State of Digitalization in European Municipal Waste Management

Comparative Study – five EU member countries

Estonia, Germany, Greece, the Netherlands, and Spain

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1. Introduction

1.1. Description of the BlockWASTE project

This comparative study is part of the BlockWASTE project, which is an EU-funded Erasmus Plus project. The project aims to address the interoperability between waste management and blockchain technology and to promote its proper treatment through educational training, so that the data collected is shared within a safe environment, where there is no room for uncertainty and mistrust between all parties involved in waste chains or cycles.

For this purpose, the objectives of the BlockWASTE project are as follows:

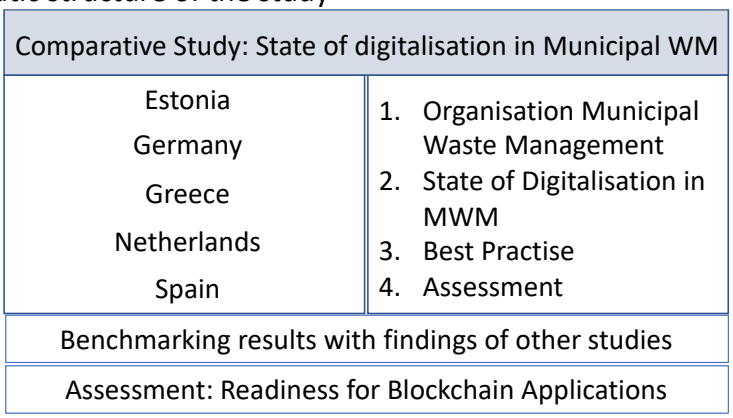
- To conduct research on solid waste generated in cities and how it is managed, so that an information base of good practices can be created that helps reintroduce waste into the value chain, promoting the idea of Intelligent Circular Cities.
- To identify the benefits of the Blockchain Technology within the municipal waste management (MSW) process.
- To create a study plan that supports the training of teachers and professionals of organizations and companies of the sector, in the overlap of the fields of Waste Management, Circular Economy and Blockchain technology.
- To develop an interactive tool based on Blockchain technology, which will make it possible to put into practice the management of data obtained from urban waste, thus visualizing the way in which the data is implemented in the Blockchain and enabling users to evaluate different forms of management

Further information is available from the BlockWASTE project website https://blockwasteproject.eu.

1.2. Objective of this study

The aim of this comparative study is to document the status quo in the digitalization of municipal waste management in EU countries, in order to ultimately examine in which areas the implementation of blockchain solutions makes sense.
Blockchain is only a database solution that allows to trace and track transactions within a waste chain, to transfer digital assets from peer to peer and to use smart contracts for automating processes. But for a database application like the blockchain, the decisive factor is of course the automatic collection of data via Internet-of-Things devices such as sensors and cameras, and the analysis of the data via AI applications. Ultimately, this comparative study is also about the question of the digital readiness of municipal waste managers as regards the use of blockchain solutions.

Figure 1: Schematic structure of the study



source: the authors

This comparative study is based on the description of the status quo of digitalization in municipal waste management in the five countries of the project partners: Estonia, Germany, Greece, the Netherlands and Spain. The IT solutions used are of course dependent on the organisation and processes of municipal waste management in each country. Consequently, the actual description of the use of IT in the municipalities is preceded by a chapter on the organisation of municipal waste management in the respective country. In addition, best practice examples of each country are briefly described where available.
Obviously, a comparative view of only five of the 27 EU member states has limited significance. To mitigate this limitation, the results of the analysis are benchmarked with the results of other studies on this topic. However, the data and the number of studies on this topic are limited.

2. Estonia: State of Digitalization in Municipal Waste Management

2.1. Organisation of Municipal Waste Management in Estonia

In Estonia waste management is the responsibility of local governments that organise waste collection and separation facilities. Local governments have separate waste management plans, which are region-specific and take population density and local capacity into consideration. Local waste management plans are prepared for certain time periods and are aligned with the main objectives of the National Waste Management Plan 2014-2020 (EC, 2014)

According to the Waste Act, one of the most important responsibilities of local authorities regarding waste management is to organize the collection of municipal waste in their territory. Household / municipal waste is collected and transported by a waste management company, contracted by the municipality through public procurement. A contract is signed for five years and the company has a monopoly in a certain waste collection area (waste collection areas are defined in the Waste Act). The company offering the cheapest rate for waste collection usually wins the tender. Organised waste collection has to cover (mixed) municipal waste generated in the area. The local authority, however, can also extend organised collection to other waste types (Tallinn Environmental Agency, 2014)

In addition to the Waste Act, waste management-related responsibilities are also regulated by the Packaging Act, according to which local authorities have the responsibility to organise the collection of packaging waste in their territory. The main objective is for local authorities to coordinate the operation of a collection system (agreements with recovery organisations, presentation of requirements for the packaging waste collection system, awareness raising and supervision) (Tallinn Environmental Agency, 2014).

In Estonia the most common way of collecting different types of waste includes bring-in points near residential areas. In addition to that, there is an extended producer responsibility (EPR) deposit refund system where the return points are located mostly close by/in local grocery stores. Door-to-door collection and co-mingled collection systems are becoming more common but vary depending on the waste management plan of a local government; they are a preferred waste collection system for private housing estates/neighbourhoods. Increasingly there are more civic amenity sites for different types of waste collection (electronic waste, garden/green waste, construction waste and other). The collection systems vary in different geographical locations depending on population and population density (Estonian Ministry of Environment, 2014, pp. Annex 4, pp. 7-22)

The collection of packaging waste (not covered by the deposit-refund system) is organised by three producer responsibility organisations. Packaging waste is mostly collected directly from companies and retailers. Packaging waste from households is mainly collected through the collection point system. In addition, there is a very well-functioning deposit-refund system for glass, plastic and aluminium beverage containers (organised by a deposit organisation) (BiPRO, 2014).

Penalties for non-compliance are low

State supervision over compliance with the requirements arising from the Waste Act are to be exercised by the Environmental Inspectorate and local governments or local government agencies. Upon failure to comply with a precept, the upper limit of a penalty payment pursuant to the procedure provided for in the Substitutive Enforcement and Penalty Payment Act is 32,000 euros.

Waste Management service fees are fixed

No special incentive system rewarding municipalities and households to prevent or reduce solid waste in the MSW sector was found. Service fees are fixed in the contract between the municipality and the contractor, differentiated by service package, whereas the minimum package is mandatory for a given type of house, i.e. each waste holder has to choose a package. The aim of municipally organized collections is clearly to include as many possible waste holders as possible in the collection scheme. Considering the remarkably low level of service fees, the outcome seems to have been successful. In several areas households pay around 1 €/month, although the average is 4-6 €/month. Those fees are paid directly to private service providers. For apartment buildings the service fee is calculated as a flat rate (Estonian Ministry of Environment, 2012)

2.2. IT solutions used in Municipal Waste Management

The results and statements obtained about the use of innovative IT solutions in municipal waste management might be incomplete and segmental. It was not possible to get personal replies from all municipal waste management companies, and the open source data available are not comprehensive. What was missing was particularly:

- information regarding the use of Blockchain for tracking the waste chain and providing reliable information
- information regarding the use of tokens or gamification strategies

IoT (sensors, cameras, waste scanners)

According to a written reply from Tallinn Wastes Reuse Centre (https://tjt.ee/) the garbage trucks collecting municipal waste in Estonia use GPS and tracking software and are of the most modern and automated type. No smart solutions on garbage bins are used in Estonia on a large scale, since the amount of MSW containers and the frequency of their emptying is too high.

Smart bins used for industrial customers only

According to an interview with the Ragn-Sells (www.ragnsells.ee) representative the company is using sensor technologies (RFID Solutions), where information regarding the filling level of the garbage bin is collected from smart bin sensors in real-time. These smart bins are currently used only for business/industrial customers, since they need *electric power* supply, which is readily accessible at e.g. manufacturing facilities. Also, industrial customers usually use large garbage containers where the waste volume can be significantly reduced before the actual collection. The sensors installed in bins are also tested in public containers for the collection of packaging waste (in about 40 containers in Tallinn). For private clients this solution could be too costly.

