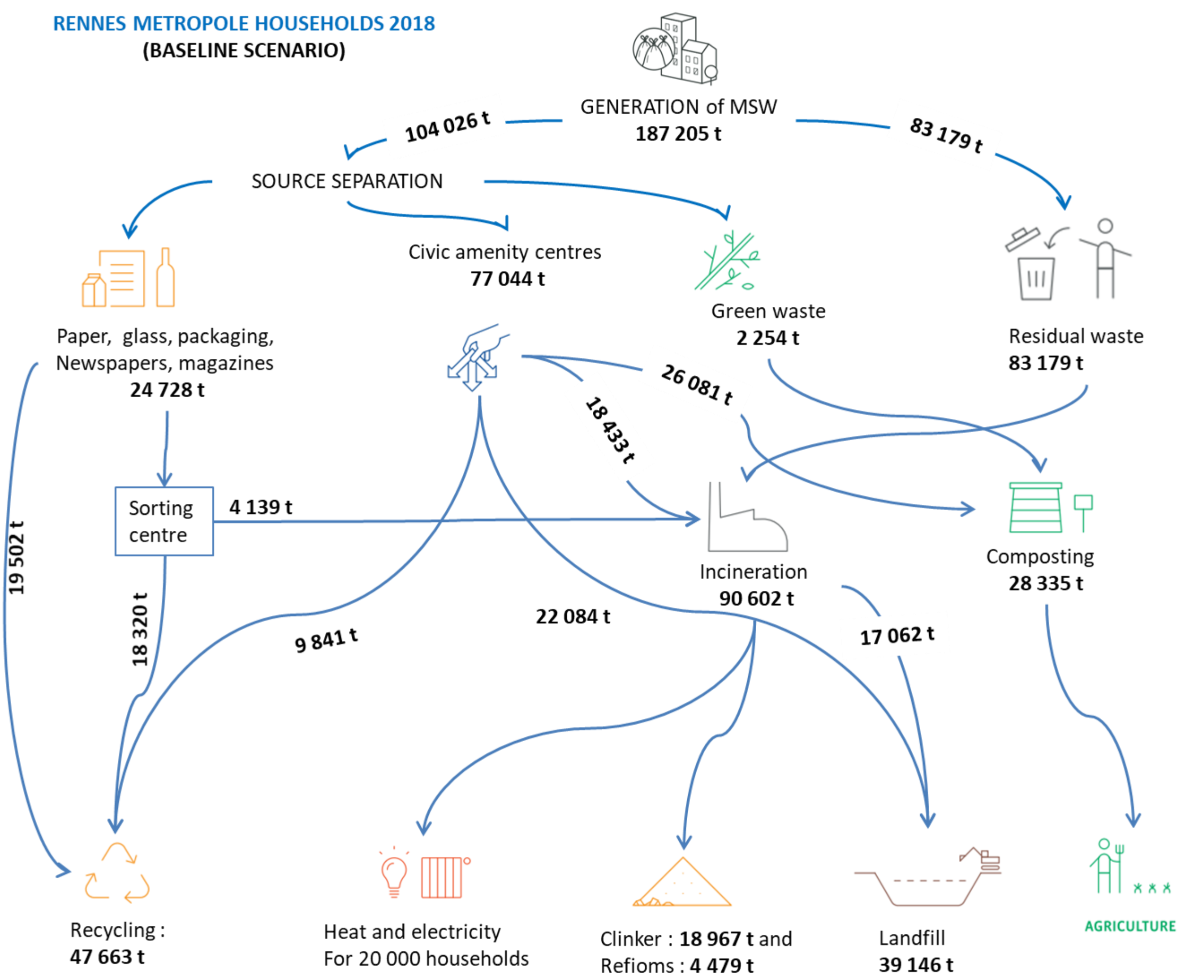


Figure 13 - Flow diagram representing the current waste management system in Rennes Métropole (data 2018).

Waste process libraries of current waste management system

The data collected covers the entire Rennes metropolitan area. The data mainly comes from a public report drawn up each year by those responsible for waste management in the metropolis. The last one was published recently and refers to 2019 (RM Rapport, 2019). However, as data collection started before this updated report was released, the database was based on the previous similar report with data from 2018. In addition, the help of Rennes Métropole Services was necessary to provide data on direct emissions from the incinerator (As, Cd, Pb, Hg, etc.).

Tables with the inventories of the waste management system related to the baseline scenario for RM can be found at the following link: Rennes Métropole Baseline inventories.xls.

Analysis of the suitability of the DECISIVE system

Rennes Métropole pursues an active communication policy in order to reduce waste production and increase the recovery of wastes that cannot be avoided. Community composting has been in place for several years. Individual composting is encouraged, composting at the foot of buildings and in subdivisions is also favoured to reach a total of 479 community composting areas and 57 collective catering composting areas have been created to enable large producers (more than 10 ton per year) to meet their obligation of source sorting and recovery.

To study the feasibility of the implementation of a DECISIVE system in RM, the most relevant stakeholders were identified. A person responsible for waste management was interviewed about the possibility of introducing the alternative DECISIVE system. Because composting has long been encouraged in RM, they see this new option of another decentralised system as an attractive alternative but are not yet ready to implement such technology. At the moment, they prefer to devote efforts to preventing the quantity of waste and to improving their offer by developing different scales of composting technologies (home composting, composting at the foot of buildings, semi-centralised composting platforms, composting platforms of green waste). However, they imagine the feasibility of a new decentralised system, based on micro-AD units, located in new districts or eco-districts specifically designed with waste management in mind. For composting as for the AD, the main problems are related to the valorisation of the digestate in particular regarding the traceability and health standards. Without a hygienic step, it can only be used on site.

Definition of scenarios

For the **baseline scenario**, BW generated by households and commercial activities is around 33,775 ton/year while 2,254 ton/year is source-separate green waste that is delivered to civil amenity centres. The rest of biowaste is mixed with RW, which is collected in DtD bins of 120L. The source-separated green waste (the only portion of BW source separated) is collected in diesel trucks of 18 m^3 and sent to a composting plant (4 km away). Natural gas trucks of 22 m^3 collect RW that is directly sent to an Incineration plant 14 km away. Neither pre-treatment of RW or GW nor trucks for transportation post-treatment and pre-treatment have been considered for this scenario. Compost obtained from the composting plant is used as a soil amendment.

For the **alternative scenario**, the current waste management system would be combined with the alternative one. It is assumed that around 2% (676 ton/year) of the total generated biowaste (33,775t/year) would be source separated in DtD systems (bins of 120 L) and sent to DECISIVE systems. In the baseline scenario, green waste would be sent to civic amenities and then to composting. The rest of BW included in the RW woulb be still sent to incineration as in the baseline scenario.

Considering that the annual capacity of the mAD is 50 ton, around 13 units would be needed in the Rennes Métropole with a radius of 1 km from the biowaste generation places to treat the source-separated biowaste. It was assumed that the source-separated biowaste would be sent to decentralised facilities by using an electric vehicle of 0.65 ton capacity. Solid digestate produced from the mAD would be used as compost while the liquid digestate would be sent to a wastewater treatment plant (on average 6 km away from the decentralised systems). Part of the solid digestate would be used to produce organic amendments and biopesticides that can substitute fossil pesticide use.

3.6 SITE 6 - VALL D'HEBRON HOSPITAL

Description of the site

There are a total of 69 public hospitals in Catalonia, of which 26 are in the metropolitan area of Barcelona (AMB). Hospitals usually have their own kitchens to prepare the meals for admitted patients and restaurants for visitors and canteens for staff. Waste composition differs in the various cases. Some of the hospitals run teaching activity as the university hospitals, in those cases the population is incremented by the presence of students (Gencat Salut, 2021).

The waste produced in hospitals is large and diverse, and high part of it can involve health hazard being then of main concern. Municipal waste is totally separated from the other categories of waste generated in the hospitals and it is managed in conventional facilities, particularly biowaste. The biowaste generated has its origin in different places, as restaurants and cafeterias and large kitchens for staff and patients admitted to the hospitals.

The waste, including biowaste, is collected by private companies that transport it to plants to be adequately treated. Most of the hospitals have records of the waste collected and the related cost. Biowaste is mainly produced in the kitchens and restaurants. The waste produced per person in hospitals is considered to be higher than for other activities (ARCASA Hospital German Trias y Pujol, 2017). Private hospitals, residences for elderly people and other activities related with health could be potential sites where to implement a DECISIVE system.

Two hospitals were pre-selected as theoretical sites in D6.3, Hospital de Vall d'Hebron (Barcelona city) and Hospital Germans Trias i Pujol (Institut Catalan Salut, 2018) (Badalona, Barcelona), but only Vall d'Hebron was selected to be simulated in this deliverable because the source separated biowaste has lower impurity content than that from Hospital Germans Trias i Pujol.

Vall d'Hebron Hospital (Hospital Vall d'Hebron, 2018) is located in Barcelona city, near the west limit with Collserola Park. The hospital campus holds specific units in different buildings, the Faculty of Medicine and several research centres. This hospital receives more than 1,200,000 patients per year of which up to 1,100 can be accommodated in the different buildings; the total staff is over 9,000 professionals. During 2018 a total of 67,646 patients were admitted (90% occupancy) with an average of 7.4-day stay. Primary health care was dedicated to 923,403 patients and 204,537 cases were emergencies. Figure 14 shows the area of the whole premises.

Figure 14 - Location of Vall d'Hebron Hospital.

In the area of the hospital there are seven main buildings and four public cafeterias. These buildings include the cafeterias but also the canteens for staff and for the preparation of meal for the patients accommodated. Altogether, more than 10 buildings are related to food preparation and consumption, with different activities.

The municipal waste generated in Vall d'Hebron Hospital is sorted into the different categories inside the hospital premises and collected separately. The main streams are paper and cardboard, plastic and packaging, biowaste and residual waste.

The biowaste generated is separated in the premises of the hospital. The yearly biowaste separately collected is about 236 ton, which is produced mainly in the kitchen where food for admitted patients and staff is prepared. The biowaste is collected by a private agent and transported to the Composting Plant of Torrelles de Llobregat, which is located 20 km away from the hospital. Refuse generated from sieving and sorting during the composting process in Torrelles plant goes to Mataró incineration (48 km away) and to Vacarisses landfill (35 km away).

The quality of biowaste is assessed through periodic characterisations to determine the content and typology of impurities. As an example, two characterisations of the biowaste from kitchen and restaurants performed during 2019 showed that the content in impurities of the biowaste is below 10%. Main impurities come from plastic bags and other waste fractions. Impurities content decreased from 8.46% (April 2019) to 4.64% (October 2019).

The biowaste collected is treated by means of composting in dynamic windrows, after mixing with pruning waste as complementary material. The process takes about 90 days in two stages (decomposition and maturation) before obtaining the compost. The compost produced in the facility is about 10% of the input materials (biowaste and green waste) while the refuse is about 10%. It is worth noting that a large part of the input material is lost as gases (CO_2, vapour) due to the microbial activity of transformation of biodegradable organic matter.

The flow diagram in Figure 15 represents the current waste management system in place in Vall d'Hebron Hospital.

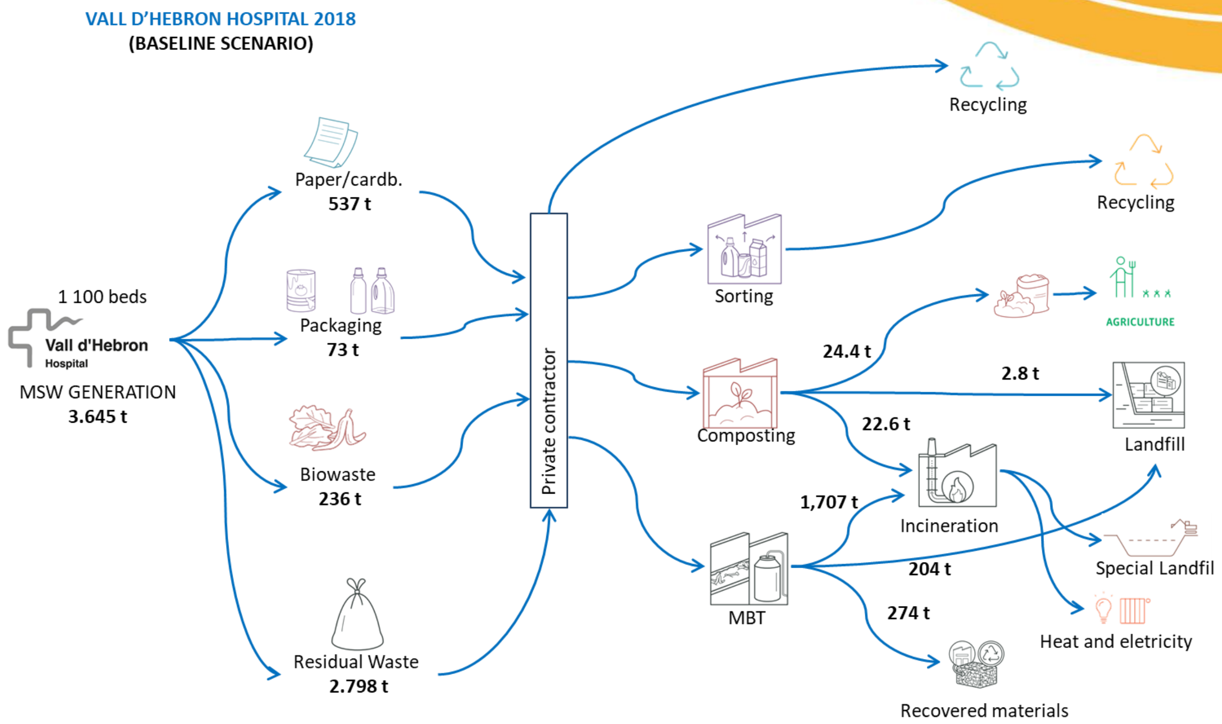


Figure 15 - Flow diagram representing the current waste management system in Vall d'Hebron Hospital (2018 data).

Waste process libraries of current waste management system

Data about Catalan hospitals were collected from the database of ARC SDR and from the interviews with the people in charge of waste management. Details about the generation of waste and separate collection and particularly the characterisations were obtained from SRC database, where records of the periodic characterisations are carried out. Hospital managers provided more details about of waste generation and separate collection. In both hospitals, interviews were arranged with the people in charge of waste management to determine other aspects related to waste generation and collection as capacity of the hospital, served meals, distribution of systems for collection of waste, etc.

Tables with the inventories of the waste management system related to the baseline scenario for Vall d'Hebron Hospital can be found at the following link: Vall d'Hebron Hospital Baseline inventories.xls.

Analysis of the suitability of the system

For the selected hospitals, the convenience of implementing the DECISIVE system requires a performance analysis of the current waste management system compared with the alternative one. However, Preliminary considerations can be done regarding the suitability of the proposed system.

To study the feasibility of the implementation of a DECISIVE system in the selected hospitals, the most relevant stakeholders were identified. The organisations' managers for waste management in the hospitals were interviewed about the possibility to introduce the alternative DECISIVE system. Based on their declaration and for a first analysis of the situation in each case the following considerations were made. It is worth highlighting that in the real case of deciding about the suitability of introducing such a change in the waste management system currently in place in the hospitals, the opinion of public administration would have been considered since both hospitals are public.

The location in a compacted and urbanised area and the facility of collection offered by the municipality to private companies could discourage the implementation of the DECISIVE system in Vall d'Hebron Hospital, particularly regarding the safety and the necessary room to avoid risks. On the other hand, this hospital is more than 60 years old and currently is undergoing some refurbishments. Nevertheless, these changes do not include a significant modification as would be required by DECISIVE (e.g., to improve the separate collection).

In the case of Germans Trias i Pujol Hospital, the biowaste generated is produced in enough quantity to be treated locally even if the quality should be improved to reduce impurities, particularly those coming from unsorted packaging. Regarding this aspect, it is worth noting that biowaste collected in the kitchen comes from both preparation of food and the residual waste on the plates that the admitted patients produce so conducting awareness campaigns could be a good measure to improve the quality of sorted biowaste. The managers of this hospital showed their interests in developing systems towards self-sufficiency and environmentally friendly work. In this case, the decentralised treatment, could incentivise an improvement in the quality of biowaste separately collected and provide, in the best operational conditions, energy could be used locally.

Definition of scenarios

For the **baseline scenario**, BW generated by the hospital of 1,100 beds is 284 ton/year while 53 ton/year is source separated. The unit of generation selected for this case study is "bed". Waste collection is DtD by using 21 buckets of 120L for source-separated waste fractions and containers of 1000L for residual waste. Source separated BW is sent to a composting plant while residual waste is sent to the mechanical biological treatment (Ecoparc2). Composting is around 20 km away from the hospital. From the composting plant, the residual outputs are sent to incineration (48 km away) and Landfill (35 km away). Residual fractions (i.e., outputs) of the mechanical and biological treatment are sent to Tersa incineration (22.8 km away), Tivissa landfill (174 km away), to recycling centres (estimated 3 km away) and Montcada i Reixac wastewater treatment plant (15 km away). For collection, it is assumed to use trucks with a capacity of 18 m^3, and for the rest of transportation it was assumed to use a truck with a capacity 1 of 4 ton and average speed of 59 km/h. Compost obtained is supposed to be used as a soil amendment.

For the **alternative scenario**, the current waste management system would be substituted with 4 units of DECISIVE system (50 ton/year) that would be located in the premises (0.2 km) of the hospital. It was assumed that the source separated biowaste would be sent by using an electric vehicle of 0.65 ton of capacity to the decentralised unit. It is assumed that the RW would be sent to the residual line of the Ecoparc2 as the baseline scenario. The current source separation and collection system would remain unvaried as DtD. The outputs from the DECISIVE package such as solid digestate would be used as compost according to regulation and considering that during the process the biowaste would have been pass through hygienisation while the liquid fraction would be sent to wastewater treatment. Part of the solid digestate would be used to produce organic amendments and biopesticides that can substitute fossil pesticide use.

3.7 SITE 7 - ZAGREB CITY

Description of the site

To analyse a city of Eastern Europe, the city of Zagreb was included in the definitive list of theoretical sites. The City of Zagreb is the largest city in Croatia with approximately 800,000 inhabitants and a density of 1,200 inhabitants/km^2. With the surrounding areas, the total population of the city is around one million inhabitants. It is the capital city and plays a significant role in the national economy, encompassing many different industries (including food and drink processing) and research centres. It also has a significant touristic activity, attracting about a million visitors each year.

