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Recycling of household plastics

Suvi Sointusalo

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Abstract <p>Thesis presents plastic recycling research assigned by Mustankorkea Ltd. The research was executed in close cooperation between Mustankorkea Ltd and Jyväskylän Vuokra-asunnot Oy JVA. The research is a part of larger project entity called Circwaste, which is an EU-wide project promoting circular economy and aiming to improve resource efficiency and material flow management.</p> <p>The research was conducted in Jyväskylä and its objective was to find out citizens' interest in household packaging plastic recycling. The research was implemented as an experiment where tenants of five apartment houses located all around Jyväskylä were given the opportunity to dispose their packaging plastics as separately collected waste. The experiment took four weeks and after it was finished a survey of tenants' experiences was conducted.</p> <p>Based on the results of the research Mustankorkea Ltd decided whether to start separate collecting of household plastic waste permanently from apartment houses or not. Unfortunately the results were such poor that collecting separate plastic waste isn't environmentally nor economically wise. The results showed that despite of opinions and general atmosphere being positive towards plastic recycling citizens still don't recycle.</p> <p>In addition to the research thesis also presents briefly circular economy since it is the driving force in Circwaste. Other main topics covered in the thesis are waste management statistics and waste legislation. Both are studied from plastic waste point of view.</p>		
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1 Introduction

During the past decades plastic has become significant problem for the environment worldwide. It is estimated that up to 12 million tons of plastic is discarded into oceans every year by coastline countries (Moore 2017). Plastic eventually breaks down into small particles but never disappears completely. It is lethal to ocean wildlife and has negative effect on the ecosystem.

Undoubtedly each and every one living in modern world has heard about the harms plastics cause and know by heart that avoiding excessive plastics usage is recommendable. But despite the obvious harm plastic causes, it might not be such unequivocally bad material after all. A report released in 2005 studying proposed plastic bag levy in Scotland assessed environmental impact of ordinary plastic carrier bags compared to other carrier bags, such as bag-for-life and paper bag. It turned out plastic bag didn't pose the greatest damage to environment. Plastic bag production requires only little resources and, for example compared to paper bag production, its emissions are just one third. The only significant downside of plastic was recycling challenges it faces. (Cadman, Evans, Holland & Boyd 2005, 36.)

Plastic is good, versatile material, but indeed a bit problematic. In order to continue plastic usage in everyday life, efficient recycling and reuse is crucial. EU has multiple projects concerning sustainable development, environmental conservation and such. One of them is Circwaste-project. It is a seven-year long EU LIFE IP -project aiming to improve material flow management, waste prevention and resource management. It consists of several even smaller projects and experimental researches. One of the researches in Jyväskylä within Circwaste is collecting of household plastics. The plastics will be collected and further sorted out for reusing and recovering purposes. Thesis studies this research. Circwaste is presented more detailed on chapter 5 *Circular Economy*.

As a raw material recycled plastic is valuable industry input with a fairly consistent supply. If all household plastics were recycled carefully and reused wisely it would form a never-ending material circulation. On the other hand, if product design was done more environmentally sustainably less plastic would end-up to waste. These both are intriguing subjects but very complex and difficult. This thesis cannot give

any straight and thorough answers or solutions to the matter of plastic waste but it can – and will – present an alternative in waste management through the experimental research of recycling of household plastics. The aim for recycling is to increase the use of recycled plastic as raw material in industry.

There is a growing interest on possibilities to recycle especially plastics. When Jyväskylä city announced its participation to Circwaste and citizens' subject proposals to the forthcoming researches were asked, some 27% of the proposals were about plastic recycling (Strategia ja hankkeet [Strategy and projects] 2017). Hence, thesis's subject is topical right now and seems the public opinion about it is very positive. Ergo, basis for writing this thesis are good.

Just a few decades ago waste management was totally different than what it is today. Waste was buried to landfill and nothing was collected separately. Slowly things started to change and collecting of separate waste materials began. Newest addition to these materials in Finland is plastics. It is fairly new material in Finnish waste management and deeper insight on the matter is needed. Thesis's goal is to gather experiences and more knowledge about household plastic recycling.

Thesis' topics form three main entities. First one is plastic waste management and issues related directly to it. Plastic waste management theme is the core of the thesis. Second greater topic is logistic side of waste management in general. It forms professional and theoretical base for the thesis and underlines for which study field this thesis is written. Research is the third theme. It's experimental and, in a way, informal part of the thesis. Its aim is not to give scientific facts about waste management but to observe it in real-life. These three together form a solid, consistent report.

Host Company Presentation

Thesis's host company is Mustankorkea Ltd.

Mustankorkea Ltd is municipal-owned waste management company. It was launched in 1998 and is owned by Jyväskylä city and municipalities of Laukaa and Muurame.

Mustankorkea is responsible of organizing waste management in practice in its

owner's regions and in addition has eight Central-Finnish municipalities as customers. In Mustankorkea's whole operating region lives approximately 220 000 citizens. (Mediapankki & Press [Media bank & Press])

As mentioned thesis research is based on Circwaste-project. For funding reasons Mustankorkea Ltd cannot operate as a project leader on the experimental research this thesis studies. Official execution for the research is therefore done by Jyväskylän Vuokra-asunnot Oy. Mustankorkea Ltd has due to nature of its business special interest on the research subject and so Jyväskylän Vuokra-asunnot Oy works in close cooperation with Mustankorkea Ltd.

