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IMPROVING THE MUNICIPAL SOLID WASTE MANAGEMENT AND RECYCLING SYSTEM IN SOUTH OSTROBOTHNIA BASED ON EUROPEAN WASTE MANAGEMENT SYSTEMS

Examiners: 1st Professor, D.Sc. (Tech) Mika Horttanainen

2nd Development and Environment Manager, MEng Mirva Hautala

ABSTRACT

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Improving the municipal solid waste management and recycling system in South Ostrobothnia based on European waste management systems

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Keywords: waste management system, waste management, recycling, household waste, optical sorting, kerbside collection, co-mingled collection, neighbourhood collection, PAYT

This thesis concentrated on improving the waste management system of Lakeuden Etappi Oy in South Ostrobothnia in Finland. The thesis includes presentations of five different waste management systems in Europe and a suggestion of the best waste management solution for Lakeuden Etappi Oy. Future change in waste management legislation and its requirements to waste management companies, waste treatment, collection, and recycling were discussed in the thesis. The change in waste legislation is aiming to improve the waste hierarchy and clarify the calculation of recycling rates and responsibilities of waste management actors. EU recycling rate targets have tightened and therefore waste management companies need to improve operations and recycling possibilities. The selection of the waste management systems was done using scientific studies and data on countries population densities and recycling rates. The waste management systems selected in the thesis are optical colour-sorting system in Eskilstuna, Sweden, kerbside collection system in Flintshire, Wales, co-mingled collection with mechanical sorting facility in Ljubljana, Slovenia, neighborhood collection in Oulu, Finland and PAYT-system in Aschaffenburg, Germany. Different waste management systems were analyzed with SWOT-analysis and qualitative comparative analysis. The best waste management solution turned out to be optical sorting and PAYT-system.

TIIVISTELMÄ

Lappeenrannan–Lahden teknillinen yliopisto LUT
School of Energy Systems
Ympäristötekniikan koulutusohjelma
Sustainability Science and Solutions

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Yhdyskuntajätteen jätehuolto- ja kierrätysjärjestelmän kehittäminen Etelä-Pohjanmaan alueella perustuen eurooppalaisiin jätehuoltojärjestelmiin

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Keywords: waste management, waste management systems, recycling, household waste, optical sorting, kerbside collection, co-mingled collection, neighbourhood collection, PAYT

Tässä diplomityössä on tarkasteltu Etelä-Pohjanmaan alueella toimivan Lakeuden Etappi Oy:n jätehuoltojärjestelmän kehittämistä. Työssä on tutkittu viittä eri jätehuoltojärjestelmää Euroopassa, joiden pohjalta on koottu parhaiten sopiva jätehuoltojärjestelmä Lakeuden Etappi Oy:lle paikalliset olosuhteet huomioiden. Lisäksi työssä on käsitelty tulevaa jätelain muutosta ja sen edellyttämiä muutoksia jätehuoltoyhtiössä, jätteen käsittelyssä, keräyksessä ja kierrätyksessä. Jätelain muutos tähtää jätehierarkian vahvistamiseen sekä jätehuollon vastuiden ja laskennan selkiyttämiseen. EU:n kierrätystavoitteet ovat tiukentuneet ja siten myös jätehuoltoyhtiöiden on kehitettävä toimintaansa ja parannettava kierrätysmahdollisuuksia. Työssä käsiteltävät jätehuoltojärjestelmät on seulottu käyttäen apuna tieteellistä tutkimusta Euroopassa käytössä olevista jätehuoltojärjestelmistä sekä maiden kierrätysasteita ja väentiheyksiä. Näiden perusteella työhön on valikoitunut Ruotsin Eskilstunasta optinen pussien värilajittelujärjestelmä, Walesin Flintshiresta kadunvarsi-keräysjärjestelmä, Slovenian Ljubljanasta kierrätysjätteiden yhteiskeräysjärjestelmä mekaanisella erottelulaitoksella, Suomen Oulusta korttelikeräysjärjestelmä sekä Saksan Aschaffenburgista PAYT-järjestelmä. Eri järjestelmiä on analysoitu SWOT-työkalua ja kvalitatiivista vertailumenetelmää apuna käyttäen. Parhaimmiksi järjestelmiksi osoittautuivat optinen värilajittelu- ja PAYT-järjestelmä.

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"The journey is more important than the destination," they say. At this point of my journey, I could not say it better. When I first opened the doors of Lappeenranta University of Technology in 2014, I had just finished my matriculation examination. I was going to entrance examinations and had no idea what to do in the next year. Environmental Technology felt interesting because I liked maths and biology. Now, I am writing the last sentences of my master's thesis. The road to this point was at times long and rocky. It took me six years, six incredible years. It included a lot of calculation exercises, lectures, long days and nights with course works, student exchange in Italy, volunteering in different societies, guild, choir, and students' union, dirty overalls with tens of badges and a rainbow collar, happy memories, hundreds of events and a lot of friends, filthy matriculation cap and technology student cap, which I will always put on my head with gratitude and honour.

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In Seinäjoki 22nd of May 2020

Mari Pirtilä

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LIST OF SYMBOLS

1000 kilogram/year	yearly quantity	[tons/a]
euro	currency	[€]
euro/kilogram	price per quantity	[€/kg]
euro/month	monthly fee	[€/mo]
euro/year	yearly fee	[€/a]
kilogram	quantity	[kg]
krona/kilogram	price per quantity	[SEK/kg]
pd	population density	[person/km^2]

Abbreviations

FTI	Förpacknings- och Tidningsinsamligen
EPR	Extended Producer Responsibility
EU	The European Union
ISO	International Organization for Standardization
MRBT	Material Recovery and Biological Treatment plant
PAYT	Pay-As-You-Throw
QCA	Qualitative Comparative Analysis
RCERO	Regijski Center za Ravnanje z Odpadki (regional waste management center)
SWOT	Strengths-Weaknesses-Opportunities-Threats
TOC	Total Organic Carbon
UK	The United Kingdom
WEEE	Waste Electrical and Electronic Equipment

1 INTRODUCTION

Waste management is becoming nowadays more important all the time. Large waste masses are damaging our oceans and soil all over the world every day. It is important to prevent waste production and decrease the harmful effect of waste. When pure materials are getting harder and harder to get, it is more important to recycle and reuse materials. There is a need for better communication and co-operation, better technologies, and waste management education for citizens. Waste management companies are the main actors in the problem. The waste management companies ensure with collection and treatment techniques that most of the waste is collected, treated, and recycled properly and that the environmental effects, pollution, and transportation costs are under control.

New solutions and innovations for the waste problem are developed all the time and current systems are improved. One of the solutions is to focus on waste collection and treatment methods. Better and more efficient technologies, for example, separating methods of household waste and recycling possibilities closer to the customers are key solutions. An interesting aspect is also the responsibility for source-separation at homes and companies. There is a need for more efficient waste recycling possibilities especially for single-family households and dispersed settlement areas.

The problem of dispersed settlement's waste management is especially in Finland, where the distance between households can be kilometres and the population density outside city centre areas is low. Daily and weekly amounts of waste may differ a lot between households and flexibility is demanded from the waste management system and companies to handle large and complex areas equally. Also, the cost-benefit ratio for the treatment of small waste amounts is lower than what it could be for bigger amounts. Organising proper waste management and recycling services to these kinds of areas is problematic when waste management should be economically and environmentally efficient.

In European countries, waste management is based on the waste legislation of the European Union (later EU). It also stands for the base for Finnish waste legislation. The European Union waste legislation is getting tighter all the time. In 2015, the European commission

composed a circular economy package, which aims to move forward to circular economy, including a higher recycling rate of waste (European Commission 2018). Waste directives tightened in 2018. According to new directives, at least 55 % of municipal waste should be recycled in 2025, in 2030 it should be 60 % and 2035 already 65 % (Salmenperä, H. et al. 2019a). Finding new solutions to tightening legislation needs fast and efficient actions in every country to achieve the goals of a country and cooperation in the EU to spread knowledge and good practices. Waste management is done in many ways around the world. Some works better than others, but the same system does not work everywhere because of different population or costs or further treatment possibilities.

1.1 Goals of the study

This thesis is about to find out how five different waste management systems in Europe would fit into the waste management of Lakeuden Etappi Oy (later, the company). Lakeuden Etappi Oy is a local waste management company in South Ostrobothnia, Finland. The main goal is to find solutions, that would fit into the upcoming waste legislation, tightening waste recycling, and separate waste collection targets and improve separate waste collection services in an economic and environmentally efficient way. Especially, the focus is on collection methods of waste. The research paper is done as an environmental engineering master’s thesis.

The research aims to find out the best and the most efficient technologies and an overall system for the company from the example systems in Europe. The company aims to achieve its strategic goals. For this thesis, the significant strategic goals are to offer its customers excellent service experiences and to operate with efficient logistics and waste treatment processes. The best-performed waste management system would be the one, where recycling rate is higher, transportation of waste and it’s pollution is same or lower than in the current system, there are manageable investments, waste management fees to the customer are not increasing significantly, waste management services are close to the customer and available equally for everybody.

The suggested waste management system should also be compatible with the future waste legislation, answer to the tightening recycling and separate collection targets, and the requirements of the area. The goal is also to find out, what kind of waste management innovations and waste management system is used in Europe. The research question of this thesis is, which would be economically and environmentally the best waste management system for Lakeuden Etappi Oy?

1.2 Methods and scope of the study

The waste management systems are filtered with population densities and recycling rates from each European country. This is because we are trying to find a system, that could be suitable for Finnish circumstances and low population density areas with high recycling rate. The systems are analysed using SWOT-model to find out the strengths, weaknesses, opportunities, and threats of the different systems. The systems are also compared using qualitative comparative analysis, QCA. The analysis is done from the viewpoint, that what kind of changes it would bring if the example system is applied to the company.

The main aspect considered in this thesis is not how to decrease the amount of waste but how to make the waste management system more efficient and sustainable. One of the limits for this research is the area and possibilities of the area for waste management. The best would be if the area circumstances in the presented systems are similar to the current circumstances of the company. Also, this research is concentrating on municipal solid waste in the area, especially household waste. The waste fractions considered in this research are combustible waste, paper, plastic, cardboard, biowaste, metal, glass, and textiles. Other ones are limited off. If some waste management system has an interesting way to manage electronic or dangerous waste, it can be mentioned, but it will not be the main interest in this research. The waste management systems considered in this thesis are limited to the border of Europe. Also, waste is considered from that point, when a customer has thrown the rubbish bag to the bin to the point, where it is going to treatment for example to incineration plant or transported to a place, where it is recycled. The risks of the actions of customers will be also considered.

2 PRESENTATION OF THE CURRENT MUNICIPAL SOLID WASTE MANAGEMENT SYSTEM AND THE COMPANY

This chapter includes a wide presentation of the main company in this research. The company and its current waste management system stands for the basis for the research. There are presented main aspects of the company, cost structure, history, and waste management system.

Lakeuden Etappi Oy is a waste management company owned by eight municipalities in Southern Ostrobothnia. Owner municipalities are Alavus, Ilmajoki, Kihniö, Kuortane, Kurikka, Lapua, Seinäjoki and Ähtäri. (Lakeuden Jätelautakunta 2015, p.5.) The company was founded on 2.4.1997 by 14 municipalities in South Ostrobothnia. The name was then Lakeuden Jätekeskus Oy. The operative actions started at the beginning of 1999 (Lakeuden Etappi Oy 2019.) Waste sorting and treatment station was set up in Ilmajoki in 2004. The same station is still working as a waste management centre of the company. At the same year, the name of the company was changed to Lakeuden Etappi Oy. (Lakeuden Etappi Oy 2018, p.6.)

The company's biogas plant started to work in 2008. Waste incineration plant company Westenergy Oy Ab was founded with five other waste management companies in Ostrobothnia in the year 2008. Lakeuden Etappi Oy became the biggest owner of it. The waste incineration process started at the plant in 2012 and Lakeuden Etappi Oy became the handler of the bottom ash with Suomen Erityisjäte Oy and Inascho Oy. In 2015, Lakeuden Etappi's shop for waste management end products and waste management services was published. In 2016, the company started a side business, Encore Pohjanmaa, with Paperinkeräys Oy. The side business sells waste management services to other businesses in the area. Lakeuden Etappi Oy extended to a group company when it started a subsidiary called Botnia Energia Oy in 2017. (Lakeuden Etappi Oy 2018, p.6.)

Lakeuden Etappi Oy's waste management is guided by local waste management regulations, which are made by Lakeus Committee for waste management. The company concentrates on the wastes that are generated in households and municipal service providers in their

responsibility area. The company manages the practical part of the municipal waste management, collection, transportation, and treatment. It also manages waste trucks coordination and competitive tendering. (Lakeuden Jätelautakunta 2015, p.5-6.)

Lakeus Committee for waste management is a committee of eight owner municipalities of Lakeuden Etappi Oy. Its function is to be a neutral waste management authority in the area. Every municipality has a deputy in the committee. The committee is coworking with municipalities' surveillance authorities and with Lakeuden Etappi Oy. The committee makes decisions about the practical part of waste management in the area and regulates the work of the local waste management company. (Lakeuden Jätelautakunta 2015.)

Along with the basics of waste management, the company also offers consultation and help on waste management problems to inhabitants and municipal service providers in the area. It also educates inhabitants in the area about a sustainable way of living, waste management, recycling, and reducing the amount of waste. Environmental education is arranged for example at day-care and schools. It informs the public through many channels, a local newspaper, their newspaper Etappiaviisi, company websites, an annual publication, newsletter, radio and social media platforms, Twitter, and Facebook. (Lakeuden Jätelautakunta 2015, p.7.)

The number of real estates in Lakeuden Etappi Oy area is around 33 000. The eco fee is paid by around 64 000 households. Based on the waste management law, operation and investment costs are covered with the waste bin emptying and eco fees from the customers. (Lakeuden Etappi Oy 2018, p. 10, 26.). Waste bin emptying fees are based on the waste collection frequency from the household or real estate and the size of the waste bin. Eco fee is a fixed fee from every real estate or household in the area. (Lakeuden Etappi Oy 2019.) Usage of emptying and eco fees are presented in figures 1 and 2.

In Finland, waste management is financed only with payments from waste management services users and waste producers. The company has the same fee for every household in the area, no matter where the household is located. Eco fee is 38,64 €/a for households in buildings with 1-9 households and 32,16 €/a for households in buildings with 10 or more

households. For part-time households, the eco fee is 12,90 €/a. (Lakeuden jätelautakunta 2019a, Lakeuden Etappi Oy 2020.) The national average of eco fees for households in a block of flat is 23,47 €/a and for detached houses 31,96 €/a. (KIVO 2019, p.8)

Emptying fee for combustible waste is 7,44 € per one emptying of a 240-litre container and 13,09 € per emptying of 660 litres container. Emptying fee for biowaste is 9,18 € per one emptying of a 240-litre container. There are also fees for 140, 360 litres containers and the fee per litre of waste is cheaper in bigger containers. The fees include value added tax and are the same for both residential buildings and detached houses. Packaging waste (cardboard, metals, glass, and plastics) have own collection fees, but the treatment of them is free. (Lakeuden jätelautakunta 2019a.)

The national average waste emptying fee of combustible waste in 660-litre container in residential buildings is 12,06 € and biowaste in 240-litre container 8,65 €. For detached houses, emptying fee for combustible waste national average is 7,17 € per one emptying of 240-litre container. (KIVO 2019, p.6-7.) As a conclusion, the waste management fees, both eco and emptying fees, are higher in Lakeuden Etappi Oy compared to the national average in Finland.

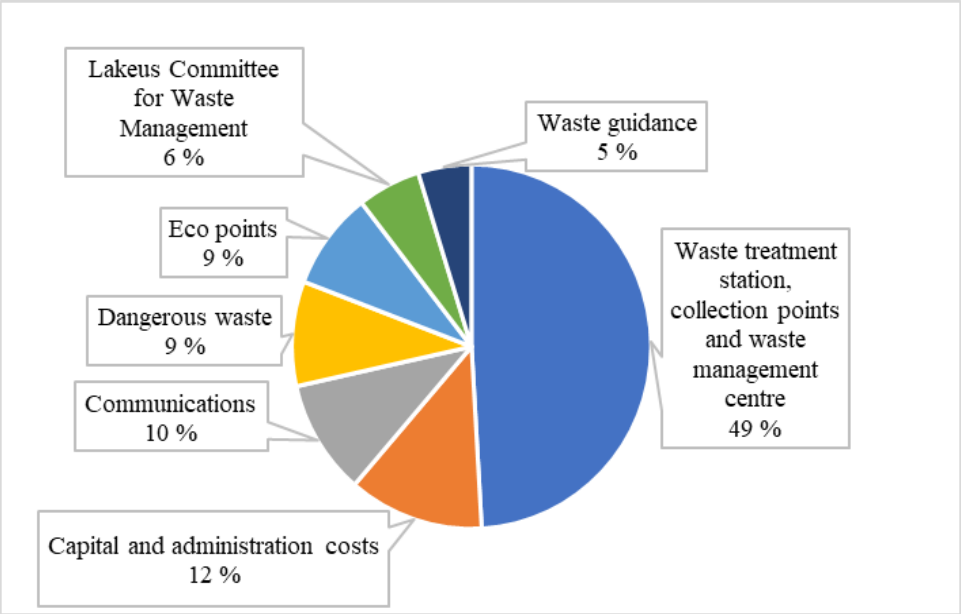

Figure 1. Use of eco fees (Lakeuden Etappi Oy 2019a).

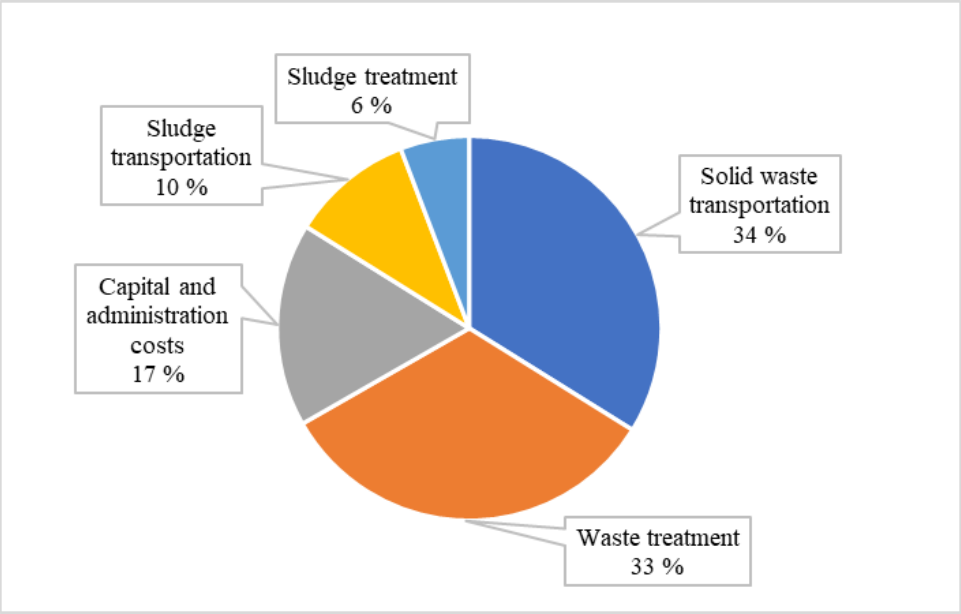

Figure 2. Use of waste bin emptying fees (Lakeuden Etappi Oy 2019a).

In the year 2017, there was worth of 16,9 million euros of paid eco fees for the company (Lakeuden Etappi Oy 2019a). Waste transportation is 40,5 % of the company's expenses, processing of waste takes 40,2 % and the rest is for taxes (Lakeuden Etappi Oy 2018, p.26.). The revenue of the company in 2018 was 22,1 million euros and the profit was 3,1 million euros. (Lakeuden Etappi Oy 2018, p.4.) The company has 40 employees in different kinds of tasks (Lakeuden Etappi Oy 2019f).

2.1 Company's strategy

Lakeuden Etappi renewed their strategic objectives for years 2017-2020. There are five strategic objectives for these years. The first of them is excellent customer service. The company is now running a customer-oriented project called Seinäjoki 2020. The project includes building a new waste station for small quantities of different waste fractions from households and starting a new OmaEtappi service on their websites, which is already running. The second one is efficient logistics and treatment processes, which are implemented by investigation of the wider possibilities for separate collection of waste.

The third is efficient support systems and personnel progression and wellbeing. Occupational health and safety of personnel are based on International Organization for

Standardization (ISO) 45001:2018 standard, which was newly audited and certificated in 2018 as one of the first companies in Finland. Also, quality and environmental systems are qualified, and they are based on ISO 9001:2015 and 14001:2015 standards. The fourth strategic objective is efficient communications through many channels. The fifth strategic objective is recycling products and knowledge. (Lakeuden Etappi 2018, p. 5.)

The company's mission is to offer responsible waste management for the good of its customers and the environment. The company’s vision is to be an efficient waste management services company, which invests in knowledge and sustainable solutions. The company’s values are a customer-oriented perspective to the business, knowledge, efficiency, co-operation, environmental responsibility, and well-being of the employees. (Lakeuden Etappi 2018, p. 7.)

2.2 Environmental responsibility of the municipal solid waste management

The company has a certified environmental system. Every waste station has own environmental permit, which is updated when needed. Regional waste collection points and stations, eco points, and waste management centre are built in a way that the actions do as less as possible harm to the environment around the area. The company has a monitoring program for pollution and environmental effects. The monitoring program includes surveillance of waters, landfill gases, littering, landfill area thickness, noise, and smells. The monitored aspects are reported to the authorities regularly. Also, the area pests’ amount is monitored. (Lakeuden Etappi Oy 2019c.)