Municipal wastes in the city of Zagreb are managed by a company called "Zagrebački holding d.o.o., Podružnica Čistoća" (ZCH). It is a city company whose purpose is the realisation of public cleaning service, collection, transportation, treatment and disposal of MSW from the city of Zagreb. For the processes of treatment, recovery and disposal landfill site Jakuševec – Prudinec is in use.

Biowaste separated collection has been progressively implemented in Zagreb, starting with a few households in 2017, and being extended to the whole city in 2019.

- Food waste is collected from several commercial activities and markets, as well as from households. For households, kitchen waste and green garden waste (grass, flowers, etc.) are collected together in a brown bin. However, leftovers from processed food, meat, fish, and dairy products are excluded from the brown bin and must be disposed in the residual waste bin.
- Garden waste is also collected from inhabitants in 10 civic amenity sites, and from public parks and gardens.
- Households are also invited to do home-composting for kitchen and garden waste. About 18,650 home composting units were distributed by the public waste company to households.

Biowaste collection from households is done once a week. Citizens were given 26 free 30-L biodegradable plastic bags, sent to their home address. Then, they are asked to put their food waste in paper or compostable plastic bags. The bags have to be put in wheelie bins (120 L, 240 L or 1,100 L) that are collected DtD. Residual waste collection is performed two to three times per week.

All biowaste is sent to composting. No data is available on the quality of the sorted biowaste. In 2021, the waste company implemented quality controls and contaminated bins are not collected, as a response to an increase of contamination.

The rest of biowaste is mixed with residual waste and sent to the landfill site "Jakuševec – Prudinec", which receives about 230,000 ton/year. It is operated in a proper way (with covers, collection of leachate and biogas), and is equipped with 3 gas engines with a capacity of 525 m^3 of gas/h/engine and a total installed power of 3MW. In 2017, it produced about 13,600,000 kWh of electricity.

The city and the public company do not own a treatment plant for biowaste, and biowaste treatment is subcontracted to private companies. In 2016, two composting plants treated the biowaste collected in Zagreb:

- The Markusevec plant, with a capacity of 10,000 ton/year, is an "open-air" composting site with windrows located at 10 km from Zagreb.
- The Prudinec plant which includes a closed, forced-air decomposition stage with a capacity of 2,000 ton/year, where hygienisation is performed. The maturation phase then takes place in stacked piles with forced aeration. Another part of the plant is a classical open-air composting plant in windrows, with a capacity of 25,000 ton/year. It is located at 8 km from the city centre.

The flow diagram in Figure 16 represents the current waste management system in place in Zagreb city.

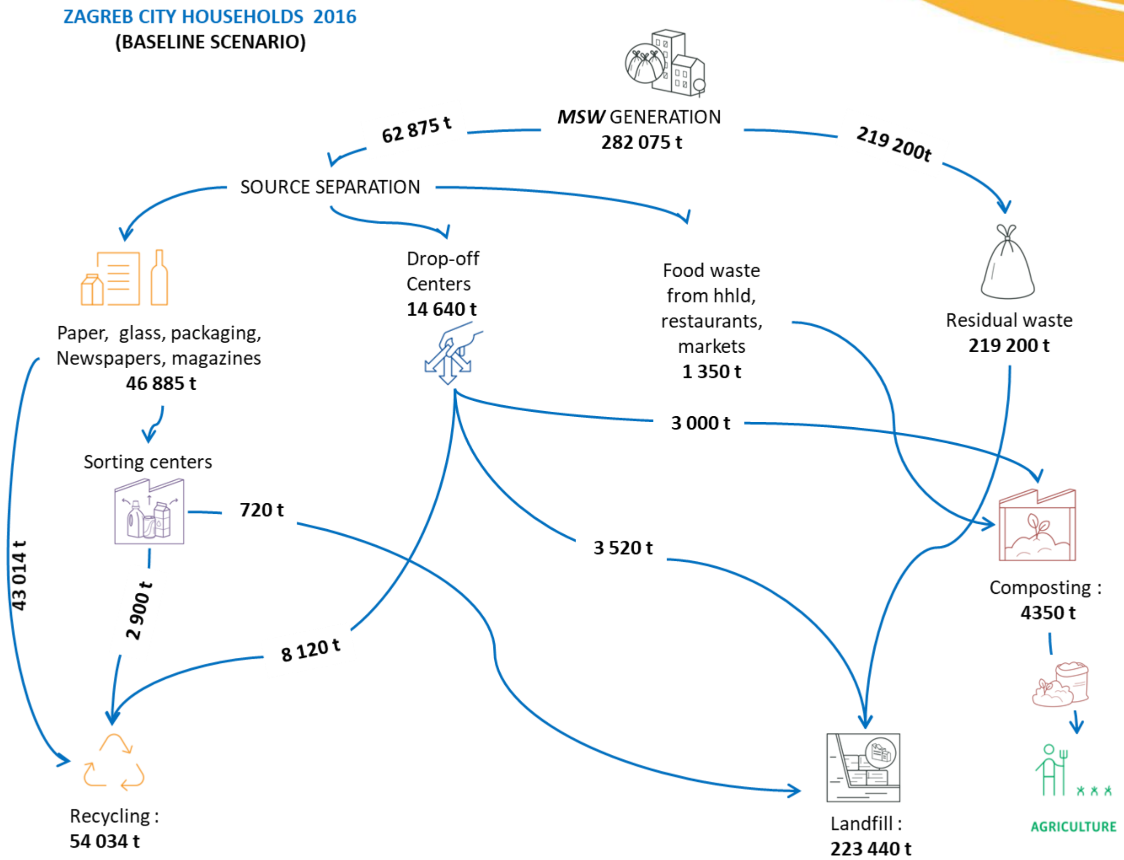


Figure 16 - Flow diagram representing the current waste management system in Zagreb City (2016 data).

Waste process libraries of current waste management system

Data included in the waste processes libraries encompass the biowaste managed by ZCH, the public company handling municipal and commercial waste in Zagreb. It includes household waste, as well as waste from restaurants, markets, public garden. The data on waste generation comes from assessment done within the framework of the EU project Bin2Grid (Bin2Grid, 2016, 2017, 2017a) while the collected quantities are those reported by ZCH in its annual report (Cistoca, 2017), and in the waste management plan of the city (Grad Zagreb, 2018). These different sources, provided by ZCH, were used to assess the total generated quantities of kitchen and garden waste, and identify the waste streams of sorted and unsorted kitchen and garden waste. The presented data are from 2016, which were the latest available when data collection took place.

Biowaste collection has made some progress since 2016. In 2020, about 26,000 ton was collected from households (compared to 1,350 ton in 2016). The quantities collected have increased by more than 300% between 2019 and 2020.

Tables with the inventories of the waste management system related to the baseline scenario for Zagreb city can be found at the following link: Zagreb City Baseline inventories.xls.

Analysis of the suitability of the DECISIVE system

It is difficult to assess if the DECISIVE system can be implemented in Zagreb. It seems that the city is facing challenges to identify proper treatment units (with sufficient capacity and the right authorisation) to treat its increasing sorted quantities (tportal.hr, 2021). Therefore, there is a need for alternative solutions which makes the DECISIVE system interesting. However, the biowaste collection system seems to face difficulties with contamination (Dnevnik, 2021), which might make the biowaste unsuitable for the DECISIVE concept.

To study the feasibility of the implementation of a DECISIVE system in the city, the most relevant stakeholders identified were the public company in charge of waste management and the Municipality.

Definition of scenarios

For the **baseline scenario**, BW generated by households and food services is around 70,867 ton/year while 4,350 ton/year is source-separated biowaste (3,000 green waste delivered to civil amenity centres and 1,350 is biowaste collected DtD). The rest of biowaste is mixed with RW that is collected DtD in containers of 1000L. The source-separated biowaste is collected in diesel trucks of 18 m^3 and sent to composting plants of Markusevec and Prudinec (9 km away). Similar trucks are used to collect RW that is directly sent to landfill of Jakuševec 8.5 km away. Neither pre-treatment of RW or GW, nor transportation with trucks other that those used for collection have been considered for this scenario. Compost obtained from the composting plant is used as a soil amendment.

For the **alternative scenario**, the current waste management system would be combined with the alternative one. It is assumed that around 2% (1,434 ton/year) of the total generated biowaste (70,867 ton/year) would be source-separated in DtD systems (bins of 120 L) and sent to DECISIVE systems. The amount of green waste and source-separated biowaste sent to composting would follow the same destination as the baseline scenario. There would be a decrease in the amount of BW mixed with RW, which would correspond to the SSBW sent to decentralised facilities by using an electric vehicle of 0.65-ton capacity. The rest of the BW included in the RW would be still sent to landfill as in the baseline scenario. Considering that the annual capacity of the mAD is 50 ton, around 28 units would be needed around the Zagreb City in a radius of 0.5 km from the biowaste generation places to treat the source-separated biowaste. It was assumed that the source-separated biowaste would be sent to the decentralisation by using an electric vehicle of 0.65-ton capacity. Solid digestate produced from the mAD would be used as compost while the liquid digestate would be sent to a wastewater treatment plant (on average 4 km away from the decentralised systems). Part of the solid digestate would be used to produce organic amendments and biopesticide hat can substitute fossil pesticide use.

3.8 SITE 8 - BRUSSELS REGION

Description of the site

The Brussels Region (Région de Bruxelles Capitale) is one of the three Belgian regions. It is composed of 19 “communes” and encompasses about 1.2 million inhabitants in a small territory of 160 km^2. Almost the entire territory is urbanised, yet there are diverse typologies across the Region, as shown by the map displaying the density of population (Figure 17).

The Region encompasses very dense areas, mainly located in the centre, and less dense areas including single houses, located on the outskirts of the Region. As other big cities, Brussels City also welcomes significant numbers of tourists and daily commuters.

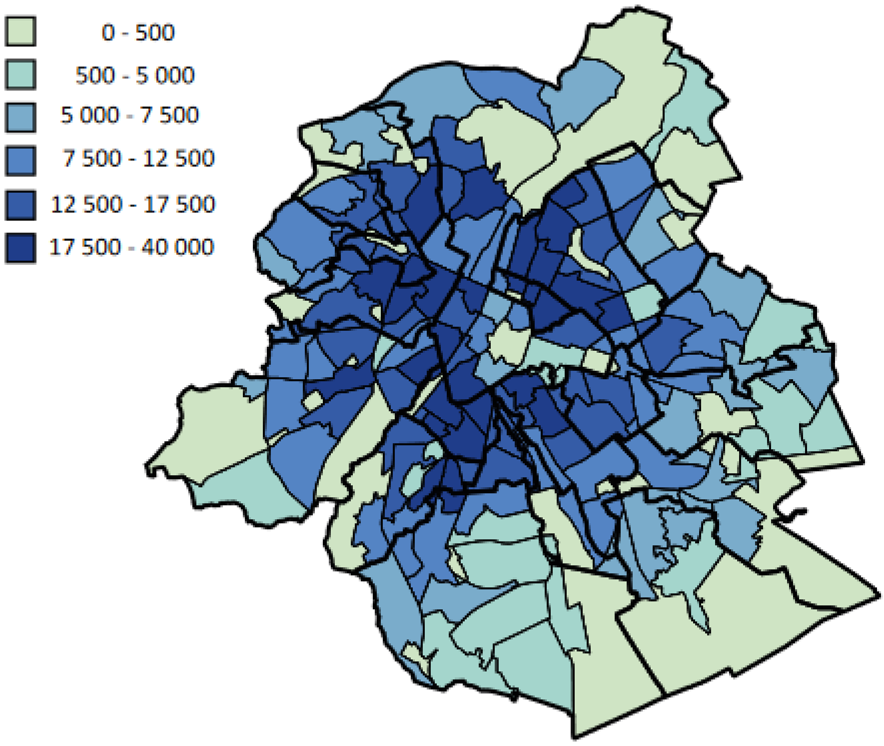


Figure 17 - Density (inhabitant/km^2) of the different districts in the Brussels Region in 2015 (Source: IBSA, 2017).

Municipal waste is managed by a public waste company, Bruxelles Propreté, which collects waste from households (including several civic amenity sites), and operates several treatment units: an incineration plant, two sorting plants (for paper and cardboard, and for mixed packaging waste), and one composting site treating garden waste. Bruxelles Propreté also collects waste from non-household sources (retailers, catering, etc.) that can decide to appoint it for the collection of their waste.

Bio-waste management is still quite limited in the Brussels Region, even though several schemes are already in place, namely:

- Food waste collection is proposed to households and commercial activities on a voluntary basis. It is collected with a DtD system on a weekly basis. Current participation rates are believed to be quite low. In some parts of the city (e.g., the denser areas), food waste is collected with garden waste. Currently, it is sent to a transfer station in the Region, and then to an anaerobic digestion plant in Flanders.
- Garden waste is collected with a DtD system on a weekly basis from households. It is treated on a composting plant operated by Bruxelles Propreté, which is owned by the public waste management company.
- Garden waste can also be brought to one of the five civic amenity sites by the inhabitants.
- Home-composting is well-developed, taking advantage of the presence of small individual gardens. About 16,500 ton per years would be composted at home or in decentralised composting units according to a local assessment[2]. On-site composting is also performed by several schools and restaurants, but the associated numbers are unknown. There are about 150 decentralised composting units where households bring their biowaste (excluding animal by-products - ABP). An average of 3 ton per unit has been measured by the organisation in charge of the coordination of the units.
- Several public parks compost their garden waste on-site.

[2] Data provided directly by Brussels Environment.

The rest of biowaste and garden waste ss collected with residual waste with a DtD system twice a week and sent to the incineration plant operated by the public waste management company. Regarding the treatment units, the following information is available:

- The composting plant is located in Forest (10 km from the centre of the city), one of the 19 communes, located in the south west of the region. The composting unit treats about 18,000 ton of garden waste per year, both from the selective collection of households and from private companies that can bring garden waste against a fee.
- The AD plant is located in Ypres, Flanders, 120 km from Brussels. It treats the food waste (and a small share of garden waste collected with food waste in a small part of the town). It is operated by a Flemish intercommunal group of municipalities, called IVVO.
- The incineration plant Bruxelles-Energie is operated by the public waste management company and processes mixed residual waste from households and assimilated producers. It is located in the northern part of Brussels.

The current management of biowaste in the Brussels region is summarised in Figure 18.

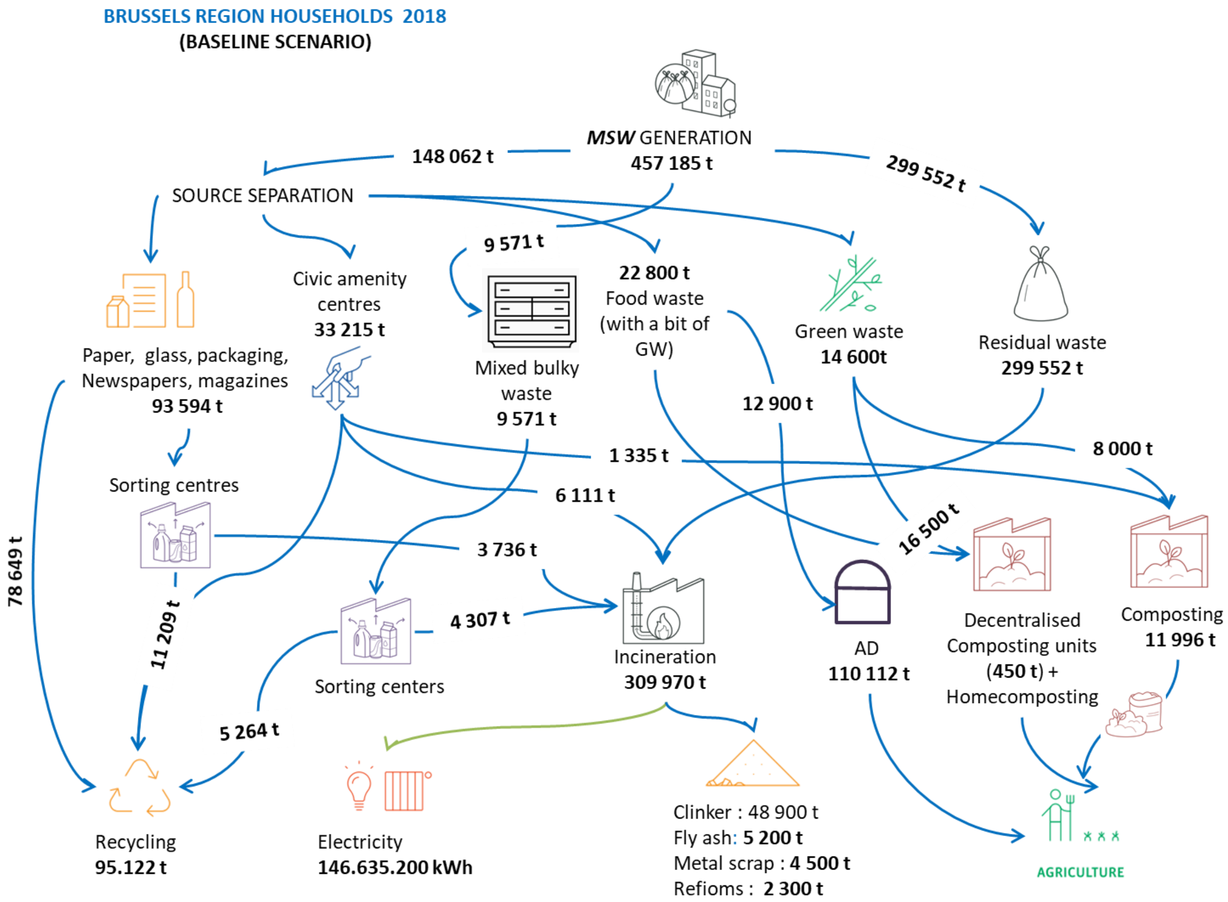


Figure 18 - Flow diagram representing the current waste management system in Brussels region (2018 data).

Waste process libraries of current waste management system

The data collected for building the waste processes libraries of this site cover the whole Brussels Region. They are based on various studies conducted by the regional environmental agency to design the biowaste management strategy. They include information on both:

- Food waste (with a distinction between waste including animal by-products – ABP; e.g., leftovers from meals or unsold food products, and food waste only including vegetable waste; e.g., uncooked waste from food preparation, or unsold fruits and vegetables).