2 Research

Thesis studies recycling of household packaging plastics. In this context recycling refers to sorting in households, collecting, further sorting and processing. There are in addition more precise terms used in waste management for specific processes but for the sake of simplicity term 'recycling' is used otherwise in the thesis if more precise expression isn't necessity for deeper understanding.

The plastic collecting research is conducted in rental apartment house buildings owned by Jyväskylän Vuokra-asunnot Oy JVA. There are five randomly chosen houses on the research. They are all located in Jyväskylä city area but in different suburbs. Structure of inhabitants varies between multiple different social characteristics.

People are believed to have the most impact in plastic collecting -research's results. Hence, what is actually studied in the experimental research is not waste management generally, it's people's behavior towards it. But, despite the realization of the behavioral aspect the research is conducted fully anonymously and no distinction between the houses nor the tenants is made during the research. The houses are named alphabetically and only once research is finished and results are obtained the possible characteristics are taken into consideration on the analysis.

During the research all of the collected waste is transported to waste management center owned by thesis' host company and sorted into pre-determined categories. After the research is finished there will be a questionnaire for the tenants.

2.1 Objectives

Thesis's main goal is to gather knowledge and experiences through plastic recycling research. Particular focus points are on tenants' experience and on quality and quantity of waste material collected during the research. These questions will hopefully be able to answer whether to start collecting of packaging plastics from households permanently. Thesis will also give insight for the host company about circular economy since it is the driving force on Circwaste-project. It is though merely just supporting subject and no defined research question is formulated from it.

Thesis's research questions are outlined to following:

How tenants' experience the research and plastic recycling overall?

What is quality and quantity of collected material?

Would it be wise to start a full-scale collecting of separate plastic waste in Jyväskylä?

First question doesn't provide too much exact data to work with. Second question is in a way sub-question to the first one. Tenants' positive experience will affect positively to quality and quantity of collected material, and negative experience likewise negatively. Question of quality and quantity is in addition more useful in developing waste management since both quality and quantity are measurable factors. The third question is the main research question and answer to it will be fully formed based on the results of the two previous questions.

The first question is as it is a very broad and undefined research problem. To clarify its expected outcome it has to be narrowed down a bit. On Appendix 1 is questionnaire with which tenants' experience is evaluated. Hence the question and its results are limited to what the presented questionnaire can offer. The question is not trying

to find any absolute truth or facts but just to get an understanding on tenants' opinions and views.

2.2 Methods

2.2.1 Qualitative and Quantitative Research

Both qualitative and quantitative methods can be implemented into the same research. Methods have different approaches and therefore they can be both useful. What is essential is knowledge of which approach is the most appropriate one in each case. (Vehkalahti 2008, 13.)

When mixing different methods it's crucial to know the differences between them. Qualitative and quantitative methods both have strengths but they differ depending on the research. It might be that particular strength is an actual strength only on some researches but fails on the others. That's why one shouldn't think which method to use on the research but to think what is the goal or goals of the research and how to achieve those. Once answered to that mix of methods will form spontaneously. (Morgan 2014, 51-52.)

Below is Table 1 in which main differences of qualitative and quantitative methods are compared with three basic distinctions.

Table 1 Comparison of Qualitative and Quantitative Methods (adapted from Morgan 2014, 48.)

Qualitative Research	Quantitative Research
Generates theory from observations.	Tests theory through observations.
Tries to understand others' perspectives.	Emphasizes things that can be measured.
Analyzes holistic systems.	Analyzes variables.

The research this thesis studies has features from both qualitative and quantitative methods. In a way it's an experiment which will just see what happens, i.e. it is qualitative research. On the other hand it still has goals that have to be measured somehow. Best practices for this are quantitative. Also analysis of the results has quantitative features.

2.2.2 Survey

Survey is an important way to gather and study information concerning for example multiple kind of societal phenomenon or citizens' behavior, attitudes, opinions and values. These subjects are often complex and multidimensional which makes them difficult to measure accurately. Phenomenon under study may in addition change or transfer over time, or appear differently in different circumstances. Hence, defining the measures precisely is important. It is good to devote to the actual measuring phase since mistakes made during it cannot be fixed afterwards. (Vehkalahti 2008, 11-17.)

In a survey measuring is usually done with a questionnaire. Once the respondent fills in the form it is too late to make any changes to it. Therefore the form has to be designed carefully. What is decisive is whether content-wise questions are asked in a statistically-wise manner or not. Designing of the questionnaire should be done step by step from starting of defining the core dimensions of the subject. From there planning should proceed gradually through various phases to complete questions. The questions should form multiple sections which measure different dimensions of the phenomenon. The sections have to be clear, understandable and concise, and the questions must be unequivocal. (ibid., 20-23.)

Questions can be either open or closed. Open questions are answered in a free-form whereas in a closed question answers are given and the respondent just chooses the most suitable one. Closed questions must be designed so that given answers do not cross each other, for example age categories mustn't overlap. Another matter affecting the answers is dispositioning the questions. Questions about age and such other

back-ground information should be asked at very end of the questionnaire since people tend to feel intruded if personal matters are asked as the first questions. (ibid., 24-25.)

