USER IDENTIFICATION FOR MUNICIPAL WASTE COLLECTION IN HIGH-DENSITY CONTEXTS

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0. INTRODUCTION

Municipal waste management is a key subject of local environmental policies and it is one of the local policies that requires most resources.

European countries have increasingly shifted their focus from disposal methods to prevention and recycling.

With respect to waste management performance, large differences exist between EU Member States particularly in relation to the generation, recycling and separation of municipal waste.

Public investment, local regulations, and communication campaigns must be used to achieve consistently improving results in the area of waste prevention and source separation.

User identification can help achieve a high degree of source separation and lower waste generation rates.

A user identification system is based on the implementation of a mechanism by which the user of the waste collection service is identified and their waste generation is recorded. This can be more easily done in a low-density context by using a door to door waste collection system; the implementation of user identification becomes more complex in high-density urban settings when communal containers are used.

This guide aims to provide local authorities in a high-density context with more information about these systems and to describe the basic steps needed for their implementation.

Economics

Waste Fractions to Control

Test, Monitor and Control

Communication

Pay-as-you-throw

Reliable Technology

User Adoption

Effects on Waste Streams

0.1 MUNICIPAL WASTE

Municipal solid waste (MSW) generation varies considerably among countries, ranging from 779 kg per capita in Denmark to 337 kg per capita in the Czech Republic **[1]**, in 2016. These variations reflect differences in consumption patterns and economic wealth, but also depend greatly on how municipal waste is collected and managed.

Municipal waste constitutes approximately 10% of the total waste generated in the EU **[2]**.

European Union (EU) countries achieved an average total recycling rate of 46 % of MSW in 2016 **[2]**.

The goal by 2025 is 55% recycling which, rises to 65% for 2035 **[3]**. The performance of each Member State and their alignment with the targets is shown on Graph 1.

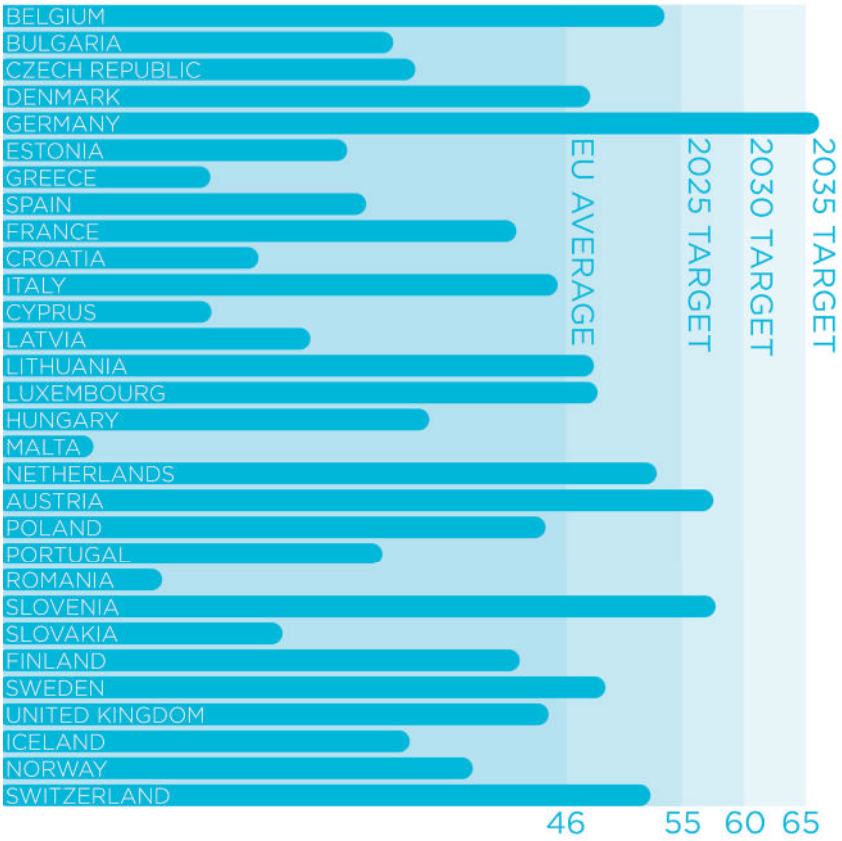
Only one Member State has reached the 2025 goal already; Germany at 66% **[4]** in 2016. Austria, Slovenia, Belgium, Switzerland, and Holland recycled at least half of their municipal waste in 2016 **[4]**.

Spain's recycling performance is at 30% **[4]** and a generation of 444 kg per capita in 2016 **[1]**.

By 2030 there will also be a landfill target with a maximum of 10% of MSW and a ban on landfilling separately collected MSW **[3]**. The total rate of municipal waste landfilling for the EU went down by 60% from 1995 to 2016 **[5]**. The performance of individual countries varied widely.

These EU goals provide a driving factor for municipalities to improve their waste management performance. In addition to this, the costs associated with ineffective waste management puts pressure on municipal budgets.

Graph 1. EU MSW PERFORMANCE AND TARGETS



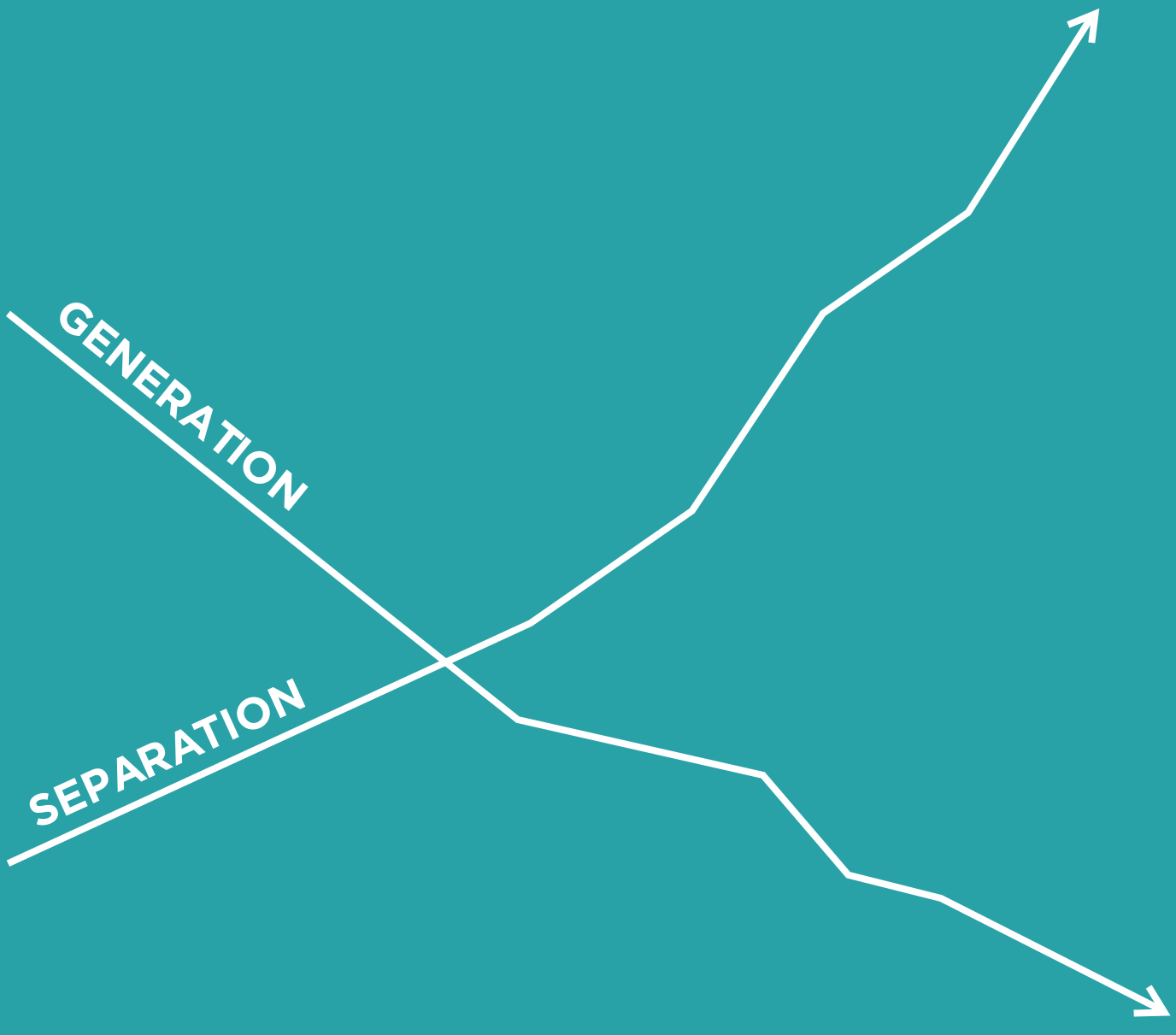
[1] *OECD Data, Municipal Waste Total, Kilogram/Capita 2000 – 2016*
[2] *Eurostat, Municipal Waste Statistics*
[3] *Waste Framework Directive*
[4] *Eurostat, Municipal Waste By Waste Operations*
[5] *Eurostat, Municipal Waste Landfilled, Incinerated, Recycled and Composted in the EU-28*
Graph 1*: Adapted from [3], [5].*

1. WASTE MANAGEMENT

There are some fundamental elements that allow for the successful implementation and maintenance of a waste management system that incorporates user identification. These elements would help provide a high degree of source separation and/or lower municipal waste generation:

Reliable Technology

Pay-as-you-throw



1.1 RELIABLE TECHNOLOGY

A user identification system is based on the implementation of a mechanism by which the user of the waste collection service is identified and in some cases their waste generation is recorded. This technology can be mandatory or voluntary for residents to use, depending on the type of technology and system implemented.

