DEVELOPMENT OF PAYT SCHEMES IN THE SAVONLINNA REGION

Lappeenranta–Lahti University of Technology LUT

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Pirkko Räikkönen

Examiners: Professor Mika Horttanainen
Associate Professor Jouni Havukainen

Supervisor: Kari Tikkanen

ABSTRACT

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Pirkko Räikkönen

Development of PAYT schemes in the Savonlinna region

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Keywords: PAYT, Pay-As-You-Throw, municipal waste management.

Pay-As-You-Throw is a paradigm for determining waste fees based on how much waste is generated and charging individual users. In this research, most common identification and measuring technologies related to waste management and collection are introduced with PAYT schemes based on volume, frequency, weight and sacks. The characteristics of the Savonlinna region are analysed and feasible development proposals for the current PAYT model of the case area are introduced. Proposals are results from SWOT and TOWS analysis, which were used to analyse feasibility and to create strategies to implement PAYT-schemes.

In the case area waste fees consist of fixed and variable fees. The variable part of the waste fee is mainly based on the volume of the waste container in use and the frequency of emptying. Such a payment system is fair and treats users equally if the waste bins are full when emptied. The size of waste bins and the maximum emptying intervals for each waste fraction are decreed in municipal waste management regulations. As a result, the size and emptying interval of the waste bins do not match the amount of waste generated in properties, especially in detached houses and summerhouses. Condominiums share the costs equally between the number of apartments regardless the amount of waste generated per resident or household. Volume, frequency and weight based PAYT schemes are possible, but to fully implement producer pay principles in the area, door-to-door collection should be tendered by municipality. Municipalities could purchase and implement systems that gather data of waste generation of individual user or household. Sack based schemes are solutions to implement producer pay principle in bring-point collection and to modify the waste fees of waste collection in civic amenity sites to be variable instead of fixed.

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Pay-As-You-Throw on ajatusmalli jätemaksujen määräytymisestä sen perusteella, paljonko jätettä tuottaa. Huomioiden erilaisia teknologioita, jätteenkeräysmenetelmiä sekä Savonlinnan seudun ominaispiirteitä, on tässä tutkielmassa analysoitu erilaisia PAYT-malleja (tilavuus-, tiheys-, paino- ja säkkiperusteiset mallit) soveltaen SWOT ja TOWS analyyseja. Luotujen strategioiden pohjalta on esitetty nykyisen PAYT-mallin toteuttamiskelpoisia kehittämisehdotuksia.

CASE-alueella jätemaksut muodostuvat kiinteistä ja muuttuvista maksuista. Jätemaksujen muuttuva osa perustuu pääsääntöisesti käytössä olevan jäteastian tilavuuteen sekä tyhjennysväliin. Tällainen maksujärjestelmä on reilu ja kohtelee käyttäjiä tasapuolisesti, mikäli jäteastiat tyhjennetään niiden täytyttyä. Kunnallisissa jätehuoltomääräyksissä on säädetty jäteastioille enimmäiskoko sekä jätelajikohtaiset enimmäistyhjennysvälit, minkä vuoksi astioiden koko ja tyhjennysväli eivät vastaa kiinteistöllä syntyvän jätteen määrää. Erityisesti pientaloissa ja vapaa-ajan asunnoilla sekajäteastian täyttöaste on hyvin matala. Taloyhtiöissä jätemaksut jaetaan asuinhuoneistojen lukumäärän eikä yksittäisen ihmisen tuottaman jätemäärän perusteella. Tilavuuteen, tiheyteen ja painoon perustuvat PAYT-mallit ovat sovellettavissa kiinteistöittäiseen keräykseen, mutta taloudellinen toteuttaminen voi olla mahdollista ainoastaan kunnan kilpailuttamassa jätteenkuljetuksessa. Kunnan voivat keskitetysti toteuttaa menetelmiä yksittäisten käyttäjien tai talouksien jätteenmuodostumisen seuraamiseksi. Säkkiperusteista mallia voidaan soveltaa aluekeräykseen, ja se on sovellettavissa myös jäteasemilla tapahtuvan jätteenkeräyksen taksojen kehittämiseksi.

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SYMBOLS AND ABBREVIATIONS

Abbreviations

CAS	Civic Amenity Site
EPA	Environmental Protection Agency
EPM	Expert Program Management
FTP	File Transfer Protocol
GPS	Global Positioning System
GSM	Global System for Mobiles
GWR	Guided Wave Radar
HSY	Helsingin Seudun Ympäristöpalvelut
IoT	Internet of Things
KAYT	Know-As-You-Throw
MML	Maanmittauslaitos
NSR AB	Nordvästra Skånes Renhållnings AB
PAYT	Pay-As-You-Throw
PDA	Personal Data Assistant
QR	Quick Response
RFID	Radio-frequency identification
R&D	Research and Development
WEEE	Waste from Electrical and Electronic Equipment

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1. Introduction

The Finnish Waste Act (646/2021), which entered into force in June 17th, 2011. According to the 32 § of Waste Act, municipalities are responsible of organizing waste management of housing, administrative and services of municipality and any waste that is collected with these. After the reinforcement in 2011, Waste Act has had variety of amendments. The latest change of the Act entered into force on July 19th, 2021, and the renewed decree on Waste (government decree YM/2021/71) that supplement the law, was forced on December 1st, 2021.

Regional waste management board of Savonlinna is a legal waste management authority meant in national waste law (646/2011) § 23 and it is formed by city of Savonlinna and the municipalities of Rantasalmi and Enonkoski. Together with the municipality of Sulkava these have incorporated a municipal waste management company of Savonlinna Area. (City of Savonlinna 2021).

Main principle for the municipal waste management is that municipalities would organize the transportation of waste from properties to their waste management facilities. In Waste Act (§ 37), there is possibility for municipalities to decide if the waste transportation from properties is organized by the property holder or the municipality itself. The regional waste management board of Savonlinna has decided the waste collection to be organized by property owner for every waste fraction (Waste management board 20.11.2012 § 16).

Renewed waste legislation of Finland requires municipalities to relinquish possibility for biowaste and packaging waste and tender waste collection by themselves. Collection of packaging waste must start on July 1st, 2023, as the collection of biowaste can be started earliest on July 19th, 2023 and latest on July 19th of 2024. Municipal waste management can be seen as necessity service that has to be organized even in areas where it might not be profitable. Areal waste management board of Savonlinna monitors the waste management in its area (City of Savonlinna 2021). Savonlinna area is geographically dispersed (MML

2021) and sparsely populated, the population is decreasing and ageing (South Savo Regional Council 2021), and the municipal waste management is being under vast transformation.

In circular economy, the materials need to be collected and recycled. Waste Act demands the separate collection of packaging and small metal waste to be reached for every household that has five of more apartments and to that the biowaste will be needed to separate from mixed solid waste in every household located in urban area with at least 10 000 habitants (Government decree on waste YM/2021/71). Considering the demands and possibilities of separating waste, the amount of mixed solid waste must reduce. As the waste management of municipal waste can be seen as a necessity service, future target should be cost-efficient and fair waste management. Identifying feasible technological solutions and innovations to apply PAYT (Pay-As-You-Throw) concept in the waste collection of municipal waste in Savonlinna area opens pathways to get everyone pay for the management of waste one has generated.

1.1. Goals of the study

Main goal is to search for feasible technological solutions to apply PAYT (Pay-As-You-Throw) concept in the waste collection of municipal waste in Savonlinna area. Vision is that Savonlinna and the municipalities around it have an optimized waste management system where everyone pays for waste management only of the waste one has generated. The reason for this study is to use it as background research in the process of creating political program for waste management and defining the service levels of waste management in the near future.

2. Methods

To form a general view, an analysis of the case area is scrutinised by factors developed by combining factors from PESTEL-analysis and The Zero Waste Masterplan (Zero Waste Europe 2020) instructions. The latter is a guide for municipality officials, policy-makers, zero waste activists, community leaders, waste professionals and city planners to implement a sustainable waste management, waste prevention activities, repair and reuse strategies and an overview on Zero Waste Business models (Zero Waste Europe 2020). Research is supplemented with applicable instructions to choose key parameters for selecting waste collection system of Collector project (Weißenbacher et al 2018). Analysis is supplemented with interviews targeted to waste collectors operating in municipal solid waste collection. Request for interview was sent for all six collectors, and four agreed.

Research is done by researching technologies and innovations that support PAYT-concept. Identified technologies and innovations are analysed with SWOT and TOWS analysis to create possible strategies for their implementation in case area. In the end the feasible ones are highlighted as potential development goals in developing the PAYT-systems.

To research applicability of different PAYT-systems in Savonlinna subregion, strengths, weaknesses, opportunities and threats are summarized with SWOT analysis. Using results of SWOT analysis, TOWS analysis is used to generate and compare strategies for implementation of PAYT-systems (EPM 2019). After identifying strategies, different models for enhancing current PAYT-system are created (EPM 2019). Context of SWOT and TOWS (threats, opportunities, weaknesses and strengths) is presented in figure 1.

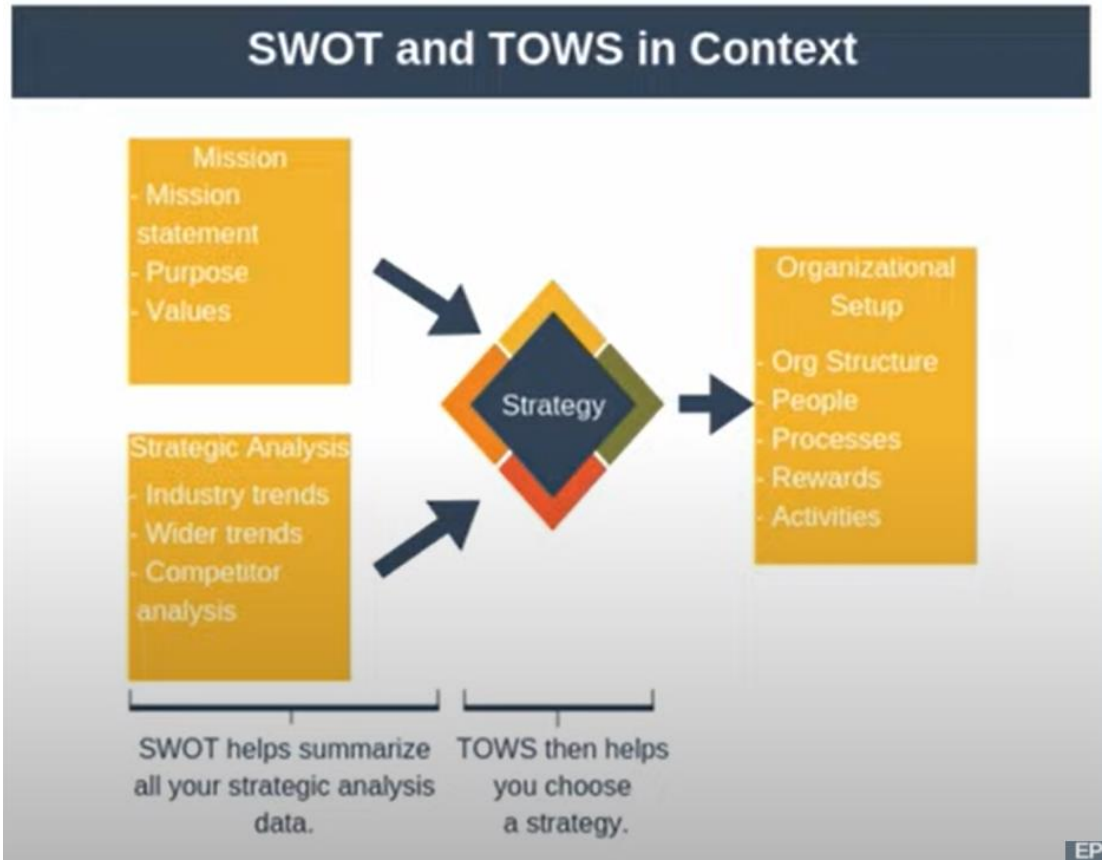

Figure 1. Context of SWOT- and TOWS-analysis (Source: EPM 2019).

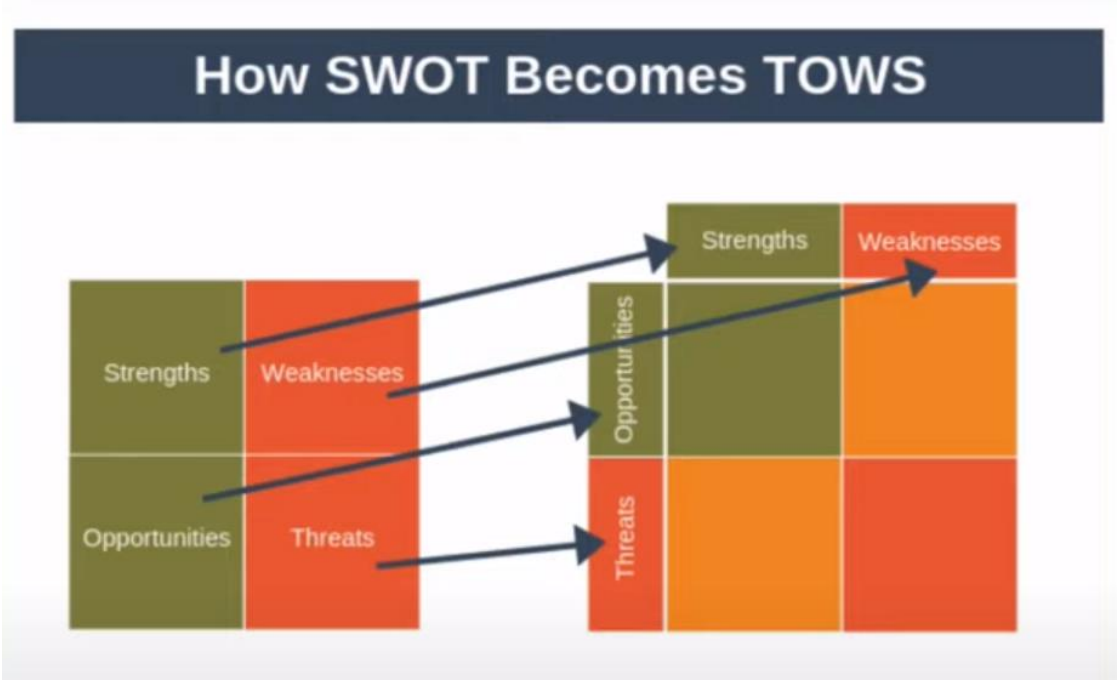

Figure 2. How SWOT becomes TOWS (Resource: EPM 2019).