Typically questionnaires are formed with closed questions. Given answers clarify measurements and simplify analyzing the information. The most common scale for answers is the Likert scale. The scale has multiple claims from positive to negative and the respondent chooses the closest one to his/her own perspective. Likert scale is a good tool for calculating averages, dispersions and correlations. (ibid., 25-37.)

Questionnaire should consist following parts:

- 1) Introduction
- 2) Instructions
- 3) Statements or questions
- 4) Demographics

Depending on what is studied the questionnaire can in addition have open questions or possibility to leave comments. (Thiel 2014, 205-208.)

2.3 Execution

This chapter presents implementation of the research in practice. Main procedures with reasoning are explained. Comprehensive introduction to the measures will guarantee the research to be fully repeatable.

2.3.1 Questionnaire

Results of the questionnaire is split into age groups according to what might be the typical life phase for different age tenants. **18-30 years** old tenants are in their young adulthood and maybe still finding their way of living. The youngest ones are possibly living for the first time on their own. Consumption habits and living itself are on development process. **31-45 years** old tenants have slowly settled down by now. They might have families of their own. By this time tenants are assumed to have stable

lives and ways of organizing everyday life. **From 46 to 63 years** is the middle age gap on this research. Pre-assumption was that people on this age group might not be as aware of importance of recycling and sustainability as younger tenants. **64 years** and on is the senior citizen age group. These tenants have retired from their work and have more free time on their hands. Maybe it affects on their recycling habits?

Division to age groups is done purely by assumption and might not reflect reality in all cases. Some kind of dividing, however, had to be done and through careful consideration excuses stated above seem reasonable.

Questions are planned so that multiple different topics are covered. Each topic has few questions with different perspectives on the matter. The topics are following:

- Practical arrangements (of the research)
- Attitudes towards recycling
- Knowhow on recycling

The questions are not arranged under headings but just as a plain list. The idea is to not lead the tenants with their answers in any way. Headings with topics as mentioned above might prompt the answers into a direction the respondents believe to be the most desirable. Answers to questions are given on a fixed scale from *fully disagree* to *fully agree*. Simple yes/no questions wouldn't have produced enough information for analysis. Scale is easy and fast way to give answers, but still informative enough.

2.3.2 Practical Arrangements

Assumption is that collecting plastic waste will reduce amount of mixed waste by one third. It could actually be a lot more since most of mixed waste is usually recyclable plastics. Tenants taking part in the research, however, aren't accustomed to recycle plastics and for this reason the amount is estimated to be low.

It is quite likely that in some houses the research is welcomed with more open arms and quantity of collected plastics is higher. Nevertheless, the plan is to change one

third of mixed waste bins to plastic waste bins in all the houses. As the research goes on, more bins can be changed if there is a need.

Plastic waste bins have additional inner sacks for easy emptying. Transport company adds new sacks to bins when collecting the waste. Usually this kind of dry waste wouldn't require inner sacks but during the research plastic waste is gathered from the five houses with a small delivery truck. In areal waste collecting points plastic waste is gathered with garbage truck or other more suitable vehicle.

Pace for emptying is estimated following: For example, building A has 42 apartments and during the research it has three plastic waste bins in usage, in total 1980 litres. Therefore it has a capacity of 47 litres per apartment. Assumed amount of plastic waste is calculated to be $\frac{1}{3}$ of the amount of mixed waste in normal situation i.e. when there is no separate plastic waste collecting. Computational number of days is calculated by dividing plastic waste collecting capacity per apartment with the assumed amount of plastic waste.

As an example is Figure 1 below representing house A. In the figure is in pale orange how it would look on calendar if the emptying was done exactly according to calculations. Green presents implemented scheduling and darker orange days when the bins are placed or displaced to house's waste collecting area. Hence, emptying schedules aren't formed directly from the outcome of calculations. Calculations are merely used just as a base for estimating suitable emptying pace. Other factors influencing the scheduling are, for instance, the terms of emptying service. Transport company is likely to give better offer for service occurring on regular intervals on weekdays. For these reasons emptying for house A is scheduled for Fridays.

week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
30					28	29	30
31	31	1	2	3	4	5	6
32	7	8	9	10	11	12	13
33	14	15	16	17	18	19	20
34	21	22	23	24	25	26	27
35	28						

Figure 1 Emptying Calendar for Building A

Emptying schedule for building B and D is planned the same as for building A. Building C and E are scheduled for twice a week emptying pace, having the service on Tuesdays and Fridays. It is rather questionable whether apartment C really needs emptying twice a week since the computational emptying pace is exactly seven days. Decision for this twice a week pace was eventually based on slight overestimating. It is better to empty a bit too often since the calculations are partly based on pure assumptions that might turn out to be wrong

Very important matter for the research to be successful is notifying all parties possibly involved in any way. Tenants will receive handouts twice delivered straight to their apartments. Notifications are send also to contractors collecting mixed waste from the buildings and maintenance companies. Notifications are in addition added to buildings' noticeboards.