For monitoring the waste generated by households and for the assessment of private clients' behavioural patterns, some pilot tests were implemented in hospitals in Norway and are planned to be implemented in Estonia in the near future.

IoT used to enhance automation and process efficiency

In Estonia, a most advanced logistics system for waste collection trucks is used, that provides notifications of need for collection alongside information on optimized routes for waste collection so that collection time and cost regarding fuel, truck material, and human resources can be reduced. Additionally, an advanced self-service platform is in use for private and business customers, where the system automatically calculates which services are provided at the «service recipient's» address. The most challenging task for system developers is to correctly calculate waste collection time intervals.

A new sorting line is tested for sorting different types of plastic waste with infrared spectroscopy (using machine learning). The system recognizes different types of plastics and separates them by the use of compressed air.

According to a written reply from *Eliko Competence Centre in Electronics, Info- and Communication Technologies* the Bepco company is using the RFID (Radio Frequency Identification) system to monitor the reusable packaging of its waste management system (http://bepco.ee/rfid-tracking/). More detailed video is here: https://youtu.be/iE-fEQsJJ07Q.

Smartphone apps for citizens' assistance in waste management are:

- Informative webpage (an app is also available for smartphones) for citizens showing where to drop different types of household waste: https://kuhuviia.ee/
- Game for citizens about how to correctly sort different household wastes: https://www.energia.ee/prugimang
- Furthermore, a delivery time notification system for smartphones is under development. This customer app would allow citizens to gather and schedule waste collection times.

Different data systems for specific waste types

The main information systems providing services in waste management in Estonia are:

- PROTO – Register of problematic products and wastes in Estonia
- PAKIS – Packaging Register that keeps records on the packaging of goods circulating on the Estonian market, packaging wastes generated, packaging reuse, packaging waste recovery, etc.
- OJS – Information system for handling hazardous wastes
- JATS – Waste reporting information system

2.3. Final assessment

Recent technological developments offer new smart solutions at all stages of municipal waste management. The implementation of new technologies, however, depends on many factors starting from economic opportunities to general waste management organization and waste generation patterns. According to VJK experts, Estonian waste companies have made no large-scale investments in technology development in recent years since possible developments in waste management have been rather unclear (OSKA, 2019). No specific public funding programs (at federal, regional or local government level) for supporting the digital transformation of public Municipal Waste Management providers have been found in Estonia so far.

3. Germany: State of Digitalization in Municipal Waste Management

According to the ECO-Innovation Observatory (2019) Germany is a well-established frontrunner in the context of waste management, recycling and environmental technologies. Most recently, increasing attention is focusing on digitalization and its potentials for the circular economy and environmental and resource protection. The German Environment Ministry launched a 'Digital Agenda' in 2020.

Furthermore "Germany has not yet developed a dedicated Eco-Innovation Action Plan (Eco-AP), nevertheless it has implemented an eco-innovation policy. Several strategies pave the way for eco-innovation, R&D and research and investment but risk to remain at a strategic level as long as they are not flanked by incentives and binding instruments steering the direction. A new R&D programme has just started with the name "Resource-efficient circular economy - Building and mineral cycles (ReMin) (2020-2024).

The Eco-Innovation Observatory publishes the Eco-innovation index, which demonstrates the eco-innovation performance of a country compared with the EU average and with the EU top performers.[1]
The scoring shows that Germany's overall performance in comparison to the 27 countries and the EU average is good. In 2019, Germany ranks sixth in Eco-Innovation Index (Figure 1). It has lost three places compared to the 2017 index and six places since 2015 when it ranked first but still counts among the eco-leaders.

3.1. Organisation of the Municipal Waste Management in Germany

In accordance with the federal structure of Germany, responsibilities, accountability, and duties regarding waste management are shared between the federal government, the 16 federal states and local communities and cities. The national Ministry for the Environment sets the priorities, participates in environmental legislative processes at national and European level and monitors their implementation, formulates strategies for implementation with targets and defines requirements for waste facilities. Federal states and local communities/cities are responsible for implementing national and European laws. For implementation each national state adopts its own waste management act containing further implementation provisions for municipalities and cities of the respective federal state to the extent permitted by national and European legislation. Since there is no central or uniform waste management planning for the whole of Germany, there are sometimes very diverse waste management concepts and rules on requirements in effect at state and municipal levels (European Environment Agency, 2016).

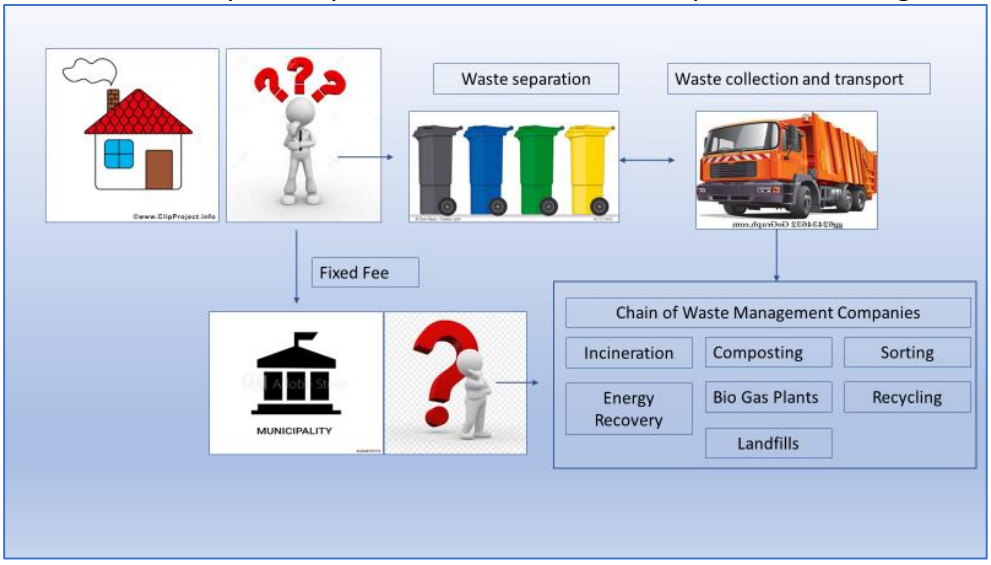
Waste separation and household information

The waste generated by German households is collected decentrally by a weekly door-to-door service. Every household is requested to separate their waste in mostly four dedicated, differently coloured bins:

- green bins for bio-waste
- yellow bins for packing waste, plastics and metals
- blue bins for paper
- black bins for residual waste
- Bulky waste can either be dropped directly at a central collection point of the municipality or, in the case of larger quantities, will also be collected by the waste service.
- Cans and other single use and refillable containers can be taken back to supermarkets, when empty, for collecting the deposit paid when buying these goods. All drinking containers with some exemptions for wine etc. have a deposit fee.
- Glass waste like empty wine bottles is dropped at central collection containers spread all over a city.

[1] EcoI Index is a composite index that is based on 16 indicators which are aggregated into five components: eco-innovation inputs, eco-innovation activities and eco-innovation outputs as well as environmental outcomes and socio-economic outcomes.

Figure 2: Information asymmetry between users and municipal waste management



Source: the authors

Fixed Household Fee

Citizens typically pay a fixed fee to municipalities for collecting household waste. The fee is defined by local authorities. In some more progressive municipalities the waste fee is dependent on the weight of the household waste produced. However, this requires firstly that the bin is equipped with an RFID chip, and secondly, that the garbage trucks measure the weight with a scale on the truck when emptying the garbage bins.