TOWS analysis is generated from SWOT analysis (Figure 2). In TOWS analysis, strategies are generated and compared. It also helps to select one or more strategies to implement. (EPM 2019). TOWS analysis does not give answers what kind of combinations of waste collection systems are best, but it helps to create the strategies needed to determine applicable collection systems in CASE-region.

3. Concept of Pay-As-You-Throw (PAYT)

Pay-As-You-Throw (PAYT) is an economic instrument of municipal waste management (Dri et al 2018, p. 180). It is a scheme in which users pay for the management of waste equal to the amount delivered to the system. PAYT schemes do not aim to prevent generation of waste, but they are adaptation to the polluter pays principle. Principles of PAYT are based on identification, calculation and unit pricing. Technical solutions have to give solutions to three elements (Ukkonen, A., & Sahimaa, O. 2021; Dri et al 2018, 218; Morlok et al 2017):

- the identification of individual users,
- measuring the waste streams of individual user, and
- defining unit pricing that effectively drives behavioural change.

It is to be noted that even best PAYT systems are to fail without adoption of the waste management system and the engagement of residents (Dri et al 2018, 218; Morlok et al 2017). Pay-As-You-Throw (PAYT) schemes are based on the idea of charging waste producers of the actual amount of waste they generate. PAYT schemes can be implemented using technologies based on volume, weight, frequency or sacks (European Commission 2021; Dri et al 2018, p.215). Sack systems are considered to be included in volume-based systems but are recognized to be an additional system for solid household waste as the volume and weight of the bag correlate directly (Dri et al 2018, 217; Morlok et al 2017). Different schemes have very different design and requirements for equipment (EPA 2016).

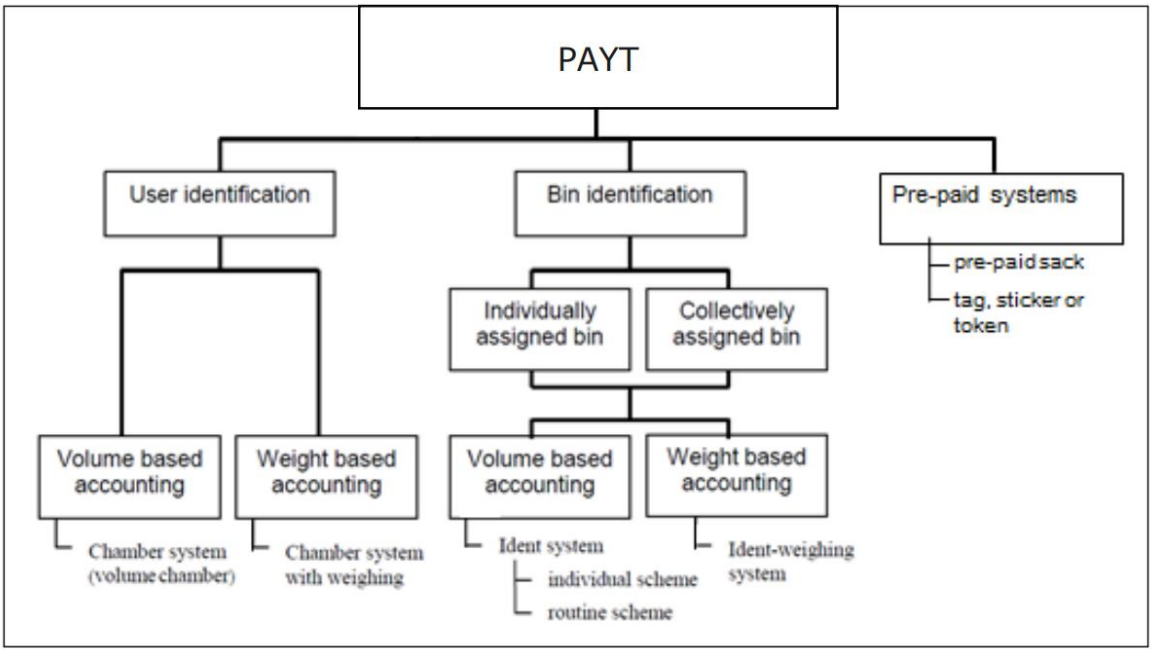

Figure 3. Overview of the different possibilities to implement the PAYT approach. (Dri et al 2018, 217).

Possible approaches to implement Pay-As-You-Throw (figure 3; Morlok et al 2017; Dri et al 2018) are:

- Identifying the user:
    - Volume-based accounting
    - Weight-based accounting
- Identifying the bin (individually or collectively assigned bins)
    - Volume-based accounting (identification system)
    - Weight-based accounting
- Pre-paid systems
    - Pre-paid sack
    - Tag, sticker, or token

Accounting per user identifier rely on identification of individual user, who is charged by personal waste generation. Accounting per bin identifier requires identification of individual bin, which can be used either by individual user or together with other users. Users are connected to this assigned bin in waste and customer management software. Pre-paid

systems don't require identifying users or bins as waste management and treatment costs are paid in advance when purchasing specific sacks, tags, stickers or tokens. Tags and stickers can be attached to any sack suitable for waste collection. Tokens are mostly used in reversed vending machines, which are combined to sack-based systems with bring-point collection.

When organizing solid waste management, approach is determined by overall waste management goals, budget constraints and other factors. Waste collection can be organized as door-to-door collection, street collection or bring-point collection (Dri et al 2018, 218). The PAYT system should cover also the civic amenity sites (bring-point) to have it implemented successfully.

As an economic instrument, PAYT system is built on charging of waste fees (Figure 4). It is experienced, that the best results are achieved when waste fees have both fixed and variable parts. The latter part of waste fee usually works as an incentive and can have positive impact on residents, improving waste separation at source and prevent waste generation as long as the balance of fixed and variable fees are right (Dri et al 2018, 2016).

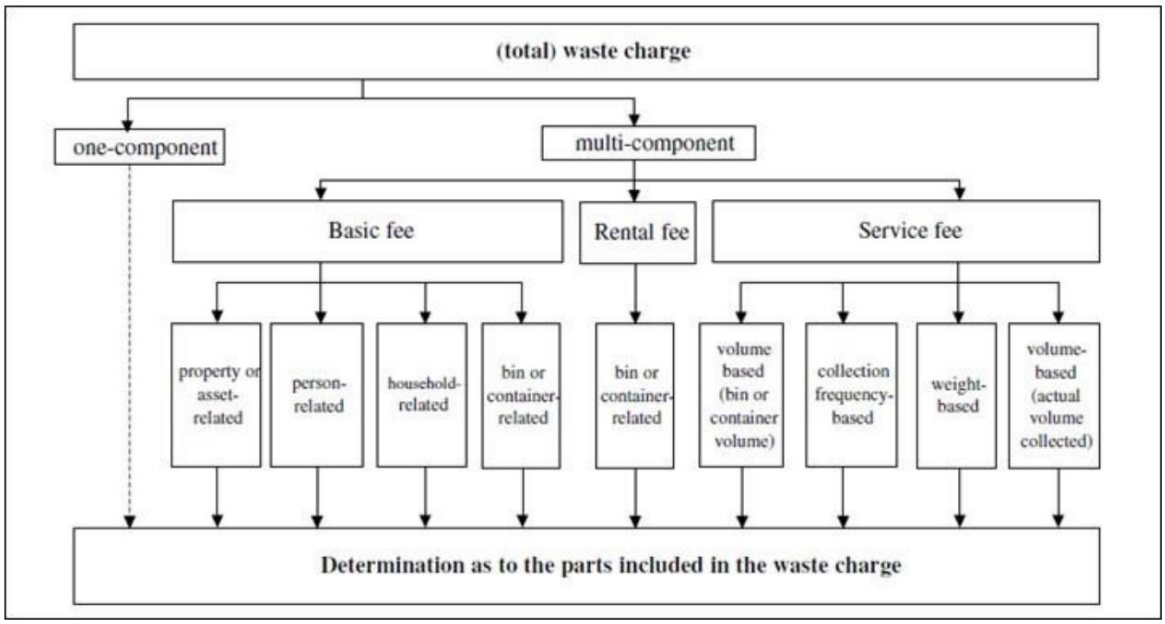

Figure 4. Different suitable components for design waste fees (Dri et al 2018, 217).

Know-As-You-Throw (KAYT) has been introduced alongside of the Pay-As-You-Throw, being an important part of waste management. KAYT has strong basis on waste advising and persuading citizens, aiming to reduce municipal waste and increase separate collection. Rethink WASTE project (2021) states that

> "the habits of citizens towards separate collection can be improved by informing them in a continuous and convenient way, combining technology, gamification, one-to-one meetings with real informers and some economic and/or social benefits".

Best results are from cases where PAYT has been combined with KAYT.

3.1. User and bin identification

Different identification technologies are necessary in any kind of PAYT scheme. Without identification, the fair sharing of the waste management fees is impossible. The best solutions to identify users and bins is to use technologies are based on Internet of Things (IoT). Internet of Things is a network connecting physical devices to internet and through that to other devices, allowing data collection and transferring over a wireless network without human intervention. With internet connection, devices with sensors and other hardware communicate via the web. These devices and hardware can also be controlled via internet. IoT is described to be

> "a giant network of connected things and people – all of which collect and share data about the way they are used and about the environment around them." (Jen Clarks 2016).

In waste management, the IoT is becoming growingly important. With IoT, the information gathered can be transferred in real-time from emptying site to the collection company. Information gathering can be automated and the errors related to manual work is minimized.

3.1.1. Radio-frequency identification (RFID)

RFID is a major technology in the field of identification. Radio-frequency identification (RFID) technologies are based on electromagnetic waves that exchange information between label or tag and a reader. Reader is used to create an interface between the identifier (ID) and database where the actual information of the object of identification is saved (Figure 5). Reader transmits a frame, the signal is modulated and collected by the tag's antenna before transmitting it to the RFID chip. Reading of the tags can be automated and that way reduce human interaction and input errors. At the same time, information can be captured faster. This enables multiple readings, and the reading can be done from a distance. RFID is normative, and because of that it can be implemented also other dimension than just identification. RFID technology is also used in authentication and localization functions. Also, sensors can be combined to RFID. (Perret 2014).

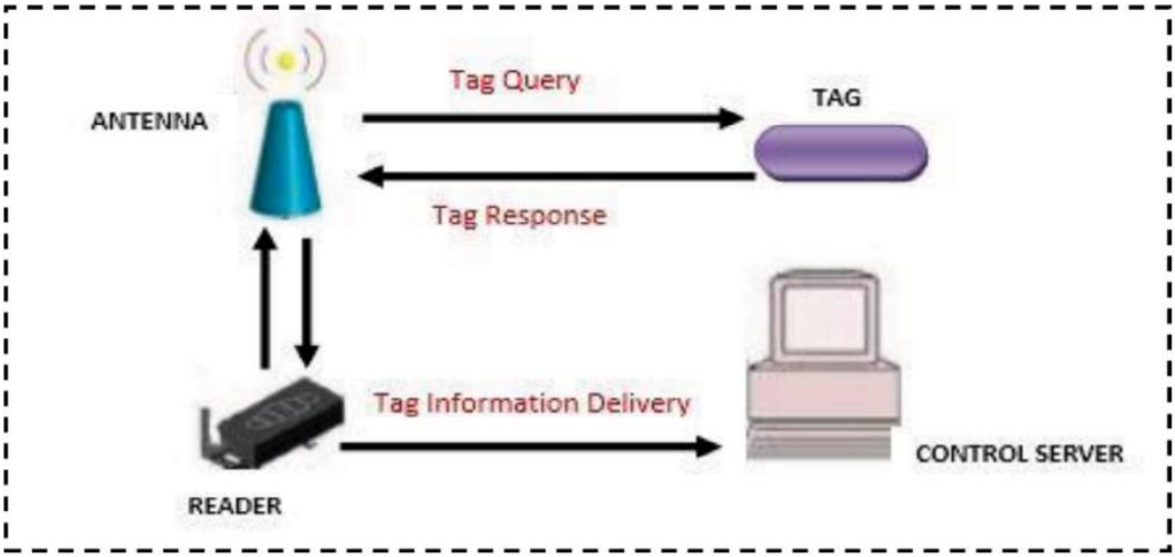

Figure 5. A typical RFID system (Olaide et al 2018, Figure 1).

In waste management RFID can be used to improve waste collection practices (Greenwalt 2017). RFID is used to track waste containers, managing emptying work, in service verification, route management, collecting productivity data of the waste management etc. (Greenwalt 2017). Waste bins that are accord to SFS-EN840 standard, there is a build-in place for RFID tags. Tags can also be attached some other way, but it might require specific

instructions depending on if the reading is automatic or done manually by the waste collector. The information these tags usually contain is just the customer number, and the reader devices that has IoT-connection and user interface to operator's customer management system opens more information. With this, RFID helps the operator to identify the equitable owner and the emptying information can be sent to database used in waste collection and management.

The RFID technology can avoid visibility, accessibility, processing quality, readability, and delays in reading process that are possible in barcoding (Kubáňová et al 2022). Readers are available up from 1 300 € per unit and antennas up from 300 € (Evifin 2022b). Tags for outdoor-use start from 1,00 € per unit (Fentec Oy 2022; Finn-id 2022).

3.1.2. Barcode

Barcoding is an automatic identification (auto-ID) technology that is based on optical scanning (McCathie et al 2005). Information is printed to paper with ink in a form of stripes (Figure 6), which are read with a barcode scanner with laser (McCathie et al 2005). Coding is based on colour contrast between vertical lines and spaces, which are unique for a product (Kubáňová et al 2022).

Figure 6. Picture of a conventional barcode from a label of 'Bioska kassi'. (Author).

Operating principle of barcode is universal and completely standardized (Perret 2014). Anyone can use a free software to generate barcode and the codes can be read using a smartphone or a webcam (Perret 2014). Both tags and readers are extremely low-cost (Perret 2014), codes starting up from few cents and readers up from 550 € (Evifin 2022a), but codes can be read via smart phones using app. Development costs of an app are not considered to be significant. Downside of the easiness is that reading barcodes require human interference (Perret 2014): reading it cannot be automated. Barcode is easy and simple to use, and very affordable to implement within the entire logistics chain (Kubáňová et al 2022; Kukharev et al 2018; Perret 2014; McCathie et al 2005).

