Mapping of digital solutions

Index

Source: European Union

Background for the study

For this mapping study, we have selected digital solutions which could be implemented in Northern Finland. It includes applications for residents and consumers, services developed for waste companies and city-level solutions.

The transition to a circular economy will change society on many levels. For the waste management sector, this means, for example, an evolution of the role of waste management from waste treatment to material management, while the focus of material targets shifts from the weight of waste to the quality of the material collected (1).

Digital solutions and their implementation are an essential part of the circular economy transition. Current and future applications of digitalization in the waste management field include various systems combining IoT and cloud computing, remote monitoring and management, machine intelligence and algorithms, data analytics and services, robotics and automation, self-driving vehicles and drones.

	Robotics	Artificial intelligence and neural networks	Internet of things	Cloud computing	Data analytics
PROCESS	Advancements in the pneumatic sorting process as a result of automation technology allow producing defined waste streams of high purity (over 90 %).	Machine learning — using neural networks based on the use of data or examples to solve problems without explicit programming — is used for classification and pattern recognition in the waste management context, improving the efficiency of sorting.	As more and more devices are connected to the internet or other networks, sensor-supported containers can collect data and transfer it to central units.	Storing and processing of sensor data and cloud based software solutions make it easy to optimise workflows and document failure to collect, failure in sorting or detect waste bins that are not paid for.	Processing and analysing data plays an important role in the recycling industry in order to identify patterns, extract information, discover trends or calibrate models. This knowledge is important in order to evaluate different options for the transition to a recycling economy.
EXAMPLES	- Robots that are able to identify and sort recyclables and critical materials through image recognition/IR scanning/ AI vision systems when dismantling used phones/electronics	- Autonomous, self-driving street sweepers, refuse trucks	- Smart waste bins with identification systems, weighing systems, level sensors, temperature sensors, sofware for optimising logistics	Cloud based software for: - Connection, standardising and optimising internal procedures - Real-time order management, route planning and optimisation, customer self-service, order-tracking and evaluation	- Electronically supported diposition of waste collection vehicles - Evaluation of sensor data for automated sorting plants - Control of waste incineration plants - Drone based data collection on landfills

Source: European Environment Agency.

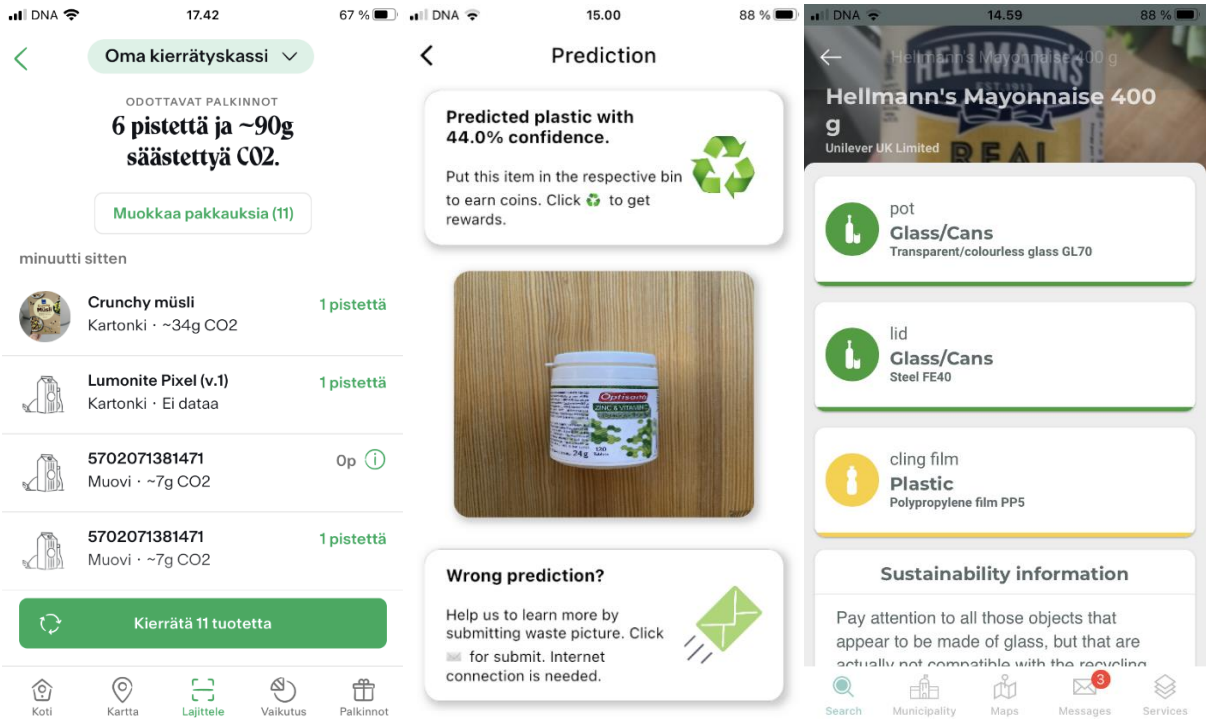
Smart systems can increase efficiency at different stages of waste management operations and value chains and improve service quality. Digital solutions have been developed at every level of the waste hierarchy to improve the efficiency of waste collection, increase recycling rates, improve the quality of collected material, enhance consumer communication and reduce the amount of waste generated.