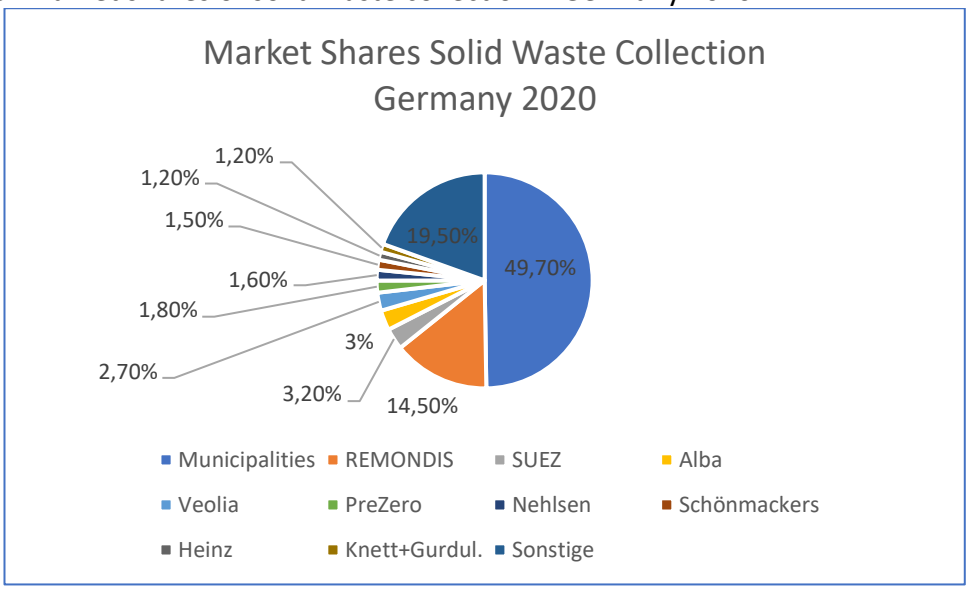
The collection of packing waste is free of charge for citizens, as the producer of a product is responsible for the product when it becomes waste (so called "extended producer responsibility – ERP"). As opposed to other EU countries, in Germany the ERP only applies to household packaging waste, whereas in most European countries commercial and industrial packing waste is included (European Environment Agency, 2016).

Collection and transport of household waste

In Germany, based on the law on the circular economy, municipalities are responsible for the disposal of private household waste and commercial waste similar to household waste. Municipalities' responsibility covers collection and transporting waste, measures to promote waste prevention and recovery, and planning, constructing and operating waste disposal facilities in line with national and regional legislation. The service can be provided by public waste management authorities themselves or in the form of third-party commissioning of PPP companies (Private-Public Partnership) or by private waste management companies following a call for tender.

The market for waste collection and transport is made up of 52% of municipality-owned companies, while private companies have a 41% market share and 7% remain for the PPP segment (ASA et al, 2020).

Figure 3: Market shares of solid waste collection – Germany 2020



Source: EUWID (2020)

3.2. IT solutions used in Municipal Waste Management

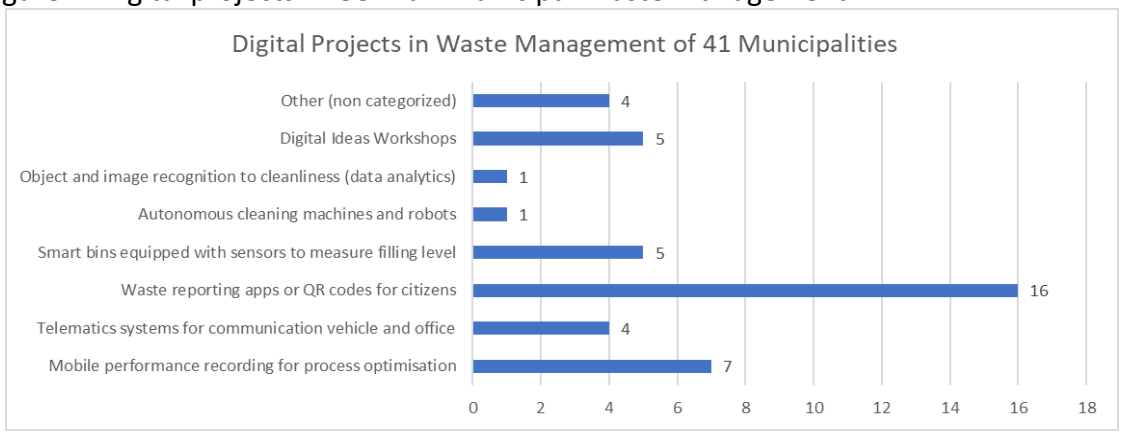
Due to the decentralized organizational structure of German waste management, there are no central statistics on innovative digital projects in municipal waste management. Only the Verband kommunaler Unternehmen e.V. (VKU), the German Association of Local Utilities runs a mapping of digital applications of their members companies and publishes all projects on its webpage. Using the keyword "Waste Management" in its search function leads to 23 best-practice examples of digital applications in local waste management utilities. Additionally, the Verband Kommunaler Unternehmen e.V. (2019) published a study "Abfallwirtschaft Digital" (Waste Management Digital) with 18 best-practice examples of digital waste management. In total, this results in 46 digital projects in municipal waste management in 43 municipalities. These were screened according to the following categories:

- Digital idea workshops
- Object and image recognition of cleanliness (data analytics)
- Autonomous cleaning machines and robots
- Smart bins equipped with sensors to measure filling
- Waste reporting apps or QR codes for citizens
- Telematics systems for vehicles-to-office communication
- Mobile performance sensors recording data for process optimization

Since none of the listed projects had a blockchain application, blockchain was not included as an explicit category.

The screening process led to the following results:

Figure 4: Digital projects in German Municipal Waste Management



Source: the authors based on data from Digital project mapping of German Association of Local Utilities of Municipalities (VKU) and Verband Kommunaler Unternehmen e.V. (2019)– for detailed statistics cf appendix.

Most of the digital projects are waste reporting apps for citizens to report trash in parks or even for error reporting during trash pickup. Ultimately, these are the first tentative steps toward communication and interaction with citizens, although they do not yet overcome the information asymmetry mentioned above. Most of these apps are not interactive, but are designed as a communicative one-way street. There is usually no data-based communication strategy that is individually tailored to the user profile of the respective household. Such a strategy would mean a completely new self-image of municipalities as service providers for households in terms of waste management.

The digital projects, which include equipping waste bins with sensors to measure fill levels, are also moving towards overcoming information asymmetry. Sensors in smart garbage bins enable a municipality to assign bins to their owners and to inform households about their individual waste generation per month. By changing fee structures from fixed fees to pay-as-you-use systems, further incentives would be set for waste avoidance. The problem here will be data protection and citizens' right to privacy. Data protection and anonymity would certainly be easier to achieve with a blockchain-based solution. Basically, overcoming these obstacles will require building trust between citizens and municipalities, which can only be installed through innovative communication and participation concepts.

Telematic systems for real-time communication between waste trucks and municipalities' offices go hand in hand with a mobile recording of performance that would prepare process optimization. Waste trucks could nowadays be equipped with all modern IoT solutions producing a mass of real-time data.

3.3. Final Assessment

To date, the following technologies are missing among the approaches to digitizing municipal waste management:

- Big Data Analysis based on AI
- Blockchain and tokenization

Basically, the approaches taken so far seem to be isolated digital projects that are hardly integrated into a coherent digital transformation strategy for the transformation of municipal waste management. The approaches are largely technology-driven and do not focus on citizens and waste prevention as a top priority. Technology alone cannot make this happen anyway. This requires a fundamental transformation of the organization and the mission of the municipalities: The goal of all activities and operations must be waste avoidance by households, i.e by citizens.