Barcode contains information on the type of the product (Kubáňová et al 2022). Barcodes can be used in smart bins with barcode readers. If waste has a barcode including information about recyclability of this certain products, smart waste bin will inform about it. (Musulin 2016). Code can also work as a sorting guide if user can read the code (Bonino et al 2016).

Possible limitations of barcoding are related to visibility, accessibility, processing quality, readability, and delays in barcode processing (Kubáňová et al 2022). For example, direct visibility is necessary between the barcode and the scanner or reading will fail (Kubáňová et al 2022).

3.1.3. QR-technology

QR (Quick Response) code is an advanced version of barcodes. Comparing to the barcode it can hold several dozen to several hundred times more information (Denso Wave Co, 2022b). The amount of information in the modules depends on character encoding and the accuracy of the error correction (Janne Luotola 2022). QR Codes needs only one-tenth of the space traditional barcode (Figure 7). Barcodes are small in size, and they are resistant to dirt and damage. QR Code can restore maximum of 30 % of the data from partially damaged symbols. This restoration might not be complete, it depends on the amount of dirt and damage. (Denso Wave Co, 2022b).

Figure 7. Comparison of barcode and QR code in size. Source: Denso Wave Co 2022b.

Reading restrictions can be imbedded to QR Codes to enhance privacy. (Denso Wave Co, 2022b). COVID-19 passport is an example of partially encrypted QR Code; it can be read with a smart phone app and even though the code contains personal information protected by the Finnish Data Protection Act (1050/2018), only essential information of the persons vaccination (meaning name and the information if passport is valid or invalid) can be seen by the reader.

Wireless readers for both 1D and 2D (barcode and QR code) are available on Finnish markets up from 550 € (Evifin 2022a), but codes can be read via smart phones using an app. Specific reader might not be needed, if the code is read manually.

3.2. Waste measuring technologies (and charging of waste fees)

With current technology, smart waste management has become a considerable option for traditional waste collection. With IoT-technology, it is possible to gather information on waste to a comprehensive database and use it to monitor waste generation. Combined with different kind of sensors in either waste containers or in collection equipment and GSM or GPS connection, data can be gathered and transferred to database automatically. Database can be connected to invoicing systems and other platforms to enable pervasive usage of data.

Most common things to measure in waste collection are weight and fill level (in municipal waste management). Other possible things to measure are temperature, humidity and smell. These measuring technologies are categorized in two for closer theoretical examination: Weighing technologies and sensor technologies used in waste collection.

3.2.1. Weighing scale systems in garbage trucks and waste bins

Most of the weighing systems used are for measuring the total load on the waste truck. For different purposes there are also weighing systems that measure the weight of content of a certain bin or container while it is being emptied to the vehicle. In waste management, most relevant weighing systems are built in front loaders, rear loaders, side loaders and waste trucks that have beam lifters. Incremental parts are load cell, weighing calculator, PDA (Personal Data Assistant) device and on-board computer.

Figure 8. Observational image of an on-board weighing system for waste collection. Source: Poul Tarp A/S 2022.

Many of commercial on-board weighing systems can be installed to new or older garbage trucks. A GPS or GSM connection is required in PDA device to transfer the information of weight measurement via IoT-platform to the operator's database (figure 8). One example of commercial on-board weighing system is offered by VPG Systems UK Ltd. Their system is meant to weigh waste bins at the kerbside during the emptying features RFID bin identification, live credit control, data backup and live GPS tracking. (VPG Systems UK Ltd 2022).

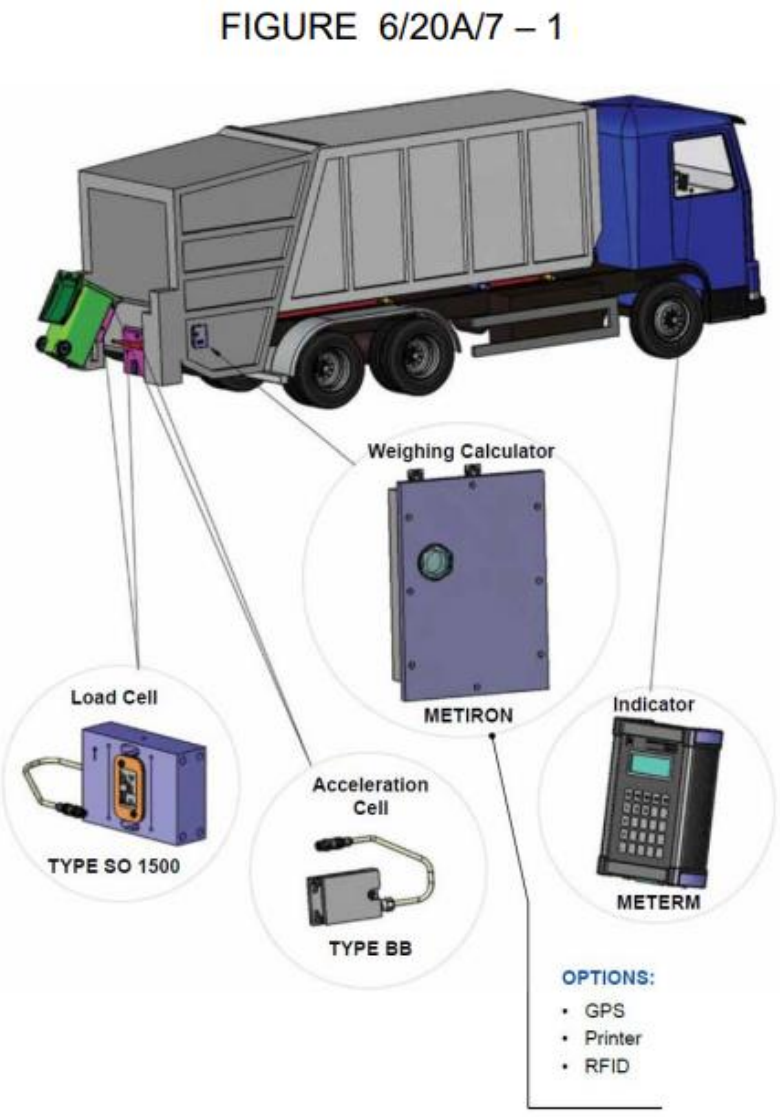

Figure 9. Observational image of Accuonboard Model Binweigh LFT RL Wheeled Loader Weighing Instrument (National Measurement Institute of Australia, certificate of approval NMI 6/20A/7).

Another example, Accuonboard BinWeigh, contains load cell, acceleration cell, weighing calculator and indicator (Figure 9) and for example RFID reader can be added to bin elevator's lifting combs. (National Measurement Institute 6/20A/7 Rev 2). Botek AB has a product for side- and rear-loading garbage trucks.

Figure 10. Tamtron ANV vehicle beam lifter weighing system (Tamtron Ltd 2019).

For lift-based emptying, the scale systems include a crane or beam that has a sensor set on the top, a PDA device and a program for data transfer to on-board computer (Tamtron 2022) as presented in figure 10.

3.2.2. Smart sensors

Linikko (2018) stated that sensor technology is needed in waste management, especially to avoid emptying only partially filled waste bins and containers. For solid waste monitoring and collection, sensors are used to detect and measure capacity, weight, temperature, air quality, tremor and humidity (Ali et al 2020; Linikko 2018). Chemical sensors are used to

monitor waste (Ali et al 2020). Most common sensor or meter in Finnish waste management is temperature meter installed in home composters, but not containers or bins used in waste collection. Smell is not commonly measured in municipal waste management. Usually, sensors are used to measure liquid levels, but there are sensor types than can be used to measure the level of solid waste in bins. Temperature and ultrasonic sensors and load cells in waste bin are presented in figure 11.

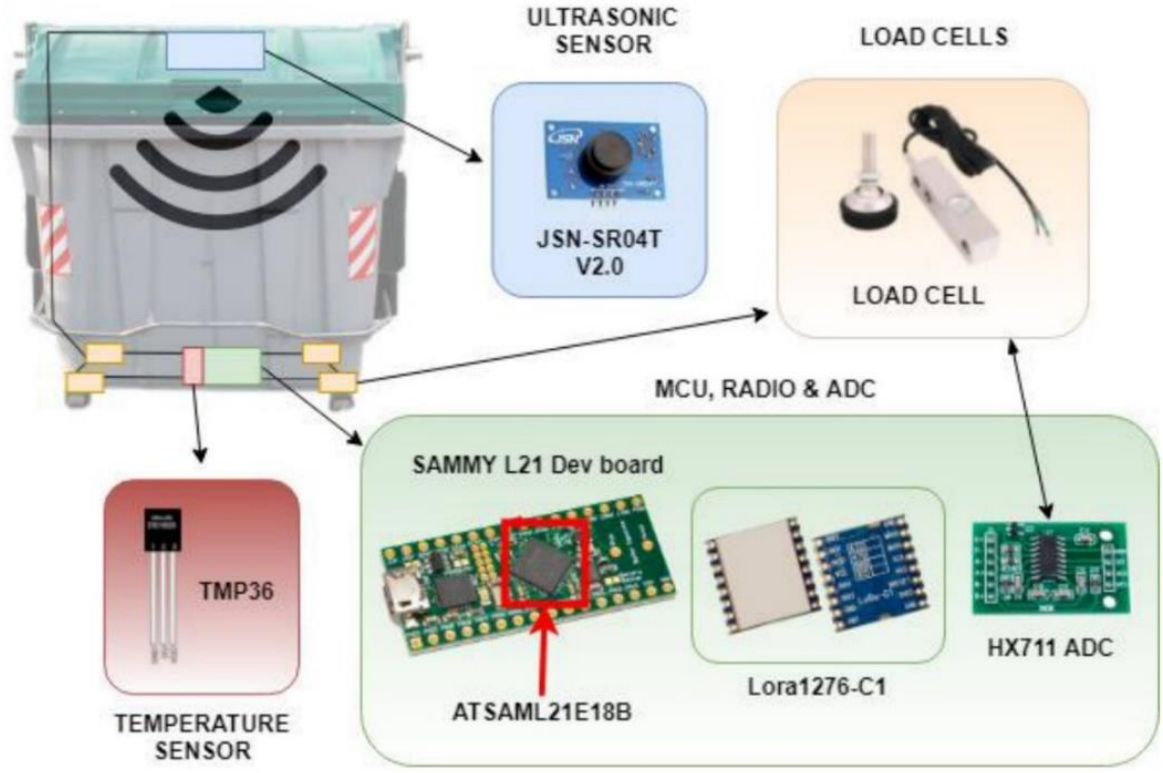

Figure 11. An example of waste measuring system in a waste bin (Lozano et al 2018, Figure 4).

Measuring contents of waste bins with smart sensors is utilized in resource and route planning in waste collection (Ramson et al 2020). Smart sensors are connected to IoT-platforms, which enables real-time monitoring of waste levels and optimizing waste collection routes (Figure 12).

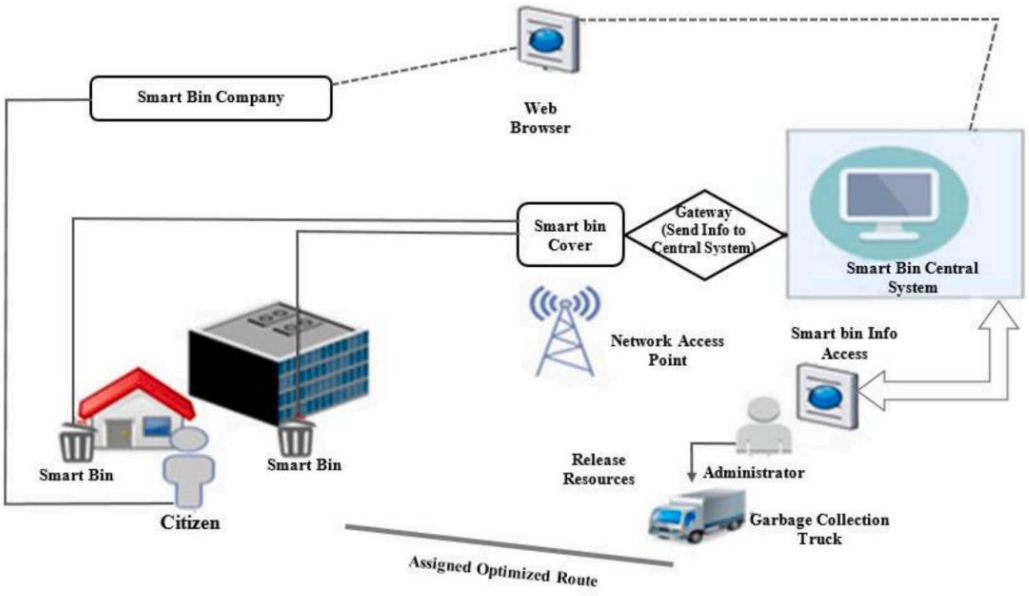

Figure 12. Example of general architecture of Smart Garbage Bin Mechanism (SGBM). (Abuga et al 2021, Figure 1).

Sensors can either have a physical contact to the substance that's level is being measured or there is no contact. In level sensors for example microwaves or sound waves are transmitted by the antenna of the sensor towards the substance and reflected to the antenna from the surface (Greenovo Enterprise Ltd 2019). The level is calculated by the sensor according to the time between transmission and reception of the waves. (Flo-Corp Ltd 2017).

Radar sensors use microwaves for detection. Of radar sensors, Guided Wave Radar (GWR) level transmitters are accurate measuring both liquids and solids. They are not affected by changes in substance's viscosity, density, or acidity or if the surface is agitated. GWR is suitable for difficult applications, for example sticky fluids. Usage in measuring waste levels might work better for industry than to household waste and small waste bins. Pulse sensors are also accurate when measuring both liquids and solids, they are easy to use and they are cost efficient.

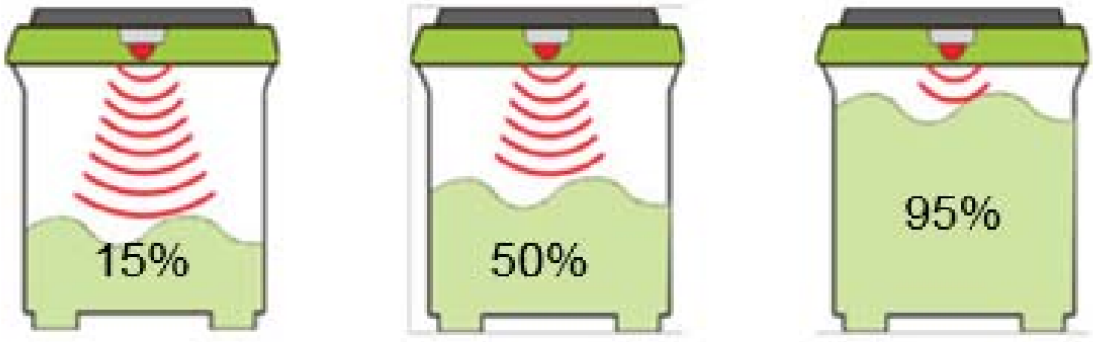

Figure 13. Ultrasonic fill level sensor (Omar et al 2016, Figure 9).