1. A wide range of consumer mobile apps

1.1 Recycling apps: help & reward for sorting

There are several B2C and recycling aid apps on the market. The Swedish Bower app, which uses barcodes on packaging, rewards consumers monetarily for recycling product packaging (2). The service also indicates the amount of CO emissions saved by recycling. Bower is also available in Finland. It is backed by FTI, the Swedish packaging recycling company, and the Junker app in Italy and Switzerland, which uses similar technology. It does not reward its users but gives more information about the type of material used in the packaging and how it can be recycled.

The material to be recycled can also be identified by sound or machine vision. Deep waste ai from Nepal uses machine vision to identify recyclable material (3). The app gives a suggestion of the material represented by the image and the probability of identification. The user can accept or reject the suggestion and earn points by taking pictures. The points can be used in the company's online shop. Lockwaste, an Australian company, has developed a sound-based application. The app identifies different types of plastic based on the sound of the material (not yet published).



Screenshots of applications: (right) Bower, Junker and Deep waste ai.

1.2 Sales platforms: outlet for recycling materials & goods

In the waste hierarchy, the reuse and recycling of a material is preferable to its recovery as energy from an environmental and circular economy point of view. Several different digital platforms for peer-to-peer trading are available on the market to buy and sell second-hand goods or recycled materials. Some platforms for selling materials to consumers exist. One of these is Canit, a Finnish-based platform that allows users to sell or buy deposit-return bottles and (4).

There are several platforms for C2C selling of goods, depending on the type of goods being sold. Tori.fi is a general platform for selling cars, apartments, clothes and equipment for sports and hobbies. More than 13.7 million advertisements were submitted to Tori.fi in 2020 and advertisers earned a total of €729 million through Tori.fi in 2020 (5). Other popular digital platforms for second-hand goods are social media, in particular the various flea market groups on Facebook and the neighborhood recycling groups in cities. Economic cycles, inflation and the emphasis on environmental values have increased the interest in recycled fashion, especially among younger generations. The Zadaa and Tise apps have increased in popularity as demand for second-hand fashion clothing has grown. There are also several mobile apps for second-hand vehicles, such as Nettiauto and Nettimoto, and Nettivene for boats.

1.3 Online food waste shops

Food and food products offer many opportunities to prevent waste. According to the Natural Resources Institute Finland (LUKE), in 2021, trade and food services together produced 118 million kilos of food waste (33% of total waste). According to LUKE, in 2021, around 25% of trade sector waste went to food aid or donations and the remaining 75% to waste (6). While campaigns and awareness-raising are aimed at reducing particularly household food waste (107-137 million kilos), food waste in the food retail and catering sector has also generated new business.

Fiksu Ruoka, through its online store and app, mainly sells leftover and discarded food that would otherwise be at risk of going to waste. Launched in 2019, the company claims to have reduced 11 million kilos of food waste (7). Another company that uses food waste in catering services is ResQ Club, launched in 2019, an app that allows restaurateurs and bakers, among others, to sell their products to consumers that would otherwise go to waste. Both apps are able to divert waste from energy recovery back into food, thus helping to reduce the amount of waste generated.