4. Greece: State of Digitalization in Municipal Waste Management

4.1. Organisation of Municipal Waste Management in Greece

The administrative structure with regard to the Waste Management in Greece includes the following stakeholders:

- The Ministry of Environment and Energy (YPEN) is responsible for the development and implementation of environmental and waste management policies at the national level.
- The Ministry of the Interior (YPES) is responsible for the supervision of Decentralized Administrations (DA) and local authorities (Regions and Municipalities).
- The Hellenic Recycling Agency (HRA) or "Alternative Waste Management" is a public interest, non-profit private entity supervised by the YPEN. Its main objective is the development, planning and implementation of policies for the recycling and recovery of waste.
- Solid Waste Management Associations ("FoDSA" in Greek), are the regional non-profit waste management entities which comprise municipalities within each region and are responsible for the development, implementation and monitoring of Regional Waste Management Plans.
- Municipalities are responsible for the implementation of the development and implementation of Local Waste Management Plans (based on Regional Waste Management Plans).
- Extended Producer Responsibility (EPR) schemes and Producer Responsibility Organisations (PRO), which are private organisations grouped by sector, that consist producers liable under the EPR policy. Greece has EPR systems (for MSW) for batteries, WEEE and packaging.
  - One PRO for the collection of batteries called AFIS S.A.
  - Two PROs for the collection of WEEE — ANAKYKLOSI S.A. and FOTOKYKLOSI S.A.
  - Four PROs for packaging:
    - ✓ the Hellenic Recovery Recycling Corporation (HERRCO), which is the most widespread system and has an extensive network of "blue bins" for packaging waste and a second network of "blue bells" for the separate collection of glass.
    - ✓ The Centre for Alternative Environmental Management S.A ("KEPED" S.A., in Greek) is a PRO, which promotes a nationwide collection of the packaging waste of lubricant oils.
    - ✓ the Rewarding Packaging Recycling, which runs separate municipal waste collection of packaging through 51 "Recycling Houses" distributed in major urban areas nationwide (see best practice example below).

- ✓ AB Vassilopoulos is a supermarket chain with the only single-member PRO in Greece and in Europe collecting packaging waste and offers a separate collection of materials in integrated recycling systems of packaging waste (paper, plastics, metal and glass). The system uses "Recycling Centres" and reverse vending machines on supermarket premises nationwide (AB Vasilopoulos S.A., 2017). They offer monetary incentives to citizens for recycling (1 euro for every 33 packages) via retail vouchers.
- ✓ PROs offering a voluntary deposit refund scheme are run also by the Athenian Brewery for beer and beverage bottles (HRA, 2019); (Athenian Brewery, 2020).

4.2. IT solutions used in Municipal Waste Management

So far there is no extended implementation of IT solutions in MSW in Greece. Specific Municipalities have started running local actions, and some new attempts have been announced mainly through pilot projects.

Pay-as-you-throw – pilot application

The municipality of Elefsina, in the Attica Region, has implemented a pay-as-you-throw (PAYT) system in a pilot application under the LIFE Environment program (Life + Environment Policy and Governance, 2011). Results have been only moderately successful. According to Vitoraki (2019) the recycling infrastructure and convenience for citizens was not appropriately designed. Improvements in the collection system are required, so as to make recycling more convenient for citizens. Door-to-door collection is an option that must be examined for certain or all municipal districts.

Various Smart Bin Projects

The region of Chania, Crete was involved in a LIFE program project entitled: "Sustainable waste management using ICT tools-LIFE EWAS" aiming to optimize waste collection in terms of collection frequency and route planning. The sensors were sending data of filling levels of each container through GPRS.

The municipalities of Metsovo and the Ziros in Hepirus were involved in the project INTERNET OF BINS which is co-funded under the Interreg IPA CBC Programme "Greece – Albania 2014 – 2020". The innovative project contains three elements:

- Integrated "Smart" Waste Management solution/Capacity Improvement: Installation of Smart Waste Management and Telematic Monitoring Equipment (Bin monitoring system-ultrasonic filling sensors and software application, waste management supplies).
- Visual disturbance reduction: Installation of underground waste collection systems at critical points and
- Eco-friendly approaches to waste management: supply and distribution of compost bins (household waste purposes), awareness campaigns, waste management optimization and monitoring plans (data analysis and management plan), mobile and web applications for thematic information.

IoT on waste trucks and in resident communication

The municipality of Halandri was involved in "Waste4Think" project funded by the EU Horizon 2020 program. The Municipality's waste management combines two features:

- Communication to residents to ensure their engagement (up-to-date municipality website, use of social media, awareness events for re-use and recycling, collection timetable for residents).
- IoT in waste trucks: GPS and informatics systems, in bio-waste and paper/cardboard collection vehicles.

Use of household data and resident communication

The municipality of Vari-Voula-Vouliagmeni implemented the separate collection of six (6) waste streams. The municipality has contracts with EPR schemes (HERRCO) and implements different collection systems according to the characteristics of households, type of waste and area (door-to-door, kerbside, communal, etc).

The municipality's waste management and recycling actions are communicated to the residents to ensure their engagement, in many ways including among others easily accessible information and guidelines to residents through the municipality's website, social events, or support given to voluntary civil and environmental protection groups.

Citizen incentives & communication combined with smart bins

In order to increase citizens' engagement in the procedure, the municipality of Voula-Vari-Vouliagmeni awards as incentives loyalty points plus discounts on admission to beaches, on kindergarden fees etc. The municipality implemented "SMART" waste management solutions including telematics for the optimization of collection routes, and "SMART" bins with sensors indicating fill-level and location of bins.

The municipality of Vrilissia implements a separate collection of twelve (12) waste streams. Continuous and innovative communication and dissemination of the municipality's waste management and recycling is designed to ensure residents' engagement, with efforts including among others:

- an on-line platform to raise awareness, informing and educating residents on composting, proper separate collection of organics, etc;
- easily accessible information and guidelines to residents through the municipality's up-to-date website, social events, workshops;
- the use of the inter-municipal recycling reward platform "Follow green" promoting recycling by training and educating residents through games, articles on recycling, etc while scoring points redeemable with local businesses;

Data collection platform for monitoring waste flows and PAYT fee scheme

Heraklion (GR) and the region of Crete were involved in the project "WIN – POL" (Waste Management Intelligent Systems and Policies, PGI04924) funded by Interreg Europe 2014-2020. The project aims to improve waste management in European cities through the use of IoT and incentive systems. WINPOL achieved an important milestone with the preparation of six action plans, each of which will be implemented in one of the six cities selected. In the case of Heraklion the following actions are going to be implemented and tested:

- an innovative system to collect data regarding bio-waste collection

- a platform monitoring waste flows and optimizing the supply chain at municipal level
- a platform monitoring waste collected at the Green Points at regional level and sharing data with users
- introduction of PAYT systems funding opportunities for municipalities

The region of Attica has announced a call for tenders for the development of a remote digital platform, which will be used for integrating reward programs addressing recycling awareness - with recycling corners and surface and underground bin systems.
The remote platform will aggregate, in a single information system, all the data obtained from recycling corners, from citizens, municipalities and all other stakeholders involved. The information will be processed by the platform to formulate procedures and present and communicate the results to the involved parties.
The main functions of the platform will be:

- Communication with the recycling corners that are part of the network and more specifically with local control bodies or equipment (local management consoles - KTD)
- Communication with citizens and recyclers through the website, apps, etc.
- Informing and raising awareness of the public.
- Rewarding citizens based on the waste recycled through the contracted recycling corners.
- Recording waste volumes collected by recycling corner, by user and by municipality.
- “Bucket full” warning and collection route optimization. In order to optimize the collection routes, a tablet with tailor-made software will be placed in each garbage truck. The software will receive data on the fill level of bins broken down by recycling corner and material bin. Based on this data broken down by entity collecting recyclables and truck available, the software will configure optimal collection routes every day and will forward them to either the respective collection agents or the tablets of the trucks, depending on agreements with collection agents.

The platform will process constantly updated data sets and will have the ability to edit and visualize them depending on the interested audience. In addition, the platform will be able to connect with any other intelligent sorting systems at the source of recyclable materials (such as static or mobile green spots) or with any other digital platforms for recycling rewards.

The Hellenic Recycling Agency (HRA/EOAN) has developed, with the technical support of D-Waste, a new specialized platform called "GRE-CYCLE ", which allows citizens to be informed promptly, easily, and responsibly about specific recycling issues. Users can also, in a matter of seconds, send photos and comments on specific recycling issues, using their mobile phone. The application is available for iOS and Android and is downloadable from free online stores. The app was developed using open-source software. Specifically, for the visualization of data Google Maps was used in conjunction with open-source CMS.

4.3. Best practice example “Rewarding Packaging Recycling”

The best known IT solution within the Extended Producer Responsibility is from a Producer Responsible Organisation named Rewarding Packaging Recycling (RPR) which established a network of 51 “Recycling Houses” in major urban areas nationwide.