Usual waste bin sensors used are ultrasonic. They are non-invasive and usually integrated on the lid. Sensor transmits sound waves which are reflected back – the fill level is calculated from the time it takes sound waves to get back to the sensor (Figure 13). There are vast variety of different commercially available ultrasonic sensors, that can be used in waste level monitoring. Some manufacturers are specialized in offering smart waste management packages for different operations, including municipal waste management. These packages include sensors and IoT-solution for waste monitoring and route planning. One commercial waste solution package based on IoT-sensors (ultrasonic sonar technology) is marketed by Enevo Ltd (Enevo 2021). Prices of ultrasonic sensors are up from 100 € per unit, and ordering larger quantities lower the unit price (MaxBotix Inc 2021; MarCom).

Kalasatama is a district of Helsinki, where smart waste bins were piloted as a part of programme Fiksun Kalasataman Nopeat kokeilut. Sensors measured the waste level in bins and informed about upcoming emptying. Information was not used in waste management, but the purpose of pilot in Kalasatama was to research the user experience of smart bins and if collected data could be used to increase resident comfort of the area. (Forum Virium Helsinki 2022).

3.3. PAYT-Schemes

Waste collection can be organized with a public waste collection point or driving the garbage truck to the residential estates to empty the waste containers. There is also recognized collection practice, in which residents bring their personal waste containers to a pre-scheduled route of garbage trucks. First are usually called bring-points, and other two are referred as door-to-door collection and street collection. In this research, street collection term is used to refer pre-scheduled route collection.

Bring-point collection is public waste collection point, where citizens can bring and drop their waste bags. These collection points are located near highways or other places where the heavy garbage trucks can be driven effortlessly and as cost-efficiently as possible. These locations need to be along natural routes of residents to have people dropping their waste bags constantly instead of littering. Civic amenity sites (CAS), or waste stations, are also referred as bring-point collection.

Door-to-door collection means that the waste collector drives to the estate and empties the waste container placed on open place. When using street collection, municipal has certain routes garbage trucks drive. Schedules and routes are public and residents bring their waste to open ground.

3.3.1. Volume-based schemes

In volume-based waste management scheme waste fees are charged based on the number and size of waste containers (European Commission 2021, EPA 2016). Charging of waste fees from equitable owner of the waste can be also based on number of bags or cans set out on the kerb (EPA 2016) like public company Contarina has successfully done in the Treviso area in Northern Italy (Zero Waste Europe 2015, Contarina Spa 2019). When using bags, the size of the bag counts when charging fees. If bins or containers are used, the waste charge is based on emptying times of specific-sized container. Volume-based schemes are very similar

to sack-based waste management schemes, but they have different kind of management systems.

In Finland, most of the waste collection is based on volume of the waste container, especially when using manually transferrable waste bins. In practice, volume and frequency are combined. Most common waste bins used in case area are 140-660 litres in volume and the emptying frequency is from days to even 16 weeks depending on waste stream. Waste regulations allow to use in door-to-door collection of household waste any mechanically loaded and manually transferable waste bin up to 660 litres. Clean packaging waste like plastics has longer frequencies and easily contaminating biowaste much shorter. Basis of this model is to proportion the volume of the bin to the emptying interval so bins would be full when emptied.

This PAYT-model is based on calculations, assumptions and observation of the user, not in-time measurements. This model is low-cost, if the bins are full or at least near it at the time of pre-scheduled emptying. In volume-based schemes the waste fee is the same for a bin regardless of the fill level.

The fairness of this model is controversial in small residential building estates if source separation is carried out and the waste generation is low (Morlok et al 2017). This usually leads to emptying only partly filled bins, which is very common in sparsely inhabited areas but also in the small residential areas in the cities. If the costs from transportation are added to the costs of emptying bins, both the economic efficiency and the satisfaction of the owner of the waste will decrease. Waste fee of emptying is usually based on the size and average amount of waste. If bins are emptied with maximum of 50 % of the capacity, environmental impacts of transportation are greater than driving to empty bins that are 90-100 % filled. This dilutes the commitment of the citizens and other users to the waste management system.

Many cities driving for smart city have organized public waste collection using sensor and IoT-technologies. Level sensors are measuring and transmitting the measurement data to

administrative waste management software, and the collection routes can be optimized to empty only full or nearly full bins and containers. As for household waste collection, the level sensors are rare.

On properties with multiple apartments, shared containers are usually full when emptied. In this sense, volume-based scheme is cost-efficient system for the owner of the property. It completely does not meet the definition of PAYT unless waste charges are billed on per-user basis according to the amount of waste generation of single user.

3.3.2. Sack-based schemes

In sack-based schemes waste fees are usually charged based on the number of waste sacks used (European Commission 2021). These sacks are specific to user or to waste fraction and are filled relatively constant in the means of volume and weight (European Commission 2021; Morlok et al 2017). Sack-based systems are very commonly implemented with pre-paid system and are usually separated from volume-based PAYT schemes for that reason (Morlok et al 2017).

Sack-based schemes do not require identification of user or bin, if costs of waste management have been paid before-hand when purchasing the specific sacks. For example, in Catalonia a payment system is based on waste generation with standardized prepaid bags for undifferentiated waste and lightweight packaging (Residuscat 2020). User identification in sack-based schemes can be combined to smart bring-points. The operation is similar to the Finnish return bottle system.

In Seoul, waste management is based on standard waste bags and for chip or RFID based system (Ki-Yeong 2017) and waste bags are collected in tube collection. Tube collection is one implementation of bring-point collection, and waste bags are transferred through underground pipeline to waste collection points where garbage trucks load it and transport to recycling facilities.

In Helsinki, some condominiums have developed a tube collection system for waste. For example, Jätkäsaaren Rööri and IMU Kalasatama are tube collection for mixed solid waste, biowaste, paper and cardboard, owned by limited liability companies (Kalasataman jätteen putkikeräys Ltd 2022; Jätkäsaaren jätteen putkikeräys Ltd 2022). Owners of these companies are the housing companies in the area. Collection points are locked, and the lid is opened with RFID tag. Costs are charged from housing companies, not per user. (Takala 2016).

On the other hand, Nordic countries have sack-based systems combined to volume- and frequency-based waste fee (Fråne et al 2015). In Norway and Sweden, sacks are not pre-paid and are collected in one waste bin at each residual property (Fråne et al 2015; Eskilstuna Energi & Miljö 2021; Eskilstuna Energi & Miljö 2020).

In several municipalities in Norway and one in Sweden, source separated (from 3-6 different) waste fractions are put to same waste container. Waste fractions are source-sorted in specifically coloured plastic bags. Containers are emptied once in every two weeks with single-compartment garbage truck and transported to sorting facility. There the bags are sorted by optical sensor technology into different fractions, which are then either sent to further sorting, recycling, biogas production or to incineration. Unloading needs caution to prevent glass breakage and contamination of waste fractions. Most common fractions to be collected and sorted like this are plastic, metal and paper packaging, newsprint, residual waste and food waste. (Fråne et al 2015).

Figure 14. Specific-coloured plastic bags are put to single waste container and separated optically in sorting facility. Source: Source: Eskilstuna Energi & Miljö (2020).

In Eskilstuna in Sweden, colour-based waste bags are used in waste management (figure 14). Waste fees have both fixed and variable parts. Fixed cost is to cover costs from administration, information, recycling of hazardous and bulky waste from households. Variable fee is determined by costs of container, emptying, transportation, separation and treatment of household waste. Adjusting the emptying frequency and container size has effect on yearly costs of household waste expenses. (Eskilstuna Energi & Miljö 2021, Eskilstuna Energi & Miljö 2020).

3.3.3. Weight-based schemes

> "In weight-based waste management scheme waste fees are charged based on the weight of the waste collected in a given container" (European Commission 2021).

Weight-based waste collection is simple and direct means to reduce waste as recycling has direct results on money spent on waste management. Waste is weighed at site and residents are billed for the collection and management of the waste collected. Weight-based PAYT systems are not common in Europe, but innovations in weighting waste at the site and to

record data are becoming more feasible for some communities. Examples of the innovations are for example bar codes, radio-frequency tags and weighting scales in trucks, but also the improvement in data collection and billing systems. Feasibility supports implementing weight based PAYT systems in practice. (EPA 2016).

Residents may use their own containers or bins, or they must use standard bins, depending on the collection equipment available. The scheme requires emptying vehicles with scaling systems and a connection to on-board computer. It is also required that the on-board computer is connected to waste management and invoicing software. Because of this, the weight-based systems tend to be more expensive than volume-based systems. The system requires greater efforts to maintain: the scales on trucks need calibrating and maintaining to make sure the vibrations directed to trucks during operation will not distort measurements (Morlok et al 2017). (EPA 2016).

In Finland, the weight-based PAYT system is quite common when using deep-collection or some other container that is emptied by lifting (usually a front loader with beam lift) (Salmenperä et al 2019). Weigh-based waste fees and collection is concentrated to business and is not that typical in residential waste management (Turun Sanomat 2019). Individualization of the containers or bins is based on geographic information, and the scales used in vehicles are either automated or mechanical. In cold weather of Finland, the IT-systems had difficulties and weighting process took more time than waste collection using volume-based waste fee. Salmenperä et al (2019) stated that transferring the information is the trickiest challenge in weight-based waste collection in Finland. (Salmenperä et al 2019). Nonetheless, this is already commonly implemented weight based PAYT system in Finland, but if individual users are not identified when bringing waste, the fees are not sincerely PAYT conformable.

On the other hand, Nuutinen (2016) stated that greatest volumes of waste are collected in traditional manually transferrable wheelie-bins. Nuutinen studied functionality of a weighing system of waste bins (140-660 litres) in a development project of Helsinki Region Environmental Services Authority HSY between 2013-2016. Then it was realized that in

Finland there were very little of waste trucks with scale systems for manually transferrable waste bins, and that they are capable of weighing just one bin at a time. They were used in the areas of Ostrobothnia and Kymenlaakso in biowaste collection, and it was recognized to work for that waste fraction but not for mixed waste. For the reasons of efficiency system was required to weigh two small waste bins at the same time, so developing new scale system with new operator was necessary. (Nuutinen 2016).

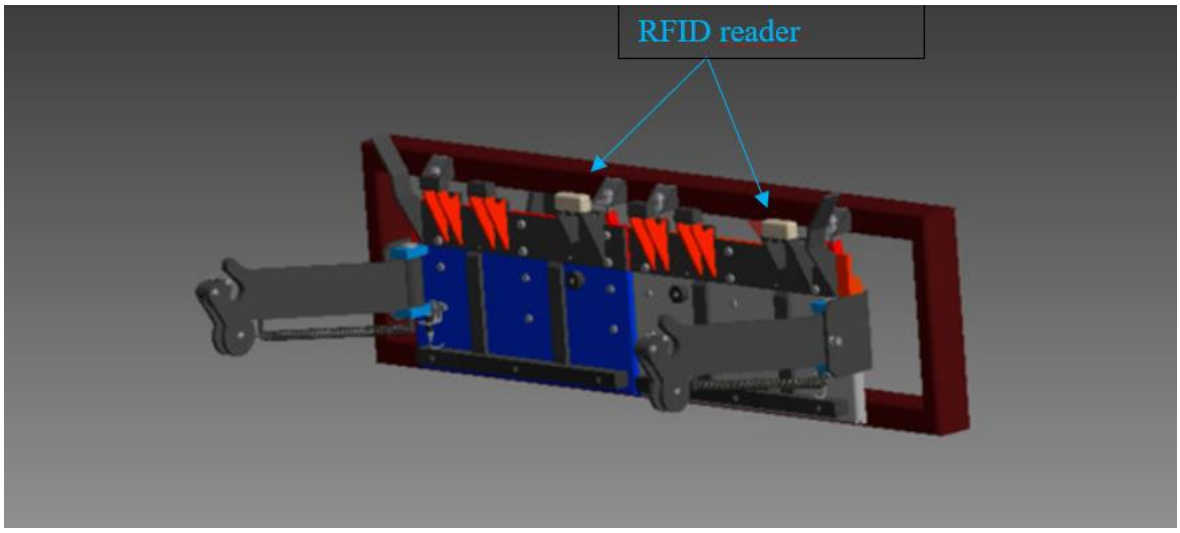

Figure 15. Sample project visualization of RFID reader installation in garbage truck lifter (Elte Group 2022). Highlighting the RFID readers: Author.

Scale system developed in HSY's project (Nuutinen 2016) was constructed from scale electronics and sensor, inclination compensation, bin elevator, RFID reader sensor, PDA (Personal Digital Assistant) device, RFID tag, Greenbox-module and user interface. Electronics are needed to control the operation of scale sensors and inclination compensation is calculates correction factor if the truck is not levelled. Bin lifts with combs and opposite bar are used to safely lock and lift the bin for emptying it to the truck. RFID reader is installed into one of the combs like presented in figure (15). PDA device can read both barcodes and RFID tags. Greenbox module is a computer that combines information gathered both from scale and RFID systems. Information combined by the Greenbox module can be read from File Transfer Protocol (FTP) server via user interface. Scale system was designed for emptying SFS-EN840 standardized waste bins that have reservation for RFID tag placement. (Nuutinen 2016).

Kymenlaakson Jäte Ltd has piloted weight-based PAYT scheme for biowaste collection (Serkkola 2016) in Kotka area (Sironen 18.2.2022). Piloting is still going on, but in the next contract Kymenlaakson Jäte Ltd will no longer continue to use weighing equipment (Sironen 18.2.2022). Waste management software, container identification and weighing system were used during the pilot. RFID readers identified the waste bin and scale system weighed bin automatically and transferred data to on-board computer. The data transfer from the on-board computer to the waste management software took place manually.