2.3.3 Sorting of Collected Material

Chief Executive Officer Vesa Soini from The Finnish Plastics Recycling Ltd gave a telephone interview concerning how sorting of collected plastics should be accomplished. Official instructions in Finland for sorting the waste in households is that dirty plastics should be disposed in mixed waste and only clean plastic is to be disposed to plastic collecting bins and containers. According to Soini all plastic could be cleaned and reclaimed in the process but due to health hazard instruction is to recycle solely clean plastics. For example, if some food stuff is left to plastic packaging

disposed to plastic collecting, the leftovers will likely start to rot before reaching the reclaiming process. Mould and other particles cause health risk when inhaled and the reclaiming process requires manual labour. Therefore sorting the collected plastics on this thesis research complies the official instructions for households. The following sorting graph (Figure 2) is adapted from Soini's counselling. It is not as elaborate as instructions used in plastic waste management industry but sufficient enough for this research.

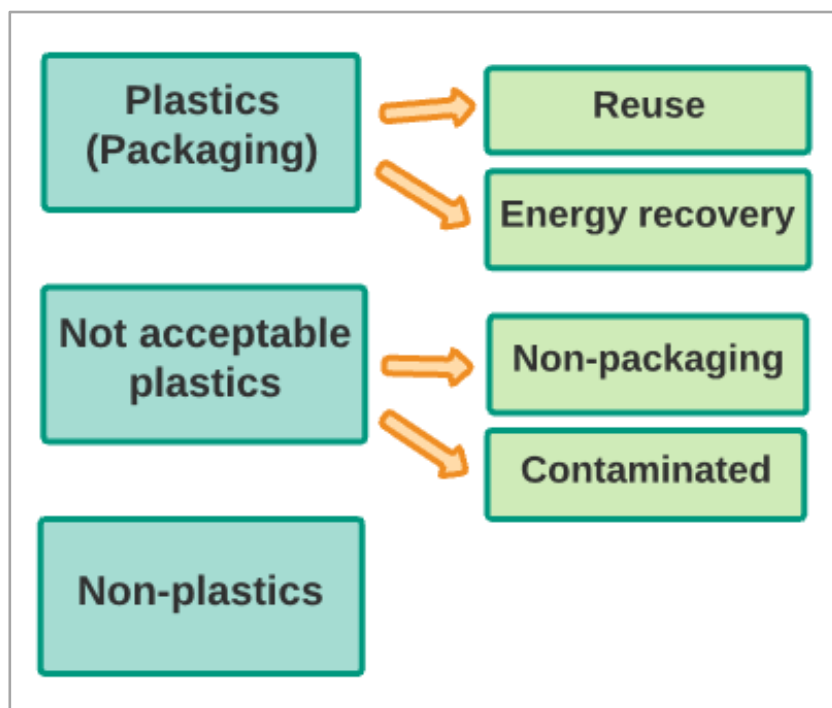


Figure 2 Graph for Sorting of Collected Plastics

There are multiple different theories on what quality is and how to define it. One traditional definition is *correspondence to specifications*. More or less all definitions agree on correspondence but the difference is what should be corresponding. Other theories highlight for example requirements or customers' needs. (K. Shridhara Bhat 2009, 1-2.) Some definitions are also broader or more detailed. All and all, quality can be defined to something being as anticipated or desired.

On this research quality of collected plastics is defined simply as meeting the requirements given on official Finnish instructions for sorting the waste. The collected plastic waste has to be household packaging plastics and is has to be reasonably clean.

2.4 Limitations

Time poses a great limitation for the research. The research lasts only a short while and it takes time for the tenants to get used to recycle differently than before. Especially quality and quantity might be poorer than in a longer research.

Highly important factor for the research to be successful is the questionnaire and how it is formed. It has to be simple enough so that participants will want to put in the effort and time of giving answers but still complex enough to give valuable information research-wise. The survey will also give the frame for the first research question. The question is very equivocal so it has to be narrowed down to concern only the experimental research.

3 Waste Management in Finland

This chapter will give the reader thorough understanding on what waste management is in Finland. The studied plastic waste collecting research is executed under the circumstances presented on this chapter and for that reason closer insight is needed.

3.1 Legislation and Decrees

Waste management is highly controlled business field. There are lots of specific instructions and regulations under which companies must operate. All the regulations aren't essential for understanding what plastic recycling is today and therefore only the most important regulations for the thesis are presented. Regulations give a frame

for the operating environment and also explain reasons for why and how plastic recycling is developing and will further develop in Finland. Main reason currently for Finland to change and stricken its legislation is EU.

On the figure (Figure 3) below is a diagram with shows what regulations are essential for this thesis and what is the relation between them. EU's so called waste directive is above Finnish waste legislation. Legislation sets a frame for Finnish waste management and decrees complement it. The four sections in the figure are the ones with most influence for this thesis and therefore are the only ones among Directive, Legislation and Decrees that are explained through in following paragraphs.