Generally, the harmful environmental effects have been low, and the amounts of harmful gases, chemicals, and other substances have passed underneath the limit values (Lakeuden Etappi Oy 2018, p.22-25). In final disposal area, landfill gases are measured regularly and burned in two torches to avoid smell and release of methane. Smelly flue gases from biogas plant are processed with odour control scrubber and bio filtering. (Hautala, M. 2020a.)

Wastewaters from the biogas plant, balancing reservoirs, and sanitation are led to the municipal wastewater treatment plant. Some of the wastewaters are also recycled for new use in the waste stations and management centre. Water flows around the waste management centre and stations are an important part of the environmental surveillance program. There are measurement points outside and inside the area. Watersheds include ground and surface waters, urban runoff, wastewaters, and underground drainage waters. Urban runoff waters are led to the close water stream if it fills the water quality regulations. (Lakeuden Etappi Oy 2019c, Lakeuden Etappi Oy 2018, p.22-25.)

2.3 The current waste collection system

There were around 1 100 000 waste bin emptyings in 2018 in the area (Lakeuden Etappi Oy 2019f). There are 130 000 inhabitants in the area, which Lakeuden Etappi Oy is responsible to arrange waste management. Also, the company is responsible for the waste management of part-time inhabitants in the area, for example, cottager in the summertime. (Lakeuden Etappi Oy 2018, p.7.). In the area of the company, the population density is averagely 16 person/km^2. The largest population density is in Seinäjoki, where the density is 44 person/km^2. The second largest is over 20 inhabitants less, Ilmajoki with 21 person/km^2. (Suomen virallinen tilasto (SVT) 2019.)

Waste is collected in the area with waste trucks from real estate to another. The collection frequency of the waste bins is regulated by the waste management regulations. (Lakeuden Jätelautakunta 2015 p.6.) There is in every real estate a waste container for at least combustible waste. It can be also common for several households close to each other in the area. Recyclable wastes are sorted at homes and carried to the eco points, regional waste stations, or waste management centre. Recycling and sorting the recyclable wastes are consumers' responsibility. (Lakeuden Jätelautakunta 2015 p. 6). Recyclable wastes are also collected from residential buildings waste rooms and municipal service provider buildings' waste rooms. The collection obligations for residential buildings are presented in table 1. (Lakeuden Jätelautakunta 2019, p. 20.)

Table 1. Separate collection obligations for residential buildings (Lakeuden Jätelautakunta 2019, p. 20).

Number of households	Biowaste	Packaging metal	Packaging glass	Cardboard	Packaging plastic	Paper
5 or more	yes	voluntary	voluntary	voluntary	voluntary	As national waste legislation orders
10 or more	yes	yes	yes	yes	voluntary	
20 or more	yes	yes	yes	yes	yes, in specified urban areas	

Round-the-clock open and customer-oriented waste sorting and collection station is planned to begin in 2020 in Seinäjoki. After all, the opening of this waste sorting and collection station was delayed to the year 2021 because of the coronavirus (Hautala, M. 2020.)There are in the regional waste stations a collection of recyclables and dangerous waste for free and collection of combustible, bio, and landfill waste with a fee. Regional waste stations are located in every owner municipality. Lakeuden Etappi Oy 2018, p.8.) The company has circa 70 eco points in the area. There are also regional waste collection points in the area, which are seasonal and for summer cottagers. There are in the area also recycling points of Finnish packaging recycling RINKI Ltd. Those recycling points can be combined with eco points, but they are not under the surveillance of Lakeuden Etappi Oy. (Lakeuden Etappi Oy 2019b).

In 2018, there were around 18 000 received waste loads at the waste management centre. The municipal solid waste processed was around 82 000 metric tons (further, metric ton, 1000 kg, is marked as tons) in 2018, where 38,7 % was used in recovered energy generation, 60,1 % was recycled, 0,7 % treated otherwise and 0,5 % disposed to landfill. (Lakeuden Etappi Oy 2018, p.12.) In 2019, the municipal waste recycling rate dropped to 46,6 %, other treatment to 0,2 % as well as landfilling to 0,2 % and energy recovery increased to 53 %. The drop in recycling rate was caused by the change in calculation methods, which is now in line with the upcoming waste legislation (Lakeuden Etappi Oy 2020a.) For energy recovery, the amount of waste delivered is around 32 000 tons/a and for final disposal to landfill 400 tons/a. Biowaste is separately collected 8,63 kg/inhabitant and dangerous waste is collected 7,65 kg/inhabitant. These amounts are based on the year 2018 quantities. (Lakeuden Etappi Oy 2018, p.12.)

The national average on municipal waste recycling rate was 42 % in 2018 in Finland (Suomen virallinen tilasto SVT 2018). Circwaste-project in Finland researched recycling rates of 13 municipal waste management companies in 2017. It showed that there are a lot of variations between recycling rates in Finnish waste management companies and areas. Kuopio area in Central-Finland achieved the highest recycling rate, 62 %. Though it must be noted, that the project researched household waste recycling rates and the recycling rate of Lakeuden Etappi Oy includes all municipal waste. Also, it is not sure that the recycling rates are in line with the new EU waste legislation, like the recycling rate of Lakeuden Etappi Oy is. All in all, the recycling rate of Lakeuden Etappi Oy could be better. Even though it is higher than the national average, there is a long way to the EU target for 2025, 55 %. (Myllymaa, T; Karppinen, T. 2018).

The company produces waste-based products, crushed concrete product Bemura (3097 tons in 2018), soil improvement material Ranu (3582 tons in 2018), and artificial stone ScanWas (72 567 tons in 2018). These products are produced in the waste management centre of the company. In the waste management centre, mixed waste is prepared for energy use, recyclables are prepared for further treatment or transportation, and waste that cannot be utilized is landfilled. (Lakeuden Etappi Oy 2018, p.12.)

The company investigated the composition of the municipal solid combustible waste in 2019. The results showed that waste was well recycled and there was only 2,9 weight-% of non-combustible waste. The results showed that there was 36,1 % biowaste, 22,9 % plastics, 12,3 % cardboard, 11,8 % paper, 8,4 % textiles and shoes, 5,2 % other combustible waste and 0,4 % wood-based waste. Composition of non-combustible waste was metal and glass 2,2 %, electric devices and batteries 0,3 %, dangerous chemicals 0,1 % and other non-combustible waste 0,2 %. Results showed that there was waste, that could have been utilized in other ways also, such as biowaste or cardboard. (Lakeuden Etappi Oy 2019e.) The investigation shows that the recycling rate could be increased with a more efficient separate collection of recyclables and technological changes.

2.4 The current waste treatment system

After separate waste collection, waste is transported to the waste treatment centre or straight to further treatment place. Such materials, that go further, are glass, metal, and dangerous waste, the waste fractions that are under extended producer responsibility (later EPR). The company does not have any responsibilities, except educational, or allowances to do anything else than collection of that kind of waste fractions. (Lakeuden Etappi Oy 2019d.) Glass and metal are utilized in industry and new glass and metal packages production. Cardboard is utilized for example in toilet paper spools. Paper is recycled and cleaned to produce new magazines and newspapers. Waste fractions under producer responsibility are recycled through Finnish Packaging Recycling RINKI Ltd. (Lakeuden Etappi Oy 2019d).

Biowaste and combustible waste are the only waste fractions, that are the company's responsibility to treat. Biowaste is transported to the waste management centre and utilized in the biogas plant to produce biogas and soil improvement material. Combustible waste is transported to the waste incineration plant. (Lakeuden Etappi Oy 2019d.) Combustible waste is at first transported to the waste management centre and after that transhipped from smaller garbage trucks to bigger side loading-trucks in the transhipment hall. (Hautala, personal conversation 2019). The incineration plant produces steam, which is used by another company to produce electricity and district heat (Lakeuden Etappi Oy 2019d).

The company's waste management system is based on the common trends in the waste management in Finland, waste management legislation, and local waste management regulations. Examples were taken from other cities in Finland and used to plan the own waste management system in the area. Also, the area characteristics were considered. The aim for the waste management was to arrange the waste management for the customers with low expenses and with necessary, high-quality waste management services. When the Finnish Packaging Recycling RINKI Ltd came, it changed the waste management system in the area. RINKI Ltd. started its recycling points in the area for the collection of extended producer responsibility waste. The waste, that used to be the responsibility of the local waste management company. Some of the points were combined with the eco points of Lakeuden Etappi Oy. (Hautala, personnel conversation 2019).

3 FUTURE CHANGES OF LAWS AND REGULATIONS OF MUNICIPAL SOLID WASTE MANAGEMENT IN FINLAND AND EU

Waste management is driven by laws and regulations. European Union legislation is the basis for the Finnish legislation. The legislation around waste management is getting tighter all the time. In this chapter, upcoming legislation in the waste management area is studied and presented. It has a markable influence on the future waste management system in Lakeuden Etappi Oy. This part especially concentrates on the parts of future waste legislation, that affect the company's actions.

3.1 Eu laws and regulations

EU's main target for improving waste management is to increase circular economy in the area. New targets are protecting the health of the environment and human beings. Circular economy aims to close the circle of products from material acquisition to waste management. It encourages to use more recycled materials, material recovery, and recycling. In the EU, it means keeping the valuable materials from the waste inside the EU and concentrating on better and more efficient use of waste to increase economic growth and circular economy. It also reduces the dependence of material imports from outside the EU. The European Commission presented the circular economy package at the end of 2015. The circular economy package includes a waste decree package that includes four new directives that are based on six previous directives. The directives came into force in July 2018. (Council of the EU 2018.)

These four changed directives are Directive 2018/851 of the European Parliament and of the Council amending Directive 2008/98/EC on waste, which regulates the changes in waste management. The second one is Directive 2018/852 of the European Parliament and Council amending Directive 94/62/EC on packaging and packaging waste, which includes the concept of extended producer responsibility. The third one is Directive 2018/850 of the European Parliament and Council amending Directive 1999/31/EC on the landfill of waste, which aims to decrease the amount of waste disposed in landfills. The last one is Directive

2018/849 of the European Parliament and the Council amending Directives 2000/53/EC on end-of-life vehicles, 2006/66/EC on batteries and accumulators and waste batteries and accumulators, and 2012/19/EU on waste electrical and electronic equipment. (Ministry of Environment 2018.)

Eu waste legislation is based on directive 2008/98/EC on waste. The directive is made to protect the environment and human health by improving waste management. The directive includes the concepts of waste hierarchy and polluter pays- principle, which is implemented for example with the extended producer responsibility and municipal waste management billing. In the directive, wastes and by-products are separated. The directive sets special requirements for the management of hazardous waste, oils, and biowaste. (EU Publications office 2009.)

Waste hierarchy means the importance order of waste management. The most important is to prevent waste production, reuse, and decrease the harmful effects of waste. The next option is to reuse with cleaning, repairing, and refurbishing the whole product or part of it. The third one is recycling, composting and material recovery in the production of new products. The second last is other recovery. Recovery can include energy recovery, gasification, pyrolysis, and backfilling operations. The bottom of the hierarchy is disposal on landfills and incineration without energy recovery. (Lakeuden Etappi Oy 2019f, International Solid Waste Association 2015).

The directive stipulates that waste management must be arranged in a way, that does not harm waters, air, soil, plants, or animals and does not produce noise or smell problems or disturb valuable attractions. Producers and holders of waste must handle the waste by themselves or give it to operators that have the proper knowledge and officially recognised permits for managing waste. These operators are controlled by the authorities. The member states must have a waste management plan and waste prevention program. There are targets for recycling and material recovery of waste to the beginning of the year 2020. These are 50 % for household waste and 70 % for construction and demolition waste. (EU Publications office 2009.)

Extended producer responsibility (later, EPR) means that the producer or importer of the product is responsible to arrange and finance waste recycling and disposal of the product. The customer pays recycling, packaging waste management, and disposal costs of the product already when buying the product. The producer responsibility includes packaging materials, glass, metal, plastic and cardboard, paper, electric and electronic waste, tires and vehicles, batteries, and accumulators. (Lakeuden Etappi Oy 2019f).

The new waste legislation defines new aspects of EPR. It defines the minimum requirements for systems to increase efficiency, effectiveness, and similarity between member states. It defines, that the producer of a product is obligated to take responsibility and pay the costs of waste management of the packaging and the product. Also, it defines that EPR must concern all producers and packaging, not just the biggest producers. (Council of the EU 2018.) There is going to be a different producer responsibility fee for different producers depending on durability, fixability, reusability and recyclability of the products. (Levinen 2019.)

The package has set new regulations and targets for waste management. EU targets for the member countries' municipal waste material recovery and recycling are 55 % by the end of 2024, 60 % by the end of 2029 and 65 % by the end of 2034. There are set targets also for packaging waste recycling in the waste legislation. They are presented in table 2 below. (Council of the EU 2018.)

Table 2. Packaging waste recycling targets (Council of the EU 2018).

	By the end of 2024	**By the end of 2029**
All packaging	65 %	70 %
Plastics	50 %	55 %
Wood	25 %	30 %
Iron metals	70 %	80 %
Aluminium	50 %	60 %
Glass	70 %	75 %
Paper and cardboard	75 %	85 %

Member countries are obligated to also start the separate collection of textiles and household hazardous waste at the beginning of 2025. By the end of 2023, biowaste must be included in the separate collection from each household or recycled at the source, for example with composting. (Council of the EU 2018). Construction and demolition waste are going to be

separated into multiple fractions. The package determines also that combined separate collection of recyclable waste fractions is possible to do if it does not decrease the waste fraction quality. There are some exceptions in the separate collection regulation, caused by environmental, economic, or technical aspects. These aspects should be estimated in the waste management plan regularly and reported to the authorities. (Levinen, R. 2019.) The new waste management package also obligates that recyclable materials or materials that could be used in material recovery, are not accepted in landfills at the beginning of 2030. (Council of the EU 2018).

Waste processing and transportation paths control and traceability are clarified in the new legislation (Ministry of Environment 2019). Member States are also obligated to work towards reducing waste production, harmful effects and to work towards increasing reuse, recycling, and material recovery. (Pajukallio A. et al 2019.) There is going to be an electronic platform for different waste management actors. Also, there will be an obligation to report, how the packages and products are reused, if they are. The amounts of lubrication oils and waste oils that are fed into the markets are measured and reported. The information channels must be improved and increased. (Levinen, R. 2019)

The new waste management package pursues to reduce the amount of food waste and better tracking of waste streams in primary production, industry, grocery stores, restaurants, and households. Food waste and excess food should be measured or estimated and reported to the authorities yearly. Excess food should be used primarily as human food through food donations and redistribution. (Levinen, R. 2019)

End-of-waste categorisation means that material is no more waste because of recycling or material recovery. Then the material does not belong under the waste legislation. Waste is according to waste act (646/2011) a thing or item, that the owner is going to dispose of, is responsible to dispose of or has disposed of already. A thing or item is not waste anymore, when it has undergone a recovery operation, it has a purpose for which it is commonly used, or it has markets or demand. It is neither waste anymore if it has all the technical requirements for specific purposes and meets with the legislative needs of the similar items

or things and usage of a thing or item does not risk or harm the health of the environment or humans. (Ministry of Environment 2019)

By-products and categorisation of waste concepts are clarified to make the material categorisation of waste more similar between member states. (Pajukallio A. et al 2019.) The categorisation is moving from waste towards by-product, new material. Those materials which fill the End-of-Waste criteria are marketed as valuable material, those materials, which do not fill the criteria, are waste. Member states' responsibilities are to make sure, that the categorization is done right. Evaluation of the value and markets of some materials are clarified. (Levinen, R. 2019)

The new waste management package determines new, tighter, calculation methods for waste recycling rates. The calculation is moving from the recycling rate from separate collection to the more realistic approach, the recycling rate after the pre-treatment. (Levinen, R. 2019.) The changes in the calculation of the recycling rate are illustrated in figure 3. The biggest change is that the recycling and reuse rates are calculated as before except that reject materials must be subtracted from the amount reported as recycled. Reject material refers to the substances produced in the pre-treatment processes of recycling and recovery, that cannot be used for recycling or utilization. (Tilastokeskus 2019.)

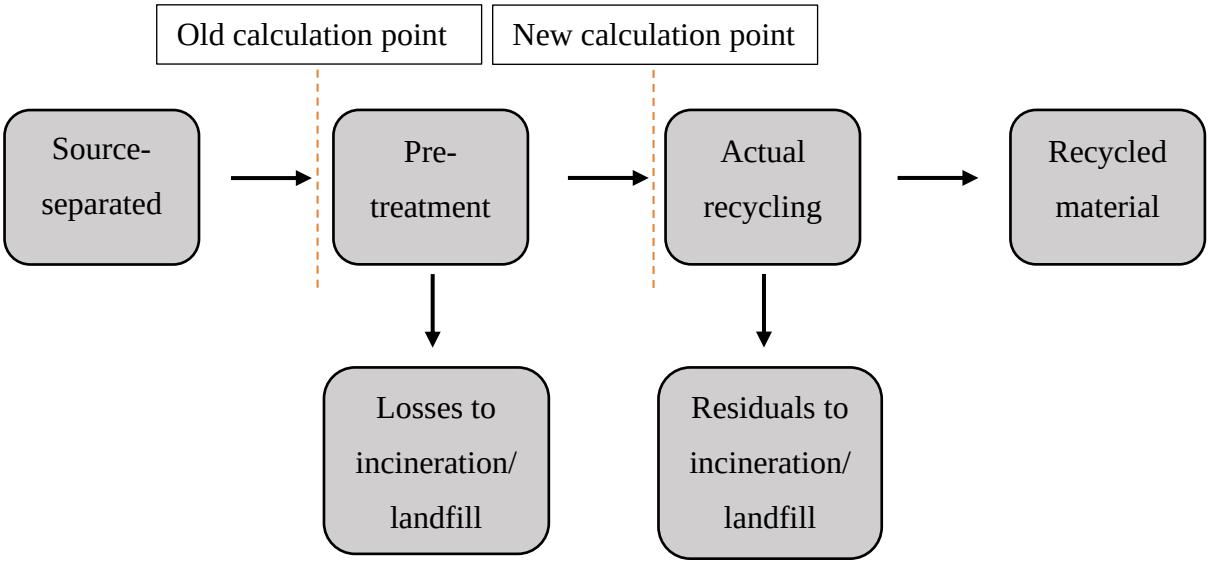

Figure 3. Upcoming changes in the calculation of recycling rate (Stén 2018, p. 10).

The amount of waste from solid waste separation or mechanical and biological treatment, that are going to landfill, must be included in the amount of municipal solid waste, that is disposed in a landfill. The same thing is for the reject that is produced in the incineration process and disposed in a landfill. Also, waste from the biodegradable waste stabilization process, that is disposed in a landfill, must be included in the amount of waste disposed in a landfill. Only the reject produced during the recovery process, such as energy recovery, is not calculated in the amount of waste disposed in the landfill. Other changes in calculation methods are that metals, that are separated from the waste incineration ash and slag, can be added to the amount of metals recycled. The amount of packaging waste, that is recycled through aerobic or anaerobic treatment, can be added to the recycling rate as well. (Tilastokeskus 2019.)

The government decree on landfills (331/2013) was legislated to reduce the waste going to landfills. There were set limitations of organic carbon amount in the waste. Waste, that includes organic carbon, must be recycled or materials recovered at first, and if it is not possible, then disposed through energy recovery or landfill. The decree came into force in 2016. The amount of carbon in the waste, measured as total organic carbon (TOC) or ignition loss, cannot be over 10 %. This decree is also changed because of new directives in the waste management package. The waste can be disposed in landfills if it is the best way from the environmental perspective for disposal. Waste, that can be recycled, reused, or utilized through material recovery, cannot be landfilled anymore in 2030. At the beginning of 2035, only 10 % of municipal waste can be disposed in landfills. (Korhonen, M.-R., Pitkänen, K., Niemistö, J. 2018.) This change is not important for Finland or the company, because the targets are already accomplished.

3.2 Finnish laws and regulations

In Finland, the waste laws are based on the European Union legislation. After the publication of the EU waste management package in 2018, Finnish Ministry of the Environment started to prepare the update of Finnish legislation. Ministry of Environment set up a working committee to work with the legislative changes needed to make the legislation correspond with the EU directives. The committee finished the report in September 2019. New waste

directives that correspond with the updated EU directives must be executed in 5.7.2020. (Ministry of Environment 2019.)

Finnish Ministry of Environment has suggested changing the Government Decree on waste (179/2012). This suggestion includes new targets for waste management recycling rates, which are in line with the EU targets. The suggestion also includes that a municipality must arrange recyclable and biowaste household separate collection at least for residential buildings with 5 or more apartments in two years after the law becomes into force. In three years after the law becomes into force, biowaste collection must be arranged separately from every household in an urban area with more than 10 000 residents. (Ministry of Environment 2020.) This wider separate collection of waste is especially important for Lakeuden Etappi Oy.

New EU legislation from the circular economy package requires changes to Finnish chemical and environment protection laws. New Finnish legislation aims to achieve the targets and requirements the EU has set with the new directives. It requires co-operation between different actors in the waste management field, clarification of the responsibilities and tasks of each actor, increase of separate collection, and improvement in economic incentives. (Pajukallio A. et al. 2019.)