3.3.4. Frequency-based schemes

In frequency-based schemes waste fees are charged based on the frequency of waste collection and are more than often combined with volume- and weight-based schemes. (European Commission 2021). Usually, the collection has a certain fee and the PAYT implementation is as simple as it gets: the waste fee is lower or higher depending on the times waste has been collected from the household. This is usually in door-to-door (AKA curb side) collection, and in bring-up point collection fees are more fixed if not combined to weight- or sack-based schemes with identification or waste measuring.

In Sweden, NSR AB (Nordvästra Skånes Renhållnings AB) studied in a 15-month project the potential of implementing waste collection from estates (curb side collection) on the basis of demand. That would mean the equitable owner to call for the emptying when it is needed, and the waste truck will come within one to two days. Waste bins are assumed to have been standard size for every housing property and the waste management costs to form only by emptying frequency. As a result, traffic increased both in time and distance, waste separation increased only a little and the costs of waste collection rise due to required technology investments and increased traffic. Project was not a total failure, as the usage of multi-department waste bins was recognized to be main issue. Most of the collection times only one or two of the four departments were full. It was stated to have potential in developing waste collection on demand, but this system needs further development. (NSR AB 2021).

An example of development of the frequency-based waste collection is ventilated container for biowaste collection (Toivari 2021) developed for pilot project Bioneeri. It is based on the technology and structure of the waste bin. Moisture is evaporated from the container and the emptying frequency can be longer due drier, more hygienic, less weighing biowaste that will not get frozen so easily or give that much bad odours (Toivari 2021, p. 38-41). This makes it possible to consider longer emptying frequencies for biowaste and to reduce costs and environmental impacts of transportation.

4. Savonlinna subregion and waste management

Subregion of Savonlinna is large area fragmented by water bodies. Population is around 37 000, and habitants per land square kilometres varies from 4,5 to 14,60. Average is 12,05 habitants per km^2 of land area. If this is calculated for whole surface area, there are 7,57 habitants/km2. Habitation is centralized in few population centres. Largest one is downtown of Savonlinna. Urbanization rate is 77 % in Savonlinna and 40 % in Rantasalmi and Enonkoski. (Table 1).

Table 1. Population and surface area information of municipalities of Savonlinna, Rantasalmi and Enonkoski. Source: South Regional Council 2021b.

Municipality	**Land-surface area, km2**	**Freshwater-surface area, km2**	**Surface area, km2**	**Habitants/ land km2**	**Population 31.12.2020**	**Urban area rate 31.12.2019**
Enonkoski	305,60	113,70	419,20	4,50	1 369	39,40
Rantasalmi	559,30	365,90	925,20	6,00	3 364	39,00
Savonlinna	2 238,20	1 359,50	3 597,70	14,60	32 662	77,30
Total	**3 103,10**	**1 839,10**	**4 942,10**	**12,05**	**37 395**	

Distances are long and population is concentrated in less than ten population centres (Figure 16). Lots of housing is located in islands and other places without road connection. For households without road connection, door-to-door collection is not possible for waste management at the moment.

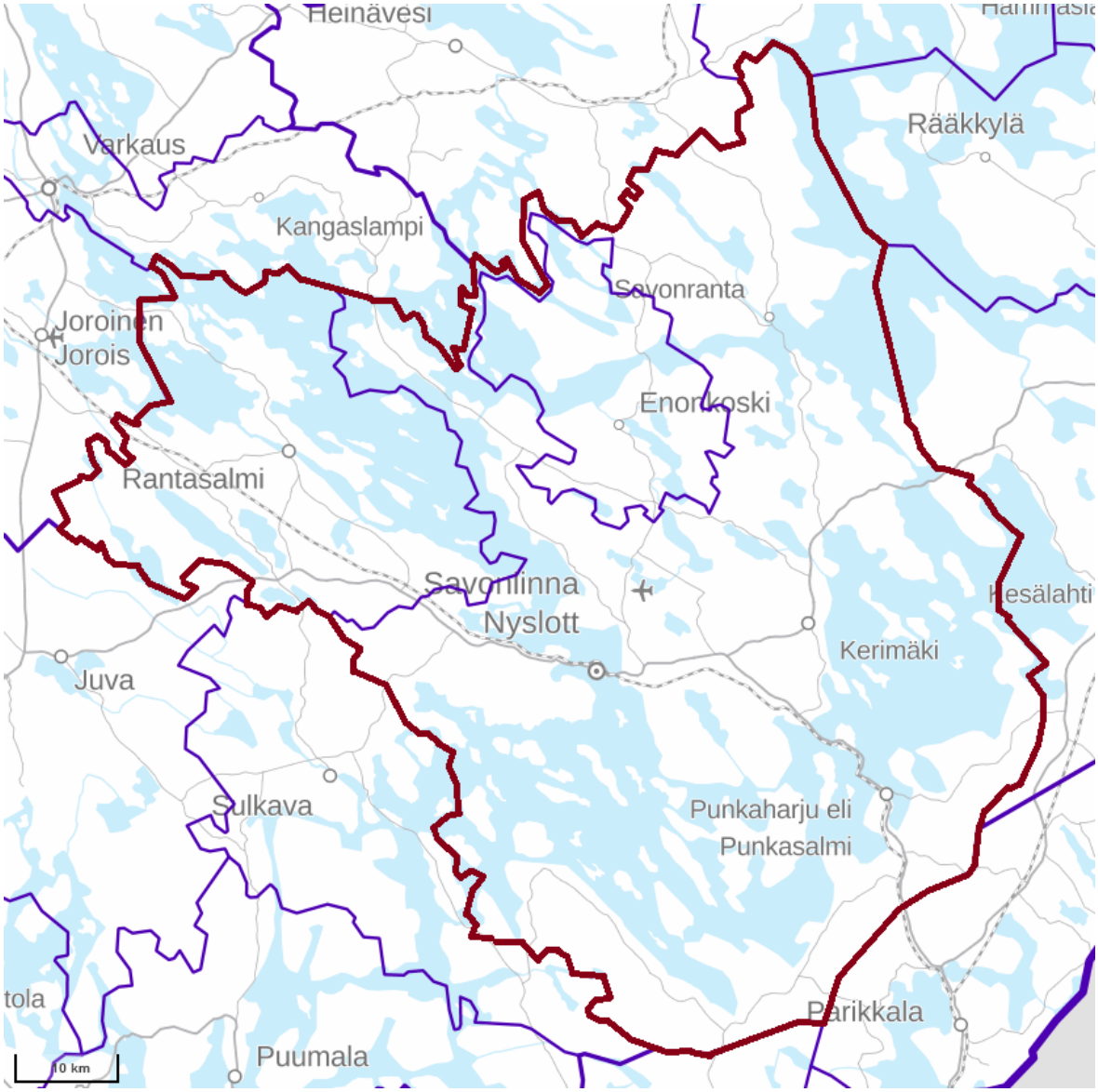

Figure 16. Map of the CASE area. Source: author. Base map: Maanmittauslaitos 2022.

Waste collection of every waste fraction is tendered in markets by the property owner in Savonlinna subregion. Exception is regional collection of household mixed solid waste, which is organized and tendered by municipal waste management company. Waste management costs of municipality are covered by basic waste fee, areal mixed solid waste collection fee and waste reception fees. Altogether, six companies operate in collection and transportation of solid household waste in the area. Every one of them have their own customers and driving control systems. Paper and packaging waste and WEEE are collected in public bring-points by producer communities. From July 2023 onwards, door-to-door

collection in urban areas is tendered by Savonlinnan Seudun Jätehuolto Ltd in the name of Finnish Waste Act.

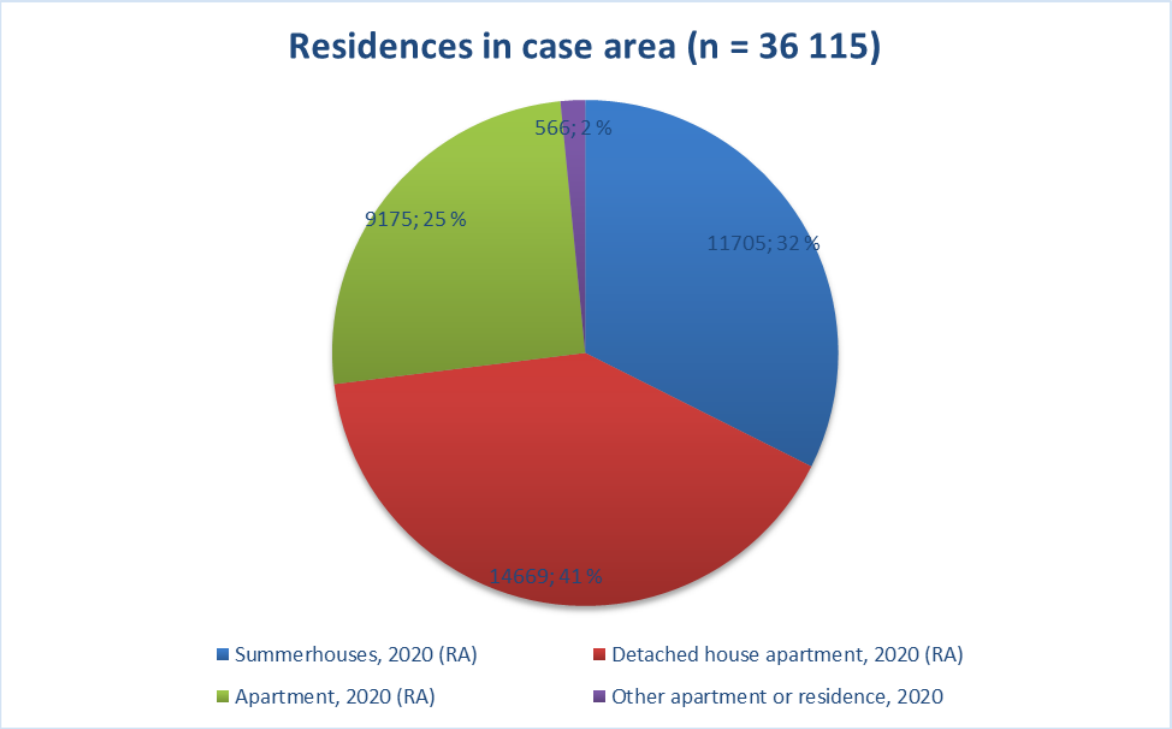

Figure 17. Apartments and summerhouses in municipalities of Savonlinna, Enonkoski and Rantasalmi. Source of information: Tilastokeskus 2022. Figure: Author.

In 2020 there were total 11 683 buildings and 8 765 summerhouses in municipalities Savonlinna, Rantasalmi and Enonkoski (Tilastokeskus 2022). The number and type of residential apartments are shown in the figure 17. The average size of household was 1,8-1,9 habitants (Etelä-Savon maakuntaliitto 2022). Utilization degree of the summerhouses was not available, but the numbers of basic waste fee customers is used to estimate it as every inhabitable building has to be joined to waste collection (Savonlinna waste management office 2022). It is assumed that number of basic fee customers and residential buildings and apartments do not match because inhabitable residences and buildings are not separated from statistics and some residences located at the same premises owned by one person are charged as one. Number of inhabitable residences is not available.

Estimated 32 000 residences and residential buildings were charged with basic fee in 2020-2021 (Savonlinna waste management office 2022a-b). Basic fee has three payment categories: residential house (detached and semi-detached houses), summerhouse (including unoccupied houses) and apartments (apartment buildings and terraced houses) (Regional waste management board of Savonlinna 24.11.2020 § 30 attachment A).

Gross Domestic Product (GDP) was 30 609 € per habitant in year 2019 in Savonlinna subregion (Etelä-Savon maakuntaliitto 2022). GDP is not available for single municipality. Between municipalities, median income varies from 18 100 to 19 800 euros per year per person. For households, the median income varies from 28 257 to 30 127 euros per year. (Etelä-Savon maakuntaliitto 2022). Savonlinnan Seudun Jätehuolto Ltd.'s expenses were 2,6 million euros (€) in 2021. As the company manages waste in four municipalities with total 39 877 inhabitants, the average cost per inhabitant in year 2021 was 64,33 euros.

This is average by calculations, and the cost may differ between municipalities of Enonkoski, Rantasalmi, Savonlinna and Sulkava. Some of the total costs are from market-based waste management, but that is small share of company's operations. From the total costs of Savonlinnan Seudun Jätehuolto Ltd, the share of area of Savonlinna waste management office for basic waste fee and areal solid waste collection fees were 800 000 euros in 2021. Regional waste collection was estimated to have costs over 270 000 euros. Costs for municipality of Sulkava are not known in Savonlinna waste management office. Most of the waste management costs are from waste treatment. Collection fees are not included because they are determined in markets by private waste collectors, so the total cost of waste management is higher than what municipality charges.

4.1. Waste generation

Total 17 568 tonnes of municipal solid waste were collected in 2021. Construction waste and soil waste taken out, total 12 400 tons of municipal waste were generated. These numbers do not include industrial or commercial waste because Finnish Waste Act has

amended them to be outside of municipal waste management. Information about paper collected in subregion of Savonlinna was scattered, so Finnish average 34,7 kg/ habitant (Helander 2022) is used.

Using the number of habitants in municipalities of Savonlinna, Rantasalmi and Enonkoski on 31st of December 2020 and assuming the number of habitants to stay for year 2021, waste generated per habitant during year 2021 can be calculated:

$$\frac{waste\ annual}{inhabitants} = \frac{17\ 568\ tonnes + 1297{,}6\ tonnes\ of\ paper}{37\ 395\ habitants} = \frac{18865{,}6065\ tonnes}{37\ 395\ habitants} = 504{,}5\ kg$$

In 2021, municipal solid waste generated in municipalities of Savonlinna, Rantasalmi and Enonkoski was 504,5 kg/inhabitant. The average in Finland was 596 kg/inhabitant in year 2020 (Tilastokeskus 2021). Summer habitants are not included to habitant number, so waste generation per habitant does not show the whole picture.

4.2. Collection equipment and technology

Based on interviews with transport companies (Rasola 28.4.2022; Hirvonen 29.4.2022; Muhonen 4.5.2022; Makkonen 4.5.2022) and information received from the Waste management office of Savonlinna region (22.4.2022), in the area a total of 18 packaging trucks transport municipal solid waste. Few of them have a crane or beam for emptying lift-based waste containers. Trucks with interchangeable container loading is estimated to be 20-30. Estimation is based on information gathered from interviews and waste management office of Savonlinna region. The transport equipment generally meets the EURO6 requirements, but the EURO4 equipment is also used. The distribution network for alternative fuels is weak in Savonlinna, so the transport equipment is fuelled by diesel.