- Garden waste (with a distinction between waste from the management of wooden areas, and waste from lawn management).

Data encompass various waste producers: households, schools and universities, offices and companies, healthcare, markets, public garden, HORECA (Hotel/Restaurant/Café), food stores. Some waste producers are not included, such as butcher shops, fish shops, micro-breweries, flower shops, bakeries. This is because their wastes are collected by specific collection services offered by private companies.

Tables with the inventories of the waste management system related to the baseline scenario for Brussels Region can be found at the following link: Brussels Region baseline inventories.xls.

Analysis of the suitability of the DECISIVE system

There seems to be a strong interest for a decentralised approach in the Brussels Capital Region. The latest regional waste plan (voted in 2018) indicates that decentralised systems are considered in parallel with a traditional, centralised approach. Community composting is being developed for several years, with about 180 units that are directly managed by groups of citizens. According to a survey (Brussels Environment, 2020), 14% of the population reports to compost their food waste at home. About 25 citizens are trained each year to become "master composters" and train other citizens. The “Phosphorus project” (Operation Phosphore – Brussels, 2021), supported by the Brussels Region, investigated the possibilities for local recovery of biowaste by developing about 20 living labs in public parks, school, restaurants, etc.

Brussels Environment is currently defining the strategy for biowaste management for the years to come. If a centralised AD plant is foreseen, it seems that the Region wants to keep a decentralised approach for part of the biowaste generated in the Region.

Decentralised solutions might be more suitable for the less dense parts of the Region where there is a demand of fertiliser. Micro-AD plants could be included in new districts or to treat commercial waste where the production could be sufficient to feed a micro-AD unit.

To study the feasibility of the implementation of a DECISIVE system in the Brussels Region, the most relevant stakeholders were identified:

- Brussels Environment, the Regional Agency in charge of the circular economy and waste strategy.
- Some of the communes that manage public parks and schools.
- Research institutes working on the topic, such as the Urban Ecology Centre that managed the “Phosphorus project”.
- Regional agencies working on economic development (such as Hub.brussels) to promote decentralised solutions and business models.

The "Good Food” strategy, which also promotes urban farming with an objective of producing 30% of fruit and vegetables locally by 2035, has mapped the current (from farm to fork) circuits giving information about the offering in the city (lists of suppliers, markets and organic food shops, etc.).

Definition of scenarios

For the **baseline scenario,** BW generated by households, schools and universities, catering in offices, hospitals, markets, HORECA sector, food stores and public parks is around 195,985 ton/year while 12,900 ton/year is source separated in a DtD system in buckets of 30L for BW, 8,000 ton/year is GW separately collected in buckets of 60 L, 16,500 is source separated for home composting and decentralized units and the rest is mixed with residual waste in buckets of 30-60L. BW and GW source separated in DtD systems are collected in trucks of 18 m^3 of capacity and respectively sent to an anaerobic digestion plant (120 km away from the centre of Brussels City) and a composting plant located in Forest (10 km away). RW is sent to the incineration located in the northern part of Brussels (26 km away from the furthest area of the region). Compost obtained from the composting and anaerobic digestion and composting plant is used as a soil amendment. For the rest of transportation, it is assumed that trucks with a capacity of 14 ton and average speed of 59 km/h are used.

For the **alternative scenario**, the current waste management system would be combined with the existing biowaste management system with a decentralised mAD. It was assumed an increase of around 2% (4,000 ton/year) of the total generated biowaste (195,985 ton/year) that would be source separated and sent to decisive systems. The collection system would remain unvaried since in Brussels the DtD system is already implemented (even if at voluntary basis). The amount of green waste and source-separated biowaste sent to composting and anaerobic digestion, decentralized composting and home-composting would follow the same destination as the baseline scenario. There would be a decrease in the amount of BW mixed with RW, which would correspond to the SSBW sent to decentralised facilities by using an electric vehicle of 0.65-ton capacity. The rest of the BW included in the RW would be still sent to incineration as in the baseline scenario. Since the mAD DECISIVE system can annually treat 50 ton of source separated biowaste, this means that 80 units would be needed around the Brussels region in a radius of 0.5 km from the biowaste generation places. The solid digestate produced by the DECISIVE system would be then used as compost since it would have been exposed to hygienisation during the process while the liquid fraction would be sent to a wastewater treatment plant (on average 6 km away from the decentralised systems). Part of the solid digestate would be used to produce organic amendments and biopesticides that can substitute fossil pesticide use.

3.9 SITE 9 - GRAND LYON

Description of the site

Lyon is the third-largest city and second-largest urban area of France. It is located at the confluence of the rivers Rhône and Saône, about 470 km south-east of Paris and 320 km north of Marseille. Together with its suburbs and exurbs, Lyon Métropole, also named the *Grand Lyon* (GL) contains a mix of large urban areas, peri-urban and rural areas with agricultural activities.

The GL is a local authority comprising of 59 municipalities around Lyon and located in the Rhône Department and the Auvergne-Rhône-Alpes region (Figure 19). The GL covers 534 km² and in 2018 its population was 1,381,249 inhabitants (GL Annual Report, 2018), which represents about 600,000 households. It is located within a greater urban area of 2.2 million inhabitants, the second largest in France. The population density of GL is 2,383 inhabitants/km², with the central city Lyon having a density of 10,583 inhabitants/km².

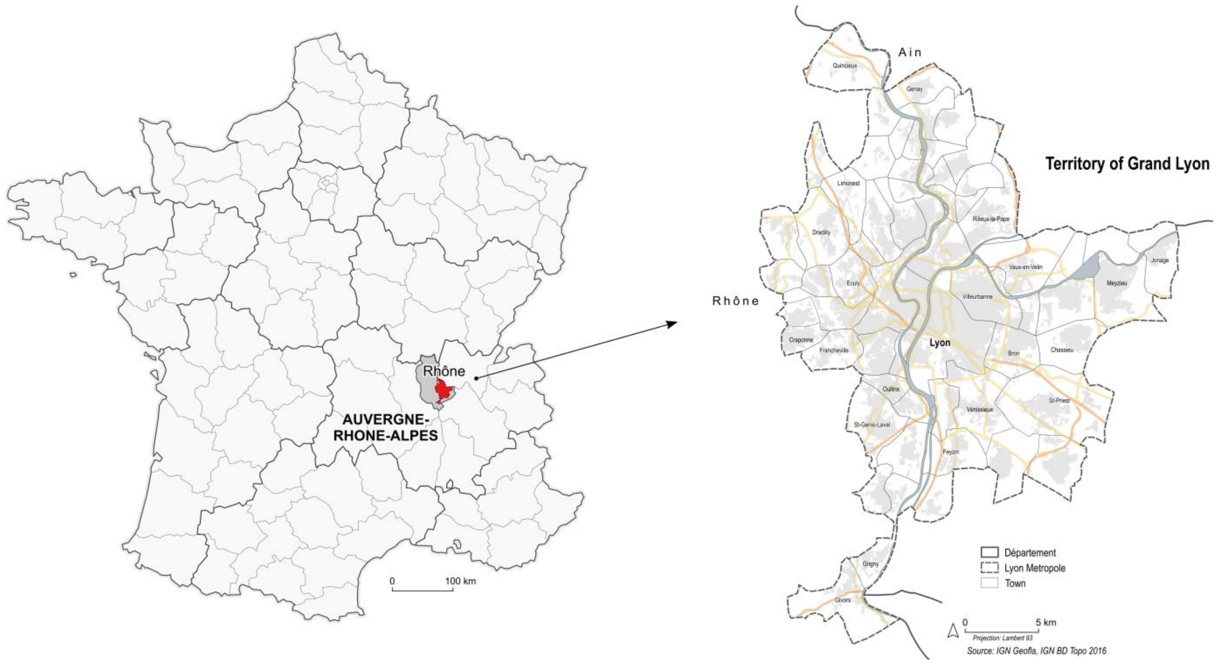


Figure 19 - Location of the Grand Lyon (GL) in France.

GL is the most important urban area in France for industry. Pharmaceuticals, chemicals, petrochemical, automotive, glass and food industries are the most prominent. In terms of services, banking and finance as well as logistics are the strongest sectors.

The agricultural area covers about 10,000 ha, corresponding to 20% of the GL surface area (Agreste, 2021). Most of the usual agricultural sectors are represented: cereal crops, stock rearing, arboriculture, horticulture and vegetables.

The Grand Lyon separately collects households' recyclables (paper, cardboard, plastics, glass), bulky and hazardous waste. The remaining waste is collected as residual waste, in containers for each individual household or building. The biowaste is not separately collected and it is disposed in the residual waste bin. Residual waste is almost exclusively collected DtD, and the container of 140L seems to be the most used one. It depends on the family size (6-7 persons: 240L, 4-5 persons: 180L, 2-3 persons: 120L). In some rare cases (very centre of town, new residential areas), "voluntary drop-off points" are used for residual waste.

In addition to waste from households, the GL also collects waste from private companies and public organisations that produce waste similar to households (type and quantities).

Collected household and similar wastes are mainly incinerated with energy recovery (62%) but also directed towards material recovery (31%) or landfill (7%) (GL Annual Report, 2018).

The GL has two treatment and energy recovery units for residual household waste, which were set up in 1989. The total capacity of the two plants is 380,000 to 400,000 ton per year. Their combustion generates bottom ashes but also residues of incineration fumes. This secondary waste is directed to suitable treatment chains. Incineration smoke treatment residues are mainly directed to a waste storage facility.

One unit is in the 7th arrondissement of Lyon, in the Gerland district at the Édouard Herriot port ("UTVE Lyon Sud") around 7 km from Lyon centre and around 25 km from the farthest area of the GL. It is owned by Grand Lyon and is managed by metropolitan staff. In 2018, UTVE Lyon Sud produced a high amount of heat that has never been achieved so far, with 250,237 MWh in the "Center Métropole" district heating network, for an increase of 4.1% compared to 2017. Along with the production of heat, the steam produced is also used to generate electricity. UTVE Lyon Sud achieved an electricity production of 72,289 MWh, covering half of its own consumption and reselling the surplus. The electricity produced and sold on the network amounts to 35,674 MWh, which represents the average annual electricity consumption of 14,270 households (average household equivalent 2,500 kWh/year excluding heating and hot water). Since January 2015, the Lyon Sud plant has been registered in the French register of guarantees of origin for electricity. Thus, for the year 2018, 17,837 MWh produced were certified as of renewable origin.

The other energy recovery unit is in the town of Rillieux-la-Pape ("UTVE Lyon nord"), around 9 km from Lyon centre. It was built and is operated by the company VALORLY (SITA - Suez Environnement), under a public service delegation contract for a period of thirty years. UTVE Lyon Nord is the main supplier of the district heating network of Rillieux-la-Pape. A wood-fired boiler room supplements the share of renewable energy supplied by the plant on the network in the event of high demand, to ensure a share above 50%. The sale of heat produced by the Lyon Nord UTVE to the district heating network represented 84,893 MWh in 2018, a level equivalent to the 2017 supply. UTVE Lyon Nord produced 42,754 MWh of electricity, of which 19,420 MWh were used for the operation of the facilities. The remaining 25,271 MWh were sold on the open market for the sale of electricity.

Green wastes are stable and represent the main flow in drop-off centres (28,639 ton/year). They are sent to three composting plants and transformed into compost, an organic amendment for cultivated soils. These three composting plants treated in 2018 an amount of green waste of respectively 11,981 ton, 8,816 ton and 8,626 ton and are respectively 8 km, 18 km and 40 km away from the centre.

Regarding home composting, 76 shared composting projects have been installed, 49 sites at the foot of buildings, 14 district-wide sites, 13 sites within schools and colleges. Unfortunately, very limited data is available about home composting.

An increase of more than 10% in furniture and textile flows was observed in 2018 (1,277 ton) and an increase of between 5 and 10% for cardboard, plaster and used oil flows. Wood waste and metal waste increased by 3 and 2%, respectively. Wood is mainly used as a material for the manufacture of particle boards. The metals are recycled in steelworks or foundries.

Light packaging and paper sorted by residents are transported to sorting centres. They are then separated by category of material and sent to recycling. In 2018, three sorting centres received selective collection from the metropolitan area's household waste (i.e., 62,692 ton of waste from selective collection for 38,772 ton directed towards recycling). Figure 20 shows the mass flow of the current MSW system in Grand Lyon.

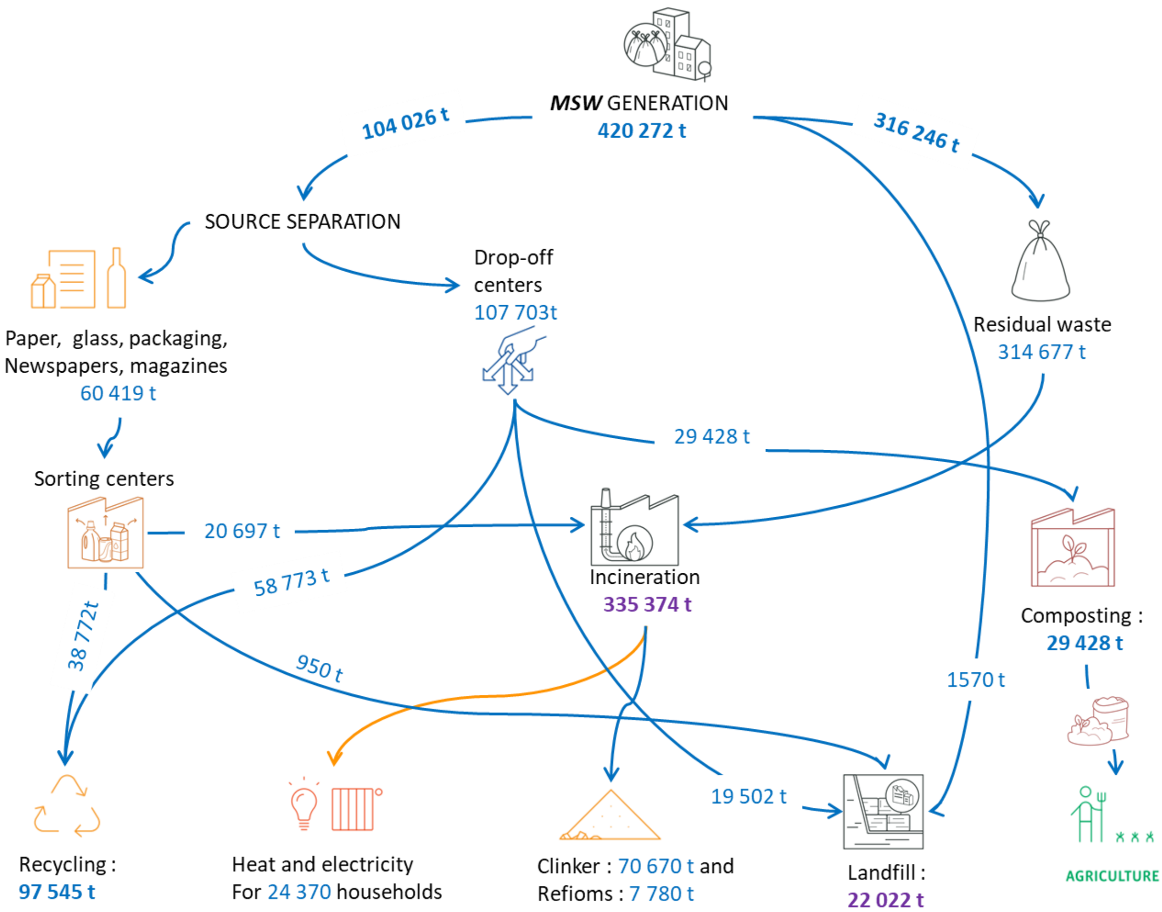


Figure 20 - Flow diagram representing the current waste management system in Grand Lyon.

Waste process libraries of current waste management system

The data collected for building the waste processes libraries of the current waste management system of this site cover all of Grand Lyon. Information gathered in D6.1 was consulted to describe the waste management stages in place in the area. The data were also provided by a public report (GL Annual Report, 2018) drawn up each year by the metropolitan waste management officials. In addition, we benefited from waste characterisation data from Grand Lyon Services, and a website (Incinérateur Rillieux la Pape, 2021) was useful for incinerators emissions, with additional information from a public report on emissions of UTVE of Lyon Sud (Usine Lyon Sud, 2016). For some emissions, additional data have been extracted from the European Pollutant Release and Transfer (Industry EEA, 2021).

Tables with the inventories of the waste management system related to the baseline scenario for Grand Lyon can be found at the following link: Grand Lyon Baseline inventories.xls.

Analysis of the suitability of the DECISIVE system

The fact that the pilot site described below could be built is proof that there is a great local interest in promoting decentralised approaches.

To study the feasibility of the implementation of a DECISIVE-System in Lyon, the most relevant stakeholders were identified. There is no source separation of biowaste in the GL, so the DECISIVE demonstration has the potential to greatly improve the environmental performance of the treatment of collected biowaste, with great potential for duplication. Local authorities have shown great interest in the alternative system and have supported the implementation of the demonstration, investing in resolving regulatory constraints. The foreseen limits for the replication of such biowaste recovery processes lie in the foreseeable regulatory difficulties. However, these limits are not crippling as evidenced by the effective implementation of the DECISIVE Demonstration site.

Thanks to the spatial optimization model described in deliverable D3.8 (with summary of results in deliverable D3.9), a theoretical scenario was applied to the entire GL area. This scenario targeted 10% of the biowaste in the GL, all sources of biowaste combined, with a maximum collection distance of 5,000 m. The final model included 27,169 biowaste sources, 3,351 potential mAD sites and 921 outlets.

The optimal decentralised processing network provided by the MILP method would involve 170 mAD plants. The network would treat 9,135 ton/year of biowaste for a total collection distance of 1,363 km and a distance per ton of collected waste of 149 m/ton. The digestate would be valorised in 194 agricultural plots, for a total transport distance of 52 km.