2. B2B applications & materials sales platforms

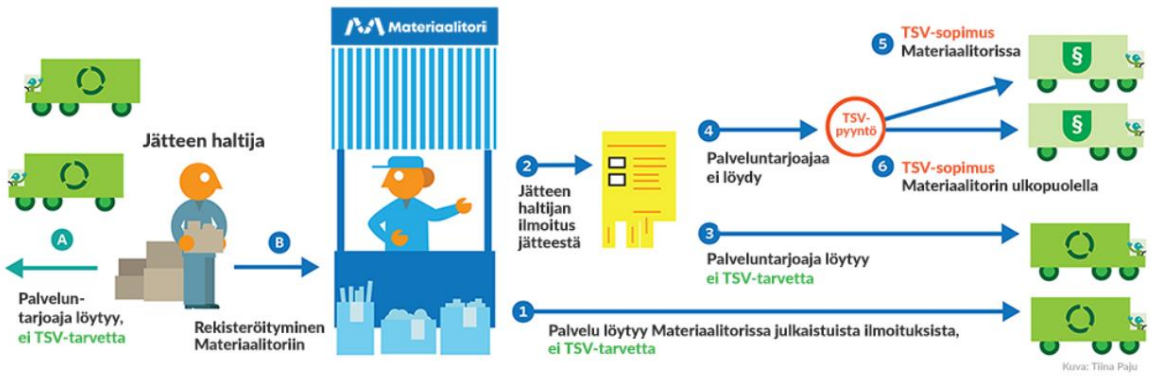
A wide range of digital services have been targeted at businesses. These services can be functional, such as Lassila & Tikanoja's Raksanappi for construction sites, which allows the ordering of waste container imports, empties, transfers and collections, and the monitoring of the progress of orders (12). The new Waste Act has tightened the accounting and reporting requirements for waste by companies. Stena recycling and Lassila & Tikanoja offer free waste reporting to their business customers. In the L&T account service for businesses, companies can monitor their waste volumes, change their collection rhythms and manage other issues related to their account.

2.1 Platforms for material sales

There are several digital material sales platforms in use around the world, including Cyrkl in the Czech Republic, Waste outlet in Denmark and Aspire in Australia (9). In spring 2019, Motiva launched Materiaalitori, a platform for the professional exchange of waste and production side streams from companies and organizations. The service is free of charge for its users. It also allows users to search for and offer related services, such as waste management or expert services (10). The main objective of the platform is to promote the recovery of waste and by-products and the circular economy by providing a meeting point where suppliers and users of recycled materials can find each other. The aim is to bring

together the material streams generated in Finland in one place, so that new ways of recovery can be created around them and materials can be increasingly recycled.

The use of the platform is mandatory for waste holders who need a municipal secondary waste management service worth at least €2000 per year, which has sometimes led to pseudo notifications with the sole aim of sending a “TSV request” (a so-called request for secondary municipal waste management) to the municipal waste management service after a 14-day notification period (11). The Materiaalitori is to be developed by 2024 and linked to other possible circular economy platform solutions (12).



Source: Materiaalitori

3. Smart waste management solutions for operators in the waste sector

Several digital solutions have been developed for waste management operators and waste collection companies. In this mapping exercise, we will not focus on robotic and automation systems for recycling plants, but on solutions for waste collection:

1. fleet and asset management,
2. optimizing logistics and workflows, and
3. Customer Service and consumer communication

All of them are based on the management of the whole and the effortless transfer of information from one system to another to enable automation and optimization. Some operators offer a comprehensive end-to-end solution, including automated workflows, route optimization based on occupancy rates, fleet and asset management, and various mobile apps for consumers and drivers.

Data analytics is an integral part of the software. Data from different systems and devices can be integrated into the main system through API interfaces and systems are often modular. The openness of the system depends on the company providing the service and its business model, but often API integration is at least one-way. Some operators have made connectivity