RPR runs an integrated separate collection system using a network of reverse vending machines (RVM), namely Rewarding Recycling Centres (RRCs) or “Recycling Houses”, which are installed in easily accessible public areas. Each RRC occupies a space area of approximately 11 m^2 and is designed to accept packaging waste of essentially four waste streams: plastics, metal, glass and paper/cardboard, while recently there has been an extra provision in some of the RRCs for packaging wood (mainly pallets). RRC keeps the disposed materials separated and reduces their size (smashing for glass, pressing for cans and pressing or shredding for plastics) while providing a monetary reward to its users (1€ for every 33 units), which is either offered as a discount voucher in cooperating supermarkets or can be donated to charities.

The PRO supervises waste management operations such as collection, transfer, treatment, personnel and equipment maintenance, which are offered by contractors. Furthermore, the PRO is responsible for reporting the data to EOAN (Greek Recycling Organization). Collaborating municipalities are responsible for the provision of electricity for the operation of the equipment when it is installed in public places.

The PRO achieved a new Guinness World Record for the "most glass bottles recycled in one week” and the second Guinness World Record for the "most plastic bottles recycled in one week". The first mobile “Recycling House” worldwide, the operation of which is based on solar energy, was created in 2020 so the service be deployed across the Athens Riviera.

4.4. Final Assessment

IT solutions in Greece have been partially implemented during pilot projects. Over the last two years some municipalities have started applying smart technologies in order to optimise mainly waste management collection and separation, but a lot of things need to be done in the near future in order to achieve the targets of the revised NWMP. The research projects currently running are promising. However, their results have not been evaluated yet. The new economic instrument, i.e. pay-as-you-throw (PAYT) that is to be implemented in the near future, according to the revised NWMP, demands many technological changes to be established on a regular basis.

5. Netherlands: State of Digitalization in Municipal Waste Management

5.1. Organisation of the Dutch Municipal Waste Management

In the Netherlands waste is collected from households by or on behalf of municipalities. As waste from shops and similar establishments is often collected at the same time as household waste, a (small) proportion will not originate from households. Waste is collected door-to-door. This also includes (bulky) household residual waste collected via (underground) collection containers. Recyclable waste is dropped off at street facilities (such as glass containers), municipal yards or environmental streets.

Within the public policy framework for household waste 2025 (VANG-HHA, 2014), Dutch politics committed to the transition towards a circular economy and to close the raw materials and material chains as much as possible. The ambition is that in 2020 a maximum of 100 kg of coarse and fine residual waste per inhabitant per year will go into final processing (incineration). By 2025, this should be further reduced to a maximum of 30 kg of residual waste per year.
The implementation programme includes various lines of action to achieve greater waste separation and less household waste.

- Chain parties working together to close chains. The chain approach focuses primarily on the products that are part of household waste in its end-of-life phase. Some products are also found in other waste flows (e.g. office waste).
- Reducing the amount of material that leaves the chain as residual waste from households reducing the amount of material leaving the chain as residual waste from households.
- Making polluters pay. Companies and citizens are given space and market failures are addressed.
- Stimulating and facilitating innovative companies and organisations to jointly formulate a sustainable ambition and take concrete steps to implement that ambition.

The polluter-pays principle was implemented with the DIFTAR fee scheme which most municipalities are using. DIFTAR is the abbreviation of differentiated tariffs, meaning households or legal entities pay different tariffs for different types of waste based on amounts. The more residual and other waste there is that cannot be recycled, the higher the waste collection charge will be. Conversely, offering less waste results in a lower variable waste disposal charge, but the fixed charge remains the same.

In 2019 a Dutch household paid €244 on average per year for the municipality's waste management service. But fees vary extremely from municipality to municipality. Municipalities with low waste management costs have generally introduced tariff differentiation on waste supply (diftar). In DIFTAR municipalities inhabitants generally separate their waste more consistently, which results in lower residual waste.

5.2. IT solutions used in Municipal Waste Management

In the Netherlands, there are several providers offering complete waste management solutions for municipal environmental and cleaning services. These include advanced technological solutions for household waste collection, route planning, vehicle technology (roadside and RFID), summer and winter services and customer support. The providers have built their own platforms that support supplier management, service level monitoring, dynamic reporting and analysis. This enables municipalities to make the most efficient use of available budgets by optimising routes, managing containers and visualising collection in real time. It provides real-time access to customer and service data so that queries can be dealt with immediately. This minimises (missed) emptying rounds and improves customer service. They provide individual, password-protected access to an environment where configurable, customer-specific information is stored. This includes collection frequency, service history, additional services available, complaints or questions, changes or

messages, and if applicable, account and invoice status, including statements, invoices and online payment options.

Mobile and vehicle solutions
Vehicle solutions can be tailored to the functional requirements and budget of each municipality. Route data is read from tablets. Driving instructions and interaction with administration are supported, as is vehicle technology for monitoring service performance, either stand-alone or in combination with RFID. A number of suppliers also provide their own certified weighing system for waste collection that is fully integrated into the back-office solution of ERP systems. Payment is based on weight/frequency (diftar), or recycling monitoring programmes.

Blockchain solution for supervision of cross-border waste transportation
To reduce the supervision costs related to European waste transportation, the Dutch Ministry wanted to combine blockchain technology with existing IT-systems. This way the inspection authorities can automate a significant portion of their tasks. This frees up knowledge and expertise for other important tasks that cannot be performed without human assistance (yet). The proof of concept of the Blockchain application is meant to demonstrate that blockchain technology can be used to create efficiency and transparency within the cross-border waste transportation process in the EU. Besides, it is meant to reduce the supervision costs related to European waste transportation. The Blockchain attributes are:

- Permit requests are checked, verified and accepted through an artificial intelligence expert machine.
- Scales connected through Internet of Things devices communicate weight to the process and the permit.
- Permit data is shared with all stakeholders and determines the next tasks in the process on the blockchain.

5.3. Best practice examples

OpenWaste - one collection platform for PROs
Due to extended producer responsibility in the commercial waste market, various waste collectors (producer responsible organisations) drive the same route in city centres to serve their own customers. Often, they also drive behind each other in connection with delivery window times. By bundling the collection of commercial waste by different collectors and collecting it with a neutral refuse lorry, the number of transport movements in difficult inner city areas can be reduced by more than 60 per cent without the end customer noticing a thing.
OpenWaste facilitates central registration for PRO-participants in the joint collection of industrial waste in an inner city or business park by a single neutral vehicle (White Label). This results in less traffic and less harmful emissions (CO2, NOx and fine dust).

Municipality of Apeldoorn - Recycleservice 2025
The key elements of Recycleservice 2025 are: reversed collection with high-level service on separated resources and pay-as-you-throw for residual waste. Reversed collection

means high-level service on recyclables (kerb-side collection via wheelie-bins) and low service on residual waste (people take it to drop-off points). If people choose a higher-level service on fine residual waste (wheelie-bin at home), bins can be emptied at notice, but they pay a higher waste fee
The first results obtained following the implementation of the new policy in only half of the city of Apeldoorn are very promising. Coming from 123kg of fine residual waste per capita and a 66% separation rate in 2017, fine residual waste dropped to 89kg per capita and the separation rate went up to 74% (WINPOL, 2019, p. 53).

Municipality of Amsterdam - object detection to recognize the littering of waste
From early 2020 a more dedicated team (Ontwikkelteam Openbare Ruimte) started to work on the productive and upscale use of the Objectdetection-Kit. This started with the deployment of Objectdetection-Kit in an approach to reduce and prevent the littering of waste around waste containers. In one neighbourhood there is a daily scan on waste. This neighbourhood has 300 locations with waste containers and it lasts 2 hours to scan everything. This provides insights in the littered locations. At this moment Amsterdam uses the data of multiple weeks to define the most problematic locations. These locations are then subject to concrete measures such as extra campaign or street coaches (WINPOL, 2019, p. 20).