The implementation of the new waste management directives is not simple and creates problems between different responsibilities in member states, including Finland. There are many different actors in the waste management field, which have different responsibilities, sometimes also overlapping responsibilities. Some fractions are the citizens' responsibility to recycle and transport to waste stations. Transportation of waste is arranged in different ways in different municipalities, in some municipalities, it is arranged by the waste management company, in others, it is the responsibility of the owner of a real estate. The same waste fraction might have also different possible treatment methods. For example, plastic waste can be packaging waste, which is in most of the cases under the EPR and belongs to RINKI Ltd. in Finland. Then again, there are also other plastic wastes, that do not belong to recycling circles at least not yet. (Levinen, R. 2019)

EU waste directive (2008/98/EY) obligates member states to make a waste plan. The waste plan aims to reduce the amount of waste and possible harmful effects of waste and waste management. It describes the strategic national targets and moves to achieve better waste management in the country. In Finland, the latest waste plan was made in 2017 and it is called “From recycling to circular economy”. The plan reaches to the year 2023 or the year when a new plan is made. The targets for waste management are made for longer periods, this time to the year 2030, even though the waste plan period is six years. The plan includes the waste management plan and the plan for decreasing the harmful effects of waste. The current plan is focused on the four waste categories: construction waste, biodegradable waste, municipal waste, and electrical and electronic equipment waste. (Laaksonen, J. et al. 2018, p. 15-16.) For this thesis, biodegradable and municipal waste are the most important categories.

Targets in the waste plan, that especially affects the waste management company, are that new, innovative, and efficient waste treatment plants and separate collection of waste fractions are important for achieving clean and high-quality waste material. Especially pre-treatment capacity addition to the waste fractions, that have further recycling possibilities or cannot be disposed in landfills because of the landfill ban of organic waste is important. The usefulness of combined mechanical and biological treatment plant is going to decrease in the future because of the low quality of the waste material produced in the process. The role of waste-to-energy plants is going to change also because of increasing recycling rate of municipal solid waste. The quality and the amount of waste incinerated are changing and this affects the need for the waste incineration capacity. In Finland, the capacity addition for the biological treatment of biodegradable waste is needed, but it is not important in this context because the company has already prepared for future needs when building the biogas plant. (Laaksonen, J. et al. 2018, p. 17-20)

Actions and advice in the waste plan, which affects the waste management companies are for the biodegradable waste. This includes an order to measure grocery stores’ and food services’ mixed waste compositions and food spill proportion. Another one is to measure the amount of garden and food waste composted onsite at the households. Guidance of sorting

the biodegradable waste is improved through national biowaste campaign and biowaste collection methods need to be improved. (Laaksonen, J. et al. 2018, p. 35-37)

Actions concerning the municipal solid waste are to make the separate collection of waste fractions compulsory considering the characteristics and possibilities of the area. This is also one of the aspects presented in the new waste legislation. Clearness of costs of municipal waste management to the customers is improved and straight correlations between the waste produced and cost are clarified to the customers. Also, co-operation between different waste actors is strengthened and waste campaigns to reduce waste production and to increase the amount of waste recycled are arranged. Collection methods and separate collection of waste fractions are improved to get a higher recycling rate of the waste. Guidance for sorting and recycling waste, that belongs to EPR is improved and increased. (Laaksonen, J. et al. 2018, p. 40-43)

European Commission gave Finland among many other member states the early warning at risk of missing the 2020 re-use/recycling 50 % target on municipal waste. It says, that even though Finland has many good things in waste management, there is still more to be done. For example, it is noticed, that landfill taxes and EPR are used in Finland, and Finnish people have a high level of awareness in these things. Then again, lacks were noticed in too generous flexibility of the system, concerning the separate collection of dry recyclables and bio-waste. Also, the obscurity of the system caused by the frequent changes in waste legislation in Finland was noticed to be a challenge. Also, the inefficiency of EPR schemes makes the change slower. (European Commission 2018b.)

More specific suggestions, which EU commission made for Finland, included incentives to municipalities and EPR, economical instruments, separate collection, technical support to municipalities, communication, and awareness-raising and long-term actions. The effects to waste management companies are communication improvements in co-operation between the actors in long-term to make all the processes and parts more efficient, implementing a pay-as-you-throw system in the waste management, the obligation of separate collection and sorting of recyclables and bio-waste from every household and kerbside collection extensions. (European Commission 2018b.)

4 CHOOSING PRINCIPLES OF CONSIDERED MUNICIPAL SOLID WASTE MANAGEMENT SYSTEMS

In this chapter, the principles for choosing different waste management systems in Europe are presented. The waste management systems are scanned through population densities and recycling rates of the countries to find the most suitable ones. Also, the requirements for the systems are presented, that the researched systems would be suitable for the waste management of the company.

4.1 Requirements of the municipal solid waste management system

One of the requirements for the waste management systems considered here is that the system would be about the same size as the current system in the company. The suitability is easier to evaluate in the same size systems and waste fractions produced would be about the same amount. Especially, if the considered system is much bigger, it is difficult to evaluate, if the specific waste fraction treatment is efficient and worth to use in the current system of Lakeuden Etappi Oy. Also, the possibilities to use the system in the area of the company is important to take into account and area characteristics, such as the amount of dispersed settlement and population density.

Especially, the separation of biowaste is interesting in the investigated waste management systems. Biowaste is heavy and therefore, higher weight-based recycling rate is easier to achieve with efficient separation of biowaste than with other fractions. Biowaste separation from the combustible waste and achieving quality high enough for biological treatment is difficult afterward. Therefore, the source separation of biowaste is a more interesting aspect. Biowaste processing alternatives are not interesting in this study because the current system in the company includes the production of biogas from biowaste. Therefore, it is already sustainable and follows the concept of circular economy. The biowaste is upcycled to a product that has marketing value. Textile waste fraction is another interesting fraction because recycling and reuse of it are in the future more important and part of the new EU waste management targets.

One important aspect, when choosing the considered waste management system, is the will of the company and what systems are they interested in. They have a wide knowledge of the current and previous systems in the company and knowledge about what would be the most suitable and possible new system. Also, the systems chosen are supposed to be different and might focus on different things. From this viewpoint, the company's main development area comes in the picture and affects the conclusions. For example, the pneumatic pipe collection system is not considered at all, because it is not possible in already built areas.

4.2 Scanning of possible municipal solid waste management systems

The possible waste management systems presented in this thesis are searched by the recycling rates and population densities of the countries and using Google search and scientific articles. The article used for the basis of the municipal waste management systems is a study made by Nicole Seyring et al. where they assessed separate collection schemes in EU capital cities (2015). *Sustainable Solid Waste Collection and Management*- book made by Ana Pires et al. (2019) is used also as a basis for the scanning of waste management systems.

There is quite a lot of research about waste management systems in Europe and how to achieve higher recycling rates and increase circular economy solutions in waste management. Still, comparable research about the solid waste management systems in Europe is missing. Salmenperä, H. et al. (2019a) have investigated suitable waste management ways to achieve the European commission's recommendations in Finland in Jätekiva- project. In the project, costs, environmental, and other aspects of the changes and separate collection of different waste fractions were investigated. Possibilities to improve the packaging waste collection and recycling were researched also in the project. The same aspects are also in the interest of this thesis. The research was a wide study about possibilities in Finland but did not concentrate in one specific geographical area or company.

Also, the Zero Waste- program is used for scanning and searching for new waste management possibilities and best practices in the field. The program gives information about the cities worldwide, which have committed to Zero Waste- goal. Even though this

program is a good place to search for the municipalities, whose recycling rate is high, all municipalities that have a high recycling rate may not be in it and some good practices may not be considered. (Zero Waste Europe 2020.) It must be paid attention in the conclusion part, that the research may not be comprehensive. When choosing waste management systems, there are also considered different technological and economic development. There are example cities from the countries, where recycling and waste management are developed nearly from landfilling everything to almost zero landfilling in ten years. There are also presented waste management systems in countries, where waste management has developed already tens of years ago and the development has been slower.

In this listing of municipal waste recycling rates of countries, the recycling rates include material recycling, composting and anaerobic digestion, but not incineration. At the top of the listing in Europe is Germany, Slovenia, Austria, The Netherlands, Belgium, and Switzerland. These top European countries have achieved more than 50 % recycling rate of total municipal waste generated. Mostly, the waste considered in this listing, are from households, but also small amounts from municipal service providers and small businesses. (Eurostat 2019.) These figures and results need to be considered with suspicion, because the countries measurement systems may vary a lot and give results, that cannot be compared to each other. For example, biological treatment reject might be included in the recycling rate, even though it has been incinerated after all. The recycling rates of European countries are presented in figure 4 below.

The recycling rate provides comparative data about European countries waste management systems. Recycling rates are usually used to measure, whether waste management is organized well. Comparing recycling rates offers a tool to search for the systems, which could include good waste management practises and innovations. These good waste management practices and innovations are the things, that are pursued to find in this study. Though, it must be noted, that the recycling rate may not tell the whole story and there might be different calculation methods used.

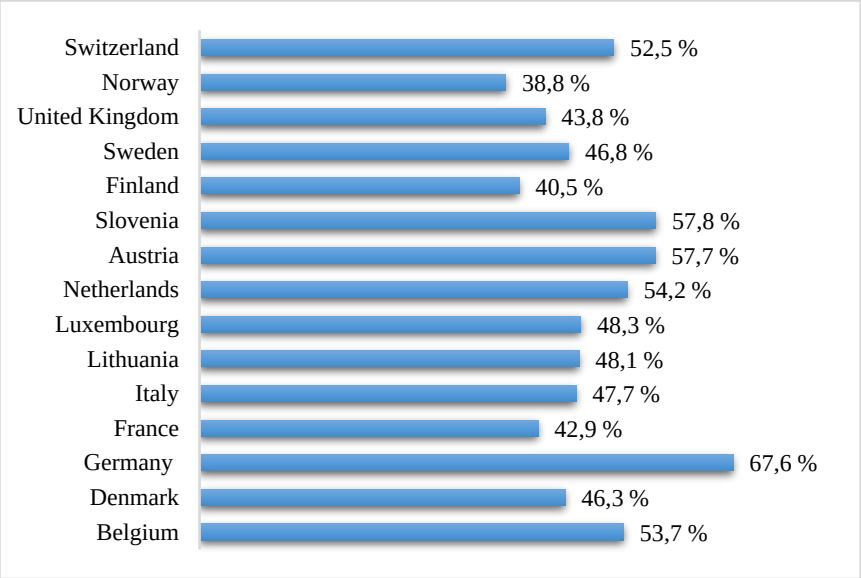

Figure 4: Municipal waste recycling rates of European countries (only the top 15 countries included) (Eurostat 2019).

The interests of the company are important when choosing waste management system research. The area of the company is sparsely populated and therefore they are interested in areas, that are sparsely populated as well. Those areas are for example in Nordic countries at least and the circumstances are similar. Winter and snow give challenges in waste management. One of the restrictive aspects might be the availability of the information from the smaller towns waste management systems.

The population density in the area is one important aspect when searching for similar areas to South Ostrobothnia. In figure 5, population densities of European countries are presented. Countries that are included in the population density figure 5, are limited to European Union countries, with a couple of exceptions. There are also included Norway, Switzerland, and the United Kingdom in the figure 5. These countries are interested because of the circumstances and similarities to the area of the company and they have advanced waste management. For the same reasons, Malta is cut out of the figure 5. With these two figures, we can search for the countries and areas, which could be similar to the area of the company. The most suitable could be the ones with a high recycling rate but low population density.

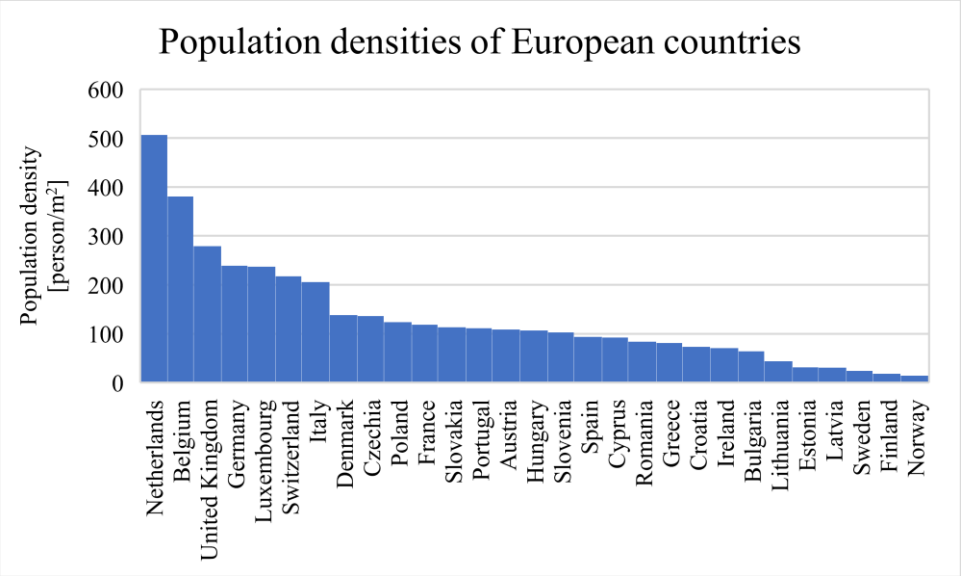

Figure 5. Population densities in European countries in 2019. (United Nations 2019)

It can be seen from these figures, that Nordic countries are important to pay attention in this research. They are sparsely populated, except Denmark, and in the recycling rates- listing, they are in the top 15 countries in Europe. Especially Sweden has a remarkably high recycling rate when compared to Finland and Norway. Nordic countries' advantages in this inspection are also the similarity in the circumstances. Also, Lithuania has a high recycling rate but also is a relatively sparsely populated European country, just like Sweden. Then again, Austria and Slovenia are in the top of the recycling rates in Europe and the countries are middle in the population density list. Even though Germany has the highest recycling rates in Europe, the population density is relatively high. It must be noted, that these figures give the information only nationally. There might be inside compared countries areas, that have a high recycling rate and a low population density, even if the national averages are not suitable for the research.

5 PRESENTING THE CHOSEN MUNICIPAL WASTE MANAGEMENT SYSTEMS

In this chapter, five waste management systems used in Europe are presented. The biggest choices in planning the waste management system are that how ready-made the system is for customers and how near the waste management is for the customer. Kerbside collection means that the waste is collected at the kerbside and the customers bring the waste itself to the kerbside containers. This concept includes, that the waste is picked up from the customer, and the customer needs to only throw the waste to own outside household waste container or the garbage room in the block of flats. (Pires, Ana et al. 2019, p.31.)

There is also a possibility, that waste is collected in smaller bags or boxes, carried to the kerbside in the morning of specified collection day, and carried back to the household in the evening after they are emptied. (Pires, Ana et al. 2019, p.31.) There might be a combined collection of recyclables in the kerbside collection system as well. That is called co-mingled collection. Recyclables are separated in the waste treatment plant. Usually, there is a separate collection of residual waste and biowaste as well. (Seyring, N. et al. 2015.)

Optical sorting concept refers to kerbside collection, where different waste fractions are sorted to different coloured bags and collected in outside household waste container (Sörme, L. et al. 2019). Multi-container concept means, that the kerbside waste container includes multiple compartments for different waste fractions. There can be also two containers, which are divided for different waste fractions and collection frequencies. Recyclable waste collection is also arranged in kerbside in this concept. Drop-off system means, that the customers need to transport the recyclable waste by themselves to the recycling station or recycling point. This usually includes mixed waste collection in kerbside from each household. (Pires, Ana et al. 2019, p.31.)

Neighbourhood concept refers to a system, where waste collection is arranged in central places in neighbourhoods and each household delivers its waste to the shared collection point. Neighbourhood collection point includes separate containers for different recyclables,

biowaste, and residual wastes. There is no kerbside collection from each household and distance to the collection point is usually under 100 meters. (Pires, Ana et al. 2019, p.31.) PAYT-concept refers to a waste management billing system, which is based on the polluter pays- principle. Different waste fractions are priced differently, and residual waste is the most expensive. (Morlok, J. et al. 2017, p.1.)

5.1 System 1: Optical sorting

The first waste management system presented here is the optical sorting. The example of this system is coming from right outside the Finnish borders, Sweden. The City of Eskilstuna is located about hundred kilometres west from Stockholm. The City of Eskilstuna has a population of 110 000 and the amount of waste produced in a year is 18 000 tons. (Envac Optibag Ab 2018, Hellström, M. 2020.) The amount of combustible waste has reduced 54 % from 2010 when the optical waste sorting system started to work. (Eskilstuna Energi och Miljö 2019). 50 % of biowaste separation was achieved already in 2011 (Eskilstuna Energi och Miljö 2018b).

According to the Environmental Manager of Eskilstuna Energi och Miljö, Hiltula, V. (2020), the current municipal waste recycling rate in Eskilstuna is 55 %, where 30 % is biodegradable waste recycling and 25 % is packaging waste recycling. Recycling rate development was fast for the first three to four years after optical sorting was applied and it achieved 40 % rate. After that, a slower, but positive increase every year. The most important thing in achieving this high recycling rate was that the collection of wastes and specifically recyclables became more closer to the customer with the new system. The recycling rate may not be completely accurate, because they don’t manage the recycling stations of Förpacknings & tidnings insamlingen (later FTI) and don’t know how much waste is recycled through these. FTI is a Swedish extended producer responsibility organisation.

The optical colour sorting system was chosen because of the simplicity to the customer to recycle. It is also flexible and minimizes the environmental effects and is energy efficient. The system is adjustable because the addition of new waste fraction is easy and only change needed is in the camera system. (Envac Optibag Ab 2018.)

5.1.1 Legislation and system management

Eskilstuna Energi och Miljö has the responsibility to manage municipal mixed waste and biowaste in the area. The packaging waste and paper collecting with coloured bags are extra services of the municipal energy and environmental service company, Eskilstuna Energi och Miljö, in Eskilstuna. The papers and packaging waste can also be transported to the FTI recycling stations by the customer. (Eskilstuna Energi och Miljö 2019.)

The extended producer responsibility organization is FTI in Sweden. It works as the same organization as Suomen Pakkauskierrätys RINKI Oy in Finland. FTI has the responsibility to make sure that the packaging materials (metals, plastic, glass, and paper/cartons/liquid board/corrugated cardboard), newspapers, tires, electronics, batteries, and medicines are collected and recycled properly. FTI has 46 unstaffed recycling stations for packaging waste, newspapers, and batteries in the area, which they manage themselves. These stations are for short-term storing of waste (FTI 2020, Hiltula, V. 2020). In Eskilstuna, the collection of packaging waste and newspaper is managed by Eskilstuna Energi och Miljö through optical sorting and they transport the collected recyclables further to FTI. Non-recyclable plastics are disposed through incineration or collected at the recycling stations for reuse possibilities. (Eskilstuna Energi och Miljö 2019c.)

5.1.2 Logistics and technologies

The optical sorting facility is made by Envac Optibag Ab and owned by Eskilstuna Strängnäs Energi och Miljö Ab. The same Optibag system is used also for example in Oslo and Tromso in Norway and Linköping in Sweden. The waste is source-separated and sorted to the seven different colour bags. The system logistics concept is the pick-up kerbside collection. Source separated waste in coloured bags can be thrown to the outside household waste container and the waste disposal is managed without customer transporting recyclables anywhere. Food waste goes to green bags, textile waste to pink bags, plastic packaging to the orange bags, paper/cartons/liquid board/corrugated cardboard packaging to the yellow bags, newspapers in blue bags, metal in grey, and residual combustible waste in black bags. (Envac

Optibag Ab 2018, Eskilstuna Energi och Miljö 2019.) The optical colour sorting system of Envac Optibag Ab is presented in figure 6.

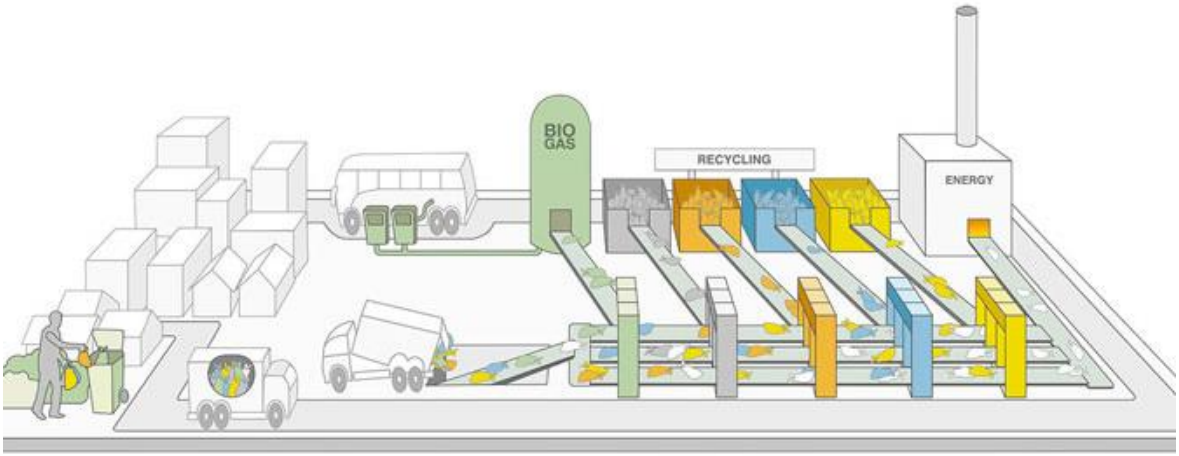

Figure 6. Optibag optical sorting facility (Envac Optibag Ab n.d.)

The glass fraction is not recycled through the optical sorting system, because glass can crash and break the plastic colour sorting bags. Glass is also heavy and bulky, which makes it problematic to store and empty the container. Glass is recycled through FTI recycling stations or Eskilstuna Energi och Miljö waste recycling centres. Also, hazardous waste is not collected through the optical sorting system. Hazardous waste is collected and treated at the recycling centres. The local energy and environmental service company offers for the customers hazardous waste boxes for free, where they can store them at home. (Eskilstuna Energi och Miljö 2019.)