Definition of scenarios

For the **baseline scenario**, BW generated by households and commercial activities is around 168,100 ton/year while 29,428 ton/year is green waste source separated and delivered to civil amenity centres. The rest of the biowaste is mixed with RW that is collected in DtD bins of 120L. The source-separated green waste (the only portion of BW source separated) is collected in diesel trucks of 18 m^3 and sent to a composting plant 26 km away). Natural gas trucks of 22 m^3 collect RW that is directly sent to an Incineration plant 17.5 km away. Neither pre-treatment of RW or GW, nor transportation with trucks other than those used for collection have been considered for this scenario. Compost obtained from the composting plant is used as a soil amendment

For the **alternative scenario**, the current waste management system would be combined with the alternative one. It is assumed that around 2% (3,362 ton/year) of the total generated biowaste (168,100 ton/year) would be source separated in DtD systems (bins of 120 L) and sent to DECISIVE systems. As the baseline scenario, green waste would be sent to civic amenities and then to composting. The rest of the BW included in the RW would be still sent to incineration as in the baseline scenario. Considering that the annual capacity of the mAD is 50 ton, around 67 units would be needed around the Grand Lyon in a radius of 1 km from the biowaste generation places to treat the source-separated biowaste. Solid digestate produced from the mAD would be used as compost while the liquid digestate would be sent to a wastewater treatment plant (on average 4 km away from the decentralised systems). Part of the solid digestate would be used to produce organic amendments and biopesticides that can substitute fossil pesticide use.

4. Analysis of the demo sites

This section describes the characteristics of the decentralised DECISIVE system implemented in the Lyon and Dolina pilots in order to build the related inventories to introduce in the DST. Then, for each demo site a general description and the waste process libraries of the waste management systems currently in place are reported. Waste process libraries for the DECISICVE technologies are based on the available data from demo sites (WP6.2).

4.1 WASTE PROCESS LIBRARIES FOR THE DECISIVE SYSTEM

Results from WP2 have been used to build the waste process libraries for the DECISIVE system. DECISIVE technologies are constituted of a micro-Anaerobic Digestion (mAD) to treat the biowaste, a Stirling Engine (SE) to valorise biogas through the production of electricity and heat, and a Solid-State Fermentation (SSF) unit to treat around 10% of the solid digestate generated in the micro anaerobic digestion process to obtain biopesticides. However, further process units and practice need to be considered to correctly implement the proposed decentralised system. First, a good source-separated biowaste needs to be obtained to avoid pre-treatment and generate valuable outputs such as biogas and digestate. Hygienisation is also fundamental to use digestate as fertiliser.

Waste processes inventories related to mAD, Stirling engine and SSF unit have been combined as it was a unique “treatment process” to introduce in the DST. The annual capacity of the SSF experimental unit developed by UAB-AERIS is around 1.64 ton/year of solid digestate. This value has been calculated considering that around 39 kg of solid digestate can be treated in a batch of SSF and considering that one batch is carried out weekly.

It is assumed that TS (Total Solid) content in biowaste input of mAD is about 15% and at least 75% of it is biodegradable, and mostly degraded during the AD process. As the mAD is conducted under wet conditions (1:2 is the mass ratio of water to biowaste), the TS content in raw digestate is about 5%. The raw digestate is sent to a solid/liquid separation: 68% of TS in biowaste remains in the solid digestate while 7% remains in liquid digestate. For a mAD of 50 ton of biowaste/year of capacity (biowaste is diluted with a mass ratio of water 1:2) around 17 ton/year of solid digestate are generated and around 10% is sent to SSF while the remaining digestate can be used as compost. To obtain results related to the entire system mAD + SSF, inputs and outputs for/from SSF (evaluated per tonne (ton) of solid digestate) have been normalised to the ton of biowaste input to mAD (considering that only around 5.57% of the digestate is going to SSF).

Besides the inventories built for the entire DECISIVE system, also the treatment inventory related to the mAD and Stirling motor only is available in the DST.

Tables with the inventories related to the DECISIVE technology package can be found at the following link: Inventories DECISIVE SYSTEM final.xlsx.

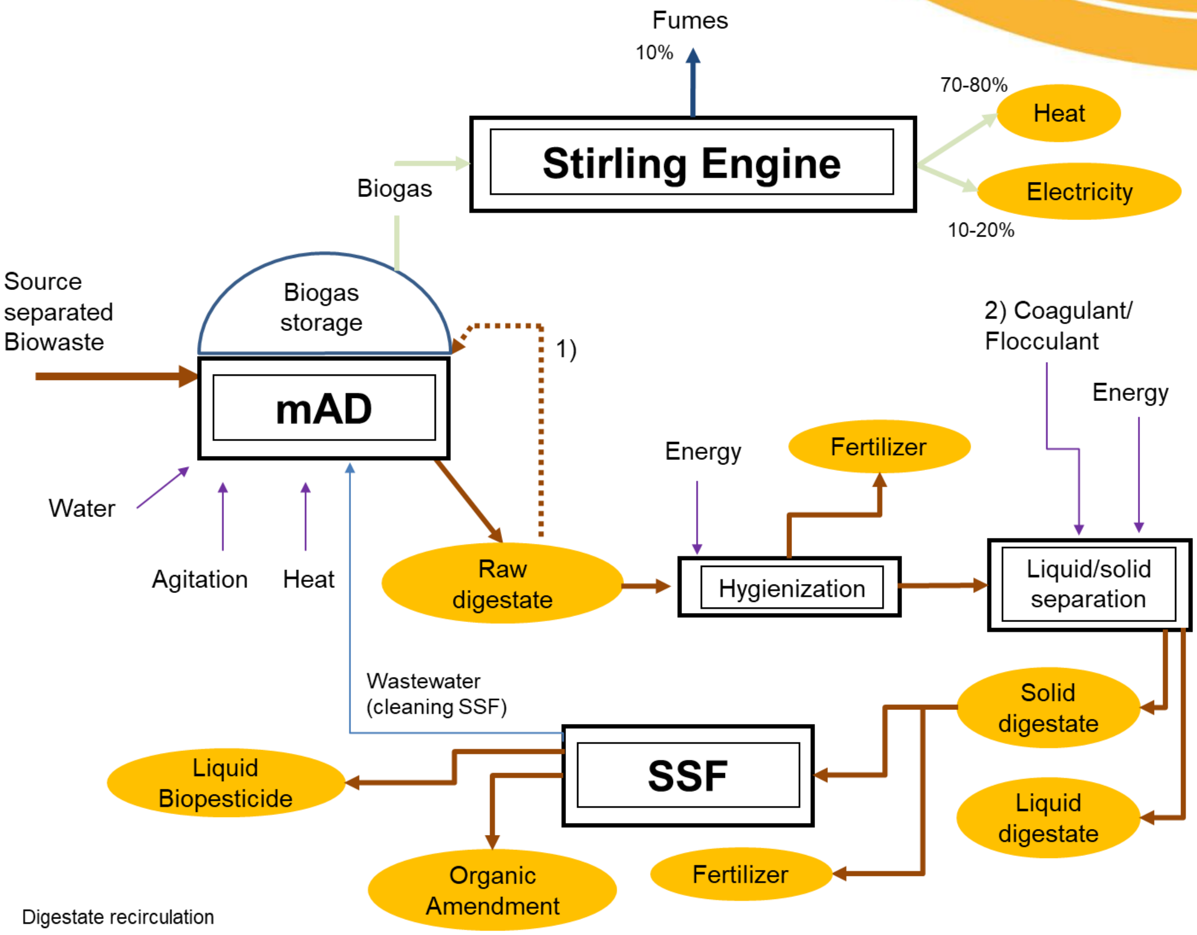
Figure 21 represents the DECISIVE system with details of the mAD and SE units. In the mAD microorganisms break down biowaste in the absence of oxygen producing two valuable products: (1) the digestate that can be used as fertiliser after hygienisation or composting (for the DECISIVE system a hygienisation unit was chosen) and (2) the biogas, consisting of methane, carbon dioxide and traces of other components. The digestate is sent to a solid/liquid separation and part of the solid digestate is sent to the SSF unit. The water coming from the SSF cleaning activities is used in the mAD to dilute the biowaste input. The generated biogas is used directly as fuel, in an external combustion Stirling engine generating heat and power. This engine works in a closed loop using a gas as thermodynamic fluid (usually air, nitrogen, helium or hydrogen or other fluids in high performance versions). When a suitable temperature difference between its hot and cold spot has been reached, a cyclic pulsation is caused (at the beginning started properly), normally changed in reciprocating motion of the pistons. The pulsation persists until the temperature difference is kept by giving heat to the hot spot and by subtracting heat to the cold one.

Figure 22 gives a detailed representation of the SSF process. The SSF process consists of the use of *Bacillus thuringiensis* (Bt) as inoculum to produce the biopesticide. Taking advantage of the ability of Bt to produce spores in adverse conditions, the aim of the SSF is to use the solid digestate as a substrate for the development of a soil amendment with biopesticide effect (option 2 in Figure 22) and/or a liquid biopesticide plus an organic amendment (option 1 in Figure 22). Inoculum production requires Bt, ultrapure water, compressed air (by insufflation) and media nutrient broth N2[3]. Once liquid inoculum is obtained, a centrifugation is carried out to extract the solid inoculum to add into the SSF. Wastewater due to cleaning activities and supernatant discarded are further outputs of the centrifugation stage. Electricity consumption of the entire process is due to (1) the introduction of compressed air to control the temperature of the inoculum production (endothermic reaction), (2) lights, (3) autoclave, (4) shakers and (5) centrifugation.

The solid digestate sent to the SSF is pre-treated in a storage tank where it is mixed with water, wood chips (used as bulking agent) and shredded biowaste (part of the biowaste input to the mAD can be used). The biowaste needs to include mainly fruits and vegetables (avoiding fish and meat to keep more homogenised waste, otherwise it might require an increase in temperature). Digestate and biowaste mixture must have a ratio of respectively 62.5%-37.5% to improve biodegradability. Electricity demand for the pre-treatment unit is due to the shredding of biowaste and stirring of the input substrate.

The SSF reactor has a capacity of around 200 L/week and requires electricity for aeration and stirring, bulking agent, water and chemicals for cleaning. Each batch treats around 33 kg of solid digestate, 18 kg of bulking agent and 20 kg of biowaste). As outputs of the SSF there are the emissions (H_2S, NH_3, CO_2) to air, wastewater due to the cleaning activities and the substrate that is sent to liquid/ solid separation. In this last stage, chemicals (solid chloride) and water are added for extracting the liquid biopesticide. The remaining part is an organic material with high amendment value. Tap water is added for cleaning activities generating wastewater. The extracted biopesticide has a high bacterial activity that permits to use it in a substitution of fossil pesticides. From the study of the potential biopesticide carried out in D4.9, the use of Bt generated by the SSF was compared with a commercial Bt. It was found that Bt-SSF brought a mortality of insects of between 67-76% compared with 100% of mortality obtained with the commercial Bt. Then, assuming that 1kg of commercial Bt is equivalent to 0.5 kg of fossil pesticide, it is estimated that one kg of active ingredient in a biopesticide corresponds to around 0.358 kg of active ingredient present in a commercial fossil pesticide.

[3] Dehydrated Culture Media (Nutrient Broth No.2) is the nutritious medium suitable for the cultivation of micro-organisms for each batch of the inoculum production.



1) Digestate recirculation

2) The requirements for flocculant/coagulant is yet to be assessed depending on the selected Solid/liquid separation unit.

Figure 21 - Representation of the mAD, the Stirling Engine and the SSF process constituting the DECISIVE system (Source: own elaboration).

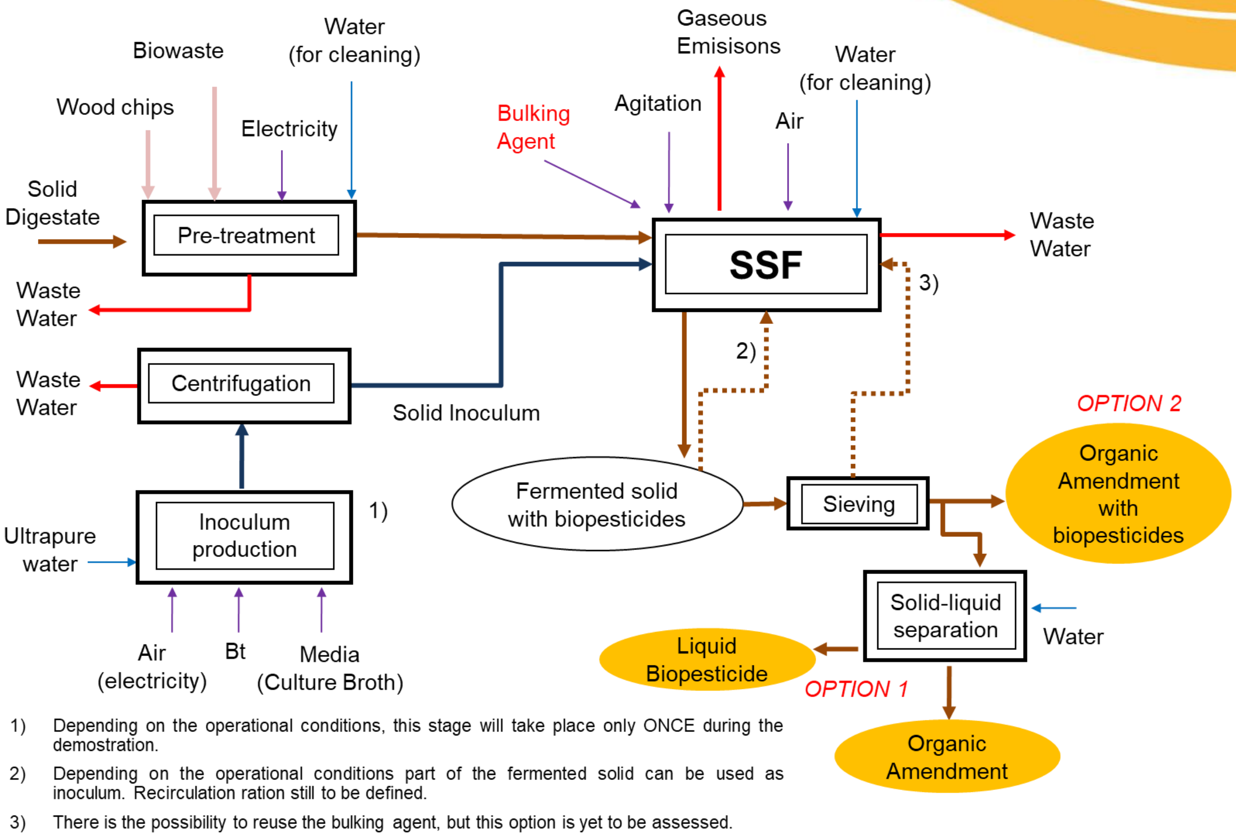


Figure 22 - Representation of the Solid-State Fermentation process details (Source: own elaboration on data from D4.6).

4.2 PILOT SITE 1 - LYON PILOT

Description of the site

The Lyon DECISIVE pilot was installed at CFPH (Centre de Formation et de Promotion Horticole), a public horticulture training and promotional centre. CFPH is based on a 10-hectare piece of land in the city of Ecully, right on the outskirts of Lyon, about 1 km from the nearest metro station and about 200 m from the limit of the city of Lyon (see Figure 23).

The demonstration site is therefore surrounded by a dense urban area but is quite unique as these 10 hectares are not built and are dedicated to horticulture and farming. CFPH is part of a local public institute, which also includes a high school, a commercial nursery and horticulture farm (1,000 m²) that is used for vocational purposes and the regional centre for apprenticeships.

This public institute (EPLEFPA – établissement public local d'enseignement et de formation professionnelle agricoles), under the Ministry of Agriculture, focuses on horticulture, landscape and agriculture, and prepares for the jobs of tomorrow in urban farming and urban biowaste management. It has a population of 300 students following a conventional curriculum (16-20 years old), 250 apprentices (14-20 years old), as well as adult students: 50 of them on long-term programmes and 1,000 on short-term programmes.

In addition to its primary educational mission, the public institute is also concerned with socio-economic inclusion, animation of the rural territory, experimentation/innovation and international cooperation. These missions are conducted in particular through the CFPH, which developed partnerships with several urban agriculture projects that are based on their site:

- Api Environnement, bee-keeping.
- La Ferme de l'Abbé Rozier: a social inclusion organic farming project.
- Refarmers (member of the DECISIVE consortium): vertical hydroponics.

Figure 23 - Location of the Refarmers site (Lyon demonstration site) (Source: Google Maps).

The current waste management system in the "Lyon study zone" is the same as in the GL. MSW and consequently the biowaste included in the residual waste is mainly incinerated. In the Lyon pilot, the mAD has a capacity of 50 ton/year but to reach this amount of biowaste it will be needed to analyse a yearly amount of 250 ton of MSW to compare baseline and alternative scenario (considering a recovery rate for biowaste of 70% (ADEME Guide pratique, 2013) and that biowaste represents around 30%[4] of total MSW).

The "study zone" for the Lyon case (called "Lyon study zone") has been defined as a theoretical area centred around the demonstration site whose position was already defined from the beginning of the project in the "Refarmers site" that should provide 50 ton of biowaste per year collected from restaurants. A radius of less than 2 km has been fixed in order to define this zone to characterise the baseline scenario.

It is important to underline that at this preliminary stage of the project, the delimitation of the study zone has been made first looking generally at the sources located in proximity of the demonstration site and then focusing only on the biowaste sources targeted by the project. The real boundaries of the Lyon study zone will be defined in a more accurate way, considering the area where restaurants willing to take part in the demonstration are located.

As mentioned above, source-separation of biowaste is not compulsory in the Grand Lyon so the restaurants that will be involved in the project will be those to which Refarmers and/or the CFPH deliver fresh products – testing a circular model – and that will agree to take part in the demonstration and voluntarily source-separate their biowaste.

It was estimated that 41 restaurants located in this area (the 2-km theoretical area) generate a total of 57 ton/year of source-separated biowaste that, discounting the macro-impurities, can feed the mAD. Figure 24 visualizes all the biowaste sources around the Refarmers site, which are reported in Table 3. It is possible that in a later stage of the project, some of the 41 restaurants needed to get the 50 ton/year of biowaste will be located outside of the 2-km theoretical area. Adding co-substrates such as lawn cuttings to the biowaste generated by the restaurants as input for the mAD could be also a possibility to investigate. It is important to underline that the map in Figure 24 was designed in 2017 but it is based on the most recent data available (oldest data are related to 2013) since the method implies the use of various

[4] Estimation on data from French environmental agency (ADEME); MSW has 31% of "putrescible" waste, which includes food waste (23%).

databases that have not been created at the same time.

Table 3 - General information in the Lyon pilot zone.