Technology allows for accurate user identification. In order to avoid system failure, two fundamental characteristics are required: reliability and robustness.

In addition to user identification technology, various sensors could be used to track and record the weight or volume of waste disposed of or the container fill levels. Sensors can also detect and record malfunctions, among other things.

Along with sensors, electronic locks are available in the area of waste management. Radio-Frequency-Identification (RFID) and Near-Field-Communication (NFC) access locks are potential choices for municipalities.

The technologies available for use in the area of waste management and user identification are described in detail in chapter 2.

1.2 PAY AS YOU THROW SCHEMES

Pay-As-You-Throw (PAYT) schemes are a form of implementing the 'polluter pays' principle in the area of waste management. Under PAYT schemes residents pay according to their waste generation.

Differentiated tariffs reflect the amount of waste disposed of by each resident and type. PAYT has proven to provide good results on recycling and also on waste prevention.

The fee can be divided into two elements: fixed and variable. The variable part of the fee is based on the real quantity of waste generated: generally, refuse waste is charged, but also other fractions can potentially be charged as well (see section 3.4 Waste Fractions to Control).

Door-to-door collection is a common and easy way to connect a household to their waste generation. However, in a high-density context, alternative models are required as communal containers are used for waste collection. Closed containers equipped with user identification technology allow to link citizens to their waste generation. Chamber systems that measure the weight or volume of waste disposed of in containers is a solution already used in Europe in some high-density contexts (see case study of Linköping, Sweden), in which PAYT can be applied.

PAYT is an optional element to apply when implementing user identification in waste management systems. For more information on the implementation of PAYT schemes please refer to the 'Guide for the implementation of Pay-As-You-Throw Systems for Municipal Waste' published by Agència de Residus de Catalunya **[6]**.

Recent trends show that PAYT schemes tend to have a higher use of technology than in the past, so there is heavy reliance on the effectiveness of the technology to ensure accurate billing is achieved.

[6] *Puig Ventosa, I., Calaf Forn, M., Mestre Montserrat, M. (2010) Guide for the Implementation of Pay-As-You-Throw Systems for Municipal Waste. Agència de Residus de Catalunya.*

2. USER ID TECHNOLOGY

A user identification system is based on the implementation of a mechanism by which the user of the waste collection service is identified and their waste habits recorded. This technology can be mandatory or voluntary for residents to use, depending on the type of technology and system implemented.

MANDATORY IDENTIFICATION

In systems that are mandatory to use, user identification solutions rely on the integration of electronic locks into containers, with Radio-Frecuency Identification (RFID), Near-Field Communication (NFC) or PIN access.

As the containers are locked, residents have no choice but to use the system.

These systems provide more accurate data and better results on waste management since residents feel more controlled than in voluntary systems. However, there is potential for increased misbehaviours or fraud. Waste can be llegally dumped outside locked containers, in city bins or high level of impurities may appear in the unlocked containers for different waste fractions.

VOLUNTARY IDENTIFICATION

In systems that are voluntary to use, NFC and QR tags are popular choices. These systems involve tagging each container with an NFC chip or a Quick Response code sticker. Then users identify themselves by scanning the NFC chip or a QR sticker with their phone when disposing of their waste.

This gives municipalities data on when each container is used and by which user.

The results of waste management tend to be better when identification is required. If they are voluntary, there is generally less participation and lower separate collection levels, but there is also less illegal dumping of waste, less bags lying on the ground and less impurities.

NOTE: *Distributing standardised bags with user identification can also connect the user to their waste. This system involves integrating the technology into the bags instead of the containers. Bags can be identified through QR-, alphanumeric or bar-codes. Standardised bags can also incorporate RFID technology.*

Although this has not yet been tested in many municipalities, it could be used as a way to control user behaviour when implementing a pilot of open or closed containers in a high-density context, so as to control their waste volume and associate better user container ID with real waste disposed of.

RFID

NFC

QR

2.1 RADIO FREQUENCY IDENTIFICATION

Radio-Frequency-Identification, better known as RFID, is the method of uniquely identifying items using radio waves. A minimum, an RFID system needs a tag, a reader and an antenna. The reader sends a signal to the tag via the antenna, after which the tag responds with its unique information.

RFID can be used for identification, authentication, and data storage with minimal human intervention. They are engineered to be tamper resistant by implementing cryptographic algorithms. RFID has recently emerged in the waste management industry.

RFID tags are either Active or Passive:

ACTIVE RFID tags contain their own power source giving them the ability to broadcast with a read range of up to 100 meters. Their long-read range makes active RFID tags ideal for where asset location and other improvements in logistics are important **[7]**.

PASSIVE RFID tags do not have their own power source. Instead, they are powered by the electromagnetic energy transmitted from the RFID reader. As the radio waves must be strong enough to power the tags, passive RFID tags have a read range from near contact up to 25 meters. They are more expensive than PASSIVE RFID tags **[7]**.

The wave lenghth of the RFID reader determines its possible use:

High Frequency (HF): read range typically between 1 cm and 1 m. A possible example for this range would be the user identification through a smart RFID card in street containers (which would include a reader).

Ultra High Frequency (UHF): much shorter wave lenght which increases the read range from 1 to 5-6 m (in some cases it can increase to up to 30 m). This wave lenght could be used, for example, to identify tags located in waste bins through the antenna located in the waste collection truck.

LOCKED CONTAINERS

The waste being deposited in communal waste containers could be controled by installing RFID readers with electronic locks. Users would need passive RFID cards or tags to identify themselves and open the containers. When an access key is held over the RFID panel, the access tag is checked and, if approved, the container opens and waste can be deposited. Each use is recorded.

Containers can also be fitted with other sensors such as weight or fill level sensors, which can be used to provide more accurate data on citizen's waste disposal habits and/or to optimise the waste collection system. These sensors are discussed in detail in section 2.5 Additional Technology.

[7] *Wikipedia, Radio-Frequency Identification*

2.2 NEAR FIELD COMMUNICATION

Near-Field-Communication (NFC) enables communication between two electronic devices, one of which is usually a portable device such as a smart-phone. Both devices must be within 4 cm of each other. Due to the fact that NFC devices must be in close proximity to each other it has become a popular choice for secure communication between consumer devices **[8]**.

An NFC device is able to act both as a reader and as a key tag.

NFC-enabled devices can act as electronic identity documents and key cards. NFC's short range and encryption support make it more suitable than less private RFID systems.

NFC has also become popular in the area of waste management.

LOCKED CONTAINERS

The waste being deposited in communal waste containers can be controlled by installing NFC locks onto communal waste containers. These containers require an NFC device to open. When an approved NFC device is held over the lock the container opens and waste can be deposited. Each use is recorded.

UNLOCKED CONTAINERS

A voluntary to use system can also be implemented using NFC technology. NFC monitors the waste habits of citizens through installing an NFC reader onto the communal waste containers. When an NFC device, usually a smart phone, is held over the NFC panel, the use of the container is recorded. This system has been piloted and more information can be found in the case study of Mancomunitat de l'Urgellet.

NOTE: *It is possible to combine these technologies. For example, in voluntary to use systems, QR and NFC can be fitted with a single sticker. The users can quickly use the NFC in a single tap, but if they do not have an NFC enabled phone they can scan the QR to track their waste disposal habits. This system has been piloted and more information can be seen in the case study of Mancomunitat de l'Urgellet.*

[8] *Wikipedia, Near Field Communication*

2.3 QUICK RESPONSE CODE

A quick response or QR code, is a two-dimensional square matrix that acts like a barcode. The main purpose of this is to store and transmit data, mainly used with smart devices.