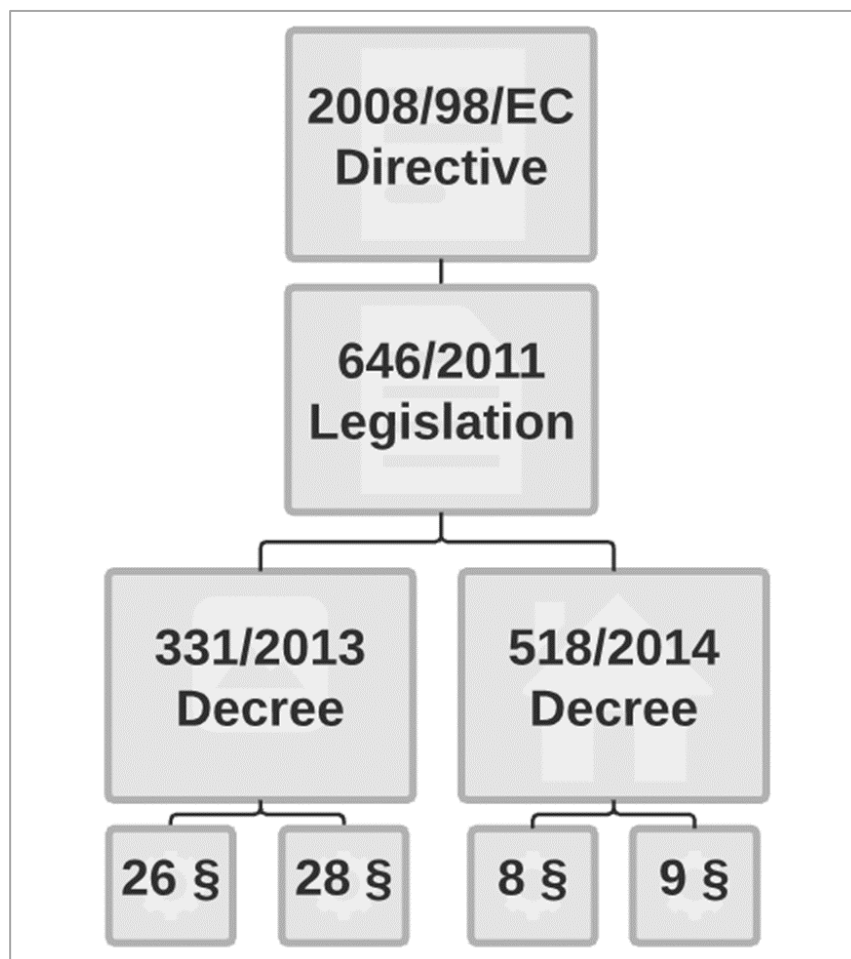


Figure 3 Waste Legislation Structure

2008/98/EC Directive is a so-called waste framework directive. It sets certain boundaries to waste management in EU Member States and the States are required to

adopt waste management plans and programmes in order to meet these boundaries. Below is a figure (Figure 4) which presents waste management hierarchy to be applied as a priority order to Member States' waste legislation and policies. The Directive sets as a target that by year 2020 50% of household waste materials should be *preparing for reuse and recycling*. (European Commission 2016.)

On the EU's waste management hierarchy different procedures for managing waste are illustrated in order of preference. Disposal means in practice usually landfilling. It is the least favorable option. Recovery is only slightly better option but right now it is the most common one in EU. As said on the previous paragraph The Directive is aiming at recycling and reuse options. Recycling cuts down the amount of waste on the two lower stages of the hierarchy and reuse develops exploiting of recycled materials more sustainably and efficiently. Prevention is the option in which unnecessary manufacturing and consuming are reduced. (European Commission 2010.)

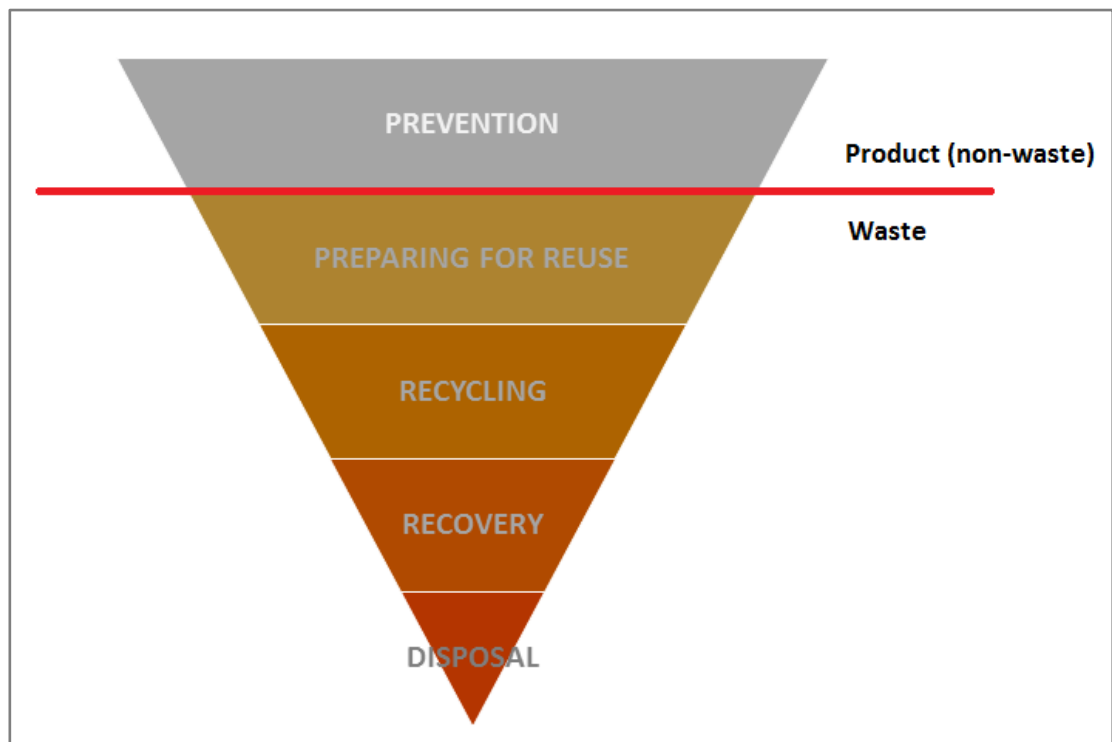


Figure 4 Waste Management Hierarchy (adapted from European Commission)

646/2011 is the Finnish waste Legislation. Its purpose is to

- prevent danger and harm caused to environment and health by waste and waste management
- decrease the amount of waste and its harmfulness
- encourage sustainable development of natural resources
- ensure working waste management
- prevent litter.