According to the recycling manager of Eskilstuna Energi och Miljö, Hiltula, V. (2020), non-recyclable, residual waste in Eskilstuna is incinerated. The waste is collected through colour sorting system and transported to the incineration plant outside the municipality. In the incineration plant, metals are sorted out of the waste. Residual waste is only fraction mechanically sorted, other fractions are source-separated and recycled. Recyclable waste fractions are sold and transported to FTI after they are colour separated, opened and the quality checks are made. (Hiltula, V. 2020.) FTI's system in Eskilstuna is an older recycling system than optical sorting. That is why some of the citizens have accustomed to using it instead of optical sorting. Some citizens may not have the possibility at home to sort every waste fraction or are not in a place, where colour sorting system is applied and therefore

prefers the FTI recycling points. Both part-time households and permanent citizens can use the optical sorting system. (Hellström, M. 2020.)

The requirements for the plastic bags are good quality and durability. (Eskilstuna Energi och Miljö 2019.) Bag quality is high in the system. There are specified quality requirements for the bags in Eskilstuna. These requirements include strength, thickness, extensibility, colour, and size. There haven't been many problems with breaking bags in the system (Hiltula, V. 2020, Hellström, M. 2020). In the colour sorting process, the bags are opened in a bag ripper and sorted out by hand. After sorting out of waste material, the bags are combined with plastic waste fraction and recycled to new plastic products in the plastic recycling industry. Only food waste bags are disposed through incineration. (Hellström, M. 2020.)

There are two waste recycling centres for waste collection, treatment, and storage around Eskilstuna. The Lilla Nyby is in the south of the city centre. The colour sorting facility is in Lilla Nyby. Customers can also bring here waste, that cannot be recycled or disposed through the optical sorting system. There are places for all kinds of household wastes, but also for bulky, garden, non-recyclable, WEEE, construction and demolition, hazardous and textile wastes. Customers can also leave items, that they don't need anymore, to be transported to ReTuna recycling galleria and buy soil materials in the Lilla Nyby recycling centre. (Eskilstuna Energi och Miljö 2016b)

ReTuna is the other recycling centre around Eskilstuna. Customers can carry there their sorted household waste, but also non-recyclable wastes, construction and demolition waste, hazardous waste and textiles, wood materials, glass, and tires. There are also deposit recycling machine for bottles. Customers can leave their unwanted but still valuable items and clothing to the recycling galleria. Items will be checked, revised, fixed, if necessary, and sold at the recycling gallery. ReTuna recycling galleria is a small mall for recyclable and reusable materials and products. It includes fourteen companies with different activities, shops, cafés, and exhibitions. The products in the gallery are second hand, organic, or sustainably produced. (Eskilstuna Energi och Miljö 2016c.)

Textile collection is arranged through the colour sorting system, but customers can also bring textiles by themselves to the recycling centres. Usable textiles can be fixed and sold at the ReTuna recycling gallery. At first, they are sorted roughly in the municipality by human workforce, where heavily wet or dirty textiles are separated off. If a company in the municipality wants some textiles, the workers will sort that kind of textiles out for the company. That way the materials stay in the municipality. Leftover textiles are transported to Germany, where they are sorted by category and quality, packed, marked and sold further. Textiles are used as it is or recycled to insulation, fibres, or tatters. The textile collection started in Eskilstuna in 2017. The textile collection rate is about 500 bags/day in Eskilstuna. That is about 13-15 tons/week. Customers can leave also broken clothes in the recycling centres, they will be fixed and sold or recycled otherwise. (Eskilstuna Energi och Miljö 2019b)

Biowaste is collected from the household in green bags in Eskilstuna. Biowaste bags are opened and plastics are removed in the recycling centre. Biowaste is watered to slurry to make it easier to manage. It will go through processes, where the non-biodegradable parts (packaging materials, bones and shells) are taken away. The amount of processed biowaste is about 8500 tons/a. Biowaste is then sent to the biogas plant. Residuals from digestion process are used for fertilizer production. Eskilstuna Energi och Miljö have also another digestion plant, where is processed sewage sludge, but the residuals from there cannot be used for fertilizing, because of legislation. (Eskilstuna Energi och Miljö 2018b.)

5.1.3 Customer perspective and economics

The municipality of Eskilstuna had to invest almost two million euros to build ReTuna, the recycling gallery and to afford subsidies for the business owners in the mall (Kalia, 2019). The optical sorting plant cost 40 million SEK, which is about 3,8 million euros. There was no financial support to build the optical sorting plant. Though, they have incomes from selling the recyclables to FTI. The waste management fees were increased approximately 10 euros in the year when the optical sorting plant came. (Hiltula, V. 2020, Hellström, M. 2020.)

In Eskilstuna, the customer gets the coloured bags from the local energy and environmental service company for free. When the bags are finished, the customer needs to hang one of the bags of the colour they need into the mailbox and the postman will bring the new package of the specific coloured bags. Customers can pick up the bags also from one of the recycling centres or the head office of Eskilstuna Energi och Miljö. In a detached house household, customers need to sort the waste into the right coloured bag and, when the bag is full, tie it with a double knot and throw it into the waste container. (Eskilstuna Energi och Miljö 2019.) The waste is collected every other week according to the waste management fees (Eskilstuna Energi och Miljö 2018.) The collection day can be changed on the customer's account in My Pages. There are different choices of subscriptions, container sizes and collection frequencies available. (Eskilstuna Energi och Miljö 2016a.)

In a block of flats, waste management is organised with colour-sorting or with a separate collection of different waste fractions. The owner of the residential building decides the waste management. The owner is responsible to offer waste management for at least biowaste and mixed household waste. There can also be both systems. In this case, the sorting room includes containers for colour sorted bags but also separate containers for the collection of different fractions. The colour-sorting bags are given by the property manager or the owner of the property. The glass waste and hazardous waste can be collected at the properties sorting rooms or at the recycling centres. (Eskilstuna Energi och Miljö 2018a.)

The waste management fees in Eskilstuna is formed of a fixed and variable fee. The fixed fee includes costs of administration, guidance, recycling, and treatment of hazardous and bulky waste from households. The variable fee includes the costs from containers, emptying the containers, sorting and treatment of the household waste. Collection frequency, size of the container and amendments changes the variable fee. (Eskilstuna Energi och Miljö 2018.)

The fixed fee is approximately 180 €/a. The variable fee is for 190-litre containers 95 €/a approximately and for 370-litre containers 285 €/a approximately. Containers are emptied every other week. (Eskilstuna Energi och Miljö 2018.) For a single-family household, the waste management fee is approximately 200 €/a in Sweden (Avfall Sverige 2018). It is assumed that a smaller container is used more often. Therefore, the fee for the single-family

household waste management in Eskilstuna is approximately 275 €/a. For bigger containers, it is approximately 465 €/a. It can be concluded that the waste management fees are a bit higher compared to the fees of other waste management companies in Sweden.

The fee for a holiday home is per 190-litre container, emptied every other week, total ten times, 40 €/a for colour sorted waste and for mixed unsorted waste, 330 €/a. Total five times, the fees are 20 €/a for colour sorted waste and 250 €/a for unsorted. Fee for one emptying of the container is 7,5 € for sorted waste and 22 € for unsorted. The fixed fee is added to the fees for holiday homes also. Also, if the wastes are unpacked or sorted wrong, there is a punishment of 19 €. (Eskilstuna Energi och Miljö 2018.)

It can be seen from the waste management fees, that it is more expensive for the customer to not use the colour sorting system. It also works for an incentive to customers in the area to recycle and sort more. Also, the customer can have the colour sorting plastic bags for free and they are brought to the household without any bother to the customer, which is simple and easy for the customer. If the wastes are not sorted properly, it causes an extra fee to the customer.

Eskilstuna Energi och Miljö provides customers also the collection service of bulky items if the customer doesn’t have a chance to bring them to the recycling centre. The collection of bulky waste is organized twice a year and it is free. The collection is organized in areas specified in advance and the customer needs to make a phone call to the service number to arrange the meeting. They also offer a pick-up service for larger amounts of bulky waste for free at any time. (Eskilstuna Energi och Miljo 2016d.) All in all, the whole system is made the easiest possible for the customer to recycle. The customer doesn’t have to transport itself almost anything to anywhere and even the collection of bulky waste is arranged, new waste colour separation bags are free and are carried to inhabitants’ post box for free.

5.1.4 Environmental aspects and progressiveness of the system

In Eskilstuna, the biogas produced from biowaste and sewage sludge is used in the local buses, garbage trucks and municipal service vehicles, but also for a few private biogas car

owners. The price for the biogas is 18,50 SEK/kg, which is about 1,8 €/kg. The biogas produced covers a third of the demand in the municipality. The rest is bought outside as natural gas. (Eskilstuna Energi och Miljö 2020.)

According to Hiltula, V. (2020) there are only 2 % of the detached houses that are not included in the optical sorting system. There are also some that in theory are taking part in optical sorting, but in practice, they don't follow the rules of it. Next year, the optical system is mandatory for every households and they can also give fines if a household does not sort properly. The biggest reasons for not taking part in the optical sorting and resistance for it is that there are no proper sorting places at homes. For most of the citizens, recycling and source separation at homes were already familiar and that is why there were not big resistance when the system came.

The system is optimal for lazy people because almost everything is collected straight from households. People are more likely to recycle with this system and waste sorting accuracy is more than 97 %. According to the manager of the ReTuna recycling gallery, the idea of a mall, where everything is recycled, second hand or organic, did not get good welcome among the citizens. The people in Eskilstuna prefers functionality over sustainability. Afterall, since the day the mall was opened and the new recycling system come into force, it has been a great success in the town and the citizens are proud of it. (Kalia, A. 2019.) The changes in the waste management system, ReTuna and increase in the circular economy in the town has also changed the citizens' attitudes towards sustainability. (Hiltula, V. 2020.)

Solving the challenge of waste management and to change people's minds needs politics with sustainability-oriented minds and better knowledge. New waste management system and the kind of recycling gallery and optical sorting plant used in Eskilstuna needs free space (Kalia, A. 2019). The new waste management targets set by the EU and changes in the legislation forces countries to make remarkable changes in the waste management systems. Eskilstuna is a good example of how brave and big changes were made to achieve big changes in waste management, even though the idea did not get a very warm welcome at first among the citizens.

5.1.5 Experiences from other users

In Finland, there have been several experiments about optical waste sorting. These have been at least in Ab Ekorosk Oy in Central Ostrobothnia and Kiertokapula Oy in Southern Finland. Both companies have already moved on to another waste collection system. In Ekorosk, the system was used from the 1990s to 2017. The system was too old and needed bigger investments to maintain it. Therefore, it was changed to separate collection of biowaste and residual waste. (Ab Ekorosk Oy 2018.) The company have also had difficulties with the coloured bags durability. 40 % of the bags were reported to be broken when the waste arrived in the sorting plant. Therefore, the sorting didn't succeed, and the waste quality dropped. (Ab Ekorosk Oy 2017.) Kiertokapula Oy started the optical sorting in 1998 and the system was stopped in 2005. (Kiertokapula 2013)

Ekorosk's plant in Pietarsaari was the first optical sorting plant in Finland. The waste was sorted to dry and wet waste. Wet waste was for biowaste and dry waste for different recyclables such as cartons, paper and plastics. Wet waste was collected to black bags and dry waste to white ones. Wet waste was further transported to biogas plant and recyclables were separated from the dry waste. In the wet waste, there was also, at first, separation of non-biodegradable compounds and the shredder separated the plastic bag from the biowaste material. (Tuovinen, H. 2002, p.32.)

In Swedish research made by Sörme, L. et. al (2019, p.3-4) was founded, that the residual waste amount decreased 15 %, with the source separation to different coloured bags. Then again, the amount of food waste was increased by 35 % with source separation to coloured bags. The inhabitants in the area, where the research was made, had differentiating thoughts about the colour sorting system they tested. Most of them thought it worked well, but some stated that there was too little space in the household for different waste fractions, or the cardboard packaging did not fit into the bag and there were too many different bags. More positive comments in the research were that the recycling was easy and educational.

5.2 System 2: Kerbside collection

Next municipal waste management system invested in this study is kerbside collection. In this situation, different waste fractions are carried out in their boxes or bags to the kerbside in the morning of the collection day. Waste is collected individually and separately from each household and emptied to multiple container waste trucks. It founded out to be problematic to find a municipal waste management system that works only with kerbside collection and not combined with a co-mingled collection of recyclables and treatment plant separation. After all, it was found out, that there is a separate municipal kerbside waste collection system in the United Kingdom, Wales. Even though the United Kingdom is not in the top of the recycling rates in Europe and neither in the lowest part in population density, it includes many different areas with different characteristics and Wales suits well in this study. At the end of this part, there is also a review on the study made in Finland about separate kerbside collection of waste.

The population density in Wales is 151 persons/km^2 (Welsh Government 1991). The recycling rate in Wales is the highest in the United Kingdom with the rate of 57,6 % in 2017 (Government Statistical Service 2019, p. 3). More specifically, the waste management system presented here is the system in Flintshire, where the recycling rate was 68,7 % in 2019 (Welsh Government 2012a). The amount of waste collected in Flintshire is approximately 85 000 tons/a. It includes also waste from commercial and industrial sources. The household waste amount is 65 000 tons, where recycled or reused waste amount is 23 000 tons and composted 13 000 tons. That means, that the recycling rate of household waste is only 54 %. (Welsh Government 2012b.) It is not clear, which of the sources in the statistics includes the waste from municipal activities, such as waste from schools. It was not able to track, what kind of treatment methods and sources are included in the higher recycling rate of Flintshire and therefore, the lower recycling rate is more trustworthy.

5.2.1 Legislation and system management

Wales invests a lot in the waste management and The Welsh Government has set Statutory Recycling Targets to increase the circular economy in Wales. Local authorities must achieve

the targets to prevent fines. The Welsh Government have made a strategy in 2010 called Towards Zero Waste to increase the circular economy and Waste improvement program to improve the waste management and efficiency of local authorities. The local authorities have the responsibility to arrange the waste management in its area and there are no separate, public-owned waste management companies there. The Welsh local government association supports the local councils to achieve the targets by providing benchmarking information and knowledge of good practices. (The Welsh Local Government Association, n.d.) In 2019 the Welsh Government made new circular economy strategy, Beyond Recycling (Welsh Government 2019).

The target set in Towards Zero Waste- strategy is to be zero waste by 2050. 70 % of municipal waste must be recycled by the end of 2024. Rest of the waste, 30 %, must be treated efficiently in a waste-to-energy plant. The local councils are achieving this by reducing the collection of residual waste and promoting the use of eco-packaging and packages with fewer materials and resources. The main improvements should be done in waste preventing and reuse, after these, recycling, and material recovery. The most important thing is to avoid waste going to landfill. (The Welsh Local Government Association, n.d.)

In Wales, the separate kerbside collection of different waste fractions is compulsory for the municipalities. The Welsh Government published a standard in 2011 about the waste collections, Welsh Governments Collections Footprint. The standard obligates the municipalities to collect biowaste, paper, metal, plastic, and glass separately. (Welsh Government 2015, p.22) Flintshire county has its' own waste management strategy, which was made in 2009. It is supposed to serve until 2025. The recycling rate increased after implementing the strategy from 40 % to the current 68,7 %. (Flintshire county council 2009 and 2020g.)

5.2.2 Logistics and technologies

In Flintshire, the waste is collected from the kerbside. The customers are obligated to carry the wastes from inside the household to the kerbside by seven o'clock in the morning when they have the waste collection day and ensure the possibilities to empty the wastes. Waste

truck drivers empty the bags to the right container and return them to the place, where they had been taken off. Garden waste is not collected through year, only from March to November, because there is no need for collecting in the winter season. (Flintshire County Council 2020a.)

Collection of recyclable materials in Flintshire is organised in four containers. The containers are in figure 7. The recyclable containers are emptied once a week. The blue box is for glass, blue bag for cartons, cardboard, and paper. Metals, plastics, and liquid packaging boards/waxed cartons go to grey sack. The small grey bag is for household batteries. Food waste is collected once a week in a green caddy. Recyclable waste and biowaste are collected with the same waste truck. Residual waste is collected fortnightly and sorted to black bins. Garden waste is collected fortnightly and sorted to brown bin except in wintertime. (My Recycling Wales 2020, Flintshire County Council 2020h.) Multiple container trucks for biowaste and recyclables collection is presented in figure 8.

Figure 7. Waste containers and bags (Flintshire County Council 2020h).

Figure 8. Waste collection trucks in Flintshire (Randall, L. 2020).

There are five household recycling centres around Flintshire. The recycling centres are manned and open almost every day throughout the year. Centres are for storing and treatment of waste. Besides recycling household waste, also wood, rubble, soil material, asbestos and hazardous waste can be recycled or treated in household recycling centres. Additionally, there are 23 local bring banks near shops and pubs in Flintshire, where residents can recycle their TetraPaks, small WEEE and textiles. These are for waste storing and unstaffed. Citizens can also donate their household stuff, good quality bulky waste they do not need any more to the local community through Refurbs Flintshire or charity shops. These sell the equipment and furniture further to the people in need with low prices. Refurbs Flintshire can collect the reusable, good condition bulky or household waste from households' doorsteps for free. (Flintshire County Council 2020c.)

Garden waste is collected from the customers in the kerbside collection system, even though the municipalities in Wales does not have the responsibility to do it. It costs approximately 37 € per one emptying if paid early, the late paid standard fee is approximately 41 €. The collection of garden waste is a service that the municipality must have a fee with. Treatment of garden waste is free when it is transported to the recycling centre. Garden waste can also be composted at the house. Garden waste is collected every other week. One garden waste bin cost about 35 €. The bins must include a tag to ensure that the collection of the waste is paid. Otherwise, the waste truck drivers will not empty the bin. (Flintshire County Council 2020b.)

Glass fraction is transported to treatment plants in England. Over half of the metals collected in Flintshire are exported outside the UK to Spain and different countries. The rest is treated in Wales or England. Biowaste is treated inside the UK, mostly inside Wales. 60 % of paper waste is exported outside the borders of the UK, mostly to Indonesia, the rest 40 % is treated in Wales or England. Plastic materials are mostly treated inside the UK, only 15 % is exported to Indonesia or India. Inside the UK, plastics are treated in different places. 49 % of textile waste from Flintshire is exported to Germany, the rest is treated inside the UK, in Wales and England. WEEE is going to treatment plants in England and inside Wales, none of it is exported to other countries. (My recycling Wales 2020) In Flintshire, garden waste is composted into nutrient-rich soil in one of the household recycling centres. Residual waste

from black bin collections is incinerated in Parc Adfer waste-to-energy facility in Flintshire. (Flintshire County Council 2020i.)

5.2.3 Customer perspective and economics

Residents of Flintshire can have free of charge the waste recycling bins to the household. Black and brown wheeled waste bins are transported straight to the household, but others need to be picked up from recycling centres, connect centres or community centres. Residents can request new waste boxes, bags, and containers in the county council websites before picking them up. The residents can have more food waste bags via waste collection by tying one bag in the handle of the biowaste container. Residents in need of help with picking up the containers, boxes and bags or moving the waste to kerbside on the collection day can request for extra help from the county council. (Flintshire County Council 2020d.)

Flintshire encourages residents to recycle with economic incentives. A resident can have a fine, if he or she leaves side waste beside waste containers or if the bin cannot be closed. At first, the waste workers will visit the resident to advise about sorting and recycling and if it is ignored, the 87 € fee must be paid. Households with six or more occupants can have larger waste bins. (Flintshire County Council 2020f.) Waste management, like most of the public services in Flintshire, is financed with council tax. Therefore, the collection of household waste is free of charge for the residents of the municipality. Residents of other municipalities cannot dispose or recycle waste through the waste collection system. (Flintshire County Council 2020b.) Bulky waste collection is arranged in the area with pick-up collection. Fridges and freezers are collected free, but other waste with a fee. A resident can have a discount for collection bulky waste, for example, if he or she has some income support or is unemployed. (Flintshire County Council 2020e.)

5.2.4 Experiences from other users

There has been an experimental study on how the separate kerbside collection would fit into the circumstances in Finland. The study was made in cooperation between Sustecon Oy and Rosk’n Roll Oy Ab waste management company in years 2017-2018 by authors Hedman Å.

et al. (2018). Even though the idea in this waste collection is not the same as in the system in Flintshire, they have many similar aspects. This system, which was tested in Finland, refers to a multi-container, pick-up, kerbside collection system. Rosk'n Roll have offered its' customers multiple waste fraction collection already from the year 2013. The service includes cardboard, glass, metal and residual waste with one multiple fraction container. The service is used by approximately 800 households in the area. (Hedman, Å. et al. 2018. p.4)

The study aimed to offer better possibilities and services for recycling for single-family households and to find solutions to increase the recycling rate. There were 190 households, who attended in the test. The waste was collected individually from every household in 10 different waste fractions. The waste fractions were residual waste, biowaste, plastic, metal, glass, cardboard, paper, textile, small WEEE and batteries. During the test, textile, WEEE, batteries and paper was cut out from the collected fractions. This change was made based on the feedback they got from the customers. The effects on greenhouse gases were also calculated in the survey. The results showed that greenhouse gases were even three times lower in the new system. The system also generated better quality waste material. (Hedman, Å. et al. 2018. p. 3-4)

The system included two waste container which included smaller compartments for different waste fractions and small individual container for WEEE and batteries. Container 1 included residual waste, plastic, metal, and glass fractions. Container 1 was emptied every fourth week. Container 2 included waste fractions of biowaste, cardboard, textile, and paper. Container 2 was emptied fortnightly. Small container for WEEE and batteries was attached to the containers when it was full. The container size was 360 litres, where residual and biowaste had 120 litres containers, plastic 180-litre container, cardboard 165-litre container, paper 45-litre container and metal, glass and textile fractions 30 litres containers. The waste management fee for the collection was 28 €/mo. The test could not be financed only with the waste management fees and there was extra financial help from the Finnish Ministry of Environment and the research and development financing of Rosk'n Roll Oy Ab. Rosk'n Roll transported the waste containers to the customers also. The waste was collected with multiple waste container trucks (Hedman, Å. et al. 2018. p. 5-6)

The customers' thoughts about the test were that the offered recycling service was useful, but the collection of some waste fractions was worthless. Worthless waste fraction to collect was textiles, WEEE and batteries. The most important fractions to collect were plastics, residual and cardboard. Almost half of the customers, who attended the test, said they wouldn't be willing to pay more about the service. (Hedman, Å. et al. 2018. p.7).