General information & biowaste generation – Lyon pilot zone			
ELEMENTS	**PARAMETERS**	**Unit/type**	**Values Sources**
Demographic characteristics of the area	Population	N inhabitants	36,240
	Area	Km^2	± 6
	Urban density	inhabitants/km²	± 6,000
	Residential area	Type (N of inhabitants/households)	36,240
	Commercial restaurants	Type (meals/year)	440,150
		N of restaurants	41
	School canteen	Type (meals/year)	117,529 for primary schools (3,711 students) 458,605 for secondary schools (4,862 students)
		N of restaurant per type	21 primary, 8 secondary
	Health facilities	Type (meals/year)	265,930 for hospitals 1,104,064 for other facilities
		N of restaurant per type	1 hospital, 32 other facilities
	Collective catering	Type (meals/year)	952,381
Source: D3.8			

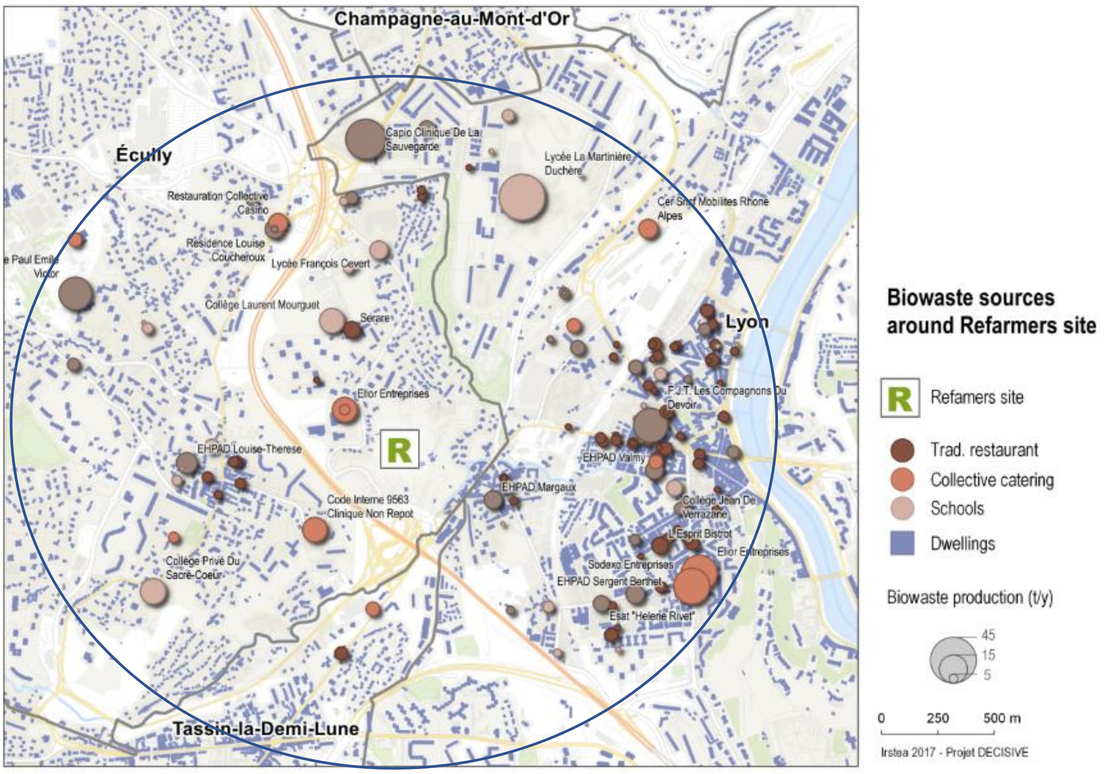


Figure 24 - Map of biowaste sources and quantity estimates in the targeted area based on the most recent data available (source: D3.9)

Figure 25 shows the mass flow of the current MSW system in Lyon Pilot.

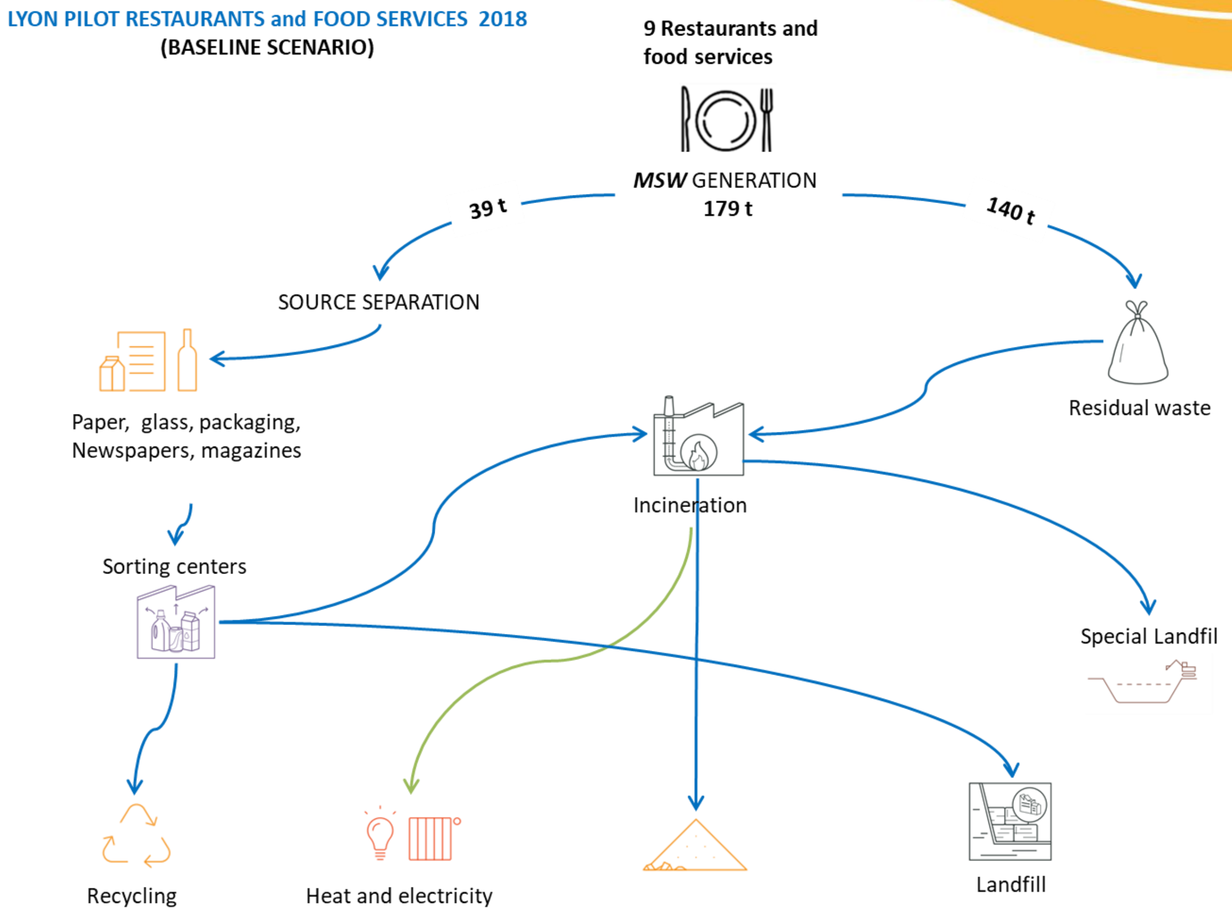


Figure 25 - Flow diagram representing the current waste management system in Lyon pilot.

Waste process libraries of current waste management system

Data collected for building the waste processes libraries of the current waste management system of the Lyon pilot are taken from D6.1 and refer to real, experimental data from the demo site.

Tables with the inventories of the waste management system related to the baseline scenario for the Lyon pilot can be found at the following link. Lyon Pilot Baseline inventories.xls

Analysis of suitability of DECISIVE system

The Lyon demonstration site was chosen at the outset of the DECISIVE project. The site was considered adequate for implementing the DECISIVE system (Hygienisation +mAD+ Stirling) for different reasons.

Local authorities have expressed great interest in the alternative system and have been supportive of the demonstration implementation because it is highly innovative. However, regulation constraints and bureaucracy for permits was recognised since the beginning as an important limitation that was overcome during the project.

Regarding the input of the biowaste, the nature of the site does not affect the quality or quantity of collected biowaste, which comes from selected external sources such as restaurants and food services. Refarmers and the CFPH already had commercial relationships with several restaurants before the start of the project and they could reach enough units to collect the needed quantity of biowaste. Biowaste collected from restaurants has normally a low content of macro-impurities.

From the logistic point of view, the proximity of biowaste generators (restaurants customers of Refarmers and CFPH) to the decentralised plant can optimize transportation of collected biowaste. Despite being surrounded by a dense urban area, the Lyon pilot site is within a 10 hectare-horticulture and farming site.

In fact, CFPH site has a surface of 10 hectares and the institute has another site (of 16 hectares) at 5 km from CFPH. Besides, the Grand Lyon has 10,000 hectares of agricultural land, most of which are located on the outskirts of the territory, up to 20 km from the pilot site. The proximity of the pilot area to peri-farms areas can avoid the cost of digestate disposal since those lands can be used to potentially spread digestate.

The surplus of thermal energy can meet local heat demand. Indeed, the greenhouse and a residential house are within a few dozen metres from the pilot and have thermal needs, which however vary with seasons. A hotel and conference centre are located about 250 m from the pilot with significant needs for thermal energy. The Lyon pilot is located just outside a hydroponic greenhouse that can use the potential electricity surplus, if any (net of auto-consumption demand). The DECISIVE demonstration has a potential to highly increase the sensibility to waste management issues to improve the environmental performance of the treatment of the collected biowaste, since currently there is no biowaste source separation in the GL.

The location and nature of the pilot site are quite unique: it has a large piece of land with farming and composting within a dense metropolitan area and is managed by a public institute with strong relationships with the farming and landscape sectors. The DECISIVE system implementation in the Lyon Pilot is considered to have a great potential for duplication in other sites with similar characteristics.

The most relevant stakeholders identified for the Lyon pilot were three. First, CFPH as responsible for the implementation and the operation of the mAD and to deal with the spreading of the higienised digestate output of the process. Second, Refarmers that is the owner of the site where the pilot has been located and represents also a user of the part of digestate, i.e., fertiliser for the greenhouses. Third, the selected restaurants and food services are biowaste generators to which Refarmers and/or the CFPH deliver fresh products.

Definition of scenarios

For the **baseline scenario**, BW generated by the selected restaurants and food & services is 54 ton/year, is not source separated but mixed with RW. The collection system is DtD and buckets of 120 L with plastic bags of 120 L are used for RW. RW is collected in a truck of 22 m^3 and sent to two incineration plants 37 km away, without any pre-treatment.

For the **alternative scenario**, the current waste management system would be completely substituted with the DECISIVE system. It is assumed that 100% (54 ton/year) of the total generated biowaste would be source separated and sent by using an electric vehicle of 0.65 ton of capacity to the decentralised unit (50 ton/year) located in Ecully, 1 km away from the biowaste generators. The DtD collection would be implemented for the BW instead of RW. No biowaste would be mixed in RW so the entire biowaste fraction avoids incineration. The solid digestate output from DECISIVE would be used as compost while the liquid fraction would be sent to a wastewater treatment plant (4 km away) or would be spread over the fields close to the pilot area. Part of the solid digestate would be used to produce organic amendments and biopesticides which can substitute fossil pesticide use.

4.3 PILOT SITE 2 - DOLINA PILOT

Description of the site

San Dorligo della Valle – Dolina is an Italian municipality of 5,729 inhabitants in Friuli Venezia Giulia Region. The municipality is located in the Istrian peninsula on the border between Italy and Slovenia, and it is almost 10 km from the city of Trieste (Figure 26). Dolina (24.22 km^2) is characterised by a heterogeneous territory hosting a protected transboundary natural area with the agricultural cultivation of grapes and olives being relevant. Furthermore, Dolina is served by Trieste free port facilities, and hosts the most important ship engine factory in the North-East of Italy.

Figure 26 - Dolina location in Friuli Venezia Giulia Region (source: A&T2000).

Dolina's density population is 235.8 inhabitants/km^2 and most of the residential buildings are on the border with Trieste municipality as one of the main industrial areas. In Figure 27 is reported the localisation of Dolina waste sources: households and commercial activities.

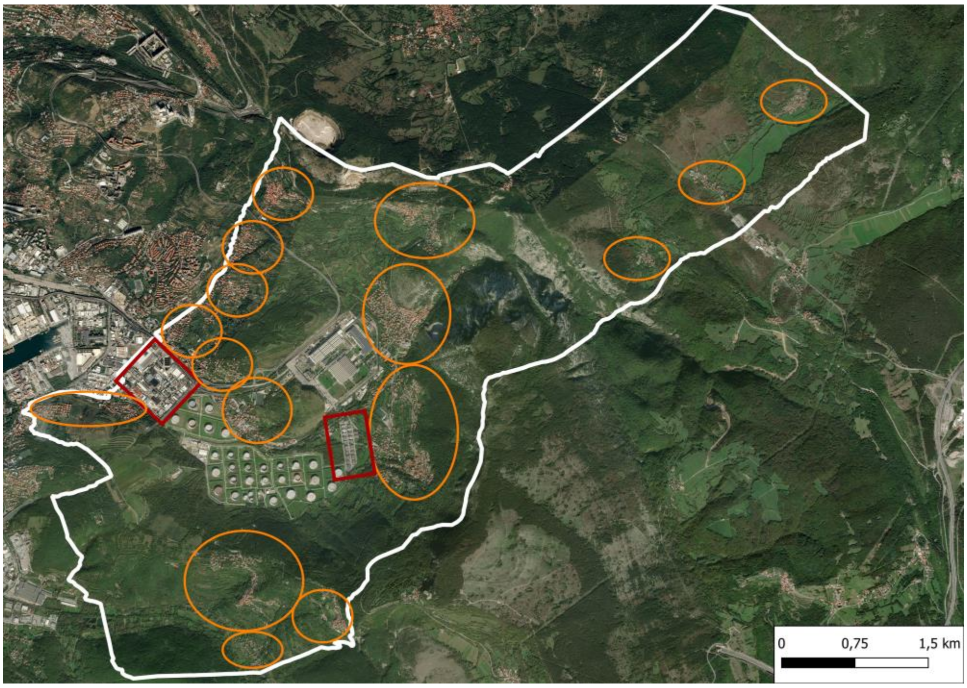


Figure 27 - Dolina waste source: orange ovals represent households and some small commercial activities (e.g., restaurants and bars) red rectangles represents the industrial activities (source: Bing, Eagle FVG, A&T2000).

Since 2017, in Dolina a DtD separated waste collection managed by A&T2000 has been carried out. The company provides every household or commercial activity with bins or bags with different colours based on the type of waste (brown bins for biowaste, green bins for glass, yellow bins for paper, blue bags for plastic and can packing waste and pink bags for residual waste).

A calendar describing the collection days for each waste fraction is provided to every user. The biowaste is collected twice a week while the residual waste is collected once a week. Glass, paper, plastic and can-packaging waste are collected once every two weeks.

To allow a fast waste collection and to reduce hygienisation problems, users are asked to deliver the biowaste in compostable bags placed inside the bin. The biowaste (mainly food waste) is currently delivered to an Anaerobic Digestion plant (that is almost 135 km from Dolina) where bags are not removed before sending the biowaste to the biological process. For this reason, users are only allowed to use paper or certificated compostable bags when they separate biowaste (i.e., to avoid negative effects on the composting process). The presence of non-biodegradable elements (e.g., plastic) may in fact cause biochemical problems in the anaerobic digestion process or lead to the presence of contaminants in the digestate.

Aware of the importance of a relationship with users for a successful separate collection of waste, A&T2000 organised in 2017 several meetings with Dolina's inhabitants with the aim of teaching them how to differentiate the waste in the right way. Collection workers control day-by-day the quality of source separated waste fractions and if waste is not correctly separated it is not collected. Waste collectors put a sticker on bins/bags that contain wrong waste fractions, describing the error done and provide information to contact the municipality for any other issue about collections.

For the waste not collected during the DtD waste collection, there is a collection centre that is a municipality area where waste such as metals, grass-mowing or WEEE (Waste Electrical and Electronic Equipment) must be delivered by the inhabitants and can be stored before going to the final plant.

During 2018, in Dolina Municipality 1,441 ton of MSW were generated: 457 ton of residual waste, 834 ton of source-separated waste in road containers (334 ton represents biowaste) and 150 ton of separated waste collected in civic amenity sites. Figure 28 shows the mass flow of the MSW in Dolina Municipality.