The Legislation defines what is waste and how waste management is to be organized. It lists common responsibilities and principles as well as authorities and their duties. In addition, planning and controlling the waste management are in the Legislation. The Legislation also states fees used in waste management. (646/2011)

331/2013 is Decree on landfill sites. Its objective is to prevent climate change and other as wide and comparable changes to it, as well as spoilage of water systems, soil and air by controlling designing, constructing, utilizing, managing and abolishing landfill sites. Landfills must not ever cause even in long terms danger nor harm to health or environment. Sections 26 and 28 state that any waste with over 10 % of organic waste are forbidden to be buried to landfills from January 1st 2016. In this case organic waste includes also plastic waste. On the Decree organic waste is defined as carbon-hydrogen compounds which is the definition for plastics as well. (331/2013)

On chapter 6 on Finnish waste Legislation is defined *producer's responsibility*. Legislation lays the responsibility of organizing waste management with own expense to manufacturers and importers once the product meets its decommissioning point. Failing to response the responsibility might cause the company to face a fine. It applies to all packaging materials created in households and similar packaging waste generated by communities. (646/2011)

518/2014 Decree issues provisions on collecting, reusing and recycling of used packaging and other waste management. It also includes qualifications on packaging materials imported to Finnish market and how the packages are marked. The Decree sets out the following on plastics on sections 8 and 9: Companies operating under the *producer's responsibility* must organize collecting and recycling of packaging plas-

tics so that by January 1st 2020 minimum level of 22% is met. The level does not include beverage packaging collected by the beverage packaging take-back system. Companies must organize the collecting so that there are minimum of 500 packaging plastics collecting points so that each conurbation with over 10 000 residents has at least one collecting point. (518/2014) Implementation in practice is explained on chapter 3.3 *Business Field*.

3.2 Municipal Regulations

In Finnish waste Legislation on chapter 10 is stated that municipalities may give detailed regulations on municipal waste management when necessary. Municipal regulations concern mainly waste under municipalities' waste management organizing responsibility and regulations must take into account local circumstances. (646/2011) Municipal waste regulations are clarifications to waste Legislation and work as implementing tools. The regulations are important in executing the Legislation in practice.

In some individual cases authorities may grant an exemption to waste regulations (646/2011). In Jyväskylä the authority is Jyväskylä region waste commission (Viranomaistehtävät [Authority duties] 2017.). Exemptions may concern for example changes in emptying household waste bins with longer interval than regulations usually allow.

Some municipalities have issued orders on more strict practices than Legislation and Decrees require. In addition waste management companies may offer better services for active citizens. For example in South-Karelia region plastic waste is collected straight from 135 apartment buildings and 45 detached houses (Mäkinen 2017.). There is no regulation for it in South-Karelia, it's just a service provided by region's waste management company. In Turku region more strict regulation will enter into force from beginning of June 2018 (Kahila 2017.). The plastic recycling experiment this thesis studies might lead also Jyväskylä to get more advanced plastic collecting system either through regulations or additional services. Either way, the experiment and the thesis gives important knowledge and experience for it.

3.3 Business Field

Finnish Packaging Recycling Rinki Ltd is a non-profit company founded and owned by Finnish industry and retail field. It offers efficient and sustainable services for implementing *producers' responsibility*. On January 1st 2016 Rinki launched collecting network for recyclable materials. The network is designed as stated in 518/2014 Decree. (Medialle [For media])

Suomen Uusiomuovi Oy or The Finnish Plastics Recycling Ltd is producers' community founded in 1992. Its task is to ensure execution of *producers' responsibility* for plastics for over 2200 companies. Finnish Packaging Recycling Rinki Ltd is the service company for The Finnish Plastics Recycling Ltd providing services such as collecting network, invoicing and accounting. The Finnish Plastics Recycling Ltd's primary task is to promote plastics recycling. (Suomen Uusiomuovi Oy [The Finnish Plastics recycling Ltd])

Circular Economy Village at Riihimäki is a municipal waste processing unit built by Fortum Waste Solutions. At the village each material flow has the best possible recycling form and waste materials cycle through Eco Refinery and either through Plastic Refinery, Gasum's Bio Refinery or Energy Plant. The Plastic Refinery is the first one built in Finland. It processes not only plastics separated from municipal waste but also separately collected household packaging plastics. At the refinery plastics are sorted, shredded, washed and granulated. Processed plastic is directed back as plastic industry's raw material to replace virgin materials. The process is presented on Figure 5 below. The Plastic Refinery has been designed to process 14 000 tons of plastic and it is the only facility in Finland that processes household plastic waste into high-quality raw materials for industry. (Kiertotalous [Circular Economy] & Muovijalostamo [Plastic Refinery])



Figure 5 Plastic Refinery Process (adapted from Kiertotalous [Circular Economy])

3.4 Statistics

Progress in Finnish waste management is nicely summarized in following sentence: *“Mixed waste is turning into mere energy waste and separately collected waste into recycled material.”* (Statistics Finland 2016.)