Transportation and collection the waste took more time than normally. Also, emptying the containers took more time because there were more individual containers to empty. The households were not located near each other, and it caused inefficiency in the collection. Also, the sorting and weighting the waste in the waste management centre took more time than usually. The results from the new waste management system were, that the amount of residual waste amount decreased. The residual waste also included less biowaste, paper, cardboard, and wood-based materials than normal mixed household waste without separate collection. (Hedman, Å. et al. 2018. p. 8-9)

Source-separation rate raised to 78 % and recycling rate to 64,6 %. The most important fractions in increasing the recycling rate were biowaste (31,8 % increase in recycling rate), paper and cardboard (17,7 %) and plastics (5,6 %). Next comes glass with 4,1 %, textiles with 2,9 % and metals with 1,9 % increase. (Hedman, Å. et al. 2018, p. 13, 14) Even though the transportation and treatment costs were bigger in multiple waste collection system, the overall emissions in carbon dioxide equivalents were lower. That is because of avoided emissions from using virgin material. (Hedman, Å. et al. 2018. p. 17.)

Rosk'n Roll decided to form a new service model to increase the recycling rate and improve the recycling possibilities in single-family household areas. The containers include one container for recyclable materials: glass, metal, plastics and cardboard and it is emptied once in eight weeks. The second container for residual waste with or without biowaste container was emptied fortnightly. The monthly fee for this service was decided to be 28 €. (Hedman, Å. et al. 2018. p. 11-12)

The conclusions of the study were that separate collection of waste and better possibilities for households recycling is important when trying to increase the recycling rate. It was noted

that the environmental knowledge and enthusiasm might have affected positively in the results because the participants had enrolled themselves in the test. Other aspect noticed was that customers attitude towards recycling is still more like service to the environment than one's responsibility to take care of the waste, that he or she makes. Customers are willing to recycle more if it doesn't cost any extra compared to only mixed waste collection. (Hedman, Å. et al. 2018. p. 20)

Also, other studies have showed, that pick-up collection of sorted household waste fractions is an efficient way to increase the recycling rate in the municipality. The system in Flintshire and multi-container system in Finland are pick-up collection systems. Swedish study made by Dahlén et al. (2006, p.1300-1301) researched six different municipalities with different waste collection schemes. They found out, that the municipalities, which afforded separate pick-up collection for common household waste fractions, achieved the biggest waste separation rate. Then again, the municipalities, which afforded only pick-up collection of residual wastes, performed the worst in waste separation.

The research made in the Netherlands by Goorhuis, M. et al (2012) concluded that the plastic packaging collection increased when the pick-up collection for plastics was arranged. One Portuguese study made by Martinho et al. (2017) researched two systems and their waste separation rates. They found out, that in the system with drop-off collection, they had 23 % higher amount of residual waste than in the pick-up system. Martinho et al. (2017) found out that there is a correlation between distance to the recycling point and the amount of separated recyclable waste. Lower distance to the recycling point and higher density of the recycling points increased the amount of separated recyclable waste.

5.3 System 3: Co-mingled collection

The third waste management system presented here is co-mingled kerbside collection in Ljubljana. Ljubljana and Slovenia represent the part of Europe, that has developed later but faster. The total area of the waste management system is approximately 1000 km^2 and it includes 11 municipalities with 400 000 inhabitants. The amount of waste produced in the area is 100 000 tons/a. (Oblak, E. 2019.)

The system in Ljubljana is operated and maintained by the public, local waste management company Javno Podjetje Vodovod Kanalizacija Snaga d.o.o., which is abbreviated to Voka Snaga. Slovenia introduced the new waste management plan after it became a member of the European Union in 2004. Because of the EU legislation and targets to reduce amounts of waste, it had to solve the waste problem otherwise than landfilling everything. The separate collection of the waste ensured that waste management was improved, and the recycling rate rose. (Oblak, E. 2019)

The municipal solid waste source separation rate and recycling rate was 68 % in the area in 2018. The change in the waste management system lead to 95 % decrease in waste disposal. The total waste production amount also decreased by 15 %, even though Ljubljana already had 31 % lower waste production compared to the average in the EU. In 2002 Voka Snaga started the separate collection of recyclables in eco-islands and residual waste collection in kerbsides. Eco-islands are similar to the Finnish unstaffed eco-points, the customers can carry source-separated recyclable waste fractions for free there and the waste management company collects the waste from there for further processing. During the years, separate kerbside biowaste collection started and the collection of recyclables was transferred from eco-islands to kerbside collection in detached house residential areas. Later, eco-islands were named as ecological collection sites. The rise in the waste fractions picked up from the kerbside in Ljubljana increased remarkably the recycling rate. Especially remarkable was the collection of biowaste. (Oblak, E. 2019.)

5.3.1 Logistics and technologies

People living in detached household residential areas have kerbside collection for separately collected fractions. Packaging plastics, metals, liquid packaging boards and TetraPaks are collected in a container with a yellow lid. Newspapers, magazines, paper, carton, and cardboard packaging are collected in a container with a blue lid. Biowaste and garden waste is collected in a brown bin. Residual waste is collected in a black bin. (Vodovod Kanalizacija Snaga, 2019g, 2019h and 2019i, 2019f.) In sparsely populated areas, the collection of residual waste is once in every three weeks and in densely populated areas once a week.

Recyclables are collected more often. This caused a rise in a recycling rate because customers didn't want the wastes to lay around weeks. (Oblak, E. 2019)

There are also unstaffed, ecological collection sites for short-term storing of recyclables: a container with blue, yellow lid and green lid. Container with the green lid is for glass fraction and other lids refers to the same waste as in kerbside collection. These are for all customers and not located in the city centre area, where waste is collected in underground containers. The ecological collection sites are like the eco-points in Finland. Ecological collection sites are presented in figure 9. Then there are mobile collection unit and collection campaigns for bulky waste. The mobile collection unit is for short time storing and collection of hazardous waste and WEEE. The mobile collection unit is manned and used also for guidance and customer service. Mobile collection unit is in the city centre area and open from spring to autumn in specific opening times. (Vodovod Kanalizacija Snaga, 2019b, 2019d and 2019j.)

Figure 9. Ecological collection sites of Voka Snaga (Vodovod Kanalizacija Snaga 2019j).

In densely populated city-centre area, the waste management is arranged in underground garbage bins, that are opened with a free, customer-specified card (Dakskobler, L. 2019). The underground waste containers in the city centre area are presented in figure 10. There are five different bins in the underground collection system; green is for glass, yellow for

packaging (plastics, metals, liquid packaging boards and TetraPaks), blue for newspapers, magazines, paper, carton, and cardboard, black for residual wastes and brown for biowaste. Glass, packaging and paper containers are open for everybody. There are 67 underground collection units in Ljubljana nowadays. Voka Snaga tries to achieve the maximum distance to the waste collection unit to be under 150 metres. (Vodovod Kanalizacija Snaga, 2019c.)

Figure 10. Underground waste collection containers in the city centre of Ljubljana (Vodovod Kanalizacija Snaga. 2019c).

There are eight manned waste collection centres, where the customers can bring the wastes that are not collected through kerbside collection or underground containers. Hazardous waste, metals, plastics, WEEE, garden waste, construction and demolition waste, tires, wood materials and products, bulky waste, clothes, and textiles, can be recycled in collection centres. The customers can also order a collection of bulky waste once a year from home. (Oblak, E. 2019.) Waste disposal in collection centres is free under specified amounts (Vodovod Kanalizacija Snaga, 2019a). Barje collection centre also includes a vending machine for packaging-free household basics, such as soap. Products that are in good condition, but the owner wants to give it away, are checked for reuse possibilities. They are cleaned, fixed, and sold to the new customers. Voka Snaga also arranges workshops for citizens to fix their products. (Dakskobler, L. 2019.)

Voka Snaga did not want to build an incineration plant for disposing of residual waste. Instead, they decided to invest in material recovery and biological treatment plant, MRBT plant. Building the RCERO, Regional Centre for Waste Treatment and Recovery, cost 155

million euros. It was funded by the EU Cohesion Fund for 77,5 million euros and the rest was financed by central government, local budgets, and waste disposal charge. (Spasic, V. 2019.) The MRBT plant RCERO Ljubljana started to operate in 2016. Only 5 % of residual waste is disposed in a landfill. (Oblak, E. 2019.) RCERO plant is one of the largest in Europe. It can process 170 000 tons/a waste, which 150 000 tons is mixed municipal waste and 20 000 tons separately collected biowaste. It serves 1/3 of the Slovenia and 43 municipalities and it is not only for Voka Snaga. (Spasic, V. 2019.)

RCERO includes expanded landfill, leachate treatment plant and waste recovery facilities. RCERO plant from outside is presented in the figure 11. Waste recovery facility includes processes for separately collected biowaste and residual mixed waste. Biowaste is processed to produce compost in anaerobic fermentation and gas from the fermentation process is used to produce electricity and heat, that is used to operate the plant. (Spasic, V. 2019.) Mixed waste is sorted mechanically to plastics, paper and cardboard, aluminium, other metals, and iron. All separated fractions are transported to further processing and remaining mixed waste is used as fuel. (Sankovic, N. 2017.) Waste-based products and production amounts in RCERO plant are presented in the figure 12.

Figure 11. RCERO Ljubljana. Biowaste recovery processes are situated in orange and yellow coloured parts in the facility and mixed waste sorting and treatment processes in blue and green coloured parts. (Vodovod Kanalizacija Snaga. 2019e.)

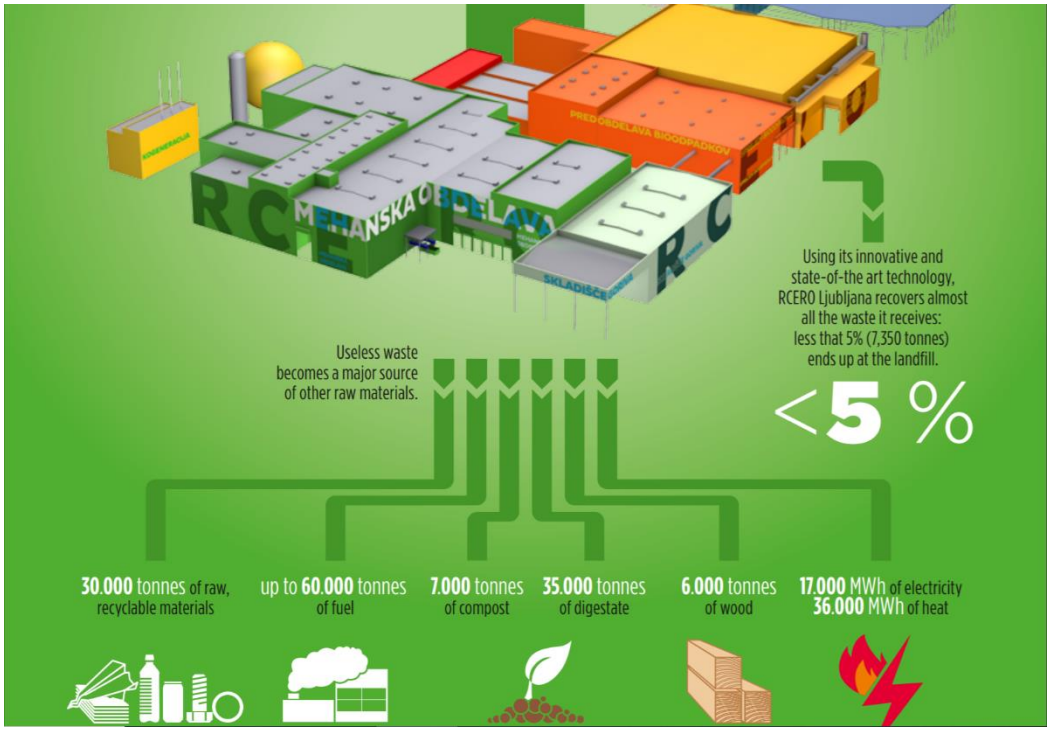

Figure 12. Waste-based products produced in RCERO Ljubljana (Sankovic, N. 2017).

5.3.2 Customer perspective and economics

Even though the waste management company made intensive communication campaigns and guides about waste management and recycling, the start was not easy. Areas with low separate collection rate, the residual waste containers were full of waste all the time, because the customers did not want to separate their wastes. Luckily, the waste management company did not give up. Voka Snaga educated people more and arranged field trips to local and national media workers to understand the system better and to spread the information about waste management. (Oblak, E. 2019)

After the customers had learned and accepted the new waste management system, Voka Snaga started to focus on reducing the amount of waste and educating the citizens of reducing waste production, reusing and responsible consuming. That change caused an increase in the customers' attitudes towards recycling and sustainable way of life and the waste management company opened a new reuse centre in 2013. (Oblak, E. 2019)

The implementation of the new waste management system in Voka Snaga made it also possible to decrease the waste management fees. The waste management fixed fee is almost 100 €/a in Voka Snaga area. Slovenian average fee was 150 €/a. (Oblak, E. 2019) The waste management fixed fee is 8,50 €/mo. If a customer gets caught on illegal dumping, sorting the waste into the wrong bin or on the side of the bin, it can get a fine of 200-800 euros. (Lostrek, N. 2018.) The variable fee depends on the collection frequency of waste and the size of the container. One emptying of an 80-litre container of residual waste costs 4,28 euros and for biowaste 0,73 euros. The fee rises directly proportionally to the size of the container. The emptying of recyclable waste containers is free. (Moji odpadki 2020.)

5.3.3 Experiences from other users

Another one of the waste management companies in Slovenia is presented. This company presents the waste management system in a more sparsely populated area than where Voka Snaga operates. The waste management system presented here is the system of Komunalno podjetje Vrhnika, which operates in three municipalities, Vrhnika, Borovnica and Log-Dragomer. The company takes care of fresh and wastewater management, waste management, gas supply, cemetery activities and maintenance of public buildings and infrastructure. (Komunalno podjetje Vrhnika 2015a)

The company manages waste of approximately 24 000 peoples. Residual waste is collected once in four weeks from single-family houses and once in two weeks in block of flats. Biowaste is collected kerbside as well or it can be composted at own yard. Biowaste is collected once a week. In winter, collection frequency is longer. There are also 225 unstaffed eco islands for collection and short time storing in the area, where customers can transport their recyclable wastes, such as glass, paper, metal and plastics. Metals and plastics are collected as co-mingled to the same container and separated mechanically, baled and packed for further transportation in the waste recycling centre. (Komunalno podjetje Vrhnika 2015b and 2015c.)

Hazardous waste in the area is collected once in autumn and once in spring in collecting campaigns. Bulky waste can be collected from the households on bulky waste collection

days four times a year, or they can be transported to a recycling centre in Vrhnika. In the recycling centre, customers can also dispose bulky waste around the year free of charge. (Komunalno podjetje Vrhnika 2015d.)

Municipalities in the area were the first ones in Slovenia to join the international Zero waste network. The waste management company in the area follows zero waste goals to reduce the amount of waste, the toxicity of waste and to increase recycling. Separate collection of municipal solid waste in the area is 76,17 %. The separate collection started already in 1994 in the area when the waste management system was in a turning point and needed changes. The municipalities didn't want to invest in an incineration plant. The landfill fees rose in Slovenia in the 2000s and the communities in Vrhnika have saved almost half of landfilling costs from the year 2006. (Van Vliet, A. 2018)

In 2002, the Komunalna podjetje Vrhnika started a campaign, where the customers could bring the recyclable waste straight to the recycling centre and get a reduction in the waste management fees. The reduction was based on the weight of the waste, they brought. For now, this kind of PAYT system in Vrhnika brings approximately 30 tonnes of waste straight to the recycling centre. The produced waste amount in the area was in 2013 80kg/capita/a. (Van Vliet, A. 2018)

The speciality of the area is the attendance of the whole community to waste prevention and recycling. Awareness-raising has been one of the important tasks for the waste management company and it has been taught to every age range. They have taught children at schools to sort their waste for getting discounts on schools' waste management fees, organised tours at the recycling centre and waste fashion shows. (Van Vliet, A. 2018)

To the companies in the area, they have taught how to save money with improving the waste management. They have changed the customers' attitudes about waste from smelly, dirty, and useless to attractive and valuable material by painting their garbage trucks, improving the attractiveness of the recycling centre with plants and more effective cleaning. Also, different kinds of campaigns, magazine and communication with citizens have had a positive effect on the waste management. The waste management company also started a reuse centre

Depo, where waste can be upcycled and recovered to further use and then sold to the ones who are in need. (Van Vliet, A. 2018)

5.4 System 4: Neighbourhood collection

The fourth waste management system presented in this thesis is a neighbourhood collection. There are no practical examples from any municipality or country, where this system would be the only waste management system used. In some municipalities, it is used as an opportunity for customers to have better ways to recycle their waste. There are some examples of the system in Finland, which are presented in this chapter. In Finland, the system is called as “korttelikeräys”. Later in this chapter will be a presentation of PAYT, pay as you throw-scheme. This scheme is not exactly a waste management system but presents a way to motivate customers to recycle and sort their waste, with different fees for different waste fractions. This scheme is used in many places in Europe and around the world.

The system is not very well-known and used, at the moment, in Europe and the world. Therefore, there is neither uniform name for the system. In some articles, it is called as shared containers or block collection points. Neighbourhood collection points can be mixed with civic amenity sites, which are usually manned recycling points, where people can bring their recyclable, hazardous and bulky waste. Neighbourhood collection points can also be mixed with bring-points that are available to use for every citizen or tourist living or visiting the municipality. These bring-points are not usually for collection of biowaste or residual waste, but for collection of recyclables.

The difference between the bring-points and neighbourhood collection points are, that the neighbourhood collection points are only for use of the inhabitants of the specified area. The area is specified to be so small, that every household in the area can walk to the collection point. The households in the area don’t have own waste containers in their yard. Every waste fraction, including residual, biowaste and recyclables are carried to the neighbourhood collection point. Some waste management companies offer shared biowaste containers for close neighbours. These shared containers are neither same as neighbourhood collection. Shared biowaste collection system is presented also in this chapter.

The system is especially usable for densely populated single-family household areas, where the waste collection includes only mixed kerbside waste collection. The collection enables short distances and better possibilities to recycle waste in the everyday routes of inhabitants in the area. The amount of residual waste can be decreased significantly when other waste fractions are sorted to own containers. (Rahkonen, J. 2019.)

There has been a survey about the aspects, which could make people to recycle more. The survey was made by Kokkonen, H. and Reijonen, H. in 2019 (p. 50-54). They found out, that dropping the waste into the waste container outside own yard was a difficult, negative thing and reduced the recycling. Distance to the recycling point is a crucial aspect of customers recycling enthusiasm. The closer recycling point is, the more people recycle. Also, easier transportation to the recycling point was another important aspect. All household wastes should be able to recycle at the same point. For example, the neighbourhood recycling points would motivate much or very much 60 % of the answerers in the survey. Especially, these systems could help the customers in detached house areas.

Runsten, S. (2014) made a study about biowaste collection possibilities in shared bins or local collection points. According to Runsten (2014) separate collection of biowaste from individual households is not cost or environmentally efficient. Composting is another option, but it needs maintaining and is not working year around. New waste recycling targets forces to increase the recycling rate and especially separate collection of biowaste. To maintain the cost and environmental effectiveness, one solution is collecting the waste at the same collection point from more than one household. Then, the separate collection of biowaste can be organized even in detached housing areas. When all household waste is collected to one mixed waste container, valuable biodegradable material is lost. Biowaste could be utilised better, for example to fertilizer production or soil improvement. (Runsten, S. 2014)

Unclear things in the collection were that is the biowaste collection point close enough to courage the source separation, are there going to be a smell-, pests-, health- or dirty issues, how to manage the transportation efficiency and freezing of the container or maintain participants source separation activity, waste quality and how to collect and manage the billing of the shared container. There might be also some problems if the shared biowaste

container system is managed by the inhabitants of the area themselves and not the waste management company in the area. Neighbours may not be able to involve other neighbours into the system or the responsibilities are not clear for example about the ploughing the snow from the area. (Runsten, S. 2014.)

Runsten (2014) searched examples of biowaste collection in other European countries as well. The countries were Sweden, Denmark, Norway, Austria and Germany. Norway and Germany didn't answer anything. In Sweden and Austria, there were some possibilities for shared collection of biowaste, but not as a neighbourhood waste collection system. There were no waste management companies, which offers shared biowaste collection in Denmark. (Runsten, S. 2014.) Though, it must be noticed, that this research is done in 2014, and the circumstances and will for better recycling have changed. Also, the recycling rate targets are tighter.

According to Runsten (2014), neighbourhood collection points should be taken into account already in town planning before building the area. There should be already marked places for the neighbourhood collection points and the containers should be in a place, that is close enough, maximum 100 meters, and via an everyday passageway to every household in the area. There should be a mention in the contract of the lots, that the buyer must join the neighbourhood collection system. Also, the billing for the use of waste containers should be thought through. Containers would be better to keep locked to avoid outside users and management of bills are easier when users are known. There could be 10-15 households for one collection point if 240 litres container is used. Otherwise, the container would become too heavy. The location of containers and responsibilities should be discussed if the container is not managed by the waste management company. The containers should be locked to some immovable thing to the ground or use underground containers. (Runsten, S. 2014.)