These vehicles drive all municipal solid waste, and there is no certainty as to how many of them would be needed to drive waste just from households and municipal administration and service activities. Information on how many of the vehicles are multi-chambered was not comprehensive.

4.3. Separate collection

In Finland, the separate collection is going to be increased by renewed Waste Act and decree on Waste in 2021, and in urban area every residential estate with 5 or more apartments will have to collect separately in door-to-door collection mixed solid waste, biowaste, cardboard, glass, plastic, paper and metals. In rural areas separate collection of mixed solid waste and biowaste is compulsory. Source separation of paper and packaging waste is compulsory, but collection is organized through bring-points Rinki Ltd has strategically located in the name of waste legislation. Separate collection regulations of Savonlinna subregion are presented in table 2.

Table 2. Separate collection regulations of Savonlinna subregion. (Data: Municipal waste management regulations, 2021; table in English: author 2022).

Waste fraction	**Minimum number of residences in property, for which collection is obligatory**
Biowaste	1
mixed solid waste	1
Cardboard packaging	10
*Cardboard packaging	5
Paper	10
*Paper	5
*Glass packaging	10
**Glass packaging	5
*Metal, small	10
**Metal, small	5
*Plastic packaging	10
**Plastic packaging	5
*Collection is mandatory from 1.1.2022 in population centres with density of 200 residents per km^2. Separate collection is not obliged if it is not economically or environmentally practical (for instance long transportation distance to collection point). ** Collection is mandatory from 1.1.2023 in population centres with density of 200 residents per km^2. Separate collection is not obliged if it is not economically or environmentally practical (for instance long transportation distance to collection point). Separate collection of biowaste is not obliged households that home compost their biowaste.	

The separate door-to-door collection of biowaste can be replaced by composting the biowaste. As Savonlinna subregion is very scarce because of large water bodies, costs and environmental impacts of transportation are expected to be high in smaller population centres like Enonkoski or Savonranta. Outside urban areas population density is very loose and because of that especially in rural areas but also in small population centres municipalities should encourage home composting and invest on monitoring it as required by Finnish waste legislation.

Separately was collected biowaste, packaging waste, paper, garden waste, wood, metal (other than packaging), glass (other than packaging) and hazardous waste, total 6 300 tons in 2021 in Savonlinna subregion (Savonlinnan Seudun Jätehuolto Ltd 2021, Helander 2022, Rinki Ltd 2022). Separate collection rate is calculated using waste numbers that do not include construction and soil waste:

$$\frac{6\ 295{,}66}{12\ 362{,}54} = 0{,}50925\ldots = 50{,}9\ \%$$

From the calculation, separate collection rate in Savonlinna subregion is 50,9 %. Share of mixed solid waste was 7 400 tons (39,0 %).

4.4. Composition of mixed solid waste

Latest research of the composition in typical mixed solid waste bin in Savonlinna region is from year 2007 (Karvonen 2007), and the results showed composition to be 9 % biowaste, 5 % paper, 7 % cardboard, 12 % incinerable plastic, 9 % of energy waste, 2 % glass, 4 % metal, 2 % wood, 1 % garden waste, 2% WEEE, 1 % hazardous waste, 4 % diapers and sanitary towels and 5 % textiles. 3 % were sizable waste (Figure 18). Total 35 % of the composition was stated to be landfill waste, and that still contained approximately 50 % biowaste. Karvonen estimated that 20-26 % of mixed solid waste is biowaste, regardless the demand to source-separate biowaste.

Figure 18. Composition of typical MSW in Savonlinna region in 2007. (Resource: Karvonen 2007, figure 1).

Composition research from 2007 might not be accurate today, but if composition of MSW has not changed much, over 80 % from 7 364,49 tons of mixed solid waste collected in year 2021 could have been recycled. Residual waste is collected to Nousiala waste station, from where it is transported to Riikinvoima Ltd for incineration. The non-incinerable fractions are separated in Riikinvoima plant.

4.5. Management of organic waste

Municipal waste management regulations order the organic waste to be separated and either collected or composted at the residential estate. Municipal waste regulations make it

mandatory to source-separate biowaste. It has to be either collected separately or composted in accordance with the regulations and instructions. If mixed solid waste is not collected door-to-door but instead in bring-point collection, home composting is mandatory.

At the moment, approximately 2 000 households and municipal buildings are collecting biowaste separately. Rest of the housing are assumed to compost biowaste as regulated but it is acknowledged that residual waste contains on average of 30 % biowaste. Contamination level of separately collected biowaste is not available. Municipal waste management company treats garden and wood waste by composting but biowaste is collected to transfer hall. Food-based biowaste is transferred to Bio10 Ltd. Bio10 Ltd has biogas plant that receives both liquid and solid biowaste, and gasify the biowaste in mesophilic digestion process after pre-treatment (Bio10 2022). Process produces fertilizers and energy. In 2023, the company begins to process compressed biogas for transportation (Vänskä 2022).

4.6. Contractual obligations

Municipal waste management office transferred the contracts of biowaste treatment to Savonlinnan Seudun Jätehuolto Ltd 1.1.2015. After that Savonlinnan Seudun Jätehuolto Ltd has made decisions of treatment of biowaste it has received or collected. Waste station of Nousiala is an intermediate landing for separately collected biowaste which is transferred to Biokymppi Ltd. One agreement is incineration of mixed solid waste in Riikinvoima Ltd, which is partly owned by the Savonlinnan Seudun Jätehuolto Ltd.

As a stakeholder and owner of Riikinvoima Ltd, the municipal waste management company has interest in higher volumes of mixed solid waste collected. If the operator of municipal waste management is not willing to enhance the recycling facilities and implement waste hierarchy, increasing recycling rates will be very difficult. There is no overcapacity of incineration facilities in Finland at the moment, unlike in Sweden (Salmenperä 2017), so there are better chances to invest more sustainable waste management practices. If the current trend of planning incineration plants continues, overcapacity of waste incineration

will deteriorate recycling rates (EEA 2013). Salmenperä (2017) stated that condensed collaboration of both public and private operators, policy makers, public officers and citizens is necessary to develop waste management and increase recycling.

Savonlinnan Seudun Jätehuolto Ltd has agreement with Fortum Waste Solutions Ltd about collecting and treatment of hazardous waste. Fortum Ltd organizes bring-point collection away from municipal waste stations and the hazardous waste received by Savonlinnan Seudun Jätehuolto Ltd is transferred to Fortum Ltd for treatment.

4.7. Disposal cost

Disposal costs of waste are included to gate fees, which are charged from waste collectors by municipal waste company. For mixed waste, gate fee is 160,00 euros per ton without taxes. With taxation included, the gate fee for mixed solid waste is 198,40 euros per ton. (Savonlinnan Seudun Jätehuolto Ltd 2022). Same fee for biowaste is 108,00 euros per ton without taxes and 133,92 euros per ton with taxation. These fees include the costs of pre-treatment, treatment and after-care of landfill. The aftercare of the landfill takes decades and incurs costs long after the waste is landfilled. Landfilling of mixed solid waste felled in the case area in 2017 when it was diverted to waste incineration.

Waste management of household waste in Finland is not covered by taxes. By Finnish Waste Act (646/2011) § 78 it is legislated that municipality must collect waste fee that covers its waste management costs. Municipality must manage the waste as non-profit community, and it considers the municipal waste management companies as well. At the minimum, waste fees must cover disposal costs but if municipality organize other waste management services, waste fees must cover them as well. Savonlinna regional waste management board has established basic waste fee and waste treatment fee. This is because door-to-door collection and transportation of municipal waste to municipal waste treatment facility in Nousiala is arranged by the property owner. Collection and transportation fees are determined by private waste collectors. If property owner has not organized waste bin for

door-to-door collection, in municipalities of Savonlinna and Rantasalmi Savonlinnan Seudun Jätehuolto Ltd has areal mixed solid waste collection points. For collection point users, there is own waste fee established by municipality. Amending the waste fees can be done by collaboration of waste management office and municipal waste management company in the frame of waste legislation of Finland and European Union.

4.8. Repair and reuse

One reuse centre is located in Savonlinna. Hyvä Kiertää Ltd receives reusable and repairable furniture and commodities like sports equipment, clothes and home electronics. It has a store for second-hand products. Company receives electrical waste and non-usable electronic equipment and forwards it for recycling. Few antiquarians and restoration business are also operating in the area. Services of home appliance maintenance are available from at least 10 companies. There are 10-15 flea markets and antique stores in Savonlinna, Rantasalmi and Enonkoski (kirppikset.info 2022; Kodinhelmen Minikirppis 2022; Kirpputori Rantasalmi 2022) where people can sell intact but products that are unnecessary to themselves.

4.9. Waste management strategies (Political factors)

National Waste Plan to 2027 has been approved by Finnish council of state on 24th March 2022. According to Savonlinna waste management office, three Centres for Economic Development, Transport and the Environment of Eastern Finland has started a collaboration to formulate a waste management plan for Eastern Finland. Municipalities of Enonkoski, Rantasalmi and Savonlinna have not created a political programme for waste management, but they have representatives in Eastern Finland waste plan collaboration. The renewed waste legislation is so defined, that the political programme is required for operation are.

5. SWOT and TOWS analysis

Using SWOT-analysis, the strengths, weaknesses, opportunities and threats for developing waste collection system and PAYT are identified (Figure 19). First, SWOT analysis is made of the current operating environment in CASE-region.

Strengths	**Weaknesses**
• Business friendly cities • Collaboration of municipalities • Municipality's experience on bring-point collection of waste and waste treatment • Private companies experience on waste collection and logistics	• Commitment to incineration • Lack of waste strategy • Fragmented waste management • Waste management resources
Opportunities	**Threats**
• Research and Development of waste management in Finland	• Changing waste legislation, • Spalled land space area (distances) • Migration and Tourism

Figure 19. SWOT analysis on current waste management in CASE-region.

Municipalities of Savonlinna region are business friendly and collaborate in many sectors like waste management and procurement. Municipalities have experience on bring-point collection of waste and waste treatment. Multiple private waste transport companies operate in the area, and they have experience on waste collection and logistics. Some private companies operating in waste collection have also experience on waste treatment, for example Punkaharjun Kuljetus Muhonen Ltd has private treatment plant that operates as a terminal for packaging waste.

Commitment to waste incineration and lack of waste strategy are weaknesses, just like fragmented waste management and resources of municipality regarding waste management. If the municipalities commit to incineration, it can compromise achievement of higher

recycling rates if quantities of mixed solid waste start to reduce. Agreements to deliver certain amount of waste to incineration can lead to contradiction situation between recycling and incineration without proper strategy to cope with different futures. As the municipal waste management sector has many operators (producers, municipality and the private waste collection companies in the waste collection system of property owners), management of the whole sector is not comprehensive or efficient.

Opportunities current situation makes possible to develop waste management nearly to any direction wanted. Threats are related to changing waste legislation, long distances in the region, migration and tourism and economic of the region. Waste legislation has renewed but it has caused uncertain situation in the region regarding organizing waste collection: door-to-door collection of biowaste and packaging waste are going to be tendered by municipality and bring-point collection by producer community, while responsibility to organize collection of MSW and sludge is left to property owners. Waste legislation has many reformations on-going and compromises made create need for new reformations, which deteriorates possibilities to efficient implementations of waste management practices.

Economic situation as well as migration and tourism have great impact on waste management solutions. Decreasing population has straight effect on permanent waste management services in the area, if the costs of waste management are kept as low or reasonable as possible. For this reason, the quantity and density of population are very important factors in municipal waste management. Tourism creates a possibility of littering if the waste collection and management system is not easily accessible and pricing reasonable. The range of users is wide in the case area, from permanent residents to tourists, and that is why engagement of users is important whatever the practices are in waste management.

5.1. Volume- and frequency-based scheme

Door-to-door collection of waste in Savonlinna subregion is based on volume of the waste bin and emptying frequency. This has pros and cons, as stated in chapter 3.5 (Volume-based schemes). Strengths, weaknesses, opportunities and threats of this PAYT scheme in current situation of Savonlinna region are identified by applied SWOT-analysis (Figure 20). TOWS analysis in generated from SWOT analysis to create strategies to enhance this PAYT scheme in case region (Figure 21).

Strengths	**Weaknesses**
• Low management cost • Based on spatial data or bin identification • Versatile • Applicable in door-to-door collection	• Emptying frequencies restricted in regulations • Underfilled waste bins • Unnecessary traffic • Low separate collection and recycling rates
Opportunities	**Threats**
• R&D of collection equipment and practices • Introducing smart sensors	• Free riders • Littering • Remote locations, road network

Figure 20. Applied SWOT analysis of the applicability of a volume- and frequency-based scheme in the case area.

Low management costs, applicability in door-to-door collection and versatility are seen as strength, and related to low costs, scheme can be based on both spatial data or bin identification. Management of combined volume and frequency-based waste collection system does not require specific technology in the case region, because collection is based on spatial data. Volumes of waste bins and the recorded data of the emptying frequency are registered to waste management software according to spatial data. This system could be based also on per bin identification. With more flexibility of emptying intervals in municipal regulations the system can be enhanced to meet the producer pay principle. Level and other smart sensors could also be introduced, and that way frequencies could be more flexible.

System also has potential to inventions of new equipment, like containers and bins, and practices. Good example of this is Bioneeri project in Lahti. Development of waste bins and containers and garbage trucks and their equipment can enhance the strengths and give solutions to overcome weaknesses.

Weaknesses of volume- and frequency-based scheme are unnecessary traffic (in both tendering models of waste collection), underfilled waste bins and restrictions in emptying frequencies. These usually lead to low separate collection rate and low recycling rate. When collection is routed based on emptying intervals in the case area, there are bins that are not full. In the case area source separation of waste has effect to bin levels of mixed solid waste especially in detached houses. This causes unnecessary traffic especially on the countryside. On the other hand, in those buildings where generation of waste is higher, source-separation usually leads to longer emptying intervals and changing bins to smaller ones. If the waste generation can be fitted to regulated emptying intervals and bin volumes, this system works well and no large-scale transition is required.

Threats to fully implement volume and frequency based PAYT scheme are identifying and managing free riders and littering. Problems are concentrated especially in remote locations which are outside road network.