Trend in municipal waste treatment is nowadays strongly towards recycling and recovering. Statistics below (Figure 6) shows that in a decade disposing the waste to landfill site banks has become more and more unlikely. Comparing the year 2005 to 2015 only about one sixth of municipal waste is buried in landfill. Recycling rate has stayed approximately the same throughout the years and energy recovery has increased in same pace as landfilling has decreased.

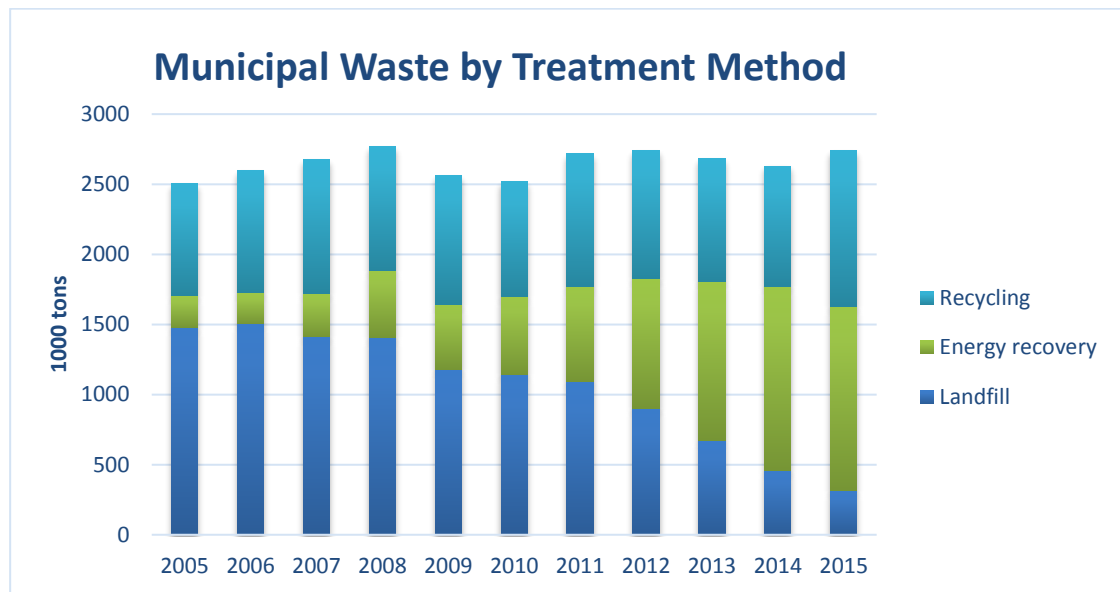


Figure 6 Municipal Waste by Treatment Method from 2005 to 2015 in Finland (adapted from Statistics Finland)

According to Statistics Finland (2016) in 2015 nearly half of all municipal waste in Finland was incinerated. The growth of energy recovery has been steady and seems that it's "winning the race". When comparing year 2014 to 2015 recycling increased considerably. This is, however, due to more precise definition of recycling of fibre packaging waste generated by field of trade and the large quantity of it.

On January 1st 2016 landfilling of organic waste was banned. Research conducted in 2015 showed that mixed waste consists up to one fourth or even more of organic waste and therefore cannot be buried to landfill sites anymore in 2016 and on. (Mustankorkea vuosikertomus 2015 [Mustankorkea annual report 2015] 2016, 14-15.) This has most likely resulted in even lower levels of landfilled waste and higher in energy recovery. Unfortunately the most reliable Finnish statistics provider Statistics Finland won't announce exact figures from year 2016 until this thesis has already been finished. Hence precise figures aren't available on the time of writing the thesis and nothing but assumptions can be made.

Figure 7 compares percentages of treatment method for plastic waste in 2015. Total amount of the waste is 41 791 tonnes. Landfilling appears to be full zero but actually some 168 tonnes of waste is landfilled. (Statistics Finland 2016.) Again, due to lack of

current statistics it is impossible to say exact situation for plastic waste today. Though, the figure will surely still give some sort of insight to the matter.