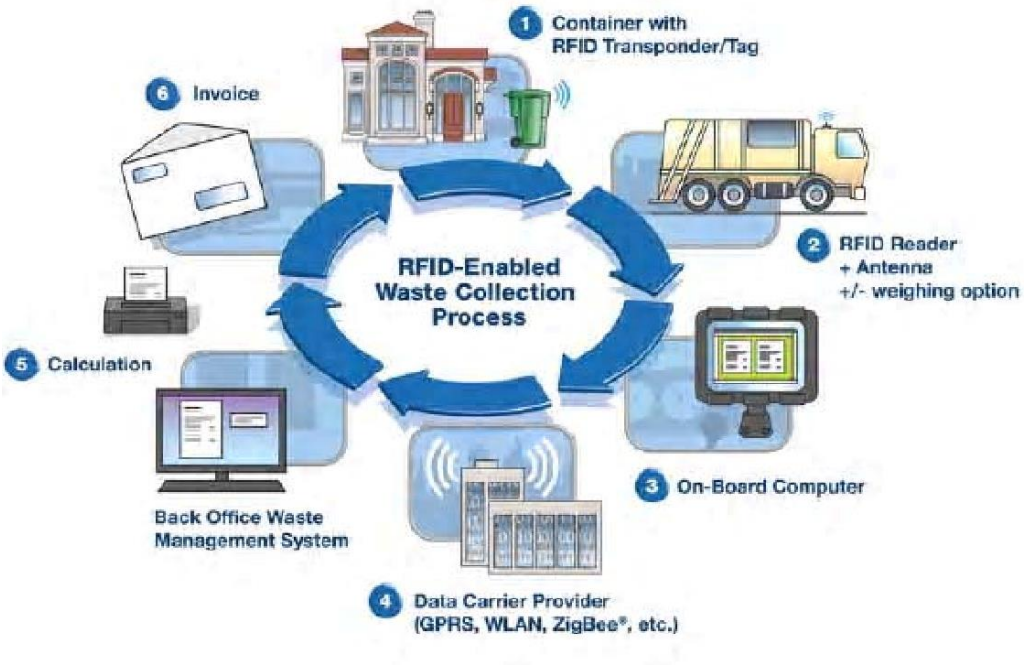
a competitive advantage by making their systems device-agnostic: they can import data from any IoT, RFID or weighing device.

Smart systems also allow for more flexible pricing to encourage residents to be more active in sorting. Research shows that feedback is a simple but effective way to influence people's behavior. In Finland, for example, residential water meters have been proven to reduce water consumption by up to 40%. Finland's bottle-bank system has led to very high return rates. These examples show that a pay-as-you-throw model based on weight, for example, could yield promising results in Finland, especially as its effectiveness has already been demonstrated in many European countries (13).

3.1 Fleet & asset management

For fleet management, several waste logistics software applications use GPS trackers on waste trucks. Other devices, such as vibration sensors, can also be connected to the trackers to schedule fleet maintenance and provide information such as vehicle idling times and traffic behavior.

The management of waste containers is made easier by radio frequency identification (RFID) technology. In this system, a passive RFID tag attached to the container works in tandem with an RFID reader attached to the collection truck. The system locates each container and automatically transfers its emptying data to a cloud service. The system can be used to verify the emptying of the container and track the life cycle of the containers. In Europe, the container identification system is often combined with a weighing feature on the waste truck: this allows the waste accumulation per container to be calculated and the customer to be charged according to the waste produced. Combined weighing and RFID systems are offered by companies such as Botek in Sweden and Tamtron in Tampere. During 2023-2024, Pirkanmaan Jätehuolto in Tampere (14) and Kiertokaari in Oulu tested the weighing system for waste collection.



Source: Semantic Scholar

3.2 Optimization of logistics & workflows

Smart containers streamline logistics

Smart waste containers aim to make more efficient use of container volume, for example by optimized emptying rates or waste compaction, as in Finbin's Citysolar packaging container (15). A 240-litre container suitable for parks or public outdoor areas can pack the equivalent of twenty 60-litre street bins. In addition, the container notifies the waste management company when it is full.

The optimization of the emptying of the smart bins can be based either on real-time level measurement data or on a forecast of the filling rate calculated from weighing data. A high-quality forecast requires several months of weighing data. In smart tanks, access can also be limited and shared by means of a smart lock. For example, the Australian Lockwaste, where the lock is operated by an app, is aimed at consumers (16).