In Finland, one of the waste management companies offering separate biowaste collection is Kiertokapula Oy in Hämeenlinna. In Kiertokapula, shared biowaste collection is typically set up with an announcement to the waste management company's customer service. The announcement must include the users and using percentages. The costs of emptying the shared collection point are divided, charged, and managed by Kiertokapula Oy. The only

limit for the collection point is that the point must be in the area, where biowaste collection trucks normally operate. In this situation, there would still be individual dry waste collection containers in every households' yards. The longest possibly collection frequency is two weeks for biowaste container. Biowaste is collected in 240 litres or 140 litres containers. Biowaste needs to be packed to a plastic bag, newspaper, or other paper or cardboard bag, but not to the biodegradable plastic bag. (Kiertokapula 2020a.)

A separate, shared collection of waste offers possibilities to increase recycling, increase in neighbourhood sense of community and possibly decrease in waste management costs. Using separate shared waste containers enables a decrease in residual waste production. The shared separate collection is suitable for example to part-time inhabitants in the area because the production of waste might be low, irregular or the real estate might be hard to achieve for normal waste trucks. (Kiertokapula 2020a.)

Kiertokapula Oy made calculations about how separate collection of biowaste could decrease the waste management costs for households. Mixed waste containers became dry waste containers, and they can be emptied once in 8 weeks or even once in 12 weeks with a specific application. Test calculations were made in two different municipalities around the area of Kiertokapula Oy. It revealed, that when there are five real estates to share a biowaste container, waste management costs to one real estate could be decreased by even 46 % compared to having only mixed waste container in every real estate. The other municipality in the test calculation got 38 % decrease in waste management costs. The cost reduction is based on that the mixed waste container is not emptied so often anymore and biowaste collection is shared. (Kiertokapula 2020b.)

The same kind of shared biowaste collection is offered by the waste management company Puhas Oy in Joensuu area. They offer also home composting of biowaste in the summertime. Puhas Oy offers new customers of separate biowaste collection the biowaste container for free and biowaste bags for half a year. Shared biowaste container is set up by 2-10 real estates close to each other and the emptying costs are divided by the users of it. Restriction for the use of shared biowaste container is transportation routes of biowaste, such as in Kiertokapula. (Kukkonen, T. 2020.) Costs of neighbourhood biowaste collection in Puhas

Oy is 6,05 euros per one emptying for 140 litres container and 8,28 euros per one emptying of 240 litres container (Puhas Oy 2020).

Biowaste container needs to be emptied once in a week in summertime and once in two weeks in the wintertime when there are 5-10 households. For 2-4 households, the emptying frequency is at least once in two weeks in the summertime and at least once in four weeks in wintertime. Waste container size is 140 or 240 litres depending on the amount of biowaste produced. The containers cannot be loaded to over than halfway, because of biowaste weight and safety issues. Starting the shared collection of biowaste is done with an announcement to the Puhas Oy. Collection manager for the shared biowaste collection must be chosen from the users. (Kukkonen, T. 2020.)

One of the waste management companies offering neighbourhood collection is Kiertokaari Oy in Oulu, Hiukkavaara residential area. The neighbourhood collection point of Kiertokaari Oy is presented in figure 13. The most efficient waste management system was investigated there before building the area and the results showed that neighbourhood collection would be the best solution. The other option was pneumatic underground pipes collection. (Hilli, M. 2018.)

Figure 13. Neighbourhood waste collection point in Hiukkavaara, Oulu (Rahkonen, J. 2019).

There, all waste containers are situated to a shared waste collection point and there are no individual mixed waste containers in the households' yard. The waste containers are locked,

so they cannot be used by anyone else than the inhabitants of that area. The test started in 2015 and is ending in 2020. Buyer of the lot from the area must join the neighbourhood collection system. (Hilli, M. 2018.) The area includes about 60 newly built single-family detached households, who share four waste collection points. There are deep containers for bio and energy waste, glass, metal, paper, and cardboard fractions. (Rahkonen, J. 2019.)

The users of the neighbourhood collection points pay a fixed annual usage fee of the neighbourhood collection and emptying fee of the containers. The annual usage fee includes the investment costs of the collection points and emptying costs depends on the collection frequency. The collection method has shown cost-effectiveness compared to the collection of only mixed waste fraction. (Rahkonen, J. 2019.)

The variable fee for neighbourhood collection is 98,27 €/a for a family household. It covers the transportation and treatment of waste. The fixed fee in the area is 32,64 €/a for a permanent household. The costs are then 130,91 €/a. For a single household, the variable fee is 49,23 €/a and the basic fee is the same as for family-household. For part-time households (used less than 1/3 of the year) the variable fee is 33,19 €/a and fixed fee 10,44 €/a. For comparing the waste management fees, one emptying of mixed household waste of 140 litres container is 7,89. When it is emptied once in two weeks, the yearly cost is 205,14 €. The total annual cost is 237,78 €/a with a fixed fee. As a conclusion, neighbourhood collection is also cheaper for the residents. (Kiertokaari Oy 2020.)

Kiertokaari Oy made a survey for the customers of neighbourhood collection in 2018. The answering-% was 51,5 in the survey. The survey revealed that the new system made recycling easier and increased recycling enthusiasm because there were collection points for recyclable waste in walking distance from home. Also, it was seen as positive, that there was less waste truck movement in the area. Challenges in the system were, that the locks in the waste containers froze during winter and biowaste froze inside the container. These challenges could be tackled with changing to a different kind of locks and using plastic bags for biowaste. Plastic bags don’t release humidity and liquids out of the bag and that way prevents freezing of container. Plastic bags are separated out of the biowaste mechanically

in the biogas plant. All in all, the users of neighbourhood collection points were satisfied with the system. (Hilli, M. 2018.)

The neighbourhood collection system is seen as a good waste management system in the area. It offers customers versatile waste management services for relatively low expenses. It also supports the principle of the waste hierarchy and reduces the amount of waste going to incineration. Inhabitants and the waste management company, Kiertokaari Oy, wants to proceed with the neighbourhood collection system, but it needs confirmation from the authorities (Kiertokaari Oy 2019.)

5.5 System 5: PAYT

PAYT Scheme means Pay-As-You-Throw. It is an economic instrument for waste management actors, that encourages customers to recycle more with lower waste management costs. It is based on the principle “polluter pays” and that different waste fractions have different fees. The main point is that residual waste collection and treatment costs more than biowaste and recyclable fractions. When combined with efficient collection of recyclable waste and environmental awareness on recycling and waste, it is an efficient way to increase recycling and material recovery, prevent landfilling and incineration of waste in municipalities. (Morlok, J. et al. 2017, p.1.)

PAYT-scheme is formed from three pillars: identification of the waste generator, measurements of the waste generated and pricing principles of one unit of waste (price per kilogram or price per emptying, for example). (Morlok, J. et al. 2017, p.1.) The scheme is used in most of the places in Europe such as in Vrhnika in Slovenia, Göteborg and Linköping in Sweden, County of Aschaffenburg in Germany and Flanders in Belgium. In Finland, the PAYT scheme is implemented volume-based combined with collection frequency in the household collection and weight-based in recycling stations (Salmenperä, H. et al. 2019b, p.13).

Waste accounting can be based on user identifier (volume or weight), container identifier (volume or weight) or pre-paid system (pre-paid sack, tag, sticker, or token). (Morlok, J. et

al. 2017, p. 2.) Container identification is used in detached households, where the user of the container is only one household. User identification can be used in shared bins, for example in block of flats' waste collection rooms. That can be for example a card, where the user is one household or apartment. The weighting of the waste is then happening in the container. This enables the use of the same container for multiple users. Waste management system in block of flats usually does not encourage individuals to recycle or reduce waste, because the waste is not identified to a specific household. PAYT-scheme could give a solution to encourage recycling also in block of flats. (Salmenperä, H. et al. 2019b, p. 27, 65)

The cost structure of PAYT- implemented waste management for customers can be single-component when it is based only on variable weight or volume of the waste or it can be multi-component when it is based on fixed basic and rental fee and variable service fee. The multi-component cost structure is better because it prevents illegal dumping and waste management companies also have fixed and variable fees for the operations. Basic fee can be per property, person, household, or container. Rental fee can be per bin or container rented and service fee per bin or container volume, collection frequency or actual collected volume or weight. (Morlok, J. et al. 2017, p. 2.)

Customers recycling enthusiasm could be increased with communication and encouraged with monthly information about the living area's average household waste production amounts and own household's production amounts. Customers can compare these and try to improve own waste management. Weighting the waste also improves waste management costs clearness and gives important information for waste management companies for example to optimize collection routes or waste truck capacities. (Salmenperä, H. et al. 2019b, p. 19, 45-46.) Waste management fees based on weight, are fair for inhabitants, the more one consumes and produces waste, the more one needs to pay for treatment and collection of it (Morlok, J. et al. 2017, p. 4).

There is also a producer responsibility aspect in PAYT. It is easier to allocate the responsibility and costs of waste management with PAYT-scheme. A customer has already paid the waste management of the product and packaging when buying the product, so the waste management should also be free. Also, it is not customers responsibility to handle the

management of waste under extended producer responsibility. It equalizes the waste management costs and responsibilities between the individual citizens and households, but also between citizens, producers, distributors and retailers. (Batllevell, M; Hanf, K. 2008.)

Implementing weight-based PAYT- scheme encourages inhabitants to compost itself biowaste because there are not uniform fees for every waste fraction and the waste is billed by the actual weight and not by assumptions. Negatively it may affect the quality of recyclable wastes if inhabitants throw residual wastes to recycling container in the purpose of cutting the costs. It may cause also illegal dumping on purpose to avoid waste management costs. The change from a volume-based system to a weight-based system requires co-operation between customers, waste transportation companies, waste management companies and authorities. (Salmenperä, H. et. al. 2016, p.19, 21.)

PAYT- systems requires investments in technological devices. That is the reason, why the systems are also vulnerable to technical problems. Technical problems cause difficulties in billing if the weighting or identification of the customer is not working properly. For these situations, there should be fair and customer- friendly backup plan. The plan should be also legally possible. Technical problems may cause suspicion in customers and decrease recycling enthusiasm. (Salmenperä, H. et al. 2019b, p. 45-46.)

According to research made by Salmenperä, H. et al. (2019b, p.79), implementation of PAYT-scheme is also good from the viewpoint of sustainability. Residual waste amount decreases, while bio and recyclable waste amounts increases. The positive effects of producing energy from waste and using recycled materials in the production of goods are greater than the negative effects of the collection, treatment, and utilization process chains of waste. The results are though still only directional and include many uncertainties and assumptions. The effects and results may vary also between areas and for example, population density may affect the results.

PAYT- scheme is defined to be the best environmental management practice, BEMP. It means that it is the most effective practice to use for waste management systems in organisations and it can result in best environmental performance when the area’s technical

and economic circumstances are considered. The effectiveness in this means, that it reduces the environmental impacts of organisational actions, such as municipality operations. The scheme should be applicable to use in every relevant organisation. (Morlok, J. et al. 2017, p. 4.)

The key performance indicators for PAYT are a collection rate of recyclables and residual waste amounts in kilograms per capita in a year. The system in Aschaffenburg represents as a benchmark of excellence for this PAYT. The most efficient use of PAYT scheme is weight-based kerbside collection of residual, organic and bulky waste with good infrastructure for recyclables collection and awareness of inhabitants, what is the case in Aschaffenburg. (Morlok, J. et al. 2017, p. 4.) Then again, it is shown, that PAYT-scheme, which is based on collection frequency and volume of the container is the least efficient instrument to encourage for recycling (Salmenperä, H. et al. 2019b)

EU Commission recommended in 2018 published early warning document the implementation of PAYT- scheme in waste management in Finland (European Commission 2018b). There is a need for significant technological improvements in waste management systems if weight-based PAYT- scheme implementation could be possible. These investments are needed in containers, transportation trucks and information systems. Also, the markets may not be ready yet for the change and more competition in the markets is needed to improve the performance of device suppliers and transportation companies. (Salmenperä, H. et al. 2019b, p.49, 66).

According to the study made by Salmenperä, H. et al (2016, p.18), PAYT- scheme affects the total amount of waste produced in the municipality and there are not so strong evidence that it affects the recycling rate. According to the study, implementing PAYT- scheme with increased public environmental awareness, the recycling rate could be increased only 1,4 %. This is strongly contradictory result compared to a study made by Morlok, J et. al. (2017, p.8), wherein County of Aschaffenburg, the most important change in waste management was the implementation of PAYT- scheme. The change between non PAYT- scheme municipalities and PAYT- scheme municipalities in residual waste production was over 50 %.

Especially these new waste management possibilities, PAYT- scheme and neighbourhood collection should be considered when building new residential areas and organize test periods in there. These test periods should include efficient communication with the customers, that they are aware, that there might be technical problems and to get feedback. People are more eager to change their waste management routines and attitudes when moving to new areas. (Salmenperä, H. et. al. 2016, p.39.) This is done for example in Vallastaden in Linköping. There, the waste management combines PAYT-scheme, optical sorting and pneumatic waste collection system, which transports the waste in underground tubes with the help of pressure to the central waste collection station (Salmenperä, H. et al. 2019b, p.41-42.)

5.5.1 Aschaffenburg, Germany

Aschaffenburg is a County of 32 municipalities, 173 000 inhabitants and population density of 247 person/km^2. The PAYT- scheme has been implemented in Aschaffenburg for almost 20 years. In the 1990's all waste was going to landfill before the landfill site was full. The new site was searched, but there was resistance from the inhabitants. Therefore, they decided to start a separate collection of plastic in 1990 and incineration of residual waste, separate collection of wood waste, and biowaste separate collection trial in one of the municipalities in 1994. After these changes, the PAYT- scheme was applied to Aschaffenburg in 1997. Nowadays, the County has accomplished to get 86 % collection rate of recyclable waste. (Morlok, J. et al. 2017, p. 3.)

In Aschaffenburg, there is a weight-based separate kerbside collection of residual, bio, paper, and bulky waste from every household. There are also unstaffed civic amenity sites for collection and short-term storing of other recyclables. Wood-based waste is incinerated in power plants, residuals are used for energy recovery, biowaste anaerobically digested and end-products are provided for household uses, green cuttings are composted, and re-usable nappies use are encouraged in Aschaffenburg. (Morlok, J. et al. 2017, p. 4.)

All waste bins and containers are identified with a chip and waste trucks equipped with barcode reading devices. Waste trucks have waste weighing devices to allocate the container and waste amount to a specific customer in the central facility, where the billing of the customers is managed. The information chip in a container work as an identifier of a container. The information chip includes a logo of a municipality, number of the bin, location of real estate, volume and the waste fraction of the bin and bar code. The waste containers or bins are available to use for specified inhabitants and can be locked if needed. Bigger containers can be used in block of flats for more than one household. (Morlok, J. et al. 2017, p. 5.)

In Aschaffenburg, residual waste is collected fortnightly and container volumes are 120, 240, 660 or 1100 litres. Biowaste is collected fortnightly, except in summertime once a week, and volumes are 60 and 120 litres. Garden waste is collected twice a year from households. Paper is collected to blue bins size 240 or 1100 litres once in four weeks. Packaging materials are collected to yellow bags monthly. There are also depot containers for metals and glasses. Bulky waste for disposal is collected from the households with a separate call or it can be transported to manned recycling stations. Recyclable bulky waste is collected kerbside twice a year. Hazardous waste is collected in a manned mobile collection unit twice a year and in civic amenity sites. Recyclable waste and special waste are also accepted in recycling centres. (Morlok, J. et al. 2017, p. 7.)

Waste management fees in Aschaffenburg have reduced since the PAYT scheme was implemented, even though the system needed investments in new technology, such as collection vehicles, weighting, and identification systems. It shows that weight-based PAYT system is not necessarily a more expensive way for waste management than others. There are still variations how much the PAYT scheme costs in different municipalities, but this depends on many other factors, such as incineration taxes and costs, as well. In Finland, colder climate enables, that biowaste can be collected fortnightly and therefore save costs when the biowaste collection frequencies are longer. The fee for waste management in Aschaffenburg is based on a basic fee, a collection fee and a weight fee. (Morlok, J. et al. 2017, p. 11, 14.)

Similar results about the efficiency of PAYT scheme have also seen in other Counties in Germany, but also in Treviso and Trento in Italy and Flanders in Belgium. Even though the PAYT- scheme is an efficient way to improve recycling in the municipality, it may not be the best solution for decreasing waste production. The total amount of waste produced and treated in Aschaffenburg stayed similar from the beginning of the scheme, only the residual waste amount was decreased, and the collection of recyclables increased. (Morlok, J. et al. 2017, p.14.)

5.5.2 Flanders, Belgium

The area of Flanders in Belgium includes 308 municipalities and a population of 6,2 million. The population density in the area is 500 person/km^2. Almost 75 % of the waste produced in the area is reused, recycled, or composted. The regional waste plan is made for the area every four or five years to update the targets and operations. (Allen, C. 2012.) The PAYT- system became in Flanders in the 1990's. The same aspects as in Aschaffenburg affected the change to PAYT: increase in residual waste treatment costs (Delatter, C. 2019.).

In single-family detached house areas, the collection is arranged in kerbside. Separately are collected residual waste, biowaste (food and garden waste), combined recyclables (plastics, metals, and TetraPaks), paper and cardboard combined and glass. Recyclables can also be carried to manned recycling parks or back to the retailer. (Allen, C. 2012.) Special, bulky, and hazardous waste are collected in recycling parks. Textile waste is collected four times a year in kerbside collection or recycling parks. (Salmenperä, H. et al. 2019b, p. 33-34.) Collection and treatment of waste are financed with fixed annual tax and PAYT tax. Biowaste is anaerobically digested in the area or composted at the households (Allen, C. 2012.)

Households, who use own waste container, have information sticker and a chip, to identify the container, the user and to know whether the container can be emptied. The waste trucks include weighting devices, which weight the container full and empty and report the change to the information system. The households, who uses common waste collection points have identification cards. These are shown to the reading devices in the container to make sure

the user can dispose the waste in the container. The cover opens if the user is right. The user chooses the bag size, or the system weights the bag. The waste disposal fees are automatically registered to a customer's account and the system automatically sends a bill, when the specified limit is full. The implementation of PAYT- scheme was financially supported by the government. Also, local EPR system organisation, Fost Plus, is supporting the collection of packaging waste. (Salmenperä, H. et al. 2019b, p. 35-37.)

Densely populated or otherwise hard to achieve areas are recommended to organize common waste collection points, such as in Ljubljana city centre area. Common waste collection points include underground containers with an electronic identification system. Common collection points are in a place that is under 100 meters from each household. (Salmenperä, H. et al. 2019b, p. 33-34.) In Flanders, residual waste collection is the most expensive and then biowaste collection. Collection of recyclables is free with few exceptions. Billing the biowaste is supporting the citizens for home composting as well. In deep containers, also volume-based billing is used. The price range for residual waste is 0,20-0,30 €/kg and for organic waste 0,10-0,15 €/kg in kerbside collection or from recycling parks. Billing of waste varies between municipalities and waste management system used. (Delatter, C. 2019.)

Waste collection workers make sure, that customers sort waste properly. In kerbside collection, recyclable waste bags are checked before emptying. If there is something that does not belong there, a sticker is attached into the bag and the bag is left without emptying. In recycling parks, customers bags and waste are checked by the workers before they can be emptied to a container. Recycling parks are available with identification cards as well. PAYT- scheme has increased the recycling rate of separately collected waste fractions 30 % and decreased residual waste amount 30 %. (Salmenperä, H. et al. 2019b, p.37-38.)

At first, the new system got resistance. The public acceptance was changed with good communication and services, courage, and perseverance of politicians. One year after the implementation of the system, the customers understood, that they have better control over their waste management costs (Delatter, C. 2019.). Citizens can track down their waste amounts, have notifications on kerbside collections, sorting instructions, journey planners to the closest recycling park and information about the parks opening times from a mobile

application. The municipal waste management actors have educated the citizens about recycling to decrease problems and incorrect recycling or illegal dumping, waste burning or transportation to cheaper areas. Other actions to increase recycling have been uniform waste fees, punishments, quality controls and wide separate collection of recyclable waste fractions. (Salmenperä, H. et al. 2019b, p.39-40.)

6 SYSTEMS ANALYSIS AND SUITABILITY FOR LAKEUDEN ETAPPI OY

This chapter includes comparing and analyzation of the waste management systems presented in the previous chapters. The comparison and analysis are done with SWOT analysis and qualitative comparative analysis, QCA. The analysis of new waste management systems is done from the viewpoint of the waste management company, Lakeuden Etappi Oy when the new system replaces the current system in the company. There are also considered advantages and disadvantages or risks the implementation of the system brings when it replaces the current system in Lakeuden Etappi Oy. The current system of Lakeuden Etappi will also be included in SWOT-analysis. There are also some aspects, that are common for every of these presented outside waste management systems. These are not included in the analysis but mentioned in the discussion.

6.1 SWOT

SWOT- analysis is developed in the 1960's in The United States of America. It is traditionally used as a strategic planning and analyzation tool for management. Nowadays, it is used in many sciences for analysing different aspects of a system, a thing, an organization, or some other case. (Vuorinen, T. 2013.) In this analysis, the cases that are analysed, are the five waste management systems presented earlier. Strengths and weaknesses represent the things that would be the system's inside negative and positive factors when the system is applied to Lakeuden Etappi Oy. Opportunities and threats represent the negative and positive factors of the system that are due to the operational environment when the system is applied to Lakeuden Etappi Oy.

Strengths are things, which needs to be strengthened even more and taken advantage of them. Weaknesses are things, that need to be cut off or reduced. Opportunities need to be utilized and threats removed, reduced, or turned to opportunities. In SWOT-analysis, the inspection is always subjective, a different inspector can see things in different ways and a thing can be negative or positive from a different perspective. (Vuorinen, T. 2013.) This SWOT-analysis aim to form a big picture of the waste management systems presented earlier and find out

the differences, pros, and cons of each system and after all, find out the best one. Analysing also the current waste management system of Lakeuden Etappi Oy helps to find the factors, what could be improved and what is done well.