	Strengths • Management costs reasonable or low • Based on spatial data • Versatility • Applicable in door-to-door-collection • Applicable in bring-points • Based on spatial data, bin or user identification	**Weaknesses** • Emptying frequencies restricted in regulations • Underfilled waste bins • Fragmented waste collection – Unnecessary traffic • PAYT is only partially realized without sensor technology
Opportunities • R&D of collection equipment • Utilization of sensor technology • Knowledge of waste management in companies	➢ Utilizing sensor technology and waste management software in route planning	➢ Volume sensors in waste level monitoring to optimize route planning ➢ Mapping the effects of extending emptying intervals
Threats • Free riders • Littering • Remote location, road network • Low separate collection and recycling rates • Lack of collaboration	➢ Investment in monitoring systems ➢ Incentive for citizens to source separate and recycle	➢ Developing a coherent approach for usage of sensors in waste collection

Figure 21. Strategies to implement volume- and frequency-based scheme in case region.

Strategies of implement PAYT with volume- and frequency-based scheme (Figure 21) are investing to monitoring and utilizing sensor technology and waste management software in route planning. Monitoring can be done with comprehensive register and data collection, using IT-technology and different measuring technologies. Data gathering can be manual or automatic, and both have pros and cons.

Developing a coherent approach to utilize sensors in waste collection will reduce costs of waste collection. Manual data gathering has always the human factor and higher risks for

mistakes. Automatic data gathering and registering is smooth and uniform, but it requires economical investments on equipment and software. For example, registering information on as emptying event: driver can enter the data manually to on-board computer or registration can be done automatically. Cameras and sensors can gather the data and transfer it automatically to computer and update the waste management software real-time.

Mapping the effects of extending mandatory emptying intervals and making few changes in regulations, users can be engaged to the system. New innovations and piloting could be taken into consideration regarding waste containers and practices of waste collection and management, allowing the development. Current regulations are made to fit for the practice of waste collection being organized by property owner. This kind of responsibility transfer in waste collection practice requires rather strict regulations. Changing the responsibility to municipality enables holistic waste management and development of practices. Engagement of users will have positive impact on source separation of household waste and recycling rates.

5.2. Sack-based schemes

Currently extra sacks beside waste bin are charged as extra and for certain price per sack in Savonlinna subregion. This might not be unquestionably an implementation of sack-based PAYT-system, but with rough generalisation it can be seen one. Not every waste fraction is collectible in sacks, but strengths, weaknesses, possibilities and threats of implementing sack-based system fully or partly in current system of case area are identified with SWOT analysis (figure 22).

Sacks are considered to be an occupational safety risk, since there is no guarantee how heavy the sacks are and the ergonomic carrying and loading the sacks to waste truck has been seen avoidable. Sharp objects, if put unsecured in sack, may pierce the sack and cause wounds for the driver. If not managed properly, bins or other containers are necessary to avoid possible health risks because containers can be loaded mechanically to garbage trucks. But

if targets of achieving circular economy are a priority and efforts to achieve it are achievable, quantity of mixed solid waste must reduce. If municipalities collect mixed solid waste less and less, collection systems for this waste fraction needs to be reconsidered. Sack-based systems can be a solution for non-recyclable waste fractions, if municipality organizes the collection.

Strengths	**Weaknesses**
• Fits with current regulations • Fair variable part of waste fee • Applicable in door-to-door collection • Applicable in bring-point collection • Based on user identification	• Willingness to develop and invest in identification systems • Renovation of regional collection points • Investments on readers and coded pre-paid sacks • Municipality tender door-to-door collection of packaging waste and producer
Opportunities	**Threats**
• R&D of collection equipment • Increase in source separation and recycling	• User attitudes • Free riders • Littering • High share of fixed part of waste fee

Figure 22. Applied SWOT analysis of the applicability of a sack-based scheme in the case area.

Strengths of sack-based scheme are fairness of the variable part of waste fee and applicability for both door-to-door and bring-point collection as presented in figure 22. If waste fees are charged based on the number of waste sacks brought to collection and treatment, everyone would pay just for the waste one has generated. This could lead to littering, if the sack-system is not properly managed. Officials and municipality would have great responsibility to ensure every citizen is participating and engaging to the system. Many questions are related on the collaboration of municipality and producers, which are both responsible of managing packaging waste. This can be seen either as a weakness or as a threat to implementing sack-based PAYT.

User based identification is seen as strength as it supports the pay-as-you-throw method at its best. It can also be implemented without changes in waste regulations. Weaknesses of sack-based scheme (Figure 22) are investments (identification systems and pre-paid or coloured sacks) and renovation need of collection points. Sack-based system needs investing either to collection or treatment. Collection can be organized using reversed vending machines or manned bring-points. Reversed vending machines need identification systems for identifying the user for the invoicing or identification system to identify pre-paid sacks. There should be enough vending machines, and each machine requires capacity to store waste between collection time. Suction pressure could be used to transfer sacks to collection point. This kind of pipe systems are usually built to new areas, so it would be noteworthy option in city planning. If the sack-system would be based on manned or automated bring-points, costs would comprehend facility and staffing or automation. Automation can be done with identification and proper mobile app that connects to invoicing systems.

If specific-coloured waste sacks are used and put to same bin, collection can be done with one-departmental garbage truck. Most probably this solution would be possible only for mixed solid waste and biowaste, because Savonlinna Waste Management Ltd has agreed to join to general agreement between municipalities and the Finnish producers' community. Emptying intervals would also be determined by biowaste, which is most easily festering waste fraction. Waste would then be transported to certain facility, where waste fractions are sorted using optical sensor or other applicable technology. New facilities and machineries require investments of hundreds of thousands to millions of euros.

Opportunities of this scheme are estimated increase in source separation and recycling and the development of collection equipment (containers, bins, loading equipment and vehicles). Barcode, QR-code, RFID-tags can be used to identify either sacks or users to open waste containers and invoicing can be arranged pre-paid or utilizing user identification to bill fees later.

User attitudes, littering and free riders are a threat of full implementation. Fixed part of waste fee might rise too high compared to variable fee because of the investments on permanent

facilities and upkeeping the waste management system. If fixed costs are high and the variable fee very low, users might think that gained benefits are not rewarding enough. That could have negative impact to source-separation and recycling. (Figure 22).

	Strengths • Fits with current regulations • Fair variable part of waste fee • Regional MSW collection organized by municipality • Based on user identification	**Weaknesses** • Willingness to develop and invest in identification systems • Renovation of collection points • Investments on readers and coded pre-paid sacks • Municipality tender door-to-door collection of packaging waste and producer community pays part of the costs
Opportunities • Increase in source separation and recycling • User-specific monitoring of waste generation	➢ Implementing sack based PAYT model for regional MSW collection	➢ Savings in waste treatment and income from increased source separation and recycling of materials ➢ User or sack identification in containers used in regional waste collection ➢ Enhanced monitoring of recycling
Threats • User attitudes • Number of users • Free riders • Littering • High share of fixed part of waste fee	➢ Identification through purchase system ➢ Strengthening the monitoring of waste management	➢ Reasonable budget for developing collection system (€ per user) ➢ Preventing littering and free riding in waste management ➢ Keeping the current producer-responsibility system and implementing sack-based system for MSW

Figure 23. Strategies to implement sack-based scheme in case region.

A realistic strategy to implement sack-based system in case area would be focusing on mixed solid waste and keep current producer-responsibility system for packaging waste (Figure 23). High share of fixed fee could have incremental effect on source-separation and recycling rate, if producers are organizing or paying large share of the collection and waste management of packaging waste. As the municipality is already organizing regional collection of mixed solid waste, it is easy to pilot and test the results beforehand. For door-to-door collection, implementing and piloting sack-based scheme is not seen as possibility for Savonlinna region if municipality does not tender the collection.

5.3. Weight-based schemes

Waste fee is weight-based when using deep-collection or some other container that is emptied by lifting (usually a front loader with beam lift) (Salmenperä et al 2019). So is in Savonlinna, but these containers are not that common. They are used in large apartment buildings, holiday villages and to collect waste from residential areas, but most of the waste containers are wheelie-bins. For them to be used, it would require investments on weighing scale systems on waste trucks, and weighing increases the time put on emptying unless the weighing is automated and results are transferred to computers without manual labour. It is also possible that bins need to meet the requirements of newest standards so automatic reading and measuring is possible.

Strengths	**Weaknesses**
• Fair variable part of waste fee • Household specific information on waste generation • Applicable in door-to-door collection • Based on spatial data, bin or user identification • Technology is on the markets	• High investment costs on on-board scaling systems and identification systems
Opportunities	**Threats**
• Automation of data gathering • Increase in source separation and recycling	• No incentives to invest weighing scales for waste bins • Fragmented waste collection system • Cheapest solution is prioritized

Figure 24. Applied SWOT analysis of the applicability of a weight-based scheme in the case area.

Fair variable part of waste fee and applicability in current door-to-door collection are seen as strength (Figure 24). Weight-based scheme can be based on both spatial data, bin or user identification, and household specific information on waste generation is gathered by measuring not estimating. Technology for weight-based PAYT is available on the markets. Weakness of weight-based scheme is high investment cost on on-board scaling systems and identification systems (Figure 24).

Opportunities and threats of weight-based scheme are presented in figure 24. Scheme makes it possible to gather required data automatically. The fair part of the waste fee makes the adaptation of the scheme easier and after implementation it can have positive impact on source separation and recycling rates. Development of waste bins and containers and garbage trucks and their equipment can enhance the strengths and give solutions to overcome weaknesses.

Threats to fully implement weight-based PAYT scheme are fragmented waste collection system, lack of incentives to invest on weighing systems in door-to-door collection where standard 140-660 L waste bins are used and when the cheapest solution is most commonly

chosen. Currently waste bins are either purchased by the property owner or rented from private waste collection company, and underground containers are purchased by property owner.

Government or municipalities in Finland have not been able to create an economic incentive to implement weight-based door-to-door collection of household waste. Piloting has not led for permanent weigh-based waste collection in Finland, beside the lift-based waste collection. Seems that reasons are related to cost-efficiency, density of population and initialization of new technologies. Implementing weigh-based PAYT-system in door-to-door collection of household waste requires scaling systems to garbage trucks and development of waste management and invoicing software. Most challenging is to maintain the system's functioning and accuracy in Finnish climate.

	Strengths • Fair variable part of waste fee • Household specific information on waste generation • Applicable in door-to-door collection • Based on spatial data, bin or user identification	**Weaknesses** • High investment costs • Incentives to promote weight-based waste collection • Emptying frequency determines fixed costs of collection • Reliability of scales and sensors
Opportunities • R&D of collection equipment • Automation of data gathering • Increase in source separation and recycling	➢ Investing on on-vehicle scale systems and automatic data recording ➢ Utilizing gathered data on waste management and waste advice.	➢ Creating incentives for weight-based waste collection in collaboration of all operators ➢ Increasing the attractiveness of recycling
Threats • No economic incentives to invest weighing scales for waste bins • Fragmented waste collection system • Cheapest solution is prioritized • Climate	➢ Making a competitive advantage of on-vehicle scaling systems in door-to-door collection of waste	➢ Centralizing waste collection to municipality

Figure 25. Strategies to implement weight-based scheme in case region.

Strategies to implement weight-based PAYT-scheme are to invest scale systems and automatic data recording. Data can be utilized on different operations of waste management, including waste advice and engaging users of the system. Considering current situation, incentives for weight-based collection needs to be created, especially in door-to-door

collection of households. In bring-point collection, identification of individual user is required along weighing brought waste so waste fee can be charged according to PAYT principle. To ensure the engagement of citizens and bring down the cost of investments and maintenance, collection has to be tendered by municipality. This is against the politics of Savonlinna and Enonkoski municipalities, and for that reason weigh-based PAYT-system might not be a good investment. (Figure 25).

5.4. Frequency-based schemes

In current waste management system of Savonlinna region, frequency-based waste collection is supplemented with volume-based waste charging. Maximum intervals of emptying are regulated in municipal waste regulations, which mitigates the possibilities of frequency-based PAYT scheme. Strengths, weaknesses, opportunities and threats of implementing frequency-based scheme in current collection system of case area are identified with applicable SWOT analysis. Currently only sizable waste and other waste not suitable to collect in door-to-door collection are charged by the frequency they are brought to waste station. Depending the quantity of waste, waste fee is charged by either volume or weight. There is no fixed fee. Strengths, weaknesses, opportunities and threats of implementing frequency-based PAYT scheme to door-to-door collection of case area are identified with applied SWOT analysis (Figure 26).

Strengths	**Weaknesses**
• Full waste bins • Fee corresponds to the frequency • Based on spatial data, bin or user identification • Applicable in door-to-door collection • Applicable in street collection • Applicable in bring-point collection	• Unnecessary traffic • Resource requirement to monitoring and routing
Opportunities	**Threats**
• Smart waste management • Waste collection based on need • Street collection in scheduled routes Applicability of sensor technology	• Littering • Low separate collection and recycling rates • Compliance with legal obligations on joining waste collection • R&D of waste management software • Ordering collection in time • Restrictions in emptying frequencies

Figure 26. Applied SWOT analysis of the applicability of a frequency-based scheme in the case area.

Strengths of frequency-based scheme are fair waste collection fee and emptying full waste bins as identified in SWOT analysis (figure 26). With help of sensor technologies and centralized waste management, the fill levels of waste bins and containers can be monitored and collection routes planned to bypass bins that are not estimated to be filled. Scheme can be based on spatial data, bin or user identification and it can be applied to door-to-door, street and bring-point collection. Waste management software and connections between it and smart sensors are main issue in this scheme. Monitoring and routing requires high resources.

To meet the demands of Waste Act, there is no possibility to leave technology out and let the property owners to order emptying when needed. This would lead to chaotic routing and unnecessary traffic. Unnecessary traffic increases transportation costs and environmental impacts. For economic and environmental reasons, frequency-based waste collection can be executable only by municipality.

Frequency-based scheme has high potential in smart waste management, especially combined with sensor technology. It enables need-based waste collection and scheduled street collection. Littering and low rates of separate collection and recycling are possible, as monitoring waste requires software connected to routing software to ensure every household is joined to municipal waste management system. Questionable is if waste collection can be organized as frequency based PAYT when property owners tender the waste collection. It would require condensed collaboration between private waste collectors and municipality.