Source: EcoctrlGSM

The market also offers solutions that combine multiple customer categories, customer identification, the PAYT pricing model and emptying optimization based on the degree of occupancy. The Italian EcoCTRL GSM has developed the Ecoisola waste container solution, which can be used to monitor the amount of waste produced by an individual user (17). Ecoisola's usage rights can be easily changed and shared: the system can weigh the amount of waste brought by each user or charge for usage times. User rights can be linked to, for example, a Kela card or a personal QR code. Thanks to the solar panels and the geographical location, the smart containers operate independently in Italy without an electricity connection. The system can be used to reward diligent recyclers, distribute discount gift cards, or use user data to determine the waste management fee. In Italy, a flexible waste fee is in use, which consists of a basic fee and a user fee, which is determined based on the waste brought by the resident in accordance with the Pay-as-you-throw model.

A waste bin can also be responsible for sorting the material, such as the Bin-e bin that uses artificial intelligence, which moves the waste to the correct sorting compartment using machine vision (18). The smart container also packs plastic and paper waste and monitors the filling level of the compartments with surface measuring sensors. Other tableware solutions that utilize machine vision include Nando, which is installed in the table afterwards, and rather assists in sorting than performs it on behalf of the user (19).

Software automation and optimization features for efficient use of resources

The actual optimization is often performed by ERP and route optimization systems using cloud services and data analytics, based on the equipment data. The Danish company WasteHero

has developed a complete waste management solution that allows routes to be optimized, for example, according to length or filling rate. In addition to route optimization, WasteHero's ERP system includes resource management (fleet, assets and personnel), automated workflows, and 24/7 customer service. WasteHero's system strives for efficiency through automated workflows and ease of use: actions that used to take 50 clicks to complete are now completed in 3-5 clicks (20).

In Finland, the most widely used ERP systems in waste management companies are Vitec's Vingo and Ecomond's TCS, and Enpros' Zewrowaste for route optimization and electronic movement documents. They all offer algorithm-based logistics planning and optimization services in their systems and can leverage IoT data through API interfaces.

Recycling and waste incineration plants are a separate chapter, with AI and algorithm-based automation and robotics for sorting, logistics, etc. Their treatment is excluded from this inventory.

3.3 Improving customer service quality

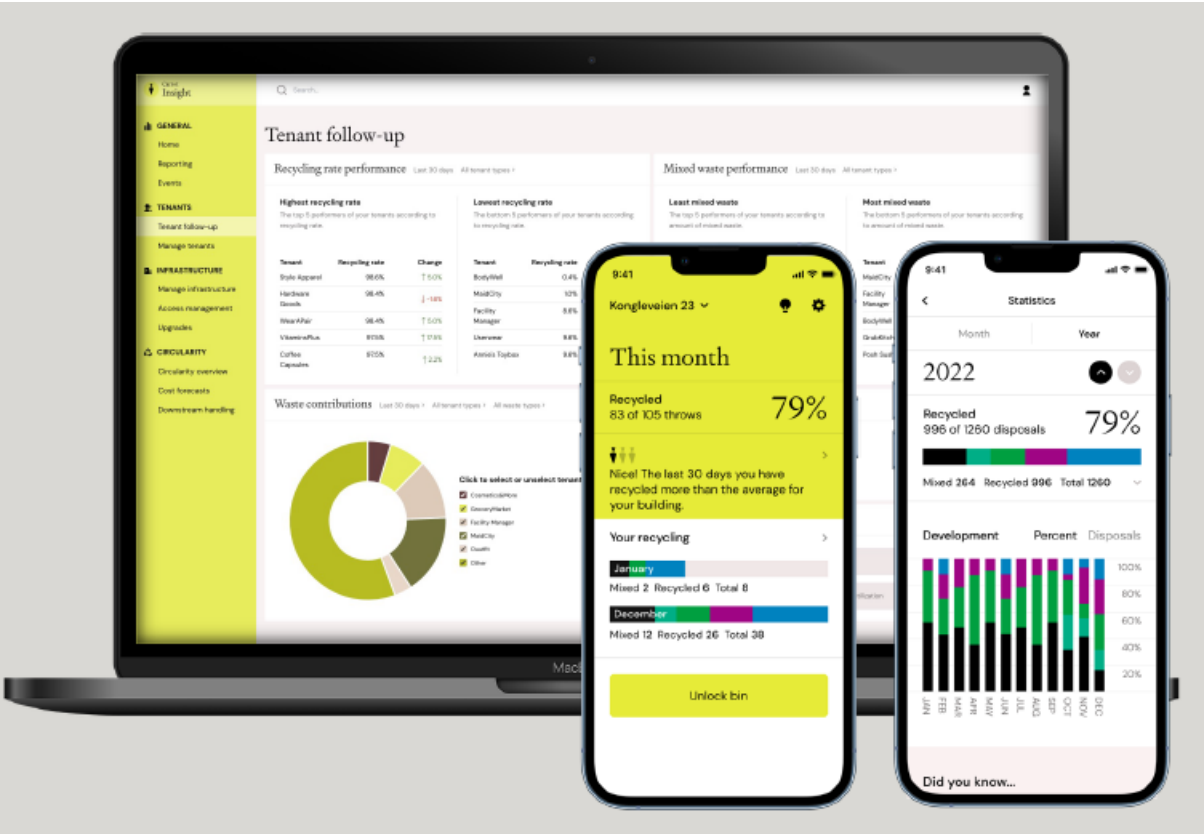
Waste companies have developed their own mobile apps as part of their customer service. These solutions often combine informing the customer about waste service stations in the area or company with the possibility to pay for the waste they bring in using an app. Lakeuden Etappi has a Re-app (21) self-service station for Re-point and Puhas-app (22) for Puhas. Vestia has developed its own model of a remote self-service point: in Vestia's Sorting Yard (23), the customer pays the waste fees on the spot using a customer terminal.