6.1.1 Current system of Lakeuden Etappi Oy

The current system of Lakeuden Etappi Oy covers municipal waste management of 130 000 inhabitants. The population density is approximately 16 person/km^2. The municipal recycling rate was 46,6 % in 2019. The company produces waste-based products and uses residual waste for energy production. Sorting and carrying the waste in the right collection point in the area is a customer's responsibility and the collection is arranged in eco-points, regional waste stations, waste management centre and waste rooms of residential and municipal service provider buildings. Only mixed household waste is collected from kerbside at the detached house households. The SWOT-analysis of the current system is presented in table 3.

Table 3. SWOT-analysis of the current system in Lakeuden Etappi.

	POSITIVE	NEGATIVE
INNER	**STRENGTHS** • Long history and early development • Own biogas plant and partly own waste-to energy plant • Manages waste transportation itself • Multiple communication channels • Independent, healthy cost structure • Standardised systems • Environmentally responsible • Own waste-based products • Low amount of waste landfilled	**WEAKNESSES** • Low population density and long distances • Low waste produced-costs connection • Recycling services • No waste sorting facility • Low recycling rate • Already high waste management fees • High amount of recyclable waste going to energy recovery
OUTER	**OPPORTUNITIES** • Developing operation area • Growing environmental awareness • Technological development in Finland	**THREATS** • Upcoming waste legislation • Public attitudes, indifference, laziness and lack of knowledge • Changes in municipal waste composition • Urbanization • Increase in waste transportation

The SWOT-analysis of the current system shows that there are many positive things in the system. The company has over 20 years history and during that, it has been developing and investing in new waste treatment operations, such as in own biogas plant and partly owned waste-to-energy plant. The owning of these operations is also a strength for the company because it makes the company less dependent on other companies. The company also have production of own waste products, which increases the incomes. Waste authority in the area has determined, that waste management company, Lakeuden Etappi Oy, has managing responsibility for waste transportation also, which is seen also as a strength for the company. The company is, therefore, less dependent on the customers' choices and can control the transportation also. Strength is also, that very low amounts of waste is disposed in landfills, only 0,2 % of municipal waste.

The company has ISO standardised quality and environmental systems and occupational health and safety of personnel systems. This is a strength and ensures workers wellbeing in the company and controlling of environmental effects and quality. The company also controls environmental effects with different kind of measurements regularly and makes sure that no harm to the environment is made. The company’s many-channel communication with its customers is a strength and offers good possibilities for waste management education and guidance. One of the company’s strength is its cost structure, they don’t get any financial support and is independent, wealthy and healthy. In the year 2019, the company used almost 2 million euros in investments and the net profit was a bit over 3 million euros. In 2018, the company used 600 000 euros for investments and the net profit was a bit over 3 million euros as well. (Lakeuden Etappi 2020b.) This means that the company is financially able to invest in the new waste management system if needed.

Then again, the outer, positive things for the company is that the area, where the company is operating, is developing, and growing. Confederation of Finnish industries has ranked Seinäjoki as the most attractive area for companies for the fourth year in a row (Huovinen, J. 2019). It may offer opportunities to largen the operation and incomes. Also, environmental awareness is rising all the time and can improve waste sorting in the area. Finnish industries might offer more ways to use the waste materials and therefore makes the collection of the waste materials more worthwhile. For example, there is a long history of the forest industry,

that produces paper, cardboard and cartons, where could be used recycled materials as well (Vesikansa, J. 2008). Many recycled materials, such as biowaste, papers and carboard are already used in the production of new newspapers and paper cartons in Finland.

Then the negative parts, weaknesses, and threats of the company. At first the inner things. In the area, there are low population density and long distances between households, which can make the collection of waste more energy and time consuming and less efficient. Also, there are not in use weight-based- PAYT-scheme, which decreases the connection between the actual waste produced and costs of the waste management for the customers. The current system uses volume- and collection frequency- based billing. There are neither separate collection of recyclables near enough to every household to ensure efficient collection of recyclables. Only combustible household waste is collected from every household. The company does not have any material recovery or sorting plant and therefore all combustible waste goes to energy recovery. The company's waste management fees are higher than the average in Finland.

Then again, outer negative things are the new waste management legislation, which might force the company to rearrange the waste management system. For example, the legislation might force the company to broaden the separate collection of wastes, which can cause an increase in transportation costs. Also, public attitudes, laziness and indifference can be threats to the system. The high recycling rate cannot be achieved if the sorting is not organised properly at homes in a situation when there is no mechanical sorting plant at the waste collection centre. For example, in optical sorting, it is highly important, that inhabitants sort the waste right at homes, or the optical sorting is worth nothing when the inside of the waste bags is bad quality mixed waste. Changes in customers behaviour can change the waste composition as well. Urbanization causes, that waste management efficiency from sparsely populated areas decreases, when there are even less population with longer distances.

6.1.2 System 1: Optical sorting

Waste management system 1 is applied in Eskilstuna, Sweden. The system covers wastes of about 110 000 persons. The municipal waste recycling rate in Eskilstuna was 55 % in 2019. In Eskilstuna, there is a waste optical sorting plant, that sorts different coloured bags to own containers. The waste is collected in a kerbside from every household. At the household, different waste fractions are separated to different coloured bags and thrown to the same outside container. There is a coloured bag for food, textile, plastics, paper, cartons, metal, and residual wastes. Residual wastes are used to energy recovery, biowaste for fertilizer and biogas production, recyclables are used for new material. The system offers good recycling services to the customers and is easily adaptive. SWOT-analysis of the system in Eskilstuna is presented in table 4 below.

Table 4. SWOT-analysis of the system in Eskilstuna, Sweden.

	POSITIVE	NEGATIVE
INNER	**STRENGTHS** • Already 10 years of experience of the system • Simple and easy for customers to recycle • Flexible system • Services close to the customer • No need for other recycling points for household waste • No need for extra waste containers • Wide waste acceptance system • No increase in waste transportation • High waste sorting accuracy • Higher recycling rate • Available to sparsely populated areas	**WEAKNESSES** • Does not include glass fraction or hazardous waste • Needs more workers • Expensive one-time investment • Low recycling-costs connection • Might increase waste management costs for customers • Needs changes in waste sorting facilities at households • Waste limitations from bags • Same fee for every fraction and colour
OUTER	**OPPORTUNITIES** • Might increase the public environmental awareness	**THREATS** • Low quality bags, breaking easy • Maintenance costs • Public attitudes, knowledge and indifference against recycling

The waste management system in Eskilstuna is varied. There are many good things, but good things come with some negative aspects. Strengths of the system are the experience for already 10 years, so it is a reliable example. The system also brings the waste collection, even for recyclables, to the kerbside of every household and the waste management services are close to everyone. The same system works in block of flats and sparsely populated areas. Also, new bags are brought straight to the post box. The services are absolutely the strengths of this system. There is no need for other recycling points than for glass recycling and hazardous waste. Households need only one waste container in the yard. The optical sorting plant is flexible and adaptive to the needs. The system does not increase the transportation of waste and leads to high waste sorting accuracy and recycling rate.

Inner, negative things are then again high investment costs and maintenance. Maintaining the system needs workers. Applying the system may also increase the waste management fees for the customers and causes changes in the household waste sorting structure. Though, the company is financially in good condition, so the investment may not be a problem. The system has low waste production and waste management costs- connection and for example, PAYT-scheme is not implemented. Every waste fraction has the same fee and colour-sorted bags are not usually quality-checked. Therefore, it doesn’t matter if the customer uses only black bags. These makes the system less encouraging for recycling. With colour sorting system, it is not able to collect hazardous waste or glass and the bags set limits for the collection of big cardboard wastes, for example.

Opportunities for Lakeuden Etappi Oy with this waste management system is that when the services are coming closer to the customer, it can encourage customers to recycle more. Threats for Lakeuden Etappi Oy about the colour sorting system are possible repairing or maintenance costs and workforce. The bag's quality is also one threat in the system. The bag needs to be durable enough, that they will not break in the waste trucks press system or it makes the system unworthy. Previous optical sorting systems in Finland have not been successful and already ended. There might be some differences in environmental awareness and enthusiasm between Eskilstuna and Lakeuden Etappi Oy area. This may lead to worse results, than what the results have been in Eskilstuna. The system also requires that

customers recycle and sort the waste at homes properly, or colour-sorting is inefficient and unworthy. The investment is unworthy if the customers do not sort waste at homes.

6.1.3 System 2: Kerbside collection

The next waste management system inspected was kerbside collection in Flintshire, Wales. The population density in the Flintshire is 151 person/km^2. The municipal waste recycling rate was 68,7 % in 2019. Separately from kerbside is collected glass, cardboard and paper, metals, plastic, food, garden, and residual waste. Different waste fractions have own bins or bags, that are emptied to the waste truck and returned to the household. The SWOT-analysis of the system in Flintshire in Wales is presented in table 5 below. It can be seen from the table, that the results of the analysis are very versatile. There are many good things in the system, but also uncertainties and negative things.

Table 5. SWOT-analysis of the waste management system in Flintshire.

	POSITIVE	NEGATIVE
INNER	**STRENGTHS** • Services close to customer • Garden waste collection • Easy recycling for customers • Fines from lazy recycling • Higher recycling rate • Low risk for waste fraction blending	**WEAKNESSES** • Requires customer action to bring the waste to the kerbside • Collection frequency increase • Requires changes in waste sorting facilities at homes • More time used on emptying, more energy needed and more workers • Need for multiple-container vehicles
OUTER	**OPPORTUNITIES** • Successful tests in Finland resulted in better waste quality and lower greenhouse gases • May encourage customers to recycle • PAYT-scheme implementation possible	**THREATS** • Different system management • Uncertainties in the system and lack of knowledge • The test in Finland required financial help or increase in waste fees • Customers willingness to pay to get extra services • Indifference to recycle

One of the strengths of the system is a high recycling rate. The other strengths are that the recycling and waste collection are close and easy to the customer and waste management services are comprehensive with pick up collection of also bulky waste and garden waste. The system includes also fines if the waste is not sorted properly and waste fractions are possible to be checked when emptied to the waste vehicles. There are also low risks for waste fraction blending and high waste sorting accuracy.

Then the weaknesses of this system are an increase in waste transportation in the residential areas when different waste fractions are collected at different times or to multi-compartment vehicles. It also requires more workers, time and energy to transport the waste. This is because the workers need to sort the waste to own compartments in the truck and then return the bags and boxes. Investments are needed for new collection vehicles, waste boxes and bags. The system also needs higher attendance from the customer when waste needs to be dropped outside the household on a specific day and time. This reduces the flexibility of the system from the viewpoint of the customer. It causes problems and requires communication with the customer if the day needs to be changed. It also needs a new arrangement for waste sorting at homes.

Opportunities of the system are possible increase in recycling enthusiasm and higher recycling rate and waste quality. The test made in Finland about this system showed good results in recycling rate, greenhouse gas amounts and waste quality. Applying PAYT-scheme in the system is possible and increase the connection between costs and waste produced for the customer. Outer, negative aspects of this system were then again uncertainties. There were not available as much information from the system as there was for example of optical sorting. Also, recycling rates were unclear, how it is calculated and what it consists. The system management was also different, so it may not suit well in Finland. The test made in Finland was not financed with waste management fees only and needed extra financial help. Also, the test showed that only a few of the customers were ready to increase the waste management fees to get better recycling collection. The system also requires customers own activity to recycle at homes efficiently.

6.1.4 System 3: Co-mingled collection

Third waste management system inspected was co-mingled collection in Ljubljana, Slovenia. It handles the waste management of 400 000 inhabitants inside almost 1000 km^2. The source separation rate of municipal waste in the area was 68 % in 2018. There is a collection of residuals, biowaste and recyclable waste at the kerbside. Recyclables and residual waste are separated in waste treatment and recovery plant. In the city centre area, waste is collected in underground waste containers in public places. Collection of recyclables is free. Co-mingled collection SWOT-analysis is presented in Table 6. There are many strengths and opportunities in this system, but there are also many uncertainties and lack of knowledge of the system.

Table 6. SWOT-analysis of co-mingled collection of recyclables in Ljubljana.

	POSITIVE	NEGATIVE
INNER	**STRENGTHS** • High recycling rate • Many years' experience • Multiple waste management services • User identification cards in city centre • Fee reductions with recycling • Recycling campaigns, strong communication with customers	**WEAKNESSES** • Large area and high population density • Expensive investment for waste treatment and recovery plant • Increased waste transportation • Need more workers for recovery plant and transportation • Need more space in households' yards for different containers
OUTER	**OPPORTUNITIES** • May increase customer responsibility on waste • PAYT-implementation possible	**THREATS** • Differences in operation environment • Uncertainties and lack of knowledge • Waste recovery plant for small areas may not be profitable enough

The high recycling rate in Ljubljana is a strength and the waste collection service also for recyclable waste is organised as a pick-up collection from kerbsides. The system has been in the area for many years already, which leads to that conclusion that the system works there well enough. In the city centre, customers use identification cards, which makes it possible to differentiate the waste management fees between customers and allocate the

amount of waste more specifically to the customer. There is also good communication with customers and different campaigns to encourage recycling, for example, fee reductions, when recyclable waste is dropped off to the waste treatment plant.

The weaknesses of the system are that the area is large and population density high. Then it is not very comparable with the current system in Lakeuden Etappi Oy. The waste treatment and recovery facility were also an expensive investment to the company, and it was partly financed with EU-funding. The system also would increase the need for workers when applied to Lakeuden Etappi Oy. Transportation of waste would increase, the energy used for transportation and the workforce need would increase. There is a need to find a good place for waste management containers at the household yards and new arrangement of waste sorting at households.

The outer positive things then again are, that the system may increase the customers' enthusiasm to waste management. The campaigns are exemplary and the work they have done to better the reputation of waste management in Ljubljana. The system also enables the implementation of PAYT-scheme. Outer, negative things are that the country and operational environment have some differences compared to Finland. This causes uncertainty in the system implementation. There are many other uncertainties in the system and lack of knowledge of how it works. It is neither sure, that building waste treatment and recovery plant are profitable to small areas, like the area of Lakeuden Etappi Oy.

6.1.5 System 4: Neighbourhood collection

Neighbourhood collection system means that single-family detached houses share the waste containers. The distance to the collection point is set under 100 meters from each of the houses included in the collection and usually includes 10-15 households. The example of this system is from Oulu, Finland. The system is still in a testing phase in a small, 60 households, newly built detached house area. The collection includes underground containers for biowaste, residual, metals, glass, paper and cardboard. The households are not allowed to have own residual waste bins at the kerbside. Neighbourhood collection strengths, weaknesses opportunities and threats are presented in table 7.

Strengths of the neighbourhood collection system are that the collection of wastes is arranged close to the households and includes the collection of recyclables. The system is also adjustable and can be applied to areas, where streets are tight for waste trucks or traffic. It offers a safer environment for residential areas when there is now waste truck traffic. The system does not need any waste sorting facility or other big investment. The neighbourhood collection system is cheaper for customers as well when the whole capacity is used and there are enough users.

Table 7. SWOT-analysis of neighbourhood waste collection system.

	POSITIVE	NEGATIVE
INNER	**STRENGTHS** • Waste collection service is close to the customer and also includes collection of recyclables • Less waste transportation traffic in residential areas, safer • No need for extra sorting facility • Available for areas, where are no space for waste trucks or containers • Decrease in waste management fees • Easy recycling	**WEAKNESSES** • Increase the distance to the waste collection point • Needs construction of new waste recycling points and organizing • Needs communication with customers • Locking the waste containers • Specifying the waste to different households • Whose responsibility is to take care of the recycling point? • Biowaste freezing • Applicable in densely populated areas • Need to be considered already in town planning
OUTER	**OPPORTUNITIES** • May have positive effect on sense of community • Offers cost and environmentally effective option for waste collection, especially for bio and recyclable waste fractions • Increases recycling enthusiasm • Enables PAYT-scheme	**THREATS** • Not very well known and not much experiences yet in Europe or in Finland • Lack of knowledge • Indifference of customers for waste recycling and sorting

Weaknesses of the system then again are an increase in distance to the waste collection point. This may be a problem for example for disabled or elderly people. The system is not applicable in sparsely populated areas, because there are not enough households close enough to each other, that it would be efficient and the best way from every viewpoint. The

system requires construction of new waste collection points and digging for underground containers. The system needs to be considered already in town planning and plan a place for the waste containers and emptying. Therefore, it might be difficult to apply in old neighbourhood areas, if there is not enough space. It requires organizing and communication with attendants and billing system and calculation that the fees are equal to every household. The containers need to be locked, that there won't be any waste from outsiders. Waste collection points need to be maintained, cleaned and in winter times snow ploughed. Biowaste freezing can happen as well.

Positive outer things are that it may affect the sense of community in the area where it is applied. The system offers cost and environmentally effective option for especially biowaste and recyclable waste collection. The system may also increase recycling enthusiasm. The system enables application for PAYT-scheme also, with electronic cards and locking system. The negative outer things are that the system is not well known yet and there is not much knowledge about it. The system requires also, that customer and attendants sort their waste already at homes and ensures the high waste fraction quality.

6.1.6 System 5: PAYT-scheme

PAYT-scheme is an economic instrument to increase recycling with lower waste management costs. It is based on the "polluter pays"- principle. The main point is that residual waste collection is more expensive for the customer than biowaste or recyclable waste collection. Relatively high cost of the residual waste collection covers inexpensive or free collection of recyclables. It requires efficient collection of recyclables and environmental awareness of inhabitants to work properly. PAYT is defined as best environmental practice. The most efficient PAYT-scheme is weight-based kerbside collection, that is applied in the example area in Aschaffenburg in Germany. The collection rate of recyclables is 86 % in the County of Aschaffenburg. The PAYT-system SWOT is presented in table 8.

Strengths of the PAYT-scheme is that different waste fractions can be allocated to specified customer and customers can easily track the waste he or she produces. This may encourage

to recycle more. Another encouraging strength is that residual waste is more expensive than biowaste or recyclable fractions. The system offers clear cost-waste production connection and the waste management fees are based on the actual waste produced and not assumptions. The system ensures that the waste management billing system is equal to every customer. One of the strengths is that the system is well-known and there is much research done about the system. There is no need for large waste treatment facilities and the system is marked as best environmental management practise. The system is cost and environmentally effective.

Table 8. SWOT-analysis of PAYT-scheme.

	POSITIVE	NEGATIVE
INNER	**STRENGTHS** • Encourages to recycle with cost reductions • Improves waste management fee equality between customers and clearness • Well-known and researched system • No need for large investment in waste treatment facilities • Best Environmental Management Practise • Cost and environmentally effective system • Offers customers a way to track waste amounts	**WEAKNESSES** • Increases work • Requires technological systems to identify customer and the amount of waste • Applying to shared waste containers need weighting or volume-identification technology • Requires efficient system for recyclable waste collection • Requires waste container lock system • Requires back-up plan if the system does not work • Functionality in winter circumstances
OUTER	**OPPORTUNITIES** • May increase recycling rate • Can decrease waste management fees • May increase environmental awareness • Applicable to different areas and systems, also in sparsely populated • Drive for new innovations and higher incomes • Important information on waste production amounts • Building eco residential areas	**THREATS** • Indifference and laziness in sorting or transporting the recyclables to waste collection points • Waste quality decrease if the bags are not checked. • May cause illegal dumping • Cost effectiveness to small areas • No required technology available • Technology negativity • Problems in technical systems

The inner weaknesses of the system are that it increases the work needed to manage and organize the system, collect, identify the customer and the amount of waste produced. There are also need for a technological system, such as the identification of a customer and

weighting. Weighing can happen in the waste container or at the waste truck. It is not sure, how the technological systems would work in winter conditions. The system works well and efficiently only if there is also a well-arranged recyclable waste collection. The containers, what are used in the system, need to be able to lock to ensure that users outside the system cannot use it. There have to be an equal back-up plan if the technologies are not working and the waste cannot be weighted, or the user identified.

Outer, positive aspects of the system are that it may increase recycling enthusiast, environmental awareness and can decrease customer waste management costs. The system is applicable to all kinds of areas, even to sparsely populated. It may drive the company to have technological innovations and therefore more incomes and offers the company valuable information about the waste amounts. The system allows building a whole eco-village.

Threats are laziness or indifference of sorting the waste at homes may cause the system unworthy. Evasion of waste management fees may cause customers to illegally dump the waste or sort residual waste into recyclable bags. This causes a quality decrease in waste fractions. System's cost-effectiveness and worthiness decrease if the area used is small or dispersed. There can be a lack of possible waste transportation companies, which offers weighting in their waste trucks. If there are only a few offers, they have a monopoly situation and the prices may get high. Same is for technologies to identify the user of the bin. The technologies can also be easily broken and need maintenance. People can have negative attitudes against new technologies and therefore do not support implementing the system.

6.2 QCA

The qualitative comparative analysis is aiming to compare different phenomena, things, and cases. The analysation method is discovered by Charles C. Rag in 1987 and is based on Boole's algebra. There are three stages in qualitative comparative analysis: getting familiar with the cases and qualitative material, defining the factors, and building the verity table, analysing the cases and formation of Boole's functions. The cases are presented earlier, but this chapter includes the stages of defining factors, formation of verity table and analysing the cases and Boole's functions. (Luoma, P. 2006.) Boole's algebra includes two conditions:

a real thing, which is marked as 1 and false, which is marked as 0. The factors analysed in this part, are significant factors for choosing the best system for Lakeuden Etappi Oy. The best system is the one, which has the highest amount of points at the end when the marks are summarized. (Luoma, P. 2006.) A research made by Salmenperä, H. et al. (2019b, p.50) is used as an example for this QCA analysis. Especially the factors have taken from the research and adapted to this research. QCA analysis is presented in table 9.