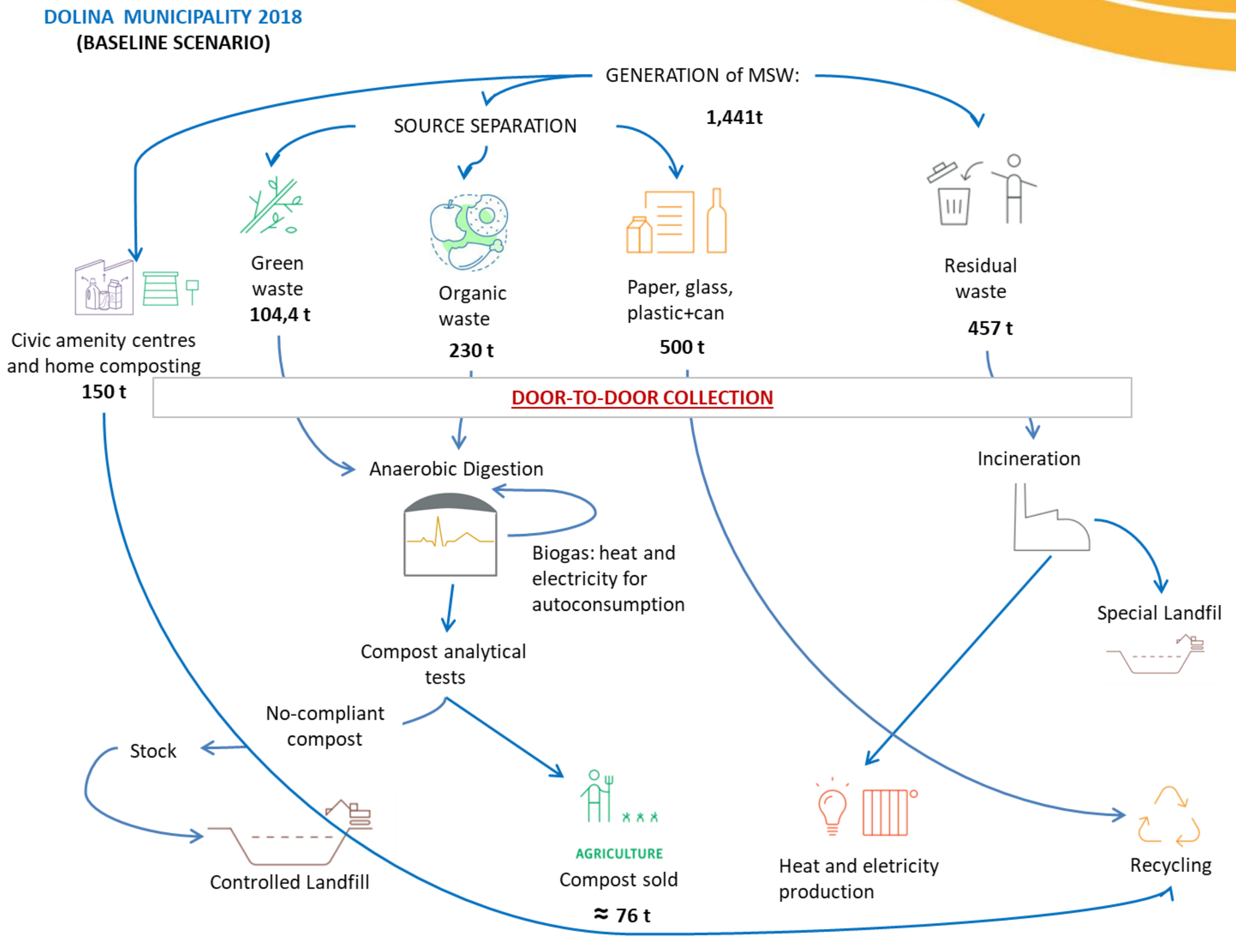


Figure 28 - Flow diagram representing the current waste management system in Dolina Municipality (2018 data).

Waste process libraries of current waste management system

Data collected cover the municipality of San Dorligo della Valle – Dolina in 2018. Data gathering process is based on A&T2000 S.p.A. database and refers to the urban biowaste (produced by households) and the biowaste assimilated to urban waste (e.g., canteens from schools, and companies). When real data were not available in A&T2000 database, as in the case of Dogna, they were obtained thanks to the collaboration of the company with the managers of anaerobic digestors plants in Friuli Venezia Giulia Region. Those data were obtained analysing the installation database of the plant of Bioman S.p.A. and looking at its environmental authorisation. Inventories of plants with similar characteristics were used in the case of data unavailability.

Tables with the inventories of the waste management system related to the baseline scenario for Dolina Municipality can be found at the following link: Dolina Pilot Baseline inventories.xls.

Analysis of the suitability of the DECISIVE system

DECISIVE circular economy concepts and a decentralised biowaste management system fit very well with Dolina's municipality needs. In Dolina, the DtD waste collection is well underway, and the municipality is looking for a cost-saving way for managing biowaste. As the composting plant currently used is 100 km from Dolina, the municipality well accepted the DECISIVE approach and strategy of implement a micro-anaerobic digestor locally. This was possible also thanks the good collaboration of A&T2000 with the local administration and the Comunela (the management of the common properties of Dolina) that provides a large and immediately available property where to set up the plant.

To study the feasibility of the implementation of a DECISIVE system in the Dolina Municipality, the most relevant stakeholders were identified. They were local authorities, households and commercial activities present in Dolina's municipality as waste sources, and farmers as main users of compost generated by the micro-anaerobic digestor. Local authorities have expressed great interest in circular economy concepts and of the possibility to manage in a cost-saving way the biowaste.

Dolina was selected as demonstration site for different reasons. First, due to the existence of a large and immediately available property where to place the plant in Comunela's (management of the common properties of Dolina) property. Second, the amount of biowaste generated by households, restaurants, schools and companies' canteens reaches around 231 ton/year, which permits to implement a DECISIVE unit of around 100 ton/year. The fact that since 2017 A&T2000 is Dolina's public urban waste management company makes the biowaste supply agreements easier. The good quality of biowaste is also a fundamental factor that permits to implement a DECISIVE system without the need of pre-treatment of the biowaste to remove macro impurities. Dolina's biowaste is transported to an anaerobic digestion plant almost 100 km away from the municipality. With the place of mAD in the municipality, the biowaste will drastically reduce its transport costs. Furthermore, in the area there are several farms interested in using the digestate produced in the mAD.

On the other side, there are also critical aspects to consider for the implementation of the pilot in the Municipality of Dolina. The authorisation and permits process according to the Italian Legislative Decree n. 152 of 2006 created delays. For the Italian legislation, the digestate produced during anaerobic digestion process is considered as waste. Moreover, the plant is not far enough from residential areas and there might be problems related to odours. To remedy this issue, the digestate could be transported to a proper plant for maturation. The different legislation and contracting procedures present in Italy and the UK (country of the mAD manufacturer) caused several delays to obtain information about the machine operation and its production.

Definition of scenarios

For the **baseline scenario**, BW generated by households and commercial activities is 516 ton/year while 319 ton/year is source separated in DtD system using bins of 25 L and mater-bi bags for BW, and bins of 70L with plastic bags of 70 L for RW. Source-separated BW is collected in a truck of 22 m^3 and sent to an AD plant 135 km away) without any pre-treatment since the quality of source separated biowaste is high. The same types of truck collect RW that is directly sent to an incineration plant 8 km away. From the AD plant, the outputs are sent to landfill (5 km away) and to a wastewater treatment plant (80 km away). For all transportations, it was assumed the use of a truck with a capacity of 14 ton and average speed of 59 km/h. Compost obtained from the AD plant is used as a soil amendment.

For the **alternative scenario**, the current waste management system is combined with the alternative one. It is assumed that around 24% (123 ton/year) of the total generated biowaste (516 ton/year) is source separated and sent by using an electric vehicle of 0.65 ton of capacity to two DECISIVE system units (50t/year), which can be placed in Dolina. The collection system remains the same since the DtD collection is already implemented. The rest of source-separated BW (195 ton/year) is sent to the AD plant while the RW is sent to the incineration plant as in the baseline scenario. The solid digestate output from DECISIVE is used as compost while the liquid fraction is sent to a wastewater treatment plant (80 km away). Part of the solid digestate can be used to produce organic amendments and biopesticides that can substitute fossil pesticide use.

A multicriteria assessment implementing the DECISIVE system in the Dolina city was carried out. It enabled the comparison of the performance assessment with the current waste management system by using the DST. The results are shown in the chapter 5.

5. Results of the simulations and their interpretation

In order to facilitate the understanding of the results coming from the simulations, Table 5 summarises the main characteristics of the biowaste management systems for BAU and an alternative scenario for each site.

Figures below (Figure 29 - Figure 34) show the radar representation obtained with the DST including the total impacts of both scenarios for each case study. Together with the radar, the DST provides an Excel file with all the contributions to the total impacts as well as a mass flow balance of each scenario. These files have been used to generate the Table 4.

Table 4 – Overview of the performance assessment of the biowaste managements systems in selected theoretical and demonstration sites in both BAU and alternative scenario.

Site	Scenario	Ton input	Climate Change	Economic Costs	Labour	Space requirement	Time	Electric Ratio	Thermal Ratio	Transport Intensity Index (km*t)
			kg CO2-eq	€	worker*h	m2				
Bellaterra Campus	Baseline	318	10,325	190,242	7,715	132	84,218	48%	100%	32,645
	Alternative	318	6,401	191,877	4,940	228	42,109	32%	89%	19,351
Lübeck City	Baseline	35,751	746,789	21,615,310	23,437	25,119	3,084,418	58%	43%	844,517
	Alternative	35,751	727,324	39,587,433	47,225	25,880	3,084,418	58%	43%	688,648
Guineueta market	Baseline	69	3,533	7,647	294	28	3,537	75%	98%	6,468
	Alternative	69	476	94,307	2,241	85	3,537	8%	55%	1,319
Dolina Pilot	Baseline	516	19,405	4,191,093	140,704	134	44,561	95%	47%	105,641
	Alternative	516	4,443	1,571,873	50,654	222	44,561	93%	47%	44,472
Dogna Municipality	Baseline	28	3,155	159,737	5,073	168	5,759	95%	47%	3,851
	Alternative	28	-348	90,455	2,678	22	2,420	88%	47%	2,189
Lyon Pilot	Baseline	54	-5,646	552,602	14,791	2	7,236	92%	100%	163
	Alternative	54	262	90,481	1,583	60	7,236	4%	50%	163

Regarding **climate change impacts**, all the scenarios showed positive net impacts, so all scenarios generated carbon emissions with a positive balance between emissions and savings. However, the total impact of the alternative scenarios appeared to be smaller than the baseline for all the case studies. As expected, the larger the amount of biowaste handled, the bigger the climate change impact associated. In all the cases, the largest contribution to climate change was the treatment due to energy consumption and emissions of GHG. These impacts were partly compensated by the GHG avoided in the scenarios with incineration as final treatment due to electricity generation.

When comparing the results of both scenarios for almost all the cases for climate change, it is possible to estimate that the decentralisation with the DECISIVE scheme, could reduce between 0.5 to 124.8 kg CO_2 per ton of biowaste input. The lowest benefit per ton was obtained in Lübeck City because the decentralisation was done for a small amount of the total waste generated. The largest benefit could be seen in the Dogna Municipality because most of the biowaste generated is decentralised in the alternative scenario and the distance travelled by biowaste to treatment are highly reduced compared to the baseline scenario. Whereases, in Lyon pilot the alternative scenario has higher impacts on climate change than the baseline due to a lower energy recovery. Actually, the environmental impact in baseline is even negative due to the fact that the generation of electricity and heat from incineration is counted negatively because of the substitution of energy mix. This can also be observed in the electric ratio of both scenarios. The electricity and heat ratios, production divided by production and consumption, of the biowaste management of the baseline scenario is higher than in the alternative scenario and this explains the results on climate change.

The alternative scenarios for all cases have a better performance in terms of **transport intensity** since the distance travelled by biowaste during management is generally reduced in the case of decentralisation.

Regarding **economic costs**, all the scenarios showed positive total economic costs. For the Dolina pilot, the Lyon Pilot and Dogna Municipality, the alternative scenario (decentralisation with the DECISIVE scheme) showed lower economic costs than the baseline and for UAB University, Lübeck City and the Guineueta market the opposite occurred. For all cases, the decentralisation meant an increase in the treatment costs and a decrease in collection costs. As for what concerns the treatment and collection costs, the most important contribution came from the labour needed to collect and treat the biowaste. Revenues obtained from the sale of energy and bioproducts are small compared to labour costs in both scenarios.

The decentralisation implied a variation of economic costs per ton of biowaste handled between -8,557.7 €/ton in the Lyon Pilot (where decentralisation appeared to have economic savings) to 1256.2 €/ton in the Guineueta market (where decentralisation showed extra costs compared to the baseline). The economies of scale play an important role comparing the performance of microscale with centralised systems.

The trend observed in the **labour i**ndicator mimics the one of economic costs. The decentralisation of the UAB University, the Dolina Pilot, the Lyon Pilot and Dogna Municipality decreased the amount of labour needed compared to the baseline scenario. The opposite occurs for Lübeck City and the Guineueta market.

The decentralisation implied a variation of labour costs per ton of biowaste handled between -244.6 worker*h/ton in the Lyon pilot (where decentralisation appeared to have labour savings) to 28.2 worker*h/ton in the Guineueta market (where decentralisation needed extra labour compared to the baseline).

The **space requirement** increases with the decentralisation in all cases except for Dogna Municipality. The increase ranges between 0.02 m^2/ton in Lübeck City to 1.1 m^2/ton in the Lyon Pilot while for Dogna Municipality there is a decrease of 5.3 m^2/ton.

The **time required** for waste generators to sort their waste remains the same in both scenarios in most of the cases except for Bellaterra University and Dogna Municipality in which the decentralisation decreases the time required because it is accompanied by a change in the collection scheme, from bring scheme to DtD.

Regarding the **electric ratio**, representing the ratio of electric production over the sum of electric production and consumption, the decentralisation decreased the electric ratio for most of the cases, except for Lübeck City that remains the almost same. Such a decrease means that the net production of electricity decreased with decentralisation. The decrease ranged between 0% (in Lübeck City) to 96% in the Lyon Pilot market and depended on the degree of decentralisation applied to each case. In the case of the Lyon Pilot, the difference is substantial since a waste treatment with high energy efficiency such as an incinerator is substituted by a mAD.

Regarding the **thermal ratio,** representing the ratio of heat production over the sum of heat production and consumption, was not affected by the decentralisation in Lübeck City, the Dolina Pilot and Dogna Municipality but decreased for Bellaterra University, the Lyon Pilot and the Guineueta market. The highest decrease (50%) occurred in Lyon Pilot. The fact that in the baseline scenario of Lyon Pilot the total amount of BW is mixed to RW and sent to incineration implies an important loss in terms of energy recovery compared to the alternative scenario.

Looking at the results of the simulations, “typical” sites for which the DECISIVE scheme creates the most "benefits" are remote areas such as Dogna or Dolina that are far from the centralised system; large producers such as Bellaterra University campus having both households and restaurants; or large producers with a high quality of food waste source separated such as the Vall d’Hebron Hospital or Guineueta Market.

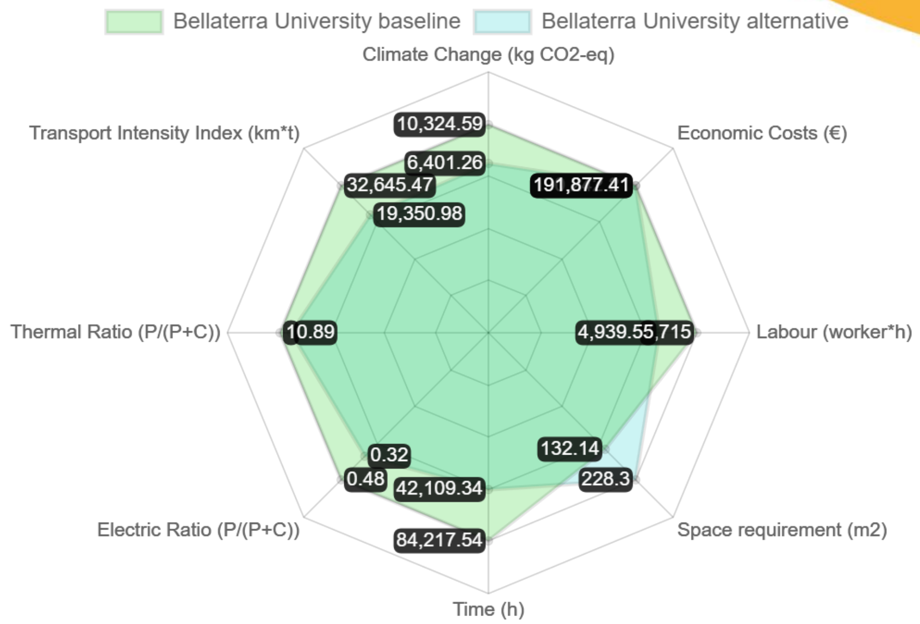


Figure 29 - Results of baseline vs alternative scenarios – Bellaterra University Campus.

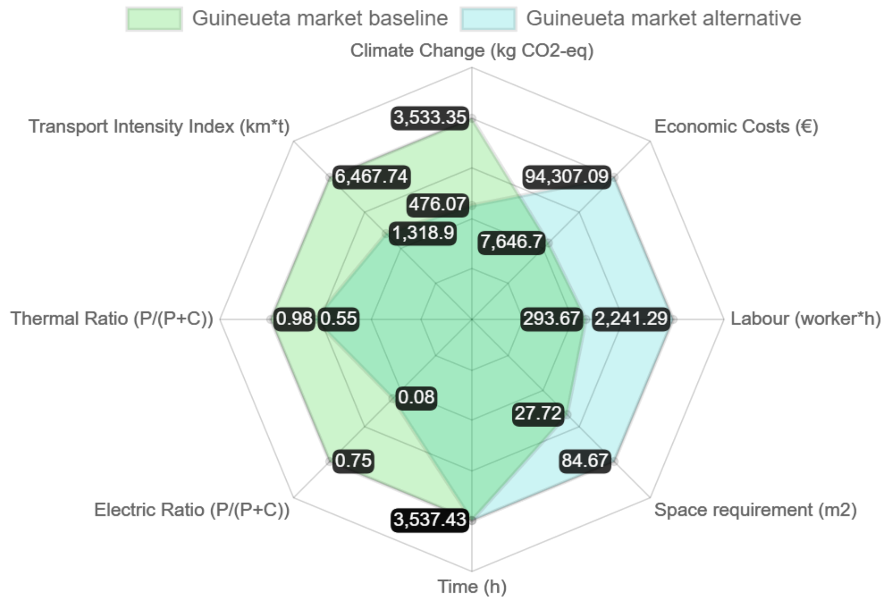


Figure 30 - Results of baseline vs alternative scenarios – The Guineueta market.

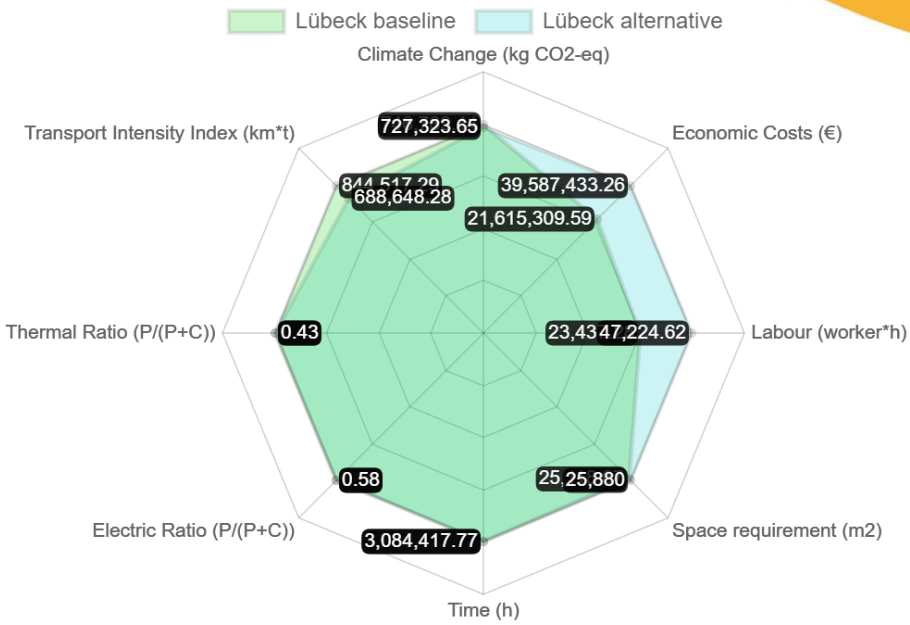


Figure 31 - Results of baseline vs alternative scenarios – Lübeck City.