	Strengths • Full waste bins • Applicability of sensor technology • Fee corresponds to the frequency • Based on spatial data or automatic identification • Applicable in door-to-door collection • Applicable in street collection • Applicable in bring-point collection • Based on spatial data, bin or user identification	**Weaknesses** • *Waste management highly depending on restricting emptying frequencies / Smell and littering* • Unnecessary traffic • Monitoring and routing systems are different between collection practices
Opportunities • Smart waste management • Waste collection based on need • Street collection in scheduled routes	➢ Utilizing smart waste bin level sensors in scheduling collection routes	➢ Reducing unnecessary traffic by using bring-point or street collection
Threats • Littering • Low separate collection and recycling rates • Not much research on • Compliance with legal obligations on joining waste collection • R&D of waste management software • Ordering collection in time	➢ Utilizing level sensors and smart waste management software in scheduling collection routes	➢ Centralized municipal waste collection

Figure 27. Strategies to implement frequency-based scheme in case region.

Frequency-based PAYT scheme are delicate when considering waste monitoring. If this scheme is implemented in Savonlinna region, best strategies (figure 27) are to centralize waste collection to municipality and utilize smart sensors in monitoring fill level of waste bins to optimize collection with emptying needs. Municipality has best prospects to invest

on smart waste management regarding household waste, including the investments on software necessary to successfully implement smart waste management solutions.

6. Suggestions to improve and implement PAYT-schemes in Savonlinna region

In this section, suggestion of enhancing PAYT principles are presented regarding door-to-door collection, bring-point collection, street collection and waste collection in civic amenity sites (Figure 28). Civic amenity site is alias for waste station and other municipal waste management facilities. Suggestions for enhancing the implementation of PAYT principle in household waste collection are based on these practices:

- Maintaining both door-to-door and bring-point collection for mixed solid waste,
- Producers organize bring-point collection and municipal waste management company door-to-door collection of packaging waste,
- Producers organize paper collection.

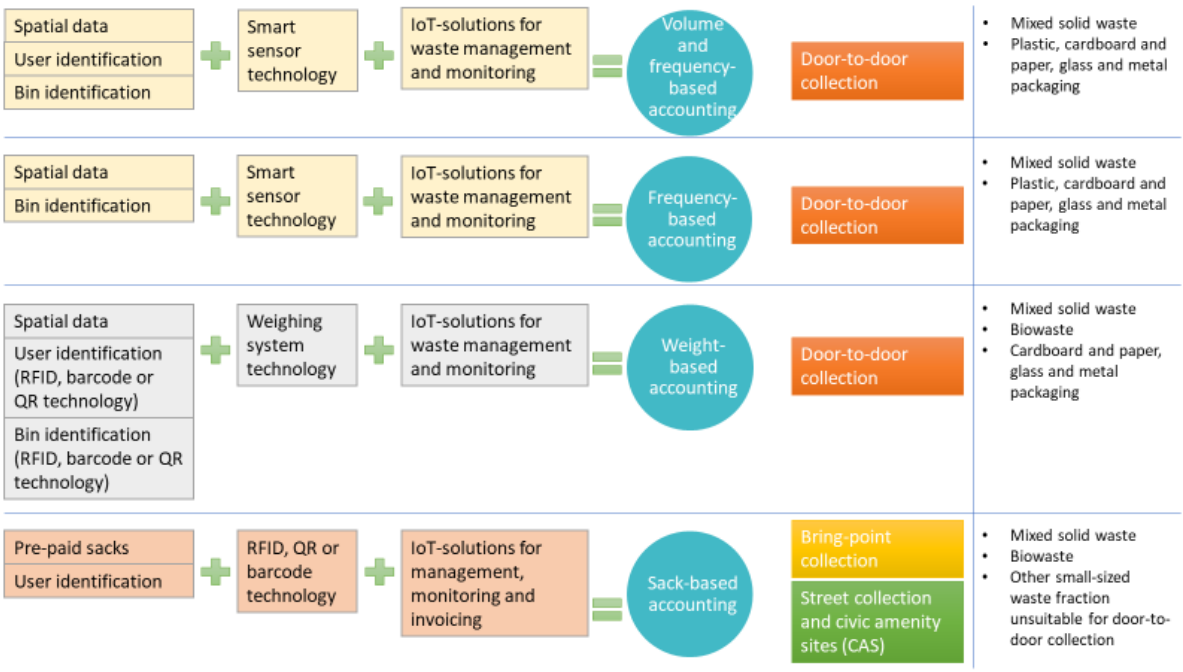

Figure 28. Suggestions for enhancing PAYT-systems in Savonlinna region.

Focus is on household waste which collection and management are the responsibility of the municipality. Most common fractions are mixed solid waste, biowaste and packaging waste. All of these fractions are regulated to be source separated in every household and are collected either door-to-door or in bring-points at the moment. Door-to-door collection is based on spatial data, as every residence is prioritized to have own waste bin for at least mixed solid waste and biowaste. Construction, garden, hazardous and other challenging waste fractions are collected at waste stations (civic amenity sites), and the waste fee is based on either volume (household waste) or weight (companies).

6.1. Door-to-door collection

Volume- and frequency-based, weight-based and frequency-based schemes are implementable in Savonlinna region. Current system is based on volume and frequency, but it has the most common challenge of emptying under-filled bins as waste regulations do not allow emptying frequencies longer than eight weeks without permit of exception. With exception, emptying frequency of 12 or 16 weeks is possible. That does not solve the problem for households that actively source-separate waste and the generation of mixed solid waste is minimal.

Current scheme could be enhanced or changed to just frequency-based scheme by utilizing smart sensors and IoT-based waste monitoring or management software (Figure 29). Sensor in every waste bin is connected to waste administrative system where filling levels are monitored, and routing is done. Implementation is very challenging and arduous if collection and transportation from residential properties stays in the responsibility of property owners. If collection is organized by municipality, benefits can be achieved centralized and cost-efficiently. Sensors could be purchased with cheaper unit prices due to numbers and only one software would be required. Haulers could be using PDAs connected to administrative software. Sensors are costly (approximately 100 €/unit) but prices will come down with technological development.

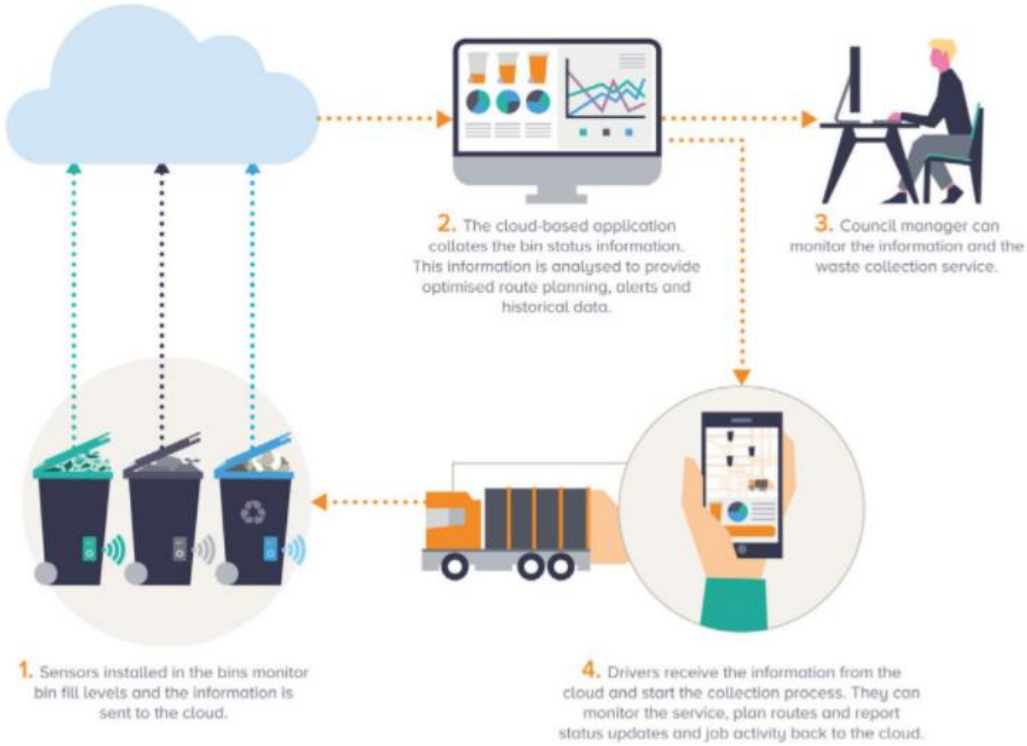

Figure 29. The Internet of Things (IoT) allows the information system with all real time data for best waste management solutions. Resource: Magic Waste Management Solutions 2022.

To implement weight-based scheme in door-to-door collection, investments on scaling systems, load cells and acceleration cells are mandatory. For lifting-based waste collection scaling systems are already in use, but they are still rather uncommon when household waste is collected to wheelie-bins. In Savonlinna region focus should be on waste bins. This scheme could be implemented also in door-to-door collection despite who organizes the collection, if IoT-solutions for waste monitoring and management is in order. In property owner's collection system economic incentives need to be created to make weigh-based waste collection an advantage in markets. In municipal collection system, piloting is possible before deciding the best practices for weight-based scheme in door-to-door collection.

Smart waste management systems that include all aspects (Evreka 2022) are available in global markets, but with development of Finland's most commonly used Vitec Vingo software transferring and registering the level or weighing data should have only reasonable

costs. This will require connections between current system and either level sensors or weighing systems in garbage trucks.

6.2. Bring-point collection

Bring-point collection of mixed solid waste can be enhanced by implementing sack-based waste management. The average amount of waste collected per user or household through bring-points is easy to calculate and with that information municipality could order standardized or colour specific waste bags meant just for bring-point collection of mixed solid waste.

Waste bags would be delivered to households according to the average waste generation. More bags could be purchased from municipality (in example straight from waste management company) if needed. To truly promote PAYT, the unused bags should be compensated to households. RFID could be used to open the containers at bring-points to ensure the prepaid bags are used in bring-point collection of mixed solid waste. With GPS or GSM connection, information on waste brought to the bin could be transferable straight to office administration system. Combined with level sensors, the emptying and routing could be optimized.

Major questions are littering and the renovation of current collection points, which require devices and software for reading. Re-organizing the regional bring-point network and changing the current bins and containers to deep-collection could be done to enhance the network. New containers for deep-collection cost up from 1 300 euros (without taxation) per container. Smallest containers are under 1 m3, but most commonly used are 3 m^3 and bigger. Size affects the price but installing and transportation to site are not included. Including the container, identification and locking systems, sensors and software, costs for one collection point are estimated to be at least 2 500 euros plus transportation and instalment. Costs of identification (RFID tag, QR- or barcode) are related to number of users and are estimated

to be up from 1 €/user. Application costs of possible mobile app are included to per user costs of QR- and barcode.

For this to be implemented successfully, municipality must be able to monitor the fulfilment of waste legislation and also invest on advice, information and education to help habitants to adapt to the new practice. Most important is to pilot the sack-based system first. If successful, sack-based PAYT can be expanded to cover bring-point collection of applicable waste fractions in civic amenity sites.

6.3. Street collection and civic amenity sites

Street collection in Savonlinna region is not common. Only hazardous waste of households is collected in pre-scheduled collection routes. This requires users to take hazardous waste and bring it to the stoppings of collecting vehicle. Costs are covered by fixed basic fee, so users can bring waste without paying anything else. There are restrictions in what kind of hazardous waste is collected.

Construction, garden, hazardous and other challenging waste fractions are collected at waste stations (civic amenity sites). For private customers receiving fee of garden waste and small batches of mixed solid waste are charged by volume. Wood to be chipped, impregnated wood, metals, carton, glass, paper and hazardous waste are received free-of-charge, but the collection and treatment costs are covered by basic waste fee. Other waste fractions are received and charged based on weight. Savonlinnan Seudun Jätehuolto Ltd has a scale for vehicles, but it is not suitable for weighing small batches of waste from private customers.

Developing current street collection of small batches of waste unsuitable to be collected in door-to-door collection in Savonlinna region, either sack- or weight-based scheme are possible. Most important thing in implementing them is to get fixed costs lower. By introducing a variable part of waste fee that is determined by weight or numbers of waste sacks users will pay more fairly for the waste they generate. A portable scale in street

collection and a smaller scale at the waste station enable for a weight-based waste charge. Sack-based scheme could be implemented using colour-specific pre-paid sacks where waste fee is included to purchase price and it would be just easy to drop to waste station.

7. Conclusions

In waste management, reducing and preventing generation of municipal solid waste are steppingstones to circular economy. Waste management is one of the last measures in circular economy, and at that end operators can only do their best with materials they have at hand. Currently, door-to-door collection of municipal waste is organized by the property owner in Savonlinna region, but from July 2023 onwards the door-to-door collection of biowaste and packaging waste will be tendered by municipal waste management company.

The best way to implement the PAYT principles in the Savonlinna region is to make small improvements to the collection methods already in use. This may mean introducing different PAYT schemes in different collection methods, but when done correctly, the whole is the best possible. For door-to-door collection, municipalities of the case area can choose between current combination of volume- and frequency-based scheme, weight-based scheme and frequency-based scheme. If fees of waste collection and transportation are determined by the markets and municipality has no means to align waste fees to be equal between urban and rural areas, weight-based scheme will be too expensive to implement. Monitoring and managing frequency-based system will take a lot of resources if municipality does not tender door-to-door collection as a whole. All options are possible, if the tendering of waste collection of household waste is done by municipality. Municipalities can centralize investments and procurement, which will also lead better monitoring of waste management. Better monitoring will reduce littering and the quantity of free riders.

Sack-based scheme is possible solution to improve bring-point collection and waste collection at civic amenity sites. Sack-based scheme could work well in regional waste collection of mixed solid waste, especially if source-separation increases and the quantity of mixed solid waste reduces. Charging mixed solid waste fees based on number of sacks brought to treatment would create economic incentive for citizens to source-separate, if the producer community organizes the collection of recyclable fractions seemingly free-of-charge. Sack-based system could also be implemented for waste fractions unsuitable for

door-to-door collection, which are collected in civic amenity sites (aka manned waste stations). With possibility to purchase sacks in advance from municipality and just delivering them filled to waste station would make transacting in waste stations more fluent.

Several cases have proven that implementing and enhancing PAYT methods increases separate collection and recycling and reduces the costs of waste management in longer period of time for municipality. There are also dozens of different waste management solutions and combinations for populous and scarcely populated areas. Waste management approach is determined by overall waste management goals, budget constraints and other factors when organizing solid waste management. Before making the decisions about the approach, the municipalities of Enonkoski, Rantasalmi and Savonlinna must determine the goals where they want waste management to be in the future and decide how much they are capable to invest in it.

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