LOCKED CONTAINERS

A QR scanner can be fitted at collection points with locked waste containers. Users can scan their specially distributed waste bag that has a QR code on the QR scanner and the appropriate container will unlock. This has been trialled in Hangzhou, China.

UNLOCKED CONTAINERS

In high-density contexts, users can be identified without locking the containers through a trust based system using QR codes. Users identify themselves when throwing waste into a container by scanning the QR attached to the container using their phone. These readings are recorded. This system has been piloted and more information can be found in the case study of Mancomunitat de l'Urgellet.

2.4 TECHNOLOGY PROVIDERS

Table 1. TECHNOLOGY PROVIDERS IN EUROPE, THEIR AVAILABLE TECHNOLOGY AND WHICH CONTAINERS THEY ARE COMPATIBLE WITH.

		MOBA	ROS ROCA	ID&A	WINTTEC TNL	MARIMATIC OY	XARXA AMBIENTAL	ALQUIENVAS	ID WASTE S.L
TECHNOLOGY	RFID	●	●	●	●	●		✱	●
	NFC	●					●		
	QR						●	✱	
	BAGS							●	
SYSTEMS	USER ID	●	●	●	●	●	●	●	●
	CHAMBER	●		●	●	●			●
	WEIGHT COLLECTION	●		●					●
	VOLUMETRIC SENSORS	●		●	●				●
COMPATIBILITY	LATERAL	●	●	●	●		●		
	REAR	●	●	●			●		
	IGLOO	●					●		
	PNEUMATIC	●		●		●	●		
	UNDERGROUND	●		●			●		
MORE	PROVIDER	EMZ	DORLET	ID&A	WINTTEC TNL	MARIMATIC OY	XARXA	ALQUIENVAS	ID&A DORLET
	WEBSITE	moba-automation.com	rosroca.es	ideabs.com	tnl.pt	marimatic.com	grupxarxa.cat	alquienvas.com	id-waste.com

✱ *More info in Table 2. Technology Specifications*

Table 1. *Adapted from ENT sources.*

2.5 ADDITIONAL TECHNOLOGY

Other technologies that could be implemented along with a user identification system are explained below.

Waste containers can be equipped with sensors with the ability to perform different tasks. Thanks to the small size of the sensors, they can be used in almost any type of container regardless of their shape, size or content.

Sensors can be used to track the weight of waste in containers, fill levels and for optimising waste collection routes.

The **WEIGHT** of the waste can be measured in several ways. Sensors can be used to measure the weight of each deposit or the entire contents of the container.

WEIGHT PER CONTAINER

When the waste is collected, it can be weighed by installing sensors on the forklift, which will weigh the container during loading the container, before emptying its content into the truck and weighing it again when empty. The difference in weight is recorded for each container.

Another option is a body scale which will weigh the body of the truck before and after loading the content of the container.

WEIGHT PER DEPOSIT

The containers can be equipped with sensors, which can calculate and record the weight of waste deposited by each user.

WEIGHT COLLECTION SYSTEM

The waste collection points (all waste fraction containers must be present) are equipped with a weight-computerized scale, which can measure and record the weight of waste deposited by each user. To dispose the waste, the user has to weigh its bag and select the waste fraction. After completing this process, the corresponding waste container unlocks and opens. This also allows for the application of a PAYT scheme.

The **VOLUME** of waste can be measured or estimated in several ways:

VOLUMETRIC SENSORS

Sensors can be installed on the lid of a container to sense when the container is full using ultrasound technology.

This information can then be sent to the administration center where it can be processed and used to optimize collection routes. In addition, the information regarding the average volume of waste and considering the number of users associated to each container, can be used by the municipality to calculate an average price per volume and user, making it possible to apply an indirect PAYT scheme.

CHAMBER SYSTEM

The main part consists of a rotating cylindrical semidrum attached to the bin flap, with a user identification system to open. The chamber system has a limited volume for disposal the waste (e.g. 20l, 30l or 50l) due to the capacity of the drum. This system allows for the application of a PAYT scheme.

The next section shows the various technology suppliers, the systems they can implement and the options within each system. Limitations are also outlined. The energy and software systems in place can also be seen.

2.6 TECHNOLOGY SPECIFICATIONS

Table 2. TECHNOLOGY SPECIFICATIONS

NOTE: For all technology providers in the following Charts, there is optional-user/container assignment and time table opening limitation.

MOBA

Systems	User identification		Chamber system
Model 1	Flex: Full open flap of the container		Adaptive version for lateral and rear collection containers
Model 2	E-Box: Full open flap with smart tag that ensures that the flaps gets closed after its use. It includes a solar panel display.		Integral version for underground and pneumatic containers.
Volume Control	No. Only number of disposals per user		20l , 30l & 50l for lateral and rear containers. / 20l & 120l for underground and pneumatic containers.
Energy System	Solar Panel (E-Box Model)	Battery, 2 year autonomy	Solar Panel Harvesting generator (lever movement)
Software MAWIS U2	Bidireccional[a] Two optional comunication systems between containers and software Option 1 GSM/GPRS[b]: SIM card in the containers (cost and mantenance by MOBA) Opció 2 ISM: Data collected by garbage truck (only E-Box and chamber)		

a) Transfer data from container to software and vice versa.
b) Wireless data transfer cellular communication system.

ID&A

Systems	User identification	Chamber system	Weight collection system
Model 1	HORUS-ID-LOCK: FUll open flap of the container.	HORUS-ID-WSD: Adaptive version for lateral and rear collection container	HORUS-ID-KG: Computerized collection point for identification and weithging
Model 2	HORUS-ID-FLAP: Open a little flap on the container	-	-
Volume Control	HORUS-LT: Volumetric sensor	22l	Electronic weight system to use the container.
Energy System	Battery, 3 year autonomy		-
Software B-STATION	Bidirectional Option 1: GPRS: SIM card in the containers. Option 2: HORUS-OBC: Data collected by garbage truck.		

DORLET

Systems	User identification	Chamber system
Model 1	DORLET: Lock kit for lateral container.	No
Volume Control	No. Only number of disposals per user	-
Energy System	4 AA Batteries, autonomy 30.000 cycles	-
Software DASS	Unidirectional [a] Option 1: Portable NFC system and PC. Option 2: Wireless radio system collection truck.	

a) Transfer data from container to software, and not vice versa.

Tnl/Winttec

Systems	User identification	Chamber system
Model 1	Lock for lateral container with RFID card.	No
Volume Control	Yes. Volumetric sensor with GPRS technology (High cost)	-
Energy System	Battery, 2 year autonomy	-
Software SICU	Bidirectional Option 1 GPRS: SIM card in the containers Option 2 firmware: Updateable for future IOT nets. Option 3: collection truck system.	

Xarxa Ambiental

Systems	User identification
Model 1	QR/NFC (PVC) codes in stickers format on containers. Containers not closed
Volume Control	No. Only number of disposals per user
Energy System	-
Software	Xarxa ambiental provides iOS/android App for QR/NFC readings. App development and maintenance. Control and data storage.

MariMatic Oy

Systems	User identification	Pneumatic chamber system
Model 1	MetroSense: Waste identification garbage bags stickers with RFID technology for waste sorting[a]	Metro Taifun: Pneumatic automatic waste collection system[b] with user identification.
Volume Control	No. Only number of bags per user, unless bags must be standardised	Chamber system: Pipes of 30 cm of diameter DN 300 mm (20l - 40l bags aprox.)
Energy System	-	Waste Transfer Terminal connected to local electricity network.
Software	Metrosense RFID detectors technology: select the correct fraction for each container.	Metro Taifun Company provides software for the pneumatic system functionality.

a) Automatic waste sorting system at waste treatment plants.
b) Pneumatic vacuum conveying system collects the waste from the waste inlets, via urderground pipe network to Waste Transfer Terminal.

Alquienvas

Systems	User identification bags
Model 1	Garbage bags supplier with QR and barcode printed on stickers. or alphanumeric codes in bags.
Model 2	Garbage bag supplier with electronic chip.
Volume Control	30l bags
Energy System	-
Software	This company only supplies the bags with user identification systems. Therefore, there is additional need for smartphone App for QR barcode and alphanumeric readings.

3. IMPLEMENTATION

The selection of a user identification system should take into consideration a set of variables, such as to which type of users is addressed, if a mandatory or voluntary system is desired, which fractions should be controlled, which type of technology should be used to identify users and is suitable for the containers used, the design of the monitoring and control system, etc. So as to have economic information to decide, a range of unitary prices is offered in chapter 3.6.

All these key aspects are discussed in the next sections.

Users

Communication

Economics

Waste Fractions to Control

Test, Monitor and Control

Collection Containers

Effects on Waste Streams

3.1 USERS

One of the first things to consider when implementing a user identification system is who the users will be. There are two main categories of users: households and commercial activities.