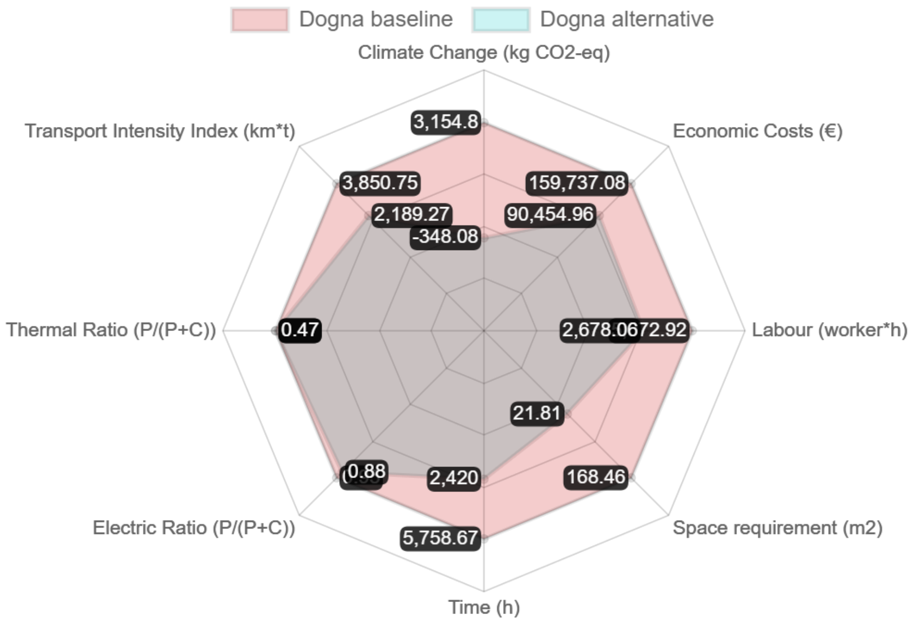


Figure 32 - Results of baseline vs alternative scenarios – Dogna Municipality.

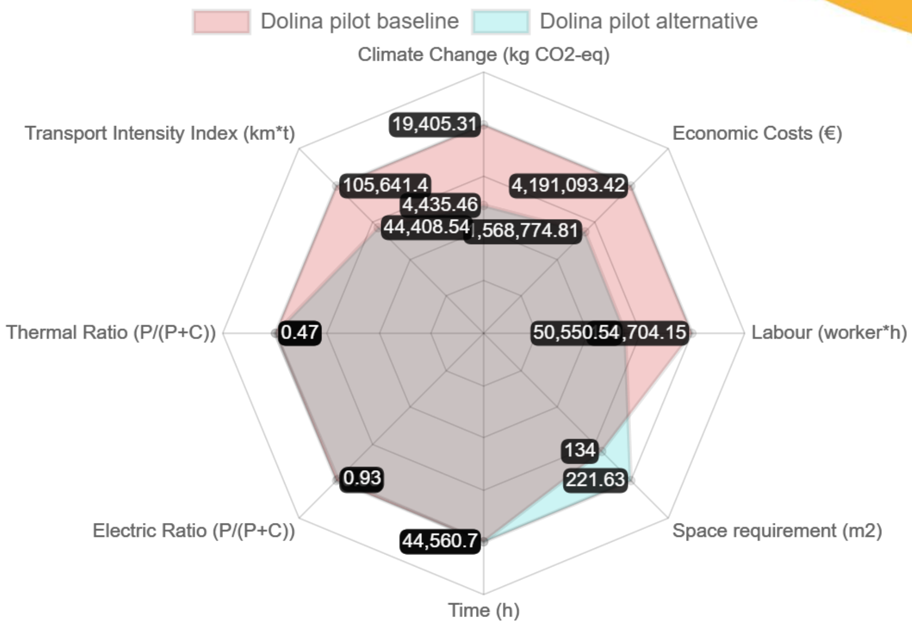


Figure 33 - Results of baseline vs alternative scenarios – Dolina Pilot.

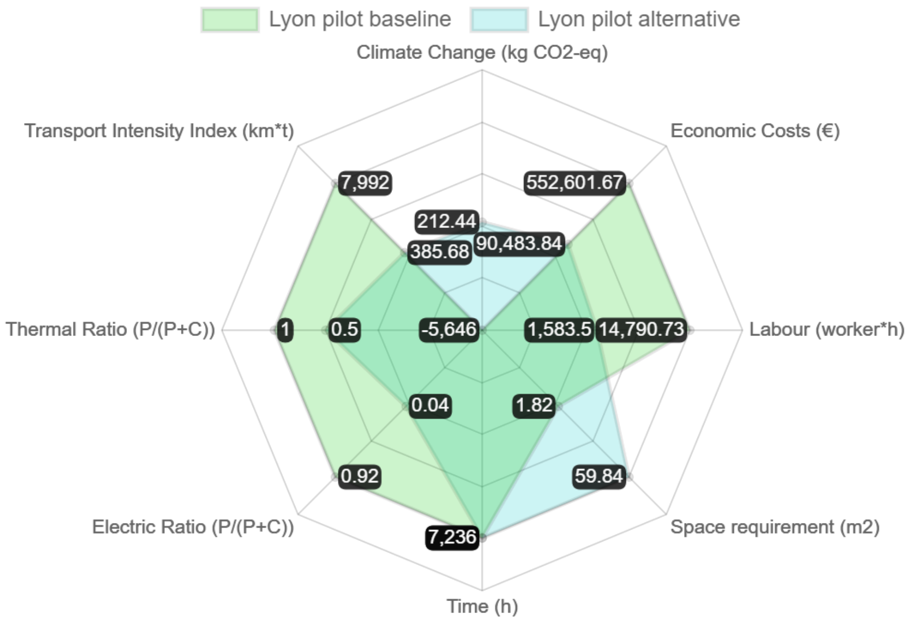


Figure 34 - Results of baseline vs alternative scenarios – Lyon Pilot.

For the theoretical sites of Grand Lyon and Rennes Métropole, there is no relevant difference between baseline and alternative scenarios since it was supposed that for the alternative simulation only 2% of generated biowaste (that is normally sent to centralised plants) would be sent to decentralisation. The rest of the biowaste management would remain as in the baseline scenario. In the case of large and highly density areas (i.e., Grand Lyon, Rennes Métropole), increasing the ratio of biowaste sent to DECISIVE systems, would imply to implement too many mADs units which might be unfeasible.

As an example, below is reported the results of simulation of Grand Lyon. For better analysing the results of the simulations and avoid overlapping of values, one radar diagram is presented for each scenario.

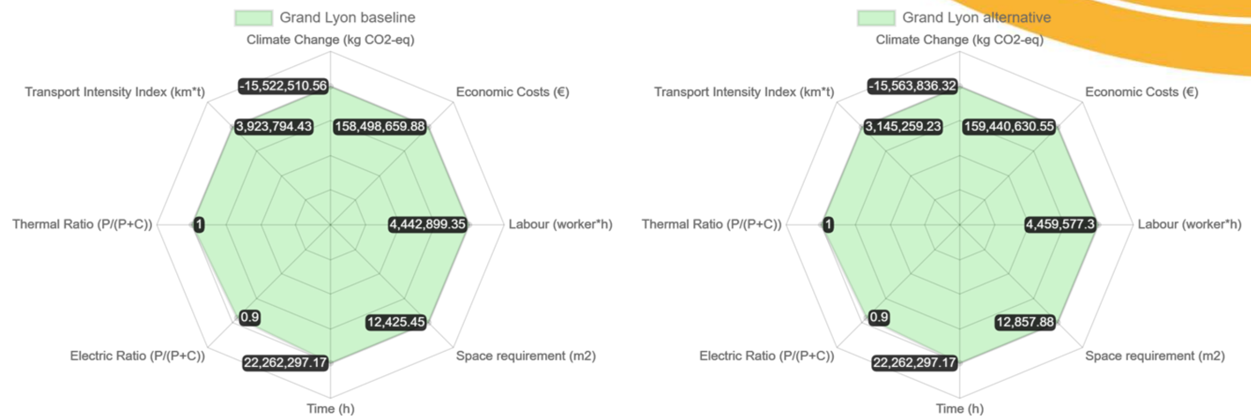


Figure 35 - Results of baseline and alternative scenarios – Grand Lyon..

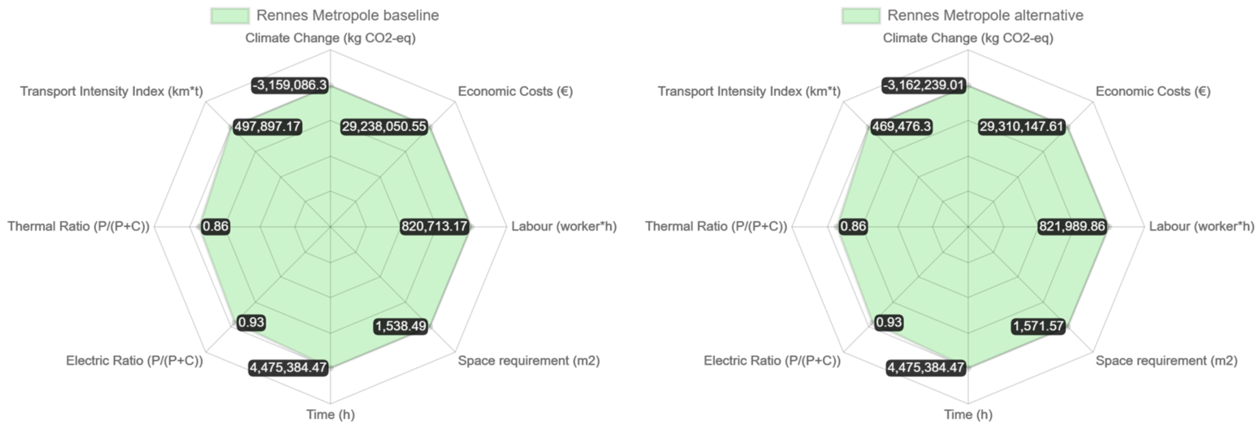


Figure 36 - Results of baseline and alternative scenarios – Rennes Métropole.

6. Identification of possible improvements for the DST

After the first version of the DST was developed, several tests were performed, and a list of potential improvements were identified by testing the theoretical and demonstration sites. From the potential list of improvements only a few were implemented within the DECISIVE project due to budget limitation. Subsection 6.1 describes the complete list of potential improvements of the first version of the tool and subsection 6.2 describes the improvements implemented.

6.1 COMPLETE LIST OF POTENTIAL IMPROVEMENTS IDENTIFIED

During the simulations carried out with the first version of the DST, the following 35 potential improvements were identified by the DECISIVE consortium. The improvements were related to results representation, error management and reporting, users' permits, data requirements, documentation, as well as additional features and simplifications.

Improvements related to Results representation:

1. Improve the **layout of the results** provided by the tool both in the Excel file downloaded from the tool as well as in the radar figure shown in the tool.
2. Allow the **comparison of scenarios** within a project in the DST.
3. Add a **traffic light representation related to the compliance with the EU fertilization** regulation next to the radar figure.

Error management:

4. Add an **error management system** that notifies when an error is likely to happen.
5. When an error occurs, the **error screen** should describe the reason for the error.
6. When all the links to connect the various processes of a scenario are made, **a summary of the items missing** in each stage could be useful.

Users' permits:

7. Allow the user to **create background processes**. For now, the user (i.e., administrator) will have to add first the new background process into the database and then the user will be able to select such processes in the tool.
8. Allow the user to **delete waste processes** created by mistake. The user can delete a process from a scenario, but this process will remain in the internal library of the tool.
9. Allow the user to **copy a scenario**; currently, it is only possible to copy projects.
10. Instead of creating new processes all the time, the tool could ask if the user wants to **"replace" an existing waste process** with the new one or use the one from the library without the option to edit it.
11. When **coping a waste process** or a source, the user can only see the name of the process, but it could be useful to see the characteristics of the process before selecting one process.
12. Be able to **skip the collection** step in the scenario. Presently, it is a mandatory stage, but it would be useful to be able to skip it (e.g., home-composting option).
13. Allow the users to **add/edit parameters** to the list option. For now, the parameters are set by the administrator and cannot be added/edited by the users.
14. In the GIS part, the user should be able to **locate new facilities in the map**, for now it is only possible to do that in the biowaste generation sources, but not for facilities. To do that in this first version, the user (i.e., administrator) will have to create the new point into the "Spatial Facility Database" before the user can select this point in the map.

15. In the GIS part, the user should have the possibility **to delete generation sources.**
16. Allow the user to **get results** even if the scenario is incomplete.

Data input in the waste processes

17. Distinguish in the tool between **mandatory and optional data input** in the process definition (e.g., put an asterisk when the data is needed to get results and no asterisk when data is only required as information). It should also be mentioned when a blank is not allowed, and the user should add a zero instead.
18. Reduce the **amount of information required** in all waste processes. The DST should be able to keep the most important parameters and skip those with marginal effects on the results.
19. Add a field in the waste process definition to enable including **references and comments** related to the waste process.
20. Limit the **drop-down/cascade lists** to items relevant for the waste stage and field definition being compiled (e.g., put only collection equipment in the collection section) and differentiate the items within the categories "material & energy inputs" and "socio-economic aspects".
21. In the GIS part, the **unit of the numbers** displayed in the maps should be cleared.
22. In the GIS part, sources could **be grouped per type** (e.g., in a zone there are green dots for restaurants, yellow dots for hospitals and blue dots for educational centres).
23. In the GIS part, introduce the possibility **to filter by type of sources (and treatment)** from a drop-down list based on the selected area.

Documents/help to facilitate the understanding of the DST working procedure:

24. A tutorial or a video demonstrating practical uses of the software program.
25. A large table with details and options that characterize each step to provide quick support to the user.
26. Add part of the manual in each screen of the DST.
27. Add descriptions for the fields that are more difficult to understand.
28. Have an initial home page of the DST with a short description of what this tool does with the link to the manual.

Feature additions and simplifications:

29. Remove the division into **Waste Management Zones (WMZ)** to simplify the use of the tool.
30. Add more indicators in the results categories:
    a. More environmental impact categories (e.g., some toxic ones, for now we only have global warming).
    b. Biowaste for Material Recovery (BW4MR): ratio of *biowaste sent to treatment (for material recovery such as composting and anaerobic digestion)* over the *biowaste generated.*
    c. Biowaste for Energy Recovery (BW4ER): ratio of *biowaste sent to treatment (for energy recovery such as anaerobic digestion)* to *biowaste generated.*
    d. Add different countries fertilisers limits. **Compliance of Bio-based products Use with the Regulation Limit:** This indicator informs about the compliance of the bio-based product generated in the scenario with the limit of heavy metals content given in JRC (2014). The tool simply states whether the bio-product is above or below this legal threshold.
31. A **waste process library** in the menu representing the waste process database could facilitate the view of the waste process database included in the tool. In this library, the user should be able to view all existing processes as well as create new ones from them without having to go inside the scenario.
32. Add **different waste process forms for treatment** based on the treatment option selected. The current treatment form is suitable for AD, but less for composting. It should give the option to have more than one treatment in line.

33. To have a **suggestion for each value** to introduce, maybe considering a range among the data that are already inserted in the tool.
34. Be able to add figures **in total values** instead of (unit/ton) to facilitate the data addition and understanding.
35. Provide the option to perform other types of **capital goods amortisation**. Presently, it is only a simple annual linear amortisation.

6.2 SHORTLIST OF IMPROVEMENTS TO INTRODUCE FOR THE DST V2

The selection of the improvements implemented in the second version of the DST was done based on the importance of the improvement (according to the DST development team) and the economic cost associated with the programming of each improvement.

The improvements implemented in the second version of the DST were:

- Improvement 1 – The layout of the Excel and radar provided by the DST v2 are clearer than the results provided by the former version of the tool.
- Improvement 2 – The user can compare the results of two scenarios within the same project in the radar figures provided by the DST v2.
- Improvement 4 – The DST v2 includes an error management system that notifies the user when an error is likely due to skipped steps or missing information.
- Improvement 24 – A video has been made to demonstrate the workflow of the DST v2 as part of the DECISIVE 2nd webinar.

7. Conclusions and limitations

The main objective of this deliverable was simulating the implementation of the DECISIVE technological-package in different types of sites using the DST to understand: (1) benefits and drawbacks of the DECISIVE technology-package in different EU contexts and (2) usability of the DST to assess biowaste management options.

To accomplish the main objective, several activities were carried out:

1. Selection of the simulation sites.
2. Data gathering to build waste process libraries and scenarios.
3. Modelling the scenarios in the DST and interpret the results.
4. Drawing some conclusions regarding the suitability of the DECISIVE technological-package and the DST.

Regarding the selection of the simulation sites, the initial step was broad enough to consider the multiple and diverse EU contexts regarding biowaste generation and management as well as geographic, economic, and demographic differences, in order to assess the technological-package and the DST. However, data availability appeared to be the most critical aspect when moving forward with such selection. Even though some sites appeared to be interesting to be evaluated due to their peculiar properties, their simulation was not possible at the time of developing this deliverable due to lack of sufficient data.