In addition to the payment feature, the api instruct customers where to take their waste at the recycling centre and provide information on opening hours, for example. Other electronic services include the Finnish Recycling Association's (KIVO) online service kierratys.info (24), which provides information on regional collection points for sorted material of household waste throughout Finland.

In Europe, there are also citizen-oriented applications for the location of waste bins, such as the Smart Waste Monitoring app from Sensoneo, which offers a wide range of smart waste management services. In Oulu, a Smart Waste Bin app allows residents to empty their own waste bin when needed. The app, which is aimed at small house owners, also calculates an estimate of the amount of waste generated. Housing associations can also use the app to fetch a garden waste skip or other additional waste. The service is provided by Haurun Jäteauto Oy.

1. Smart cities & urban solutions

Pay-As-You-Throw based pricing is increasingly being developed in waste management and in some European countries it is already an integral part of waste management pricing. Waste charges can be based either partly or entirely on use or on the amount of waste generated. In addition to Italy, the second largest city in Norway, Bergen, for example, has a per-household waste management charge. The municipally owned waste company BIR has introduced RFID technology combined with surface measurement and Bergen also has one of the largest waste pipe collection systems in the world. The system was supplied by Envac of Sweden, part of the Stena Group (25). Data from the different devices and systems are combined into a manageable whole in the Carrot data service. The introduction of intelligent systems and the flexible waste collection fee according to use reduced the amount of mixed waste in the city by 9 % and the amount of plastic collected increased by 28 % (26).



Source: Carrot

In large cities, digital twins have started to be developed to support urban planning. The term "Digital Twin" is generally used for an application that aims to digitally represent and predict the physical world and its activities. These applications usually create a 3D digital model of an object, which is then guided and enriched with data from the real world. The model can be used to perform analyses and simulations of different situations.

The digital twin receives data from various sources such as vehicles, buildings, infrastructure (e.g. electricity and water networks) and inhabitants. This data is enriched with data from smart city and IoT devices and supplemented by artificial intelligence (AI) and advanced analytics. The technology combines historical, static and real-time data to provide valuable insights into city performance.

The digital twin acts as a kind of "strategy accelerator" that can be used to make better decisions and identify important links between model components and data. Singapore, Sydney and Amaravati in India are already using the digital twin for smart city development (27). Digital twin experiments have been conducted in Helsinki, Hervanta in Tampere and the Port of Oulu to assist urban planning (28). In Hervanta, the service has been used to test and develop automated mobility solutions (29).

Digitaalisen kaksosen moniulotteisin taso on se, jossa kaikesta kerätystä datasta pyritään muodostamaan analyyseja ja tulevaisuuden ennusteita tilannekuvan rinnalle. Kun kaikki saatavissa oleva data esimerkiksi kaupungista ja sen rakennuksista, liikenteestä ja ihmisistä saadaan tuotua digitaaliseen kaksoseen, on mahdollista muodostaa analyyseja ja ennusteita myös tulevaisuudesta. Analyysia voidaan hyödyntää esimerkiksi tulevien rakennustarpeiden suunnitteluun tai sen avulla voidaan myös löytää esimerkiksi kaupungin hiilineutraaliustavoitteen kannalta kriittisimmät pisteet tutkimalla, miten eri datat käyttäytyvät ja korreloivat keskenään virtuaalisessa muodossa.