RESIDENTS will have to adopt new habits in relation to their waste when a user identification system is implemented. It is important to ensure they are involved in every stage of implementation, from planning, to testing and full roll out. Informed citizens will help achieve a smooth transition from the old to the new system. A communication campaign is often used to encourage participation and engagement within a new system. This is detailed in section 3.2.

COMMERCIAL users have different waste habits. As commercial users will produce more waste, it is important to consider their needs, especially when implementing a mandatory user identification system that restricts the volume of waste per deposit, for example a chamber system. A solution must be in place to deal with any bulky waste they may produce. An alternative option is to collect commercial waste through a door-to-door system: this could provide better waste separation results and easier tracking of misbehaviours.

When focusing on a **VOLUNTARY** to use system, high engagement is important in order to achieve good results. Each user should be assigned to one or two containers for each fraction for ease of inspection.

When using NFC or QR technology, the users will re quire a smart-phone and a dedicated app to participate in the system. Prior to having the ability to use the app, citizens could first sign a contract with the details of the expected behaviours, outcomes, etc. Each member of the family should have the ability to download the app, but use a single household account.

When considering a **MANDATORY** system, distributing access passes is of up-most importance, as each household has to be granted access to at least one collection point.

Again, each user should be assigned to one or two containers for each fraction for ease of inspection. With this mandatory system, there is the option to restrict the number of days each user can have access every week, month, etc. This could apply to both commercial and household users.

When using NFC technology, the same approach is taken as in the voluntary system, described above.

When using RFID technology, each household and business should receive at least two access passes. It is suggested to also provide them with an information pack, including the access passes, providing any key information the users may need to know in relation to the new waste management system.

3.2 COMMUNICATION

A key consideration when implementing a new system is user adoption. Therefore, a communication campaign should be undertaken. The material can include the following: service schedule such as which and how many days per week each fraction container can be opened or is emptied and information about collection, types of services provided, changes to payment, how to acquire required items such as user identification 'accessories', how to use the new system, sanctions, rewards, educational material on how to reduce and separate waste correctly, etc.

Fears must be addressed regarding illegal waste disposal, the perception that the introduction of the system will reduce privacy or any other concerns.

Prior to the communication campaign addressed to residents it is important to start a discussion aimed purely at providing information about the current waste collection model and gathering opinions, criticisms, positive aspects and shortfalls of the system. This should be a participative procedure. Proposals should be communicated to the residents providing information on the new model.

Finally, residents should be informed of the results achieved by the new system.

3.3 COLLECTION CONTAINERS

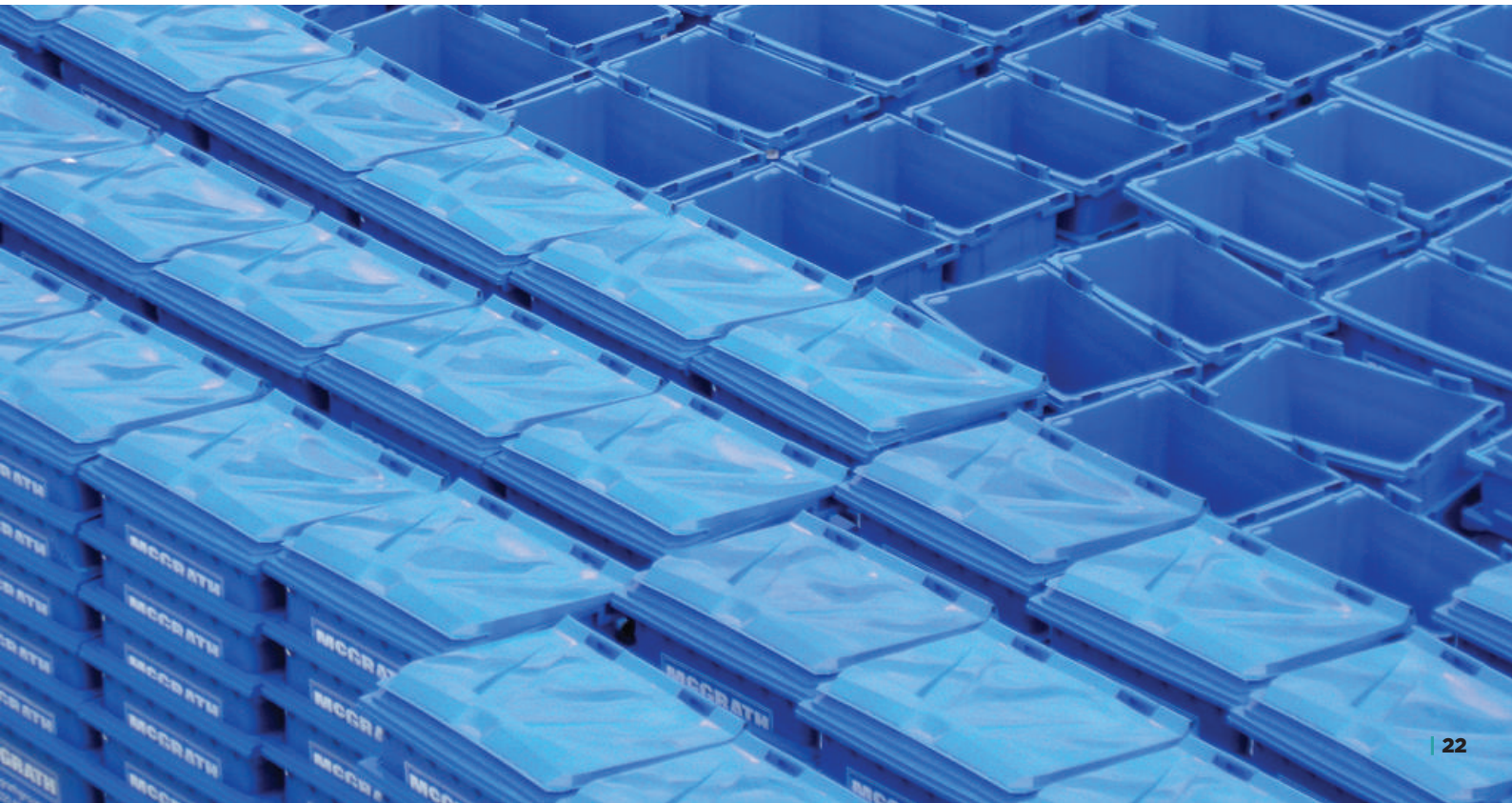
As there are a variety of containers used for waste collection in any given municipality, the technology chosen must be suitable for implementation across the chosen area of the municipality, allowing for an optimal waste collection service to be provided to citizens.

The number and placement of containers is an important issue. A reduced number must be prioritized, although a maximum distance from citizens to containers should be guaranteed (100-150 meters). In addition, it is highly recommended that at least one container for each waste fraction is present at each waste disposal point.

NOTE: *Collection point distribution can be more easily optimised if implementing sensors into containers. See section 2.5 for more information.*

Introducing user identification technology to existing containers, usually needs some adaptation of the container, for example changing the lid, allowing a chamber system, inserting an upper-little-lid over the main lid or cleaning to allow for QR stickers to be affixed. This may differ depending on the container type and manufacturer and can also differ depending on the waste fraction.

Another key consideration is the multi-level assignation to locked containers: which users can have access to each container. Common practice is to provide each resident with access to a restricted number of collection points; one or two is common. This facilitates inspection. If only provided with access to one collection point, it is essential to ensure collection is efficient, as illegal dumping may occur if the containers are full.



3.4 WASTE FRACTIONS TO CONTROL

The selection of which waste fractions are to be monitored or locked needs to be made carefully, both for economic efficiency and to prevent excessive technological complexity.

RESIDUAL WASTE

It is clear that residual waste could be better separated. Therefore, when applying technology to waste collection containers, so as to reduce the amount of residual waste and get higher recycling levels; locking the residual waste container and/or controlling user access seems the obvious choice. This is unavoidable if a pay-as-you-throw scheme is put in place.

Some systems only based on incentivising separate collection of biowaste and recyclables, to prevent impurities in these fractions, prefer to leave residual waste unmonitored.

ORGANIC WASTE

Impurities in the organic waste very sensitively affect the final quality of the product.

Locking the organic waste containers and therefore controlling access tends to increase the quality of the separately collected biowaste.

If the residual container is locked, the biowaste container indeed needs to be locked as well.

PACKAGING

The manufacturing industry produces vast amounts of packaging that end up as waste, and therefore strategies need to be put in place to incentivise reduction and separate collection.

For this reason, if residual containers are locked and pay-as-you-throw implemented, it could also be recommended to lock packaging containers and charge for their use. Otherwise, packaging containers could receive other materials apart from packaging itself.