The data gathering process to build the waste process libraries and the scenarios was intense in terms of time and effort. The main difficulties were related to the lack of data available and the necessity to make estimations as well as the need to convert the data in the formats required by the DST. The limited access to representative data of the state of the biowaste management in Europe is one of the main constraints encountered in this work. Although data might be available at local level from the competent authorities, there is a lack of standardized datasets that properly describe biowaste management systems at local scale. The official standardized data that make up the statistics are data on quantities treated and ideally also include information on the quality of the biowaste treated. Other more specific data may be available at the level of the treatment facility, i.e., at the individual level but a few are available in standardised formats. The quality of the data used in the simulation varies between the sites but in general it can be said that is poor. Data are in fact mainly based on single measures that may not represent the reality. In addition, during the simulation, it was possible to identify data values that are necessary and those that would be useful to have. From this lesson, what could be concluded is that: (1) to improve the quality of the simulation results further effort on data gathering should focus on key data values and (2) to improve the usability of the DST further effort should focus on shortlisting the data requirements to request only the necessary data to obtain the results.

Regarding the modelling of the scenarios in the DST and the interpretation of the results, it is important to highlight the potential of a systematic and automatic tool to simulate different types of biowaste systems. However, the objective of having a flexible tool able to assess a broad range of situations has made the tool more complex than desired initially. For further development of the DST, the trade-off between flexibility of its applicability and its user-friendliness should be reconsidered. For example, if the tool is only meant to be used for a few types of waste management situations, then the tool could be improved to be more user-friendly to model these more limited number of situations. Further development of the tool should be made considering the most common application of the tool.

Nevertheless, it must be considered that the tool offers an objective comparison at first sight. Then, the final decision needs experienced people/teams that can adequately interpret the results produced.

The use of DST to build scenarios for different types of sites demonstrated that this tool can be an effective instrument to assess the performance of biowaste collection and treatment schemes and support competent authorities in the decision-making steps.

The indicators included in the DST can be used as a uniform basis for the comparison of scenarios, even though other indicators specific to each situation might need to be added before making final decisions.

The DST may be used in fact for planning, to visualise the current biowaste management system and identify deficits that can be approached by using alternative scenarios. Moreover, it can be used to have a holistic view about the performance of the current waste management system and comparing it with alternative scenarios.

The DST can be of great interest also for local authorities or large biowaste generators to promote the development of local solutions in some specific contexts, and to demonstrate that decentralised solutions are not in conflict with centralised ones but can be complementary to them.

Waste management planning is in most European countries mainly focused on centralised systems (at regional or even supra-regional level) to take advantage of economies of scale and to occupy the minimum space. However, under specific contexts and local conditions, the decentralisation could be an interesting and complementary solution compared to centralised systems. In terms of communication, the decentralised treatment facility may have a powerful effect on improving the quality of biowaste collection. When waste producers interact with the unit, there might be more motivation in improving biowaste collection. Therefore, it could also be an effective tool to work in combination with centralised biotreatment facilities where quality is a key factor for efficiency.

“Ideal” profiles for decentralising biowaste treatment resulted: in disperse or rural areas, areas with low population density and high quality biowaste collected selectively, and large producers, such as groups of restaurants, university campuses, markets or hospitals.

Rural areas may be convenient places to implement decentralised solutions for biowaste, as they are normally characterised by high quality source-separated biowastes. Indeed, micro-AD system implementation requires as input a very high quality biowaste (food waste, green waste excluding woody waste) with reduced presence of impurities. A high quality of biowaste can avoid or reduce pre-treatment and related costs. Second, rural areas are often isolated and far from centralised waste treatment plants and decentralisation could impact positively in terms of climate change, i.e., shortening distances travelled for transportation.

Also, decentralised solutions might be more suitable for the less densely populated areas of the region where there is a demand for fertiliser or where compost can be directly used in local activities. Micro-AD plants could be included in new districts where synergies with other local services or activities can be planned in line with the principle of circular economy, or to treat commercial biowaste where the production could be sufficient to feed a micro-AD unit.

The application of the DST to theoretical sites resulted in the mentioned set of considerations that could suggest which “ideal” profile(s) could typically characterise the locations better served by the DECISIVE scheme. The identification of a “typical” site for which the DECISIVE scheme is particularly appropriate could also be used in the future to choose the most promising locations where such novel biowaste management schemes could be implemented successfully.

In all the analysed sites, DECISIVE system performed better in terms of transport intensity index since locating the mAD in the premise of biowaste generator reduces the distance travelled. DECISIVE solution also gave better results in terms of time required for sorting biowaste, especially when the biowaste collection in street containers was substituted by the DtD scheme. Indeed, this change in collection system implies a reduction of hours dedicated from the biowaste generator in delivering its waste. The decentralised system is less interesting in terms of electricity recovery index especially if the alternative scenario is compared with a centralised anaerobic digestion or even with incineration.

Finally, the results of the simulation show that the decentralisation of the biowaste management using the DECISIVE technological package should give better results than current centralised, linear systems in terms of transport intensity and climate change, under local specific conditions. However, these results should be taken with caution due to the poor quality of the data available at the time of finalising this deliverable. Some of the data inserted in the tool might have uncertainties and this can impact the results. For example, time needed to sort waste would require a closer look when exploring different options since the values can vary according to the type of collection (frequency, biowaste generator). Moreover, limited experience is available on how well a network of mAD would actually work in terms of coordination, maintenance, etc. which could affect the economic costs for the operation of the decentralised system and the related results of the simulation.

The possibility to update/change the data in the DST to build scenarios of biowaste management options will make it easier for users to adapt their projects to the local contexts and introduce more precise values able to give more accurate results which may better support them in a decision-making when planning a change in the existing biowaste management.

Table 5 – Main characteristics of the biowaste managements systems of the 11 sites (2 demo and 9 theoretical) in both BAU and alternative scenario.

Name		Country	Type of biowaste source	Type of scenarios	Ton input/year (generated)	Streams	Ton input/year (separated)	Generation	Source separation	Collection	Pre-treatment	Treatment	Transport	Bio-products use	Final Disposal
Site 1	Bellaterra University Campus	ES	University	BAU	318	BW in SSBW bin	49	Households and 10 Restaurants	Bring Scheme containers 2200L	Truck 22m3 diesel	Mechanical & Manual Sorting SSBW	AD & CHP + Post Composting SSBW	Truck14t 59km/h	Application of compost as soil amendment	WasteWater Treatment, Landfill
						BW in RW bin	269		Bring Scheme containers 2200L	Truck 22m3 diesel	Manual Trommel & Magnets separation RW	Biostabilisation-Composting RW	Truck14t 59km/h	-	Incineration; Landfill
				Alternative	318	BW in SSBW bin	114	Households and 10 Restaurants	DtD bins 1000L	e-vehicle 0.65t	-	Micro Anaerobic Digestion+ hygienisation+ Stirling+SSF_50t	-	Application of compost as soil amendment; Application of Biopesticide	WasteWater Treatment
						BW in RW bin	204		DtD bins 1000L	Truck 22m3 diesel	Manual Trommel & Magnets separation RW	Biostabilisation-Composting RW	Truck14t 59km/h		Incineration; Landfill
Site 2	Guineueta Market	ES	Market	BAU	69	BW in SSBW bin	66	1 market 378m2	Bring Scheme containers 360L	Truck 18m3 diesel	Mechanical & Manual Sorting SSBW	AD & CHP + PostComposting SSBW	Truck14t 59km/h	Application of compost as soil amendment	WasteWater Treatment, Landfill
						BW in RW bin	3		Bring Scheme compatting container 15m3	Truck 18m3 diesel	Manual Trommel & Magnets separation RW	Biostabilisation-Composting RW	Truck14t 59km/h	-	Incineration; Landfill
				Alternative	69	BW in SSBW bin	66	1 market 378m2	Bring Scheme bins 360L	e-vehicle 0.65t	-	Micro Anaerobic Digestion+ hygienization+ Stirling+SSF_50t	-	Application of compost as soil amendment; Application of Biopesticide	WasteWater Treatment
						BW in RW bin	3		Bring Scheme compatting container 15m3	Truck 18m3 diesel	Manual Trommel & Magnets separation RW	Biostabilisation-Composting RW	Truck14t 59km/h		Incineration; Landfill
Site 3	Lübeck City	DE	Household	BAU	35,751	BW in SSBW bin	17,037	Households	DtD bins 120L	Truck 18m3 diesel	Mechanical Sorting SSBW	Wet continuous AD_SSBW	Internal Transport_BW Excavator 2t; Truck14t 59km/h	Application of compost as soil amendment	WasteWater Treatment, Landfill

						BW in RW bin	18,714		DtD bins 240L	Truck 18m3 diesel	Mechanical Sorting RW	Wet continuous AD Biostabilisation RW	Truck14t 59km/h	-	Incineration; Landfill
				Alternative	35,751	BW in SSBW bin	849	Households	DtD bins 120L	e-vehicle 0.65t	-	Micro Anaerobic Digestion+ hygienisation+ Stirling+SSF_50t	-	Application of compost as soil amendment; Application of Biopesticide	WasteWater Treatment
							16,188		DtD bins 120L	Truck 18m3 diesel	Mechanical Sorting SSBW	Wet continuous AD_SSBW	Internal Transport_BW Excavator 2t; Truck14t 59km/h	Application of compost as soil amendment	WasteWater Treatment, Landfill
						BW in RW bin	18,714		DtD bins 240L	Truck 18m3 diesel	Mechanical Sorting RW	Wet continuous AD Biostabilization RW	Truck14t 59km/h	-	Incineration; Landfill
Site 4	Dogna Municipality	IT	Household and commercial activities	BAU	28	BW in SSBW bin	17	Households and commercial activities	Bring Scheme containers 2200L	Truck 18m3 diesel	-	AD & CHP + PostComposting	Truck14t 59km/h	Application of compost as soil amendment	WasteWater Treatment, Landfill
						BW in RW bin	11		Bring Scheme containers 2200L	Truck 18m3 diesel	-	-	Truck14t 59km/h	-	Incineration; Landfill
				Alternative	28	BW in SSBW bin	22	Households and commercial activities	DtD buckets & mater-bi bags 25L	e-vehicle 0.65t	-	Micro Anaerobic Digestion+ hygienisation+ Stirling+SSF_50t	-	Application of compost as soil amendment; Application of Biopesticide	WasteWater Treatment
						BW in RW bin	6		DtD buckets & plastic bags 70L	Truck 18m3 diesel	-	-	Truck14t 59km/h	-	Incineration; Landfill
Site 5	Rennes Métropole	FR	Households and commercial activities	BAU	33,775	BW in SSBW bin	2,254	Households and commercial activities	DtD bins 120L	Truck 18m3 diesel	-	Composting Green waste	-	Application of compost as soil amendment	-
						BW in RW bin	31,521		DtD bins 240L	Truck 22m3 gas natural	-	-	-	-	Incineration
				Alternative	33,775	BW in SSBW bin	676	Households and commercial activities	DtD bins 120L	e-vehicle 0.65t	-	Micro Anaerobic Digestion+ hygienisation+ Stirling+SSF_50t	-	Application of compost as soil amendment; Application of Biopesticide	WasteWater Treatment
							2,254		DtD bins 120L	Truck 18m3 diesel	-	Composting Green waste	-	Application of compost as	-

														soil amendment	
						BW in RW bin	30,846		DtD bins 240L	Truck 22m3 gas natural	-	-	-	-	Incineration
Site 6	Vall d'Hebron Hospital	ES	Hospital	BAU	284	BW in SSBW bin	236	Hospital	DtD bins 120L	Truck 18m3 diesel	-	Composting	Truck14t 59km/h	Application of compost as soil amendment	Incineration, Landfill
						BW in RW bin	48		Bring Scheme containers 1000L	Truck 18m3 diesel	Manual Trommel & Magnets separation RW	Biostabilisation-Composting RW	Truck14t 59km/h	-	Incineration; Landfill
				Alternative	284	BW in SSBW bin	236	Hospital	DtD bins 120L	e-vehicle 0.65t	-	Micro Anaerobic Digestion+ hygienisation+ Stirling+SSF_50t	-	Application of compost as soil amendment; Application of Biopesticide	WasteWater Treatment
						BW in RW bin	48		Bring Scheme containers 1000L	Truck 18m3 diesel	Manual Trommel & Magnets separation RW	Biostabilisation-Composting RW	Truck14t 59km/h	-	Incineration; Landfill
Site 7	Zagreb City	HR	Households and food services	BAU	70,867	BW in SSBW bin	4,350	Households and food services	DtD bins 120L	Truck 18m3 diesel	-	Composting		Application of compost as soil amendment	
						BW in RW bin	66,517		DtD bins 1000L	Truck 18m3 diesel	-	-	-	-	Landfill
				Alternative	70,867	BW in SSBW bin	1,434	Households and food services	DtD buckets 25L	e-vehicle 0.65t	-	Micro Anaerobic Digestion+ hygienisation+ Stirling+SSF_50t	-	Application of compost as soil amendment; Application of Biopesticide	WasteWater Treatment
							4,350		DtD bins 120L	Truck 18m3 diesel	-	Composting		Application of compost as soil amendment	
						BW in RW bin	65,083		DtD bins 1000L	Truck 18m3 diesel	-	-	-	-	Landfill
Site 8	Brussels Region	BE	Households, schools and universities, catering in offices, hospitals, markets,	BAU	195,985	BW in SSBW bin	12,900	Households, schools and universities, catering in offices, 23 hospitals, markets,	DtD buckets & plastic bags of 30L	Truck 18m3 diesel	-	Anaerobic Digestion	-	Application of compost as soil amendment	WasteWater Treatment, Landfill
						SSBW	8,000		DtD buckets &	Truck 18m3 diesel	-	Composting of Green Waste	-	Application of compost as	-

			HORECA sector, food stores and public parks					HORECA sector, food stores and public parks	plastic bags of 60L					soil amendment	
						SSBW	16,500		-	-	-	10 Decentralised composting units and home composting	-	Application of compost as soil amendment	-
						BW in RW bin	191,585		DtD buckets & plastic bags of 60L	Truck 18m3 diesel	-	-	-	-	Incineration
				Alternative	195,985	BW in SSBW bin	4,000		DtD buckets & plastic bags of 30L	e-vehicle 0.65t	-	Micro Anaerobic Digestion+ hygienisation+ Stirling+SSF_50t	-	Application of compost as soil amendment; Application of Biopesticide	WasteWater Treatment
						BW in SSBW bin	12,900		DtD buckets & plastic bags of 30L	Truck 18m3 diesel	-	Anaerobic Digestion	-	Application of compost as soil amendment	WasteWater Treatment, Landfill
						SSBW	8,000		buckets of 60L	-	-	10 Decentralised composting units	-	Application of compost as soil amendment	
						SSBW	16,500		DtD buckets & plastic bags of 60L	Truck 18m3 diesel	-	-	-	-	Incineration
						BW in RW bin	154,585		DtD buckets & plastic bags of 60L	Truck 18m3 diesel	-	-	-	-	Incineration
Site 9	Gran Lyon	FR	Households and commercial activities	BAU	168,098	BW in SSBW bin	29428	Households and commercial activities	DtD Bin 120L	Truck 18m3 diesel	-	Composting Green waste	-	Application of compost as soil amendment	-
						BW in RW bin	138,670		DtD Bin 240L	Truck 22m3 gas natural	-	-	-	-	Incineration
				Alternative	168,098	BW in SSBW bin	3,362	Households and commercial activities	DtD Bin 120L	e-vehicle 0.65t	-	Micro Anaerobic Digestion+ hygienisation+ Stirling+SSF_50t	-	Application of compost as soil amendment; Application of Biopesticide	WasteWater Treatment
							29,428		DtD Bin 120L	Truck 18m3 diesel	-	Composting Green waste	-	Application of compost as soil amendment	-

						BW in RW bin	135,308		DtD Bin 240L	Truck 22m3 gas natural	-	-	-	-	Incineration
Demo Site1	Lyon pilot	FR	Restaurants and food&services	BAU	54	BW in SSBW bin	0.0	9 Restaurants and food&services	-	-	-	-	-	-	-
						BW in RW bin	54.0		DtD buckets & plastic bags 120L	Truck 18m3 diesel	-	-	-	-	Incineration
				Alternative	54	BW in SSBW bin	54.0	Restaurants and food&services	DtD buckets & plastic bags 120L	e-vehicle 0.65t	-	Micro Anaerobic Digestion+ hygienisation+ Stirling+SSF_50t	Truck14t 59km/h	Application of compost as soil amendment; Application of Biopesticide	WasteWater Treatment
						BW in RW bin	0.0		-	-	-	-	-	-	-
Demo site 2	Dolina pilot	IT	Household and commercial activities	BAU	516	BW in SSBW bin	319	Households and commercial activities	DtD buckets & mater-bi bags 25L	Truck 22m3 diesel	-	AD & CHP + Post Composting	Truck14t 59km/h	Application of compost as soil amendment	WasteWater Treatment, Landfill
						BW in RW bin	198		DtD buckets & plastic bags 70L	Truck 22m3 diesel	-	-	Truck14t 59km/h	-	Incineration; Landfill
				Alternative	516	BW in SSBW bin	123	Households and commercial activities	DtD buckets & mater-bi bags 25L	Truck 18m3 diesel	-	Micro Anaerobic Digestion+ hygienisation+ Stirling+SSF_50t	-	Application of compost as soil amendment; Application of Biopesticide	WasteWater Treatment
							195		DtD buckets & mater-bi bags 25L	Truck 22m3 diesel	-	AD & CHP + Post Composting	Truck14t 59km/h	Application of compost as soil amendment	WasteWater Treatment, Landfill
						BW in RW bin	198		DtD buckets & plastic bags 70L	Truck 22m3 diesel	-	-	Truck14t 59km/h	-	Incineration; Landfill

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- Deliverable D3.8 "Methodologies to geographically design an optimized network of micro-AD and SSF sites at the urban and peri-urban scale" Confidential.

- Deliverable D3.9 "Results of the spatial approach for designing the decentralised urban biowaste valorisation network".

- Deliverable D4.6 "Protocol of the strategies to develop a sustainable long-term SSF at a bench scale".

- Deliverable D4.9 "Bioproduct Valorisation - Field test report Season 2018".

- Deliverable D5.1 "Methodology for planning of decentralised biowaste management behind the Decision Support Tool".

- Deliverable D5.2 "DECISIVE Decision Support Tool".

- Deliverable D5.3 "User manual of the DECISIVE Decision Support Tool".

- Deliverable D6.1 "Methodology of characterisation of the biowaste management system in the DECISIVE demonstration sites: Current and new systems simulation for the LYON and CATALONIA cases".

- Deliverable D6.3 "Set of criteria for the selection of locations where the Decision Support Toll could be applied".

- Deliverable D6.5 "Report on communication actions and incentives implemented –number, type of public, results".

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