First of the factors is knowledge and data acquisition, which refers to the amount of the available, reliable knowledge about the system and how easy is to get more information. 1 means that there is a lot of available information and 0 that there is lack of information. The second factor is investments and indicates the need for large investments. 1 means that there are no large investments and 0 that there is, for example, a need for a specific treatment plant or facility. The third factor is waste transportation, where 1 means that waste transportation is not growing significantly compared to the current system, 0 means that there is notable growth in waste transportation. The fourth factor is a need for more workforce and 1 means that there is no need for more workforce and 0 means that there is a need for more workforce.

The fifth factor is the recycling rate. Though this includes a bit uncertainty because of different calculation methods and there are no specified sources of waste in the recycling rate. In this situation, 1 means that the recycling rate is higher than the EU target for the year 2035, 65 % and 0 that the recycling rate is lower. The sixth factor is distance and how close to the customer, the waste management services are arranged. 1 refers to that the recycling and waste management is organised close to the household and 0 refers to own transportation or other inconvenience, for example, longer walking distance.

The seventh factor is effort caused for the customer to handle the waste. 1 means no extra effort, compared to the current system and 0 means that there is some extra effort. The eight factor is waste management fees. 1 refers to that there would not be increases in waste management cost to the customers. 0 refers to an increase in fees. This is also uncertain because many things cause variation in waste management fees and increase in other countries or cities does not mean instantly that it is the case also in Lakeuden Etappi Oy. Nineth factor is viability. 1 means that there are no problems in viability and 0 refers to that

there might be problems for example in transportation, infrastructure, or areas, that causes extra inconvenience to the waste management company. The tenth factor is unwanted consequences, are there a risk, for example, illegal dumping or waste incineration at own yards. 1 means risks are low and 0 that there is a risk for these.

Table 9. Qualitative comparative analysis.

	Cases				
Factors	**System 1: Optical sorting**	**System 2: Kerbside collection**	**System 3: Co-mingled**	**System 4: Neighbour-hood**	**System 5: PAYT**
Knowledge	1	0	0	0	1
Investments	0	0	0	0	0
Transportation	1	0	0	1	0
Workforce	0	0	0	1	0
Recycling rate	0	1	1	0	1
Distance	1	1	1	0	1
Effort	1	0	1	1	1
Fees	0	0	0	1	1
Viability	1	1	1	0	1
Consequences	1	1	0	1	0
SUM	**6**	**4**	**4**	**5**	**6**

In the knowledge factor, the PAYT-scheme and system 1 was the best ones. In system 2 and 3, lack of knowledge resulted from that they did not answer to emails and there was no additional, personal information from the system. The emails included questions about parts in the system, that were not clear and could not be found from the websites or other documents. In neighbourhood collection, the lack of knowledge was caused by the newness of the system, there were not many examples of it in Europe. Then again, PAYT-scheme is widely researched and used system and therefore there was plenty of information available. In Eskilstuna, there was a lot of information already on their websites and they answered in the emails to give additional information about the system.

All systems require investments and estimation of the costs of implementing the new waste management system is not possible with this information. Systems 1 and 3, optical sorting and co-mingled collection require investments in the waste treatment facility. Then again, system 4, neighbourhood collection, requires plenty of new waste collection points and system 5, PAYT, requires information technology systems, weighing devices, and possibly

new collection vehicles. System 2, kerbside collection requires new multi-container waste collection vehicles and new waste containers, bags, and boxes. Transportation points went to system 1, where colour-sorting does not increase the waste transportation and system 4, neighbourhood collection, where waste transportation decreases when the collection is not arranged from every household individually.

The only system, where the extra workforce is not needed, is neighbourhood collection, system 4. Systems 1 and 3, optical sorting and co-mingled collection, includes building and running a facility, which needs workforce. In system 2, kerbside collection, the increased need for workforce is coming from the increased amounts of waste collection and checking, emptying the bags, and returning them to the household. In the PAYT- scheme, the extra workers are needed in managing the bills, maintaining the IT-systems, weighting, and identification of the waste producer.

In recycling rates, the highest recycling rate is in system 2, kerbside collection with 68,7 % then in co-mingled collection with 68 %, and optical sorting with 55 %. PAYT-system in Aschaffenburg achieved 86 % collection rate of recyclables. The recycling rate of neighbourhood collection was not available. The only system, that did not achieve the 65 % recycling rate was system 1, optical sorting. Neither neighbourhood collection, system 4 is not getting points.

Distance points were not given to system 4, neighbourhood collection, where the collection point of waste can be further than in the current system. In effort-factor, the points were not given to the kerbside collection system, because it requires the customer to carry the waste in the morning of the collection day to the kerbside. All systems require rearrangement of waste sorting at homes.

Waste management fees could be decreased with neighbourhood collection and PAYT-scheme. In PAYT-scheme, customers can manage the waste produced by themselves and therefore manage the waste management fees and in neighbourhood collection, the fees are decreased because of the combined collection with other households. Even though there was said in the presentation of system 3 that the waste management costs to the customer was

low, and were decreased after the implementation of the new waste management system, there were a lot of money from EU funds and the waste management fees were compared to the situation, where all waste would have gone to landfill.

In viability, zero points are only for neighbourhood collection. Neighbourhood collection may not be possible in areas that are old or where the collection is not considered in the area planning. There are no such restrictions in other systems. In consequences factor, system 1, 2 and 4, optical sorting, kerbside collection and neighbourhood collection have points, because the risks for illegal dumping or other bad consequences are not so markable than in other systems.

7 DISCUSSION AND CONCLUSIONS

This research showed that there are inside Europe and even inside the same country, a lot of different solutions for waste management. There are also great investments done to improve waste management. Some countries, for example, Sweden is remarkable innovative in waste management compared to other countries. For example, optical sorting in Eskilstuna and Linköping are great examples of brave action towards bigger recycling rate. There are also a lot of research done and long history in the area of waste management in Sweden. Then again, Slovenia is a country, where the development has happened fast but later, nearly landfilling all to efficient separate collection and high recycling rate in about ten years. Though, there has been also a lot of outside financial help from EU to Slovenia.

During the project, there was some interesting and innovative waste management system outside Europe. For example, it could be scientifically intriguing to investigate the waste management innovations in San Francisco, Singapore or Seoul. Especially the population in Asian countries put a whole new dimension to waste management and forces to innovate more effective ways to recycle. Singapore is known for its sustainability and other environmental innovations. Though these large cities with a population of millions could not have fitted into the aim of this research, there might have been efficient innovations, that could be scaled and changed to work also in smaller areas and areas with lower population densities. There would have been also problems with legislation if there had been waste management examples from outside Europe.

One of the challenges in this thesis was that there was not enough scientific information about the waste management systems in Europe. Most of the information used about the waste management systems in this thesis was from the waste management companies own websites. Only PAYT-scheme was more widely and scientifically researched. These website references may not tell the whole truth and the viewpoint to the waste management system might be more positive than the reality. The viewpoint is also from the company to the customers and therefore some parts of how the system works were not available. Languages, especially in case Slovenia, caused problems as well. In Flintshire, some websites and information were only available for the residents of the area. Different calculation methods

and low traceability of the waste sources and treatment methods caused problems in recycling rate comparison.

Finding interested and advanced waste management systems was like finding a needle in a haystack. For example, there were no data about the population densities and recycling rates in city-level, only on country-level. Inside the countries, there was some city-level data, but when there were no clear calculation methods presented and therefore the cities could not be compared with other countries cities. Then also, the waste management company areas usually include many cities, for example, case Slovenia. There are no clear measures and methods to investigate, whether the waste management system is good and recycling rate may not tell the whole story. During the project, interesting waste management systems to study were stumbled upon. One of these examples was Flanders in Belgium or Trondheim in Norway.

Naturally, the waste management system in bigger, and capital cities are more publicly spoken, reported and they pay more attention than the waste management system in smaller cities. Then again, the smaller cities could have fit into the research better. This caused, that there was a lack of information from the smaller cities waste management systems. Also, big cities and capital cities usually work as an example to other cities inside the country and as a front page for the whole country to the other world. In capital cities, there are probably also most resources to improve the waste management.

One of the interesting waste management systems that were stumbled upon during the project was pneumatic solid waste collection. This means, that the waste is transferred with a vacuum system from the households or buildings and collected jointly. This could be the future of waste management, but there is a problem. It is not applicable in already build areas, because of the underground vacuum pipes. It is also not applicable in sparsely populated areas. This system could solve the problem, that the customer does not need to transfer the waste anywhere and the waste collection trucks don’t need to drive in tight residential areas. This would increase the efficiency of waste collection.

The thesis makes to think about the future of waste incineration. Naturally, when the recycling rate is getting higher, the collection of recyclable waste is increasing and residual, combustible waste collection decreasing. This means that waste fuel to incineration plant is decreasing and it may affect the profitability of plants. Though, it will probably take still for a long time, that all waste material could be utilized and recovered to new, recycled materials and new products. Waste incineration is not as bad as landfilling, but worse than material recovery, recycling, and reuse. New EU waste legislation is already paying more attention to the waste hierarchy, recycling, reuse, and material recovery.

Markets for recycling materials is an interesting aspect of future waste management. According to Salmenperä H. et al. (2019), there may not be markets yet for all materials that could be recycled. All materials cannot be utilized, even if there is an efficient collection. This is because there is no suitable use for the material, the material is too dirty or otherwise low-quality. Are markets ready for increasing amounts of recycled material, are there going to be enough receivers and places to utilize recycled materials? Though, according to the waste hierarchy, overall waste production should be decreased. Then again, new waste legislation is also driving for new marketplaces for recycled materials. In Finland, this is organised through “Materiaalitori” by Motiva.

Especially important is to find economically and environmentally effective collection of biowaste from detached household areas. At the moment in general, there is no separate biowaste collection from detached household areas of Lakeuden Etappi Oy. Some might compost at own yard or have started shared biowaste collection with neighbours or there are some test areas, which includes separate biowaste collection. Then again, for recyclable waste, there are eco points, RINKI recycling points and regional waste stations. Biowaste in combustible waste lowers the efficiency and heating value, therefore it is not efficient to lead to incineration. It is also mandatory in new waste legislation to widen the separate collection of biowaste or composting at site soon.

All in all, to conclude the thesis there is a need for wider research about the waste management systems in Europe. The lack of knowledge caused many problems in this thesis. Especially, there is no recently done research about what is the main waste management

system used in a country or are there multiple systems used. Latest this kind of research is from 2015 by Seyring, N. et al. The study only presented the waste management systems in European capital cities. There is a clear need for more research about waste management systems and practices that leads to the best results. Also waste management performance indicators, such as recycling rate should be developed.

It was noted already during the study that some waste management systems could be more suitable for Lakeuden Etappi Oy than others. For example, the system in Eskilstuna was easily feasible also to sparsely populated areas. Therefore, the system was more interesting for deeper investigation. The workers in Eskilstuna Energi och Miljö were also communicative and gave openly more information about the system. There are also other optical sorting examples in Scandinavia. This could be a hint, that the system could work well also in here.

Customer's burden to sort, carry and transport the waste is one important aspect to consider in the new waste management system. All systems require more sorting and source separation at homes, even the co-mingled collection in Slovenia requires separation of recyclables, biowaste and residual. Besides more sorting, neighbourhood collection and kerbside collection cause extra burden to the customer. Customers may need support for waste sorting at homes. Then again, all of these presented systems offers better possibilities for separate waste collection than the current system in Lakeuden Etappi Oy.

There are many socioeconomic factors, that influence the household sorting enthusiasm. Though, these are things, that are not under the control of the waste management company but are good to notice. One of these is financial status, which causes different kinds of lifestyles, household structures and levels of consumption and therefore leads to variations in waste generation amounts as well as time and space available for sorting. Second is education level, which causes different knowledge about waste management systems and ability to understand waste management instructions. Education level is also related to age. Then again, age causes variations in physical capabilities. (Batllevell, M; Hanf, K. 2008.)

Even though the households manage to reorganise the waste sorting at homes, it is not certain, that the sorting is done right. This causes uncertainty. It is researched, that less distance to the waste collection point increases recycling, but these are always made in specific areas. The tests are usually also based on voluntary attendance. This causes uncertainty in the results if the attendants are already interested in recycling. Therefore, the situation in Lakeuden Etappi Oy may be different or customers not so willing to recycle, even if the recycling services is closer. Testing the systems is recommended before applying to get more information and to lower risks.

The change in waste management systems, when it considers all households in the area, causes in all cases extra burden to the waste management company. All of them includes communication with customers and education about the new system and recycling of waste. Optical sorting and co-mingled collection require a new waste treatment facility. Neighbourhood collection, kerbside collection, co-mingled collection, and PAYT-scheme require for new waste containers and possibly new vehicles with multiple compartments for different waste fractions or weighting devices. Some of the systems might require also changes in local waste management regulations. New workers are needed as well.

For further development and research of Lakeuden Etappi Oy, it would be valuable to investigate the composition of household waste. For now, it is not possible to differentiate the recycling rate of household waste and waste from other municipal waste sources. All waste is collected in the same routes and with the same vehicles. The research would offer valuable information for the company about waste sorting at homes, municipal service providers and other companies. It would offer information about what is the level of waste knowledge and sorting enthusiasm in the households and whether there is a need for waste management education. Also, the differences in waste sorting between inhabitants of the block of flats and detached houses would be interesting to know. It would be interesting to know, what is the customers' opinion about the future waste management in the area, are they willing to pay more fees and what kind of services would increase recycling. This questionnaire should be directed especially to those, who are not interested in recycling.

After the analysation, the best waste management systems for Lakeuden Etappi Oy turned out to be PAYT-scheme and optical sorting. These systems got 6 points. The second best was neighbourhood collection with 5 points. Kerbside collection and co-mingled collection got 4 points. SWOT- analysis of optical sorting showed that there are many important strengths and with few changes, some of the weaknesses could be tackled also. PAYT-scheme is not applicable alone, and it requires an efficient collection of recyclables and biowaste besides. That could be arranged with neighbourhood collection or separate kerbside collection.

The co-mingled collection was left out first. The reasons, why it is not suitable is that the case example is not very well compared with the area of Lakeuden Etappi Oy and there is lack of knowledge. Also, the system requires a large investment in material sorting and recovery facility but at the same time decreases recyclable waste quality. It also requires three waste containers in the household yards and therefore requires space and increases waste transportation. The profitability of building the material recovery plant to the small area is unclear. The waste management facility requires also professional workers to maintain and operate the facility. The strengths of the system could still be utilized also in Lakeuden Etappi Oy. These are the active communication and work towards more environmentally friendly attitudes, customer-specified cards in city centre area and mobile app to improve the services, education and communication. Mobile collection units were interesting innovations and could be used also in Lakeuden Etappi Oy.

Kerbside collection also got the least points, four points, in the QCA. The system as it is in Flintshire is not the best system for Lakeuden Etappi Oy. It requires a few changes to be applicable in Lakeuden Etappi Oy. The burden to the customers could be cut out with the system that is used in the example from Finland. In this example, waste is collected in different compartments at the household kerbside waste container. The customer does not need to carry the waste in the specific day and time outside because the containers are outside whole the time. Still, the amount of waste transportation is high in this system and the costs could get higher as it did in the example from Finland. The system requires also new waste vehicles with multiple compartments. Separate collection of garden waste and fines from lazy recycling could be also introduced in Lakeuden Etappi Oy.

PAYT-scheme is not applicable alone and requires an efficient collection of recyclables, which means kerbside waste collection or neighbourhood collection. Combining PAYT with neighbourhood collection would decrease waste transportation in the residential areas and waste management fees, increase recycling rate, offers equal billing and clear connection between waste produced and costs. It also makes residential areas safer, is applicable to areas, where driving with waste trucks is difficult or impossible and can include all waste fractions. Then again, there is not much knowledge about it and it includes risks in devices and identification systems, requires workforce for maintaining the system, grounding and maintaining the waste collection points, increases effort for the customer to carry the waste to the neighbourhood collection point, may not be applicable everywhere and includes a risk for illegal dumping, freezing of waste or reduction in waste material quality. In the areas, where neighbourhood collection is not possible, the collection could be arranged with separate kerbside collection.

Waste management system in Eskilstuna, optical sorting, got six points in the QCA. Optical sorting offers recycling services close to the customer, does not increase waste transportation, is simple and flexible for the waste management company and customers, is applicable to everywhere, even in sparsely populated areas, offers high-quality waste and can increase the recycling rate. Breaking bags and low-quality waste- threat could be tackled with testing and education. The system is also used in many places in Scandinavia with great success, so it can be assumed that it could work well also in Lakeuden Etappi Oy. Glass, hazardous and larger household waste (large cardboard boxes, for example) collection could be arranged as before with a possible increase of the collection points or introduction of a mobile collection unit. One thing, that concerns in optical sorting, is relatively low municipal recycling rate, only 55 %. Even though every usual household waste fraction is collected separately from the kerbside, the recycling rate is still not higher.

The weakness of large investment may not be a problem for a wealthy company and changes in waste management in the near future is anyways mandatory. Though, the waste management fees are already higher than the average in Finland. It must be noted in the waste fees, that the area of Lakeuden Etappi Oy is large and sparsely populated. Lakeuden

Etappi Oy has also the same fees for every customer in the area, no matter where the property is located. These increase the waste collection costs to the company. Also, differences in development level and investments in the Finnish waste management companies' waste management systems are in different stages. At the moment, municipalities can decide, whose responsibility is managing the waste collection. Customers can manage it by themselves or the municipality. Therefore, the waste collection fee statistics may not be reliable, and many factors affect the fees. From the viewpoint of a customer satisfaction, the fee increase is not recommended.

From the legislative viewpoint, the PAYT-system is more suggested. Implementation of weight-based PAYT-scheme and increase in the separate collection was suggested in the early warning document from the EU. It was also said at the beginning of this thesis, that the suggested waste management system could be also a mix of systems. Therefore, the suggested system could be a combination of optical sorting and PAYT. This could be implemented with two containers. One container would be for residual waste and another one for recyclables and biowaste. Residual waste collection would have high fees and recyclable and biowaste much lower. This could encourage customers to recycle more with financial incentives. This tough requires more quality-checks for bags in collection. Biowaste collection is arranged with recyclables because there is no need to encourage for home composting. Then again, the lower fee also for biowaste increases the separation of biowaste at homes. Risks for illegal dumping are low because all wastes are collected at the kerbside and recyclable fraction and biowaste also have a collection fee.

8 SUMMARY

This thesis concentrated on improving the waste management system of Lakeuden Etappi Oy in South-Ostrobothnia. The area of interest is to improve the separate waste collection services and the recycling rate in the area. Especially the problem is biowaste and collection from detached household areas. Lakeuden Etappi Oy pursues to achieve their strategic goals, which includes excellent service experience and efficient logistics and waste treatment processes. These goals were also in the background of the study. Difficult areas for waste management in Lakeuden Etappi Oy and Finland, in general, are low population density and sparsely populated areas.

New EU waste legislation forces changes in waste management systems, increase in recycling rates, stronger implementation of the waste hierarchy and wider separate collection of waste. The thesis aimed to find the solutions for waste management of Lakeuden Etappi Oy to fulfil the requirements of future waste legislation in an environmentally and economically efficient way. Five different waste management systems were used to research for the best waste management systems, technologies, and practices. The target was to find a waste management system, that has high recycling rate, efficient separate collection, the investments and fees to the customers are manageable, transportation of waste is not increasing significantly and the waste management is equally available to everyone. The suggested system should also take into account the area characteristics of Lakeuden Etappi Oy. The research question was, which would be economically and environmentally the best waste management system for Lakeuden Etappi Oy?

The thesis gave a wide review of five different waste management systems in Europe. Different waste management systems were selected with the help of scientific research, recycling rates and population densities of European countries. Different waste management systems were optical sorting system from Eskilstuna, Sweden, kerbside collection from Flintshire, The United Kingdom, co-mingled collection from Ljubljana-area, Slovenia, neighbourhood collection from Oulu, Finland and PAYT-scheme from Aschaffenburg, Germany. The systems were analysed with using SWOT-analysis and qualitative comparative analysis. The systems were analysed from the viewpoint of Lakeuden Etappi

Oy in the situation, where the current system is replaced with the analysed system. The worst systems turned out to be kerbside collection in Flintshire and co-mingled collection in Ljubljana-area. The best ones were the optical sorting system and the PAYT-scheme.

After all, the suggested waste management system was the optical sorting system with PAYT. This would be applied with two containers, one for residual waste and another for recyclables and biowaste. These different containers would have different collection fees to enable PAYT-scheme. The combination offers a high recycling rate and wide separate collection possibilities to all kinds of residential areas. PAYT-scheme offers clear, equal billing system, that encourages to recycle with financial incentives. The system neither increases transportations significantly and investments are manageable for Lakeuden Etappi Oy. The advantages of this combination are greater than the caused burden and costs. It offers a waste management system, that is economically and environmentally better than the other system and supports achieving strategic targets and is compatible with the new waste legislation.

There was a lack of information on three of the waste management systems presented in the study. PAYT-scheme was the only system, which was largely scientifically researched. Most of the information about the systems were from the websites of the waste management companies. Also, it was difficult to scan the waste management systems and all well-performed systems were not able to be considered in this thesis. These reduced the scientific value and reliability of the thesis. Scanning of the possible waste management systems could be done differently and more scientifically and for example with short questionnaires to national waste management associations. There were also some interesting waste management systems, that turned up after, the waste management systems were already decided. The thesis showed that there are many interesting topics to study and need for more research in the waste management area. After all, the targets of the thesis were achieved, and the results and overall success of the thesis are good when the lack of knowledge is considered.

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