Conversely, if the system is based on incentivising separate collection of recyclables, monitoring this fraction could be also an option, although not ideal as it could give the signal that separate collection is preferable to prevention.

PAPER AND CARDBOARD, AND GLASS

These waste fractions typically present good results, and low levels of impurities.

For this reason is not common nor necessary to lock the containers for this fraction, unless the municipality wants to put in place discounts in the waste charge for these recyclables.

3.5 TEST, MONITOR AND CONTROL

Once the various implementation stages have been detailed, an implementation plan needs to be drawn up. A suitable implementation strategy is proposed with no start or end date. Each municipality can adjust the time dedicated to each element, but follow the suggested order.

Although not essential, a test stage is also advised. The aim is to get residents used to the new system.

The test period can be defined by the municipality, and can be used to check the accuracy and effectiveness of the technology, ensuring the system is flawless before complete deployment.

Once the new system is fully implemented it is important to maintain a high level of participation. For the first few weeks of operation, the system should be monitored on a daily basis to ensure residents are using the system correctly.

If misbehaviours are detected, the municipality should inform the resident and notify that a penalty will be applied if the misbehaviour persists. This should be regulated through a municipal ordinance.

NOTE: *If a PAYT scheme is introduced in addition to the user identification system, it would be recommended to do it in subsequent stages, so as not to have the added difficulty of implementing all the new elements at once.*

3.6 ECONOMICS

To implement user identification technology into a municipal waste management system, different factors must be taken into account. And costs will play a central role in the selection and implementation of such a system.

It is vital to carry out a preliminary study of the area into which the system is to be implemented, so as to ensure the selected system solution is as appropriate and cost effective as possible.

The initial costs can be high due to the installation and adaptation of the current infrastructure to suit the new system. These initial costs consist of: the installation of the technology into the containers, the purchase of all the technological material for the system, advertising campaigns for citizens, etc.

After the initial implementation, the costs are in the form of monthly fees, such as maintenance, software, etc.

Estimated costs are included in the next table:

Table 3. ESTIMATED PRICE FOR THE TECHNOLOGY NEEDED TO LOCK THE CONTAINERS

		User identification systems price range	Chamber system price range
Technology per container		355 € - 900 €	1,382 € - 1,400 €
Installation per container		90 € - 100 €	50 €
Hardware maintenance		5 €/container/month	9 €/container/month
RFID Cards or Smartcards		1.35 € - 3.76 €	
SmartTag		2.65 €	
Volumetric sensor		325 €-390 €	
Waste limitation metallic mesh[a]		193 €	
SOFTWARE	A	**Software online (manteinance is included)**	8 €/container/month 0.25 €/month/smartcard
	B	**Software license**	1,950€ - 6,900 €
		Software installation[b]	1,000 € - 6,000 € (for 3,000 inhabitants)
		Software and hardware maintenance	150[c] - 472 €/month
Project implementation[d]		700 € - 6.500 €	
QR bag		0.098 €	
Alphanumeric bag		0.079 €	

a) Consist of a metallic shape grill with square holes for the main purpose of distributing the material homogenously, it also helps to control the material volume the user can introduce in the container.
b) It depends on the number of inhabitants registered.
c) It refers only to software maintenance, for the unidirectional systems.
d) It depends on the number of containers installed.

Note: Price ranges for a minimum of 5 technological manufacturers and suppliers, prices of 2017.

Table 3. *Adapted from ENT sources.*

3.7 EFFECTS ON WASTE STREAMS

The implementation of user identification systems makes people feel accountable for their waste habits and provides an incentive to reduce and separate waste.

A PAYT scheme creates an additional incentive. As the highest tax tends to be put on refuse, the main incentive is to reduce this fraction either by sorting more waste for selective collection or by reducing the total amount of waste that is produced.

In Pay-for-Participation schemes (which try to count the number of times each user throws recyclable materials so as to apply some reduction in their waste charge) separate collection of recyclables will increase.

A decrease in waste generation and an increase in selective waste collection translate into lower waste treatment costs.

The magnitude of the effects may be highly variable, and will depend on the town's initial situation, the selected model and other aspects.

POTENTIAL FRAUD

Connecting the user to their waste through user identification and changing waste management models, can cause a change in the habits of most residents. Antisocial and fraudulent behaviours can also appear.

These behaviours include illegal waste disposal in bins and/or places that are not permitted, *waste tourism* (disposal of waste in neighbouring towns) or mixing waste in other fractions (which leads to an increase in impurities).

All these behaviours have the same aim: to avoid or reduce payment in a PAYT system. If no PAYT scheme is in place, these misbehaviours will be less common.

4 CASE STUDIES


LINKÖPING
LEIDEN
ARNHEM
SASIETA
URGELLET
LA GARROTXA

SEOUL, SOUTH KOREA

In 2012, the South Korean Government announced a nationwide roll-out of Pay-As-You-Throw for organic waste in the hopes to reduce food waste.

Prior to this, South Korea already had the world's strictest food waste laws, for example the country banned all food waste from landfills in 2005 **[SK1]**.

61% of the food waste treatment cost is supported by the municipal government. The remaining 39% percent is covered through the new waste charge **[SK1]**. There was also some sales generated from food waste which turned into animal feed, which amounted to approximately US$11,693,520 per month.

Focusing on Seoul, South Korea's capital city, it is home to 25 million people, and it had a recycling rate of 65.3% as of 2012 **[SK2]**.

In 2013, the system was implemented in the capital's largest district Songpa-gu, with 680,000 residents, including 290,000 residents living in apartment buildings.

TECHNOLOGY

The weight-based food waste disposal system can be done in four ways: through using designated waste containers, prepaid authorized plastic bags, RFID chipped containers or containers with RFID locks.

The prepaid, authorized plastic bag method involves putting food waste into an authorized bag before throwing it into a food waste container.

Authorized waste bags are sold at grocery stores, and vary in price between districts (for example, a one-litre bag costs 35 won (0.027€) in one district but 80 won (0.062€) in another district). The prices have been raised by 30% since the beginning of the project **[SK3]**.

The bags are labelled with educational material informing about which waste can go into them. Bones and shells, for example should be removed. There are also fixed hours for taking out the food waste bags for collection. Anyone found violating the rules can be fined.

Waste containers with integrated RFID involves residents putting their food waste into a communal container that is electronically locked. An RFID access pass is connected to each residence, and households are charged by the weight of food waste disposed of and receive a monthly bill.

RESULTS

A 9-31% reduction in food waste is seen depending on the region and collection system implemented **[SK3]**.

Initially there was confusion due to a lack of publicity or promotion for the method. Residents did not know how the new RFID system worked or the costs associated with it.

Each district has a designated day for waste disposal. For instance, residents in Jegi-dong can dispose of their garbage every Tuesday,Thursday and Saturday.

However, most residents do not appear to be aware of the designated days and dispose of their garbage whenever they want. Residents dispose of their garbage at arbitrary times and days.

It was found that the RFID method was the most efficient way of reducing the food waste volume, according to the Government. Using this high-tech radio-frequency identification tracking system, South Korea has waged one of the most successful campaigns against food waste in the world. However, it has a high installation cost, which averages around 2 million won (1,570€) per container.

[SK1] *Seoul Solutions, Minimizing Food Waste: Zero Food Waste Seoul 2018*
[SK2] *Seoul Solutions, Municipal Solid Waste Management*
[SK3] *Seoul Solutions, Volume Based Waste Fee (VBMF) System for Municipal Solid Waste*

LINKÖPING, SWEDEN

Sweden is home to just over 10 million people, generating 446 kg of MSW per capita **[1]** with a recycling rate of 48% in 2016 **[4]**. Landfilling represents only 0.6% of their waste **[4]**.

Vallastaden is a new densely populated district within Linköping, Sweden. The district consists of over 1,100 residences.

TECHNOLOGY

The waste management system consists of an automated vacuum delivery system for organic and residual waste. The system includes 15 waste collection stations with 30 waste inlets (15 for organic waste and 15 for residual waste) that connect to a pipeline that leads to a waste management reception facility. Everything goes through the same pipe system but on different days. While waiting to go through the pipeline the waste is held in an intermediate container.

Each inlet is electronically locked, and an RFID access pass is required to dispose of waste. Each household is provided with two access passes, one per each fraction.

When you deposit your garbage bag, the waste is weighed, and the weight is recorded in order to calculate the waste charge. The system is therefore a PAYT system based on weight.

Other recyclable waste fractions are not charged for. They can be dropped by the residents into collection points, these are unlocked and normally located further apart (about 500 m) than the inlets for organic and residual waste.

RESULTS

Residents from Vallastaden, during the pilot generated 418 kg per capita in 2016, just over 6% less than the per capita generation of the whole country in the same period **[SW1]**.