City of Amsterdam – sharing waste data with the public
Amsterdam has an open and real-time data portal for waste. It has an agreement with each supplier that the data collected belongs to the public, is accessible and understandable. Stakeholders and suppliers can easily access necessary data. Amsterdam achieved valuable data for different workers in the city: e.g. city planners, law enforcers, social workers. They all can use the data to enhance their activities. (WINPOL, 2019, p. 29)

5.4. Final assessment

In the Netherlands,the attention given to the circular economy and the concrete 100-kilogram target for household residual waste in the public framework have made many municipalities work on plans for diftar and/or reverse collection. There are also many plans for post-collection. Almost half of the municipalities have already introduced diftar and/or reverse collection, and some forty are working with a combination of source and post-separation.
There are also some hurdles and dilemmas to report. Many residents and administrators believe that source separation is no longer necessary, which undermines the plans in that direction. But post-separation is not a solution for paper, glass and especially not for VGF. The organic waste component is, to a small extent, in fact fermented during post-separation and converted into biogas, but there is not yet a circular solution for the remaining (contaminated) digestate. In addition, the PMD from post-separation cannot easily be used as a really high-grade raw material, particularly because of the separation problems, pollution and odour caused by the organic waste.
Another obstacle to urban circularity is the regulations and agreements that prevent municipalities from taking care of industrial waste that resembles household waste. This results in major disadvantages such as inefficient collection, inconvenience caused by the many collection vehicles and, above all, poor separation and recycling of industrial waste.

It seems that the Netherlands is a negative exception in this respect internationally. So, there are considerable opportunities here.
On the other hand, there is a lot of attention given to circularity, which is high on the municipal agenda. Digital innovations are currently limited to IoT and data collection, for insight, more efficient administrative processes and especially for route optimisation. The use of technology is still fragmented and little or none of it is geared towards closing the chain.
Blockchain applications in municipal waste are not yet available, but it is expected that with further digitalisation and technologization of the industry, these applications will not be long in coming.

6. Spain: State of Digitalization in Municipal Waste Management

6.1. Organisation of Municipal Waste Management in Spain

In Spain, the management of household urban waste is mainly the responsibility of local authorities and, to a greater or lesser extent, the Autonomous Communities. The challenge faced by administrations is to articulate efficient management models that allow them to comply with the obligations and legal objectives derived from the multiple and diverse community, national and autonomous community legislations that affect this waste.
The control, inspection and surveillance systems have improved in recent years, but are still insufficient. In this area, it is worth highlighting the action of the Nature Protection Service (SEPRONA), with which the administrations must cooperate closely.

At state level, Spain does not have any incentive system that rewards municipalities and households for preventing or reducing waste production. Fees for waste collection in Spain vary geographically and range between 25 and 52€ per year. Taking into account that the average gross annual salary in Spain is 24,009.12 € according to the INE, the expenditure incurred in the local waste collection fee varies between 0.10% and 0.22%, which is a low fee. Despite the low fees illegal dumps are growing exponentially in the country.

Within the Extended Producer Responsibility scheme some PROs established a deposit system for recyclable waste rewarding citizens for returning containers after use. In Valencia, the reward is the recharge of virtual balance or "reciclos" in return for each container recycled either to conventional yellow containers or to special deposit machines installed at stations, shopping and leisure centers. The reward of "reciclos" is redeemable for transport vouchers, voucher spent in local stores or for the use of electric scooters.

6.2. IT solutions used in Municipal Waste Management

At state, regional or local levels, there are no public funding programs in Spain to support digitization in waste management. Cities, communities and municipalities have been trying to involve themselves in EU projects to get funding for innovative solutions. Otherwise, the innovation process is driven by the commercial sector.

IoT – Smart bins and trucks

Regarding IoT for waste management, many waste managers are making use of this tool. Some cities, such as Seville or Barcelona, have already opted for the development of this type of innovative solutions, achieving significant cost savings and also reducing CO2 emissions and inconveniences caused by waste collection traffic or disturbances of people's rest.

The company Hirisens, an environmental control operator specializing in the search for technological solutions based on the Internet of Things, has developed a new service called Hiriwaste. This solution is based on the placement of a sensor in waste containers and its subsequent connection to its IoT platform, which operates in web format. This allows to visualize the status of each container in real time. It enhances process the efficiency of collection, helps to optimise collection routes and leads to an increase in user satisfaction. The system can also be adapted to other types of waste.

Sharing of waste data via platform and data analysis tools

As for Big Data, Minsait together with Ecoembes, the entity in charge of managing the recovery and recycling of plastics, cans and bricks, and cardboard and paper in Spain, created a data platform designed for stakeholders of the waste chain to share access to data in 2018. Data analysis tools transform raw data into knowledge for public managers, who use it for better planning and decision-making when, for example, establishing dynamic collection routes which can be adapted to the increase or decrease of waste per route or per container, depending on the time of year or the demographic composition of the area, thanks to the estimates made on the basis of the data collected.

Pilot applications of Blockchain technology

Heura together with Signeblock applied the Blockchain technology to the recycling of agricultural waste. It is a solution to ensure traceability and optimization of the management of packaging used in agricultural processes, enhancing environmental protection and the generation of efficient circular economy models.

At the beginning of 2021 Ecoembes and Minsait announced the deployment of a Blockchain network to increase transparency and encourage collaboration in the Circular Economy. This is a project that has involved a major technological innovation challenge and will have a notable impact on environmental sustainability. This network of distributed registries will make it possible to help public administrations, local entities, operators, recyclers and other organizations to securely share and control all the data in the system and speed up all transactions linked to the waste sorting process.

Several smart phone apps for assistance

There is a wide variety of mobile applications mostly offered by PROs available for assisting citizens' in recycling.

- App "Recicla y suma" (Recycle and add up), which pays Spaniards for recycling. The company PENSUMO, promoter of innovative business models framed in the Circular Economy and Top SDG 8 of the Spanish Global Compact Network, bursts in with a new simple but powerful proposal: "You recycle, we pay".
- App "RECICLA" informs registered users on how prepaid recycling and what waste is in demand. It will start with one million to be spent on prepaid recycling (from

0.02€ and up to 1€). The process is initiated bya photo sent through the app in which the material to be recycled appears with the container in the background.

- App “EMTRE” is tested in the Valencian Community by the Metropolitan Entity for Waste Treatment (EMTRE), informing users on how to get to the nearest ecopark, how many times they have been to the ecopark during the last months or what kind of waste that is to be recycled they have produced.

6.3. Best practice examples

Municipality Gijón – identification of user of eco parks

The practice consists of the installation of access control mechanisms and deposit registration in a civic amenity site (CAS). The system enables control of access using an identification card. In addition, users must register the type of waste to be deposited as well as its quantity.

In order to be able to control entries to civic amenity sites and the deposits of citizens and companies, it is necessary to set up an access control system. This allows control of what is delivered, by whom and how often. It enables blocking access to users misusing the service. In the future, it could facilitate the implementation of a pay-as-you-throw system.

Municipality Gijón – smart phone apps

EMULSA has developed two free mobile apps for the city of Gijón - the Citizen app and the Reusapp – and a map of sustainable businesses as part of its Strategic Business Plan and the Municipal Waste Management Plan of Gijón. The main goal is to achieve the 50% of reuse and recycling target set by the European Union for the year 2020. These three projects also prevent miscommunication with citizens.

COGERSA SAU - “COOMIDA” -App facilitates food donations

COOMIDA is an innovative technological and cooperative tool aimed to ease food donation (including surplus food), thus reducing food waste. COOMIDA connects local donors, food banks, volunteers, and charities through a collaborative network for an efficient and sustainable management of food donations. COOMIDA allows donors and charities to keep contact directly; therefore, it can reduce time, emissions and expenditure. COOMIDA also allows to recover little and remote donations that otherwise could exceed the Food Bank capacity.

6.4. Final assessment

Although there is no central government funding programme for the digitalization of municipal waste management, there are a considerable number of decentralised local initiatives by municipalities or regions with innovative approaches. These decentralised solutions should be systematically promoted and their transferability to other regions should be examined. Many of the initiatives come from the private sector or are based on the voluntary commitment of NGOs. Overall, there is a positive trend towards changing environmental behaviour, although this trend could still be supported by increased use of new technologies.

With the increased use of IoT, be it on refuse vehicles or in refuse bins, the foundation has been laid for a future connection to a blockchain database.