Source: Sitowise

The digital twins are also expected to transform waste management in the future. The digital twin of waste management will combine real-time data on equipment condition, container location, quantity and filling rate, waste accumulation, the status of collection routes and staff location, among other things. The technology uses sensors and analytics to collect data from

physical objects and create an accurate digital model. The data is then used to simulate how the object would perform under different conditions, enabling predictive analytics. This can be very useful for the waste management industry as it allows systems to be monitored and analyzed in real time, identifying potential problems before they occur.

The digital twin can also help reduce waste and increase recycling rates. By monitoring the performance of waste management systems and analyzing the data collected, it is possible to identify where waste collection and treatment can be further improved. This in turn can reduce the amount of waste going to incinerators. By providing real-time monitoring and analysis of systems, technology can help improve accuracy and efficiency, reduce waste and increase recycling, and reduce waste management costs. Digital twin technology is expected to revolutionize the waste management field in the near future (30).

Source:

1 ETC/WMGE Report 4/2020: Digital waste management https://www.eionet.europa.eu/etcs/etc-wmge/products/etc-wmge-reports/digital-waste-management

2 https://getbower.com/fi/

3 https://www.deepwaste.ai/

4 https://www.canit-app.com/fi/mika-canit

5 https://media.tori.fi/tori/

6 https://www.pty.fi/wp-content/uploads/2023/01/PTY_Ruokahavikki-kaupan-sektorilla-Suomessa_Luke_2022.pdf

7 https://www.fiksuruoka.fi/page/46/tietoa-ruokahavikista

8 https://www.lt.fi/fi/raksanappi

9 https://cyrkl.com/ , https://www.waste-outlet.com/about-us/ , https://aspiresme.com/

10 https://www.materiaalitori.fi/tietoa-palvelusta

11 Hankimo Katja (2023): Materiaalitorin kehittäminen, HAMK Tieto- ja viestintätekniikka, biotalouden koulutus opinnäytetyö. https://www.theseus.fi/bitstream/handle/10024/794816/Hankimo_Katja.pdf?sequence=2

11 https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/163978/YM_2022_13.pdf?sequence=1&isAllowed=y

13 Ukkonen, Aino & Sahimaa Olli (2021): Weight-based pay-as-you-throw pricing model: Encouraging sorting in households through waste fees, Waste Management Volume 135, p 372–380. https://www.sciencedirect.com/science/article/pii/S0956053X21005006?via%3Dihub

14 https://businesstampere.com/fi/kiertotre-hankkeen-haastekilpailu/

15 https://www.finbin.fi/en/smart-bins/37-smart-bin-citysolar

16 https://www.lockwaste.com/

17 https://ecocontrolgsm.it/en/teca-eng/

18 https://bine.world/

19 https://www.re-learn.eu/nando/

20 https://wastehero.io/solutions/

21 https://www.etappi.com/palvelut/jatteiden-vastaanottopaikat/re-piste/

22 https://www.puhas.fi/asiointi/lataa-ilmainen-puhas-mobiiliapp.html

23 https://www.vestia.fi/lajittelupihalla-asiointi/

24 https://www.kierratys.info/tietoa-sivustosta

25 https://projects2014-2020.interregeurope.eu/fileadmin/user_upload/tx_tevprojects/library/file_1653912943.pdf

26 https://carrot.tech/articles/rewarding-households-for-sorting-efforts

27 https://www.pwc.com/m1/en/publications/documents/how-digital-twins-can-make-smart-cities-better.pdf

28 https://www.sitowise.com/fi/uutiset/digitaaliset-kaksoset-avaavat-uuden-maailman-kaupunkisuunnitteluun

29 https://tamperetestbed.fi/testialue/

30 https://ts2.space/en/digital-twins-and-the-future-of-waste-management/

31 https://kiertotalous2.turkuamk.fi/uploads/2020/10/2d1877f6-hiilijalanjalkilaskuriopas.pdf