Pay-as-you-throw system, in theory, acts as an incentive for people to separate their waste correctly and reduce the amount of residual and organic food waste generated. Results on waste separation or recycling from the district have not been found.

However, there is a high student population that pay for the waste as a collective sum with an annual waste generation allowance. Only if they exceed the allowance will they pay extra, and this has not affected any students as of 2016, because the allowance is too high.

The fact that the recycling points are located further away than the general and organic waste inlets, results in many residents disposing of all their waste in the general waste inlet as it is more convenient.

When there is a fault in one inlet, it may affect the whole system. This has been reported to have happened on several occasions. If there is a blockage in an inlet caused by large amounts of wastes disposed of at once, the door gets stuck and the entire system locks. This causes illegal dumping of waste beside the containers.

[1] *OECD Data, Municipal Waste Total, Kilogram/Capita 2000 – 2016*
[4] *Eurostat, Municipal Waste By Waste Operations*
[SW1] *Metrotaifun, Automatic Solid Waste Collection System*

ARNHEM, HOLLAND

Holland produced 520.9 kg of MSW per capita in 2016 **[1]** and recycled 53% of it **[4]**. This makes Holland one of the best performers in waste recycling in Europe.

The municipality of Arnhem is carrying out a pilot titled 'Reversed Waste Collection' (RWC) in three neighbourhoods (see next table), totalling approximately 8,000 households. The project started in July 2013 and was fully introduced in January 2014. The main goal of the project is to increase recycling of household waste and reduce CO2 emissions **[HA1]**.

RWC makes it easier to present recyclable waste for collection, encouraging more people to separate their waste. This pilot and waste collection in Arnhem does not include a PAYT scheme.

The neighbourhoods were primarily selected on the basis of the following criteria: size, distribution across the city, clear-cut neighbourhood borders, active residents' associations, and the lack of other major projects currently in progress **[HA2]**.

REVERSED WASTE COLLECTION

Residents are responsible for taking residual waste to an underground container in the neighbourhood. Every underground container for residual waste has an access control system. To open them, residents use an RFID Waste Card, which provides access to all the underground residual containers in Arnhem. The system records when a household uses a container.

The number of times that a container is used also provides an indication of the fill level of the container and this is used to adapt the collection routes. The access control system in combination with the waste card prevents residents from other municipalities from dumping their waste in the underground bins in Arnhem.

Glass can be deposited in glass bins (most of which are underground).

For the other waste fractions two types of operations can be distinguished:

a) LOW RISE building occupants have a maximum of three mini-bins for kerbside collection: one for organic waste, one for plastic packaging materials and one for paper and cardboard (the mini-bin for paper and cardboard is not mandatory, but 97% of residents have it).

All mini-bins for organic waste and plastic packaging materials in low-rise building households were chipped. The minibins for paper and cardboard were chipped during the manufacturing process. Every RFID chip is unique and corresponds to a household.

Waste collection vehicles for emptying the minibins in the trial neighbourhoods are fitted with equipment to read the RFID chips automatically. This way, every household is registered and the system can track how often and when the minibins are put out.

b) HIGH RISE building occupant take their waste to underground collection containers in the neighbourhood. There are separate containers for plastic packaging materials, paper and cardboard. Residents interested in recycling their organic waste can do so using the organic 'city bin'. The 'city bin' is collected fortnightly, if located on an existing organic waste collection route.

OUTCOMES

The results of Reversed Waste Collection are very positive. According to sorting analyses, six months after introduction, the amount of residual waste in the three neighbourhoods decreased by an average of 23%: from 264 to 204 kg per resident **[HA3]**.

ARNHEM PILOT - ONE YEAR RESULTS

Trial neighbourhood	Recyclable material / waste material	Baseline measurement	Goal	Results	Improvement
Over het Lange Water	Paper / cardboard	26	35	43	65%
	Plastic packaging materials	4	12	18	350%
	Other (residual) waste	206	186	205	0%
De Laar-West	Paper / cardboard	31	43	61	97%
	Plastic packaging materials	5	17	22	340%
	Other (residual) waste	270	238	212	-21%
Malburgen-oost Noord	Paper / cardboard	26	35	36	38%
	Plastic packaging materials	2	6	18	800%
	Other (residual) waste	305	287	225	-26%

Paper and cardboard together with plastic and packaging were recycled more, whilst residual waste decreased.

Communication around the pilot project was very successful. Residents were aware of the changes occurring and how the system worked. Common concerns such as privacy were addressed by making the information about a household's waste disposal habits saved under address only and neither linked to personal data nor shared for commercial purposes. This was clearly communicated to residents.

Education was a focus in this pilot. Four 'waste coaches' were appointed in each trial neighbourhood to educate residents effectively. They are in the neighbourhood on a daily basis, including in the evening and on weekends, to answer residents' questions about separating waste. They actively provide information, check the waste bins and report problems **[HA4]**.

Thanks to the good results of the RWC, the municipal board decided in June 2015 to roll out the new system across the whole of Arnhem.

[1] *OECD Data, Municipal Waste Total, Kilogram/Capita 2000 – 2016*
[4] *Eurostat, Municipal Waste By Waste Operations*
[HA1] *Arnhem, Reversed Waste Collection*
[HA2] *Arnhem, Reversed Waste Collection*
[HA3] *Arnhem, Underground Bin Location Choice*
[HA4] *Arnhem, Waste Coaches*

LEIDEN, HOLLAND

In 2015, the urban area of Leiden (Holland) had a total of 121,562 inhabitants.

Due to the increasing demand from the residents, for a better waste management system, innovative initiatives are being launched and implemented in Leiden.

Previously, a door-to-door collection system was used for organic, residual, paper and plastic waste, operated by different companies. The glass is always thrown away into a communal container.

In 2018, the introduction of underground containers for the residual waste fraction aimed to tackle many of the problems arising in Leiden.

TECHNOLOGY

Over 550 underground containers are available to the residents of Leiden for the residual waste.

Each container is electronically locked. With the use of the RFID access passes every household can access the containers, each access pass is registered to a specific household and only provides access to a designated set of containers.

Containers are equipped with fill sensors: when 80% full, an electronic signal is sent and the container will be emptied as soon as possible **[HL1]**. They have also a chamber system that restricts the volume to 60 litres per use.

The system in Leiden incorporates a PAYT scheme based on the volume of residual waste. There is an annual flat fee of 136 € and an additional charge of 1.40 € per use (of a maximum of 60 litres). Residents receive a bill annually. If residents do not put their waste into the container, but instead leave it outside, it will be collected, identified and fined.

Other waste such as recyclables and biowaste are collected free of charge at other collection points **[HL2]**. These containers do not require an access pass to be opened.

OUTCOMES

Initially there were some issues with people not using the containers due to problems with the access passes. As a result, the old door-to-door system was used while transitioning to the new system.

Plastic and metals are disposed of into residual waste containers, therefore residents are paying a premium price to dispose of this type of recyclable waste in Leiden.

RECOMMENDATIONS

While this city provides separate containers for inhabitants to dispose of their residual waste, paper, organic waste and glass, it currently does not have a separate disposal for plastics or metals on the street. This would further increase the already high recycling (53%) rate **[4]**.

[4] *Eurostat, Municipal Waste By Waste Operations*
[HL1] *Municipality of Leiden, Waste Containers*
[HL2] *Avri, What Do You Pay For Your Waste*

URGELLET, SPAIN

The Mancomunitat d'escombraries de l'Urgellet is located in Alt Urgell, in the North of Catalonia, Spain.

The Mancomunitat serves eleven municipalities: Alàs i Cerc, Arsèguel, Cava, Estamariu, Josa i Tuixent, Montferrer i Castellbò, Pont de Bar, Ribera de l'Urgellet, Seu d'Urgell, Valls de Valira and Vansa i Fórnols.

These eleven municipalities have a total of seventy-two population centres with more than 16,000 inhabitants.

A pilot test was carried out with 200 families for four months in 2017 to encourage better waste separation in the region.

Previously, the region used a communal collection point system. Each collection point consists of five types of containers (for biowaste, packaging, glass, paper/cardboard and residual waste).

TECHNOLOGY

The new system involved equipping each container in the pilot region with an NFC and QR tag.

Users could install an app on their smartphones that could read the code each time they disposed of their waste at a collection point. Adoption of the system was voluntary; the containers were not locked and the users did not necessarily have to scan every time they disposed of their waste.

Families were selected and had to sign a contract, download the app and request an activation code. The code is only available to those who signed the contract.

To use the QR option, the user simply opens the app and taps the screen while pointing the camera at the QR code on the container. The phone vibrates and emits a sound to signal a successful scan. The QR code can be read even if the code is dirty and with the help of the phones flashlight at night.