7. Benchmarking findings with other studies

In the following, the results of the preceding analysis of the status quo in digital transformation in waste management in five countries are compared with the results of other countries.

7.1. EIONET Report "Digital Waste management"

The 2020 EIONET Report by Berg and Sebestyén (2020) entitled "Digital Waste management" analyses the status quo, opportunities and risks resulting from the digital transformation of the waste management sector. The main drivers of digitalization in the waste sector are seen in the following factors:

- cost pressure, as competition between public and private waste services is high and digitalization is seen as a tool to save costs
- emerging new business models created by technology-driven start-ups.
- customers expecting to have near-time information on status of orders and wishing to monitor their utilities
- the shift towards a circular economy combined with increasing legal pressure and targets from the EU and national policies
- the climate crisis forcing reduction of greenhouse gases
- Extended Producer Responsibility triggering current materials management policies in the corporate sector; EPR schemes expected to be applied to more products to meet political goals
- growing urbanization increasing pressure within cities

The authors identified three main areas of digitalization in municipal waste management: communication, waste collection and internal processes, and provided examples of digital application in the respective field – cf table below.

Figure 5: Main areas of digitalization in municipal waste management

Communication	Waste Collection	Internal processes
Websites	Sensor-equipped vehicles	Billing
Mobile apps	Route planning	Accounting
Integration in other services	Resource planning	Controlling
Third party social media apps	Inventory tracking	Processing of orders
	Documentation	Documentation

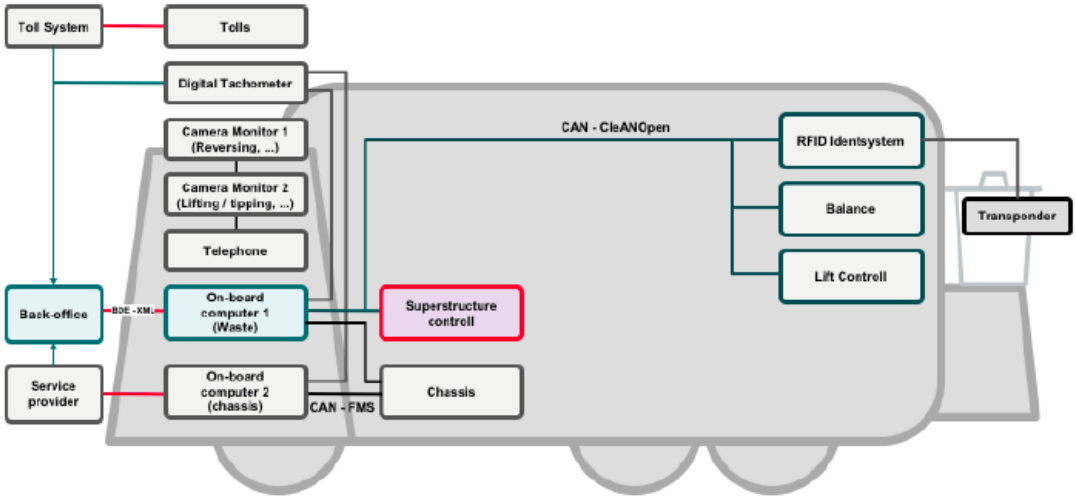
source: Berg and Sebestyén (2020, p. 23)

According to Berg and Sebestyén (2020) "Communication technology makes up the biggest part of digital solutions already in use in the waste sector. Here the transfer from other sectors is easy because the necessary investment in hardware is relatively low." In the area of waste collection processes, the use of IoT should be emphasized; this concerns, on the one hand, the use of sensors in the waste bin (smart bins) or on the waste collection vehicle. In the internal processes

of waste management, digitalization is used to automate process flows towards paperless documentation and registration. Ultimately, this is the digital transformation that has already taken off in the private sector for several years.

The illustration of a waste truck with all the possibilities of using IoT solutions gives an excellent overview of the digitalization of the waste collection process.

Figure 6: IoT solutions integrated in the waste truck



Source: Adapted from a BDE/VKU publication (BDE - Bundesverband der deutschen Entsorgungs-, Wasser- und Rohstoffwirtschaft and VKU - Verband Kommunaler Unternehmen, 2015

Berg and Sebestyén (2020, p. 22)

When benchmarking the EIONET results with the results of the analysis from five countries, the following similarities can be observed. Ultimately, all digitalization projects fall into the categories defined by EIONET: communication, waste collection and internal processes. Little was reported on the digitalization efforts related to internal processes, which is ultimately due to the lack of transparency about the efficiency of public organisations and their processes. The country reports confirm the positive role of the Extended Producer Responsibility scheme, which is also identified as a key driver of innovation. Two aspects are missing from the EIONET reports, but emerge from the country reports: Communication with customers or users and digitalization of waste collection processes are mutually dependent. Without intensive upstream communication with users, further digitalization of the processes is hardly possible. The second point is the target of setting incentives for changes in user behavior. In the country reports, there are certain projects that deal precisely with the design of incentives via digital solutions. Communication, incentivisation and digitalization should be considered in context.

7.2. WINPOL Project "Waste Management Intelligent Systems and Policies"

WINPOL is a European project funded under the Interreg Europe programme, that fosters the use of intelligent equipment and policies in municipal waste management. Since June 2018, nine partners across Europe – eight public authorities represented by the municipalities of Antwerp (BE), Drobeta Turnu Severin (RO), Heraklion (GR), the county of Mehedinti

(RO), the region of Crete (GR), EMULSA (ES), Snaga (SI), ERA (MT) and ACR+ (BE) as advisory partner – have been cooperating in this 4.5-year project.

In 2019 WINPOL (2019) published a "Good Practice Guide" listing 26 best practice examples in municipal waste management all over Europe. A screening of the 26 good practice examples listed, according to the following three categories (1) incentives (PAYT etc. fee model or other incentives), (2) communication with the users and (3) digitalization of the waste collection process confirms the statement of the EIONET report as well as the results from the preceding five country reports. Most projects relate to communication with users via digital media and to the optimization of the waste collection process through the use of IoT.

Figure 7: Main areas of digitalization in best practice projects

	Best Practise Project	Incentive	Communication	Waste Collection	Others
1	Civic Amenity site access control			x	
2	Connecting online with users: Citizen app, Sustainable businesses map and Reusapp		x		
3	Container sensors for optimized waste collection			x	
4	Customer portal for collected bulky waste at civic amenity sites		x		
5	Electronic closure on waste containers and use of information		x	x	
6	Information-based waste collection		x	x	
7	Mobile app on bulky waste for reuse and recycling		x		
8	Operating aid system and waste collection weighing			x	
9	Route optimization for waste collection				
10	Sharing data on waste and resources with the public		x		
11	Smart bins to recycle anytime, anywhere			x	
12	Solar compact waste bins			x	
13	Waste management datacenter		x		
14	Waste management data warehouse		x		
15	COOMIDA – Reducing surplus food waste and food needs		x	x	
16	From door-to-door collection to pay-as-you-throw	x			
17	G'scheit feiern – Reducing waste of events and festivals				x
18	Pay-as-you-throw to reach 80% recycling	x			
19	Pop-up civic amenity sites		x	x	
20	Raising awareness on plastic waste with the CAPS Contest	x	x		
21	Recycleservice 2025 – A reversed waste collection system for residual waste	x	x	x	
22	Reuse Box – New collection scheme for reusable items			x	
23	Second Chance – Reuse on marketplaces			x	
24	Smart collection system to optimise used cooking oil to the biodiesel value chain			x	
25	The Collection – Improving textile waste collection			x	
26	Treatment of biodegradable waste			x	
	sum	4	12	15	1

source: screening based on project data of WINPOL (2019)

It is striking that two of the listed WIPOL projects involve data sharing with stakeholders in the waste chain over an information platform. Such data sharing and data analysis projects are also reported by certain countries (Greece and Spain). This indicates a need for common data pools and a move away from building one's own databases ("data silos"), which requires complex interfaces for the automatic exchange of data.