The NFC option involves passing an NFC enabled device with the app across the NFC tag on the container. The phone also vibrates and emits a sound to signal a successful scan.

The app identifies and records the user, the container type, its location and the time of disposal. The phone will then display the information and transmit it to the server. The app can store information when there is no data connection and transmit it later.

If the citizen scans regularly, showing that they are separating their waste and not using the residual container with a high frequency, they are rewarded. The maximum incentive is a 50% reduction of their waste charge.

PAYMENT

Before implementing the system, the fiscal ordinance was changed to allow for a waste charge reduction to be used as an incentive for the pilot system.

Prior to the pilot there was no bill for the waste charge, such as the ones that exist for electricity, gas, water, etc. The new system has introduced a bill for the waste charge and the App also includes additional information.

Now, the users can see how much money they pay for the service and why. They can see the discounts applicable to them, which are reflective of their waste separation rates. The bill also shows the possible discounts that they can get with improved separation efforts and their level of separation compared to others.

The discount obtained is 2 € per week. The maximum annual discount one resident can get is 60 €, therefore they must have good behavior for 30 weeks. Then the net annual waste charge per domestic taxpayer if they recycle for at least 30 weeks is 60 €, and if they do not recycle any week, 120 € per year. According to this, if one taxpayer has good behavior for 10 weeks, the annual discount will be 20 €.

The following table shows the expected behaviour rules that the citizen have to follow to have the weekly discount on the waste charge.

Table 4. EXPECTED BEHAVIUOR PER HOUSEHOLD TO BE ENTITLED THE WEEKLY DISCOUNT ON THE WASTE CHARGE

Waste Fraction	Rules	Info
Organic	Min 1 bag per week	
Packaging	Min 1 bag per week	
Glass	1 bag every 2 or 3 weeks	
Paper/cardboard	1 bag every 2 weeks	
Residual	1 bag every 2 weeks	Residual waste cannot exceed 50% of the selective separated waste.

OUTCOMES

The pilot started with 200 families, 189 downloaded the app and 168 used it, with 143 receiving some discount and 105 families receiving the full discount offered. There was a total of 13,710 readings during the four-month pilot (Table 4).

Following the pilot, but also with the old system, in place for most of the region, separate collection reached 51% in 2017, which is one of the highest in Catalonia, well above the national average of 30% in Spain **[4]**.

It is worth noting that only 1% of the pilot users adopted the NFC technology option. This may be attributed to the fact that people without an NFC enabled mobile phone cannot use this feature of the system.

Table 5. DATA ABOUT THE PARTICPATION OF THE ENGAGED FAMILIES IN DIFFERENT ASPECTS OF THE PILOT

Participation	Number of families	App downloaded	Reading on different days	Discount on waste charge (>0€)	Full discount (60€)
Signed contract	200 (100%)				
Initial	189 (94.3%)	x			
Active	168 (84%)	x	x		
Effective	143 (71.3%)	x	x	x	
Efficient	105 (53%)	x	x		x

[4] Eurostat, Municipal Waste By Waste Operations

SASIETA, SPAIN [SG1]

The Sasiesta Mankomunitatea is an association of Municipalties for waste management, located in the Goierri region of Gipuzkoa, Spain. It serves 23 municipalities: Altzaga, Arama, Ataun, Beasain, Ezkio, Gabiria, Gaintza, Idiazabal, Itsaso, Itsasondo, Lazkao, Legazpi, Legorreta, Mutiloa, Olaberria, Ordizia, Ormaiztegi, Segura, Urretxu, Zaldibia, Zegama, Zerain, Zumarraga.

The overall population is 60,984 inhabitants.

The previous collecting system in the zone consisted of 5 different open containers for glass, paper, packaging, biowaste and residual waste.

The new system implemented, consists of replacing the existent open residual waste container and maintaining the other selective waste.

The green old residual open containers are replaced by grey locked containers.

In some municipalities they also changed the organic brown container for a big brown locked container.

Mankomunitatea Sasieta also put a new container for diapers that can be opened all days of the week, for those families that need it.

The system also includes a kit to improve biowaste separation:

- Brown small bin for the kitchen
- Key
- Compostable bags

They started to implement the pilot test on 30th October 2015 in two of the smallest municipalities of the region: Idiazabal and Olaberria.

Subsequently, they extended the pilot test to other municipalities:

- Legorreta
- Ormaiztegi
- Zumarraga
- Urretxu
- Beasain
- Ordizia
- Legazpi

Currently in the Gipuzkoa region there are more than 3,000 locked containers and more than 100,000 households with RFID cards.

TECHNOLOGY

The grey container is always locked and it can only be opened by citizens at specific times in a week (once a week for instance; see table 6 for more details of each municipality). To open the container the user needs to have an RFID card, which the users have to apply for to the Town Hall.

PAYT is not applied in any of the municipalities.

Containers are from Ros-Roca with RFID technology from Dorlet.

Sasieta has also introduced in some municipalities a new container for diapers that those users who need it can use and which can be opened at any time.

In the following table some specifications of the systems applied in each municipality are shown.

Table 6. MUNICIPALITIES IMPLEMENTATION EXAMPLE

Municipality	Date of implementation	Residual Waste	Biowaste	Diaper especial container
Idiazabal	30/10/2015	Open Wednesday from 00:00 to 24:00 RFID Card	Closed. Physical key to open it	Yes
Olaberria	30/10/2015	Open Wednesday from 00:00 to 24:00 RFID Card	Closed. Physical key to open it	Yes
Legazpi	30/10/2015	Open every day from 18:00 to 24:00 RFID Card	Closed. Physical key to open it	No
Legorreta	27/09/2017	Open Monday from 00:00 to 24:00 RFID Card	Closed. RFID Card to open it	Yes
Ormaiztegi	05/10/2017	Open Monday from 00:00 to 24:00 RFID Card	Closed. Physical key to open it	Yes
Zumarraga	06/02/2017	Open Monday and Friday from 00:00 to 24:00 RFID Card	Closed. RFID Card to open it	Yes
Beasain	16/09/2016	Open Monday and Friday from 00:00 to 24:00 RFID Card	Closed. RFID Card to open it.	Yes
Urretxu	06/02/2017	Open Monday and Friday from 00:00 to 24:00 RFID Card	Closed. RFID Card to open it.	Yes
Ordizia	24/10/2016	Open Monday and Friday from 00:00 to 24:00 RFID Card	Closed. RFID Card to open it.	Yes

Table 6. *Adapted from Mankomunitatea Sasieta sources.*

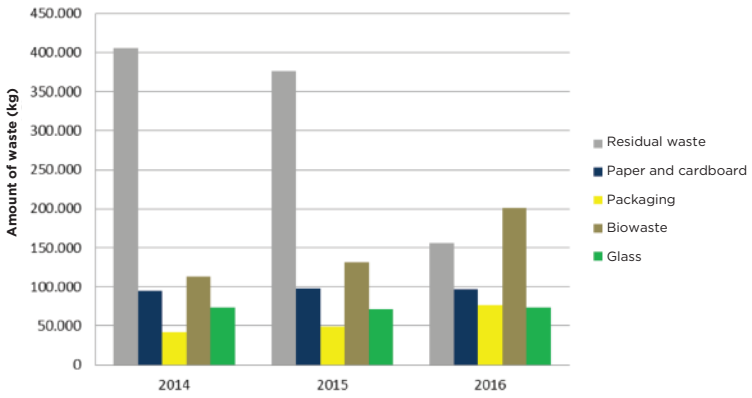
OUTCOMES

The new system decreased the collection cost, as now residual waste is generally collected only 1 day per week compared to the former 4 days. The reduction in residual waste also leads to a reduction in waste treatment costs.

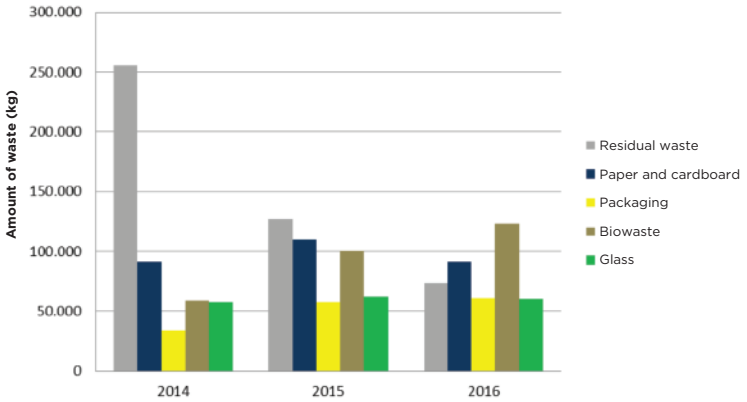
The pilot test shows that the amount of residual waste decreased by 50%, organic biowaste increased by 50% and packaging increased by 70%.