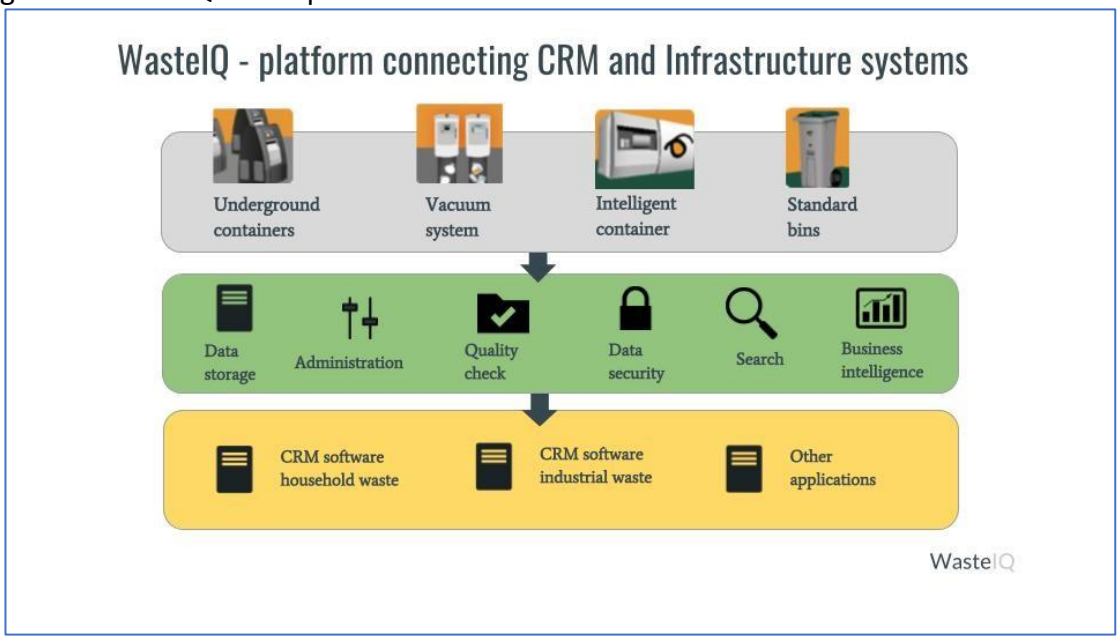
7.3. WasteIQ - a case study from Norway

The following case study, WasteIQ, is remarkable in that it takes a holistic approach, combining several aspects: The use of IoT in smart bins or containers, data storage and analysis on a common platform (data sharing with stakeholders) and an incentive system, which also includes behavioural economics components of nudging.

WasteIQ is an open waste management platform that integrates with modern digitized waste management equipment to enable a customized waste pricing model. The project

originated in a collaboration between BIR (municipal waste management organisation in Bergen, Norway) and a digital startup, WasteIQ.
The system runs the different stations for residual waste and recyclables in Bergen that are equipped with digital locks and sensors. Some of the inlets are also connected to an underground vacuum system that automatically moves the waste to a central collection terminal.

Figure 8: WasteIQ – data platform



https://www.iswa.org/home/news/news-detail/article/guest-blog-the-4th-industrial-revolution-in-practice-wasteiq-the-open-waste-management-platf/109/

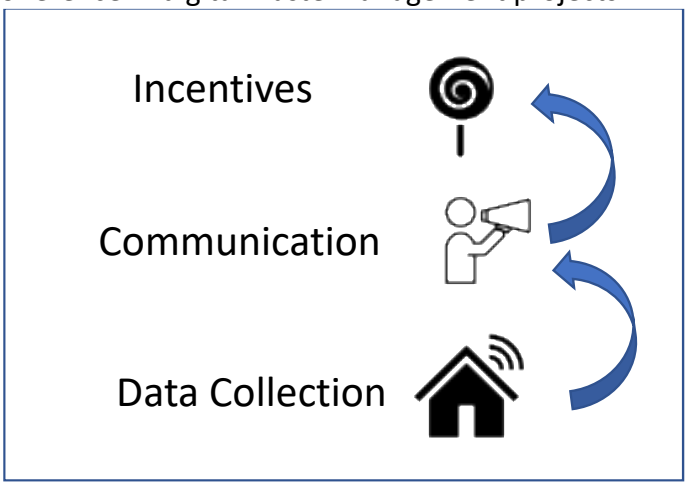
WasteIQ has developed a system that gathers data, enriches it and distributes the data to a variety of actors and technical systems. The IT system aggregates data on disposal volumes for individual households and businesses. It also provides an overview of containers' waste levels and indicates when they should be emptied. Furthermore, the waste management system is capable of weighing and calculating each citizen's waste consumption and utilizes the data to enable an individualized payment system in order to motivate the reduction of personal waste levels. Bin stations have free sorting bins for plastics and cardboard. This further nudges Bergen's citizens to sort their waste properly. The combination of smart containers, data collection and new economic incentives has so far decreased the level of general waste by 10% and increased the level of plastics collection by 29%.

8. Readiness for Blockchain applications in waste management

The results of the country studies and the comparison with other studies show that the digitalization process in the municipal waste sector is still in its infancy. Or else, with the authors of the EIONET report (Berg & Sebestyén, 2020) putting it more diplomatically: *It shows that the waste management sector is in an early phase in this development. The opportunities as well as the impact of its digital transformation are still emerging and can still be shaped.*

There are a large number of innovative projects in the various countries in the areas of communication with users, incentive systems and, in particular, the use of IoT in waste collection, but there is no comprehensive promotion of these projects in the countries, neither through state financial support programmes nor through the targeted transfer of know-how. For now, it is only the associations of municipal public or private waste disposal companies that are multipliers of information and hubs of innovation.

Figure 9: Lack of coherence in digital waste management projects



If focusing exclusively on the IT-tools used in projects, everything seems to be in place: communication via smartphone apps with users, incentive structures and a multitude of data about IoT use in smart bins and trucks. But most of the projects are isolated approaches to implementing tools either for communication or for collecting data or for setting incentive structures. What is missing is the connection between these tools: user data could be used to create user profiles and establish profile-based communication with users, which also includes the choice of appropriate incentives. The effectiveness of the incentives set in terms of behavioural change can in return be measured against the household's waste data. Ultimately, it is a matter of a coherent approach to planning in the use of IT which consistently prioritizes the solution of the problem (keyword "design thinking").

Furthermore, most of the projects presented are also non-collaborative in nature with regard to sharing data with a large number of stakeholder groups and to generating synergy effects between the partners involved. But the circular economy, to be successful, requires collaboration between stakeholders, be it producers, consumers, supermarkets, municipalities or PROs, who need to share data in their collaboration.
This is exactly the point PwC (2016) emphasizes when writing:
"Collaborative technology, such as Blockchain, promises the ability to improve the business processes that occur between companies, radically lowering the "cost of trust." For this reason, it may offer significantly higher returns for each investment dollar spent than traditional internal investments.
So what's the catch? You cannot get the return by yourself; you must be willing and able to collaborate with customers, suppliers, and competitors in ways that you have never done before."

Therefore, the development and implementation of a Blockchain project consists largely of change management and process management work. Contrary to expectations, the selection of the technical Blockchain solution plays a subordinate role. Intensive communication, understanding each other's interests, taking stakeholder and individuals along and convincing them, explaining the technical possibilities of the Blockchain in simple terms - these are the components of a successful project and the selection of project team members. (Lenz, 2019, p. 46)

The digitalization projects described in municipal waste management are very much driven by the use of new technology. The installation of telematics and IoT on waste trucks are typical tasks of mechanical engineers. The accomplishment of these tasks is of utmost importance for the smooth running of logistical processes within an organisation. But blockchain is about creating a win-win situation between stakeholders of a chain so that each of the partners involved ends up benefiting from the collaboration.
When answering questions about the readiness of municipal waste management for the blockchain, we realize that solutions to technical problems are sometimes easier and quicker to deal with than changing an entire organizational model with a view to close cooperation in a network of partners. To finally answer the question about readiness for the application of blockchain technology, it can be stated that, yes, from a purely technical point of view, most municipal waste management companies are up-to-date and use IoT extensively. What is missing is a clear data strategy which includes the analysis and the sharing of data with a variety of stakeholders. However, these are not technical problems but problems of the organisational development of municipal waste management companies.

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