In Idiazabal and Olaberria, after two years of implementation, the waste separate collection results increased from 45% to 75% and from 49% to 82%, respectively (see next figures).

Idiazabal



Olaberria



In all Mankomunitatea, thanks to the implementation of the new system, the percentage of selective waste collection in May 2017 was 53%, 2.8 points more than in 2016.

[SG1] *Sasieta Mankomunitatea*

LA GARROTXA, SPAIN

During a six month period in 2017, four different waste management pilots were carried out in different municipalities of La Garrotxa, Girona, Spain. The aim was to find which system best suited the needs of the region.

The company in charge of carrying out the tests was the Consortium for the Environment and Public Health of La Garrotxa (Consorci de Medi Ambient i Salut Pública de La Garrotxa (Sigma)). Technology and containers were provided by Dorlet and Ros Roca.

In 2017, according to the Catalan Waste Agency (Agència de Residus de Catalunya), La Garrotxa reached 45% waste separation.

The tests were carried out in the following municipalities:

- Argelaguer (235 inhabitants)
- Sant Joan les Fonts, La Roureda (165 inhabitants)
- Santa Pau, Can Blanch (194 inhabitants)
- Vall d'en Bas, Les Olletes (74 inhabitants)

ARGELAGUER

The pilot in this municipality focused on residual and packaging waste. The containers for those fractions were locked and residents could only access them with the use of a personalised RFID card. Each resident only had access to one specific container, near their household.

A technical problem is that containers could not lock themselves if users left their lid open.

Garbage bags used by residents also carried an alphanumeric code to facilitate identification of the user in subsequent inspections. Citizens were provided with two 30l bags for residual waste and three 30l bags for packaging waste per week. Personalized alphanumeric bags required per some sort of administration or bag manager in case citizens needed more bags. This introduced some difficulties.

There were also difficulties with user adoption: waste was seen accumulating next to the locked bins. As the pilot region was small, residents could drive to the next neighborhood to discard of their waste without having to identify themselves.

The use of alphanumeric bags could not be made compulsory in practice. The pilot included random inspections such as opening bags to identify misbehaviors of the residents. However, containers did not reject regular bags, and this made user identification during inspections very difficult.

SANT JOAN LES FONTS, LA ROUREDA

The pilot in this region focused on residual and packaging waste. The citizens were provided with garbage bags that have QR codes printed stickers on them to identify the household from which the waste comes from.

Containers remained as they were.

The QR codes were used by the municipality to facilitate the inspections of the bags, with a specific app.

The main idea of using QR printed stickers codes on bags and keeping the bins open is to keep unchanged the habits of the users and make it simple. However, users not using QR bags are not possible to identify.

The administrative burden associated to managing QR bags is high.

SANTA PAU, CAN BLANCH

The pilot in this municipality focused on residual and packaging waste. In this case the system was different from that of Argelaguer, in that the containers were permanently open, there was no need to use RFID tags to open them.

Users threw the garbage bag and registered themselves at the container using an RFID card. Using this identification system the habits of the citizens could be tracked. The garbage bags carried a code for future inspections.

Fraud was possible as containers were not locked, and citizens could place regular garbage bags that did not carry an identification code and without using the RFID card. The pilot included random inspections, such as opening bags to identify the misbehaviors of the residents.

VALL D'EN BAS, LES OLLETES

The system applied in Les Olletes is the typical door to door collection scheme. It consists of a calendar for waste collection, a different fraction per day, including organic, packaging and residual waste.

Door to door collection allows immediate visual control of waste collection in each household. The collection system forced users to use personalized alphanumeric bags to track recycling behavior. It was also complemented by an inspection of the system during the collection process.

The difficulties in relation to user identification here arised with user identification in apartment blocks with communal containers, and *waste tourism*.

Table 7. PILOT TEST SUMMARY

Municipalities	Monitored Waste Fraction	Containers Technology	Garbage Bags Technology	General Problems
Argelaguer	Residual and packaging waste	Closed container with personalised RFID card	Alphanumeric codes printed in garbage bags. (2 bags of 30 l for residual waste and 3 bags 30 l packaging waste per week)	Garbage on the floor and insufficient technology adaptation by users
La Roureda		Open containers	Garbage bags with QR code	Few uses
Can Blanch		Open containers with personalised RFID card	Personalized alphanumeric codes printed in garbage bags	Insufficient technology adaptation by users
Les Olletes	Residual, organic and packaging waste	Door to Door system	Personalized alphanumeric codes printed in garbage bags	User identification problems in apartment blocks, *waste tourism*

OUTCOMES

Table 8 shows the initial waste production for each pilot for residual, packaging and organic waste. The differences before and after the pilot are calculated for each neighborhood in Table 9.

Table 10 shows the amount of improper waste found in the pilot tests and Table 11 shows final results of separate collection per material.

Table 8. INITIAL WASTE PRODUCTION (Kg/day)

	Waste Fraction	Argelaguer	La Roureda	Can Blanch	Les Olletes
Initial Production (kg/day)	Residual	195 58	221 86	297 81	82 46
	Packaging	19 02	34 35	32 97	7 50
	Organic	48 96	68 04	92 92	5.89
Total		263.56	324.25	423.70	95.85

Table 9. WASTE PRODUCTION VARIATION (Kg/day)

	Waste Fraction	Argelaguer	La Roureda	Can Blanch	Les Olletes
Initial Production (kg/day)	Residual	-72.08	-28.73	-72.30	-70.81
	Packaging	25.10	2.59	17.40	2.52
	Organic	33.80	12.88	59.28	23.45
Total		-13.18	-13.26	4.37	-44.84

Table 10. IMPROPER WASTE IN PILOT TESTS (%)

	Waste Fraction	Argelaguer	La Roureda	Can Blanch	Les Olletes
Improper waste (%)	Packaging	14	22	22	13
	Organic	9	20	7	2.5

Table 11. FINAL RESULTS OF SEPARATE WASTE COLLECTION (%)

Waste Fraction	Argelaguer	La Roureda	Can Blanch	Les Olletes
Residual	**49%**	**62%**	**53%**	**50%**
Packaging	18%	12%	12%	13%
Organic	33%	26%	36%	37%
Packaging+ Organic	**51%**	**38%**	**47%**	**50%***

**In Les Olletes a correction has been made, as it was noted that about 20 kg/day (19.47%) of the waste was lost as "waste tourism".*

In the following table a qualitative assessment of the different systems is presented.

Table 12. QUALITATIVE AUTO EVALUATION OF THE RESULTS

	Les Olletes (Door to Door)	Argelaguer (Close container + RFID Card)	Can Blanch (Open container + RFID Card)	La Roureda (QR Bags)
Level of waste selection	Very good 8	Good 7	Acceptable 5	Low 4
Service cost	Strong increment of personnel + Bags 4	Container + RFID Cards + Bags 6	RFID Cards + Bags 8	Bags 9
Application of PAYT	Feasible 7	Feasible 7	Bonuses 6	Difficult 4
Citizen acceptance	Medium 6	Good 7	Very Good 8	Very Good 8
Inspection and control	High 5	High 5	High 5	High 5
Global score	**7.5**	**8.0**	**7.5**	**7.5**

Table 7. *Adapted from Consorci Sigma sources.*
Table 8. *Adapted from Consorci Sigma sources.*
Table 9. *Adapted from Consorci Sigma sources.*
Table 10. *Data collected by Consorci Sigma through waste inspections.*
Table 11. *Adapted from Consorci Sigma sources.*
Table 12. *Adapted from Consorci Sigma sources.*

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GLOSSARY

| USER IDENTIFICATION

User identification is a logical entity used to identify a user on a software, system, website or within any generic IT environment. It is used within any IT enabled system to identify and distinguish between the users who access or use it.

| WASTE MANAGEMENT

Waste management refers to collection, transportation, treatment and disposal of waste.

| WASTE GENERATION

The weight or volume of materials that enter the waste stream.

| RESIDUAL WASTE

Residual waste refers to the material that remains after the process of waste separation.

| SOURCE SEPARATION

Source separation consists of separating materials by type at the point of generation so they can be separately collected and subsequently recycled.

| PAY AS YOU THROW

Pay as you throw (PAYT) is a usage-pricing model for disposing of municipal solid waste. Users are charged a rate based on how much waste they present for collection to the municipality or local authority.

| DOOR TO DOOR

Separate collection per household mostly known for the situation where a truck stops at every house building and collects the bin assigned to that household building.

USER IDENTIFICATION FOR MUNICIPAL WASTE COLLECTION IN HIGH-DENSITY CONTEXTS

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