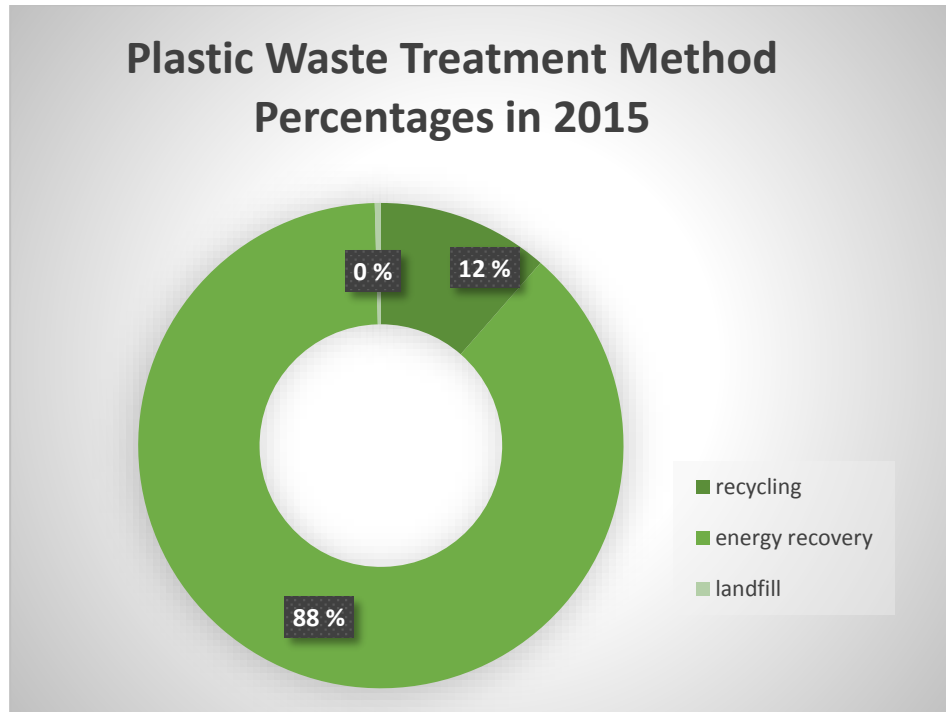


Figure 7 Plastic Waste Treatment Method Percentages in 2015 (adapted from Statistics Finland 2016.)

Mixed waste in 2015 is almost half of all municipal waste with portion of 1 268 259 tonnes (ibid.). In reality mixed waste consists partially of separately collected waste. The experiment this thesis studies tries especially to decrease the amount of plastics in mixed waste. This will obviously increase the amount of separately collected plastics. The increase might help to contribute recycling of the plastic. The more there is material the easier and more efficient it is to exploit it.

4 Waste Management Worldwide

Knowing some facts about worldwide waste management helps the reader to get broader picture of plastic recycling in general. This chapter presents some of them.

4.1 3R Initiative and Waste Management Concepts

Original waste management R-approach was introduced as 3R; reduce, reuse and recycle. It is the base theory for waste management worldwide.

3R initiative was originally presented by Japan at Sea Island Summit in June 2004 and agreed as a G8 initiative. It was formally launched at The Ministerial Conference in Tokyo in April 2005. (3R Initiative)

Implementation of the 3R initiative is the main tool in creating Sound Material-Cycle Society (SMS). SMS is defined as following: *“Society that is realized by reducing the generation of waste from products, suitably utilizing waste generated as resources whenever possible and appropriately disposing of waste that cannot be used in any way, thereby controlling consumption of natural resources and reducing the environmental load.”* (Japan Ecology and Nature Protection Handbook 2015, 64-72.)

Importance of the SMS is clear. Global economics has grown and population increased causing the amount of circulative resources to increase too. And not only the amount has risen but also diversity of the resources has expanded. Along with the increase of resources awareness of environmental matters and pollution has improved. The 3R initiative acts as a perfect guidepost for implementation of SMSs both in global level as well as domestically. (ibid.)

Sound Material-Cycle Society has similar features to circular economy. Differences are mainly in slightly different approach to the matter of which both concepts are based on. Circular economy focuses more on economical aspect, whereas on SMS environmental matters weigh more. SMS aims to decrease harmfulness of the used resources and circular economy balances the use of resources (Sakai, Yoshida, Hirai et al. 2011.). There are also regional differences. Circular economy has strong foot-step in European Union and SMS is promoted mainly in East Asia Japan being the leading promoter. What these both concepts have in common is 3R initiative. It was originally presented by Japan but adapted world-widely. Japan developed the concept further towards SMS but the initiative gave free hand to all countries and regions to implement it on a level and with manner most suitable. Circular Economy is explained in detail on chapter 5 *Circular Economy*.

Another concept based on 3R is Integrated Solid Waste Management (ISWM). ISWM's aim is to optimize management of solid waste generated all sectors and involve all stakeholders in the optimization. 3R approach helps ISWM to minimize the amount of waste in each step from generation to disposal, and maximize recovering of resources. (Memon, M.A. 2010.)

There are in addition other R-approaches, such as 5R which is an advanced theory on 3R adding two more Rs, or other concepts based 3R. All of those cannot be gone through here, so the purpose of this chapter was mainly to give brief insight on waste management approaches across the globe. Also, not all concepts and theories promote being based on 3R even though interface between them is visible. Furthermore, 3R has significance to plastic recycling as it is and therefore further developed theories are not significant enough for thorough business field study in this case.

4.2 Statistics

Figure 8 shows treatment methods for municipal waste in EU 27 -region from year 2000 to 2015. The graph is slightly different than corresponding Finnish graph. In Finland incineration of waste means in practice energy recovery whereas in some European Union States there is a distinction between energy recovering incineration and incineration without it. In the graph distinction isn't, however, done because Member States have different criteria for it and comparing is difficult. On the graph is also section 'Other'. In some countries are areas which are not covered by municipal waste management system. Countries have to estimate the amount of generated waste on those areas. Estimation isn't necessarily correct – usually countries report more than they actually generate – and section 'other' states the difference between total amount of treated waste and total amount of generated waste. Section also includes recycled or landfilled incineration residues, double-counting of secondary waste, imported and exported waste, temporary storages and such. (Eurostat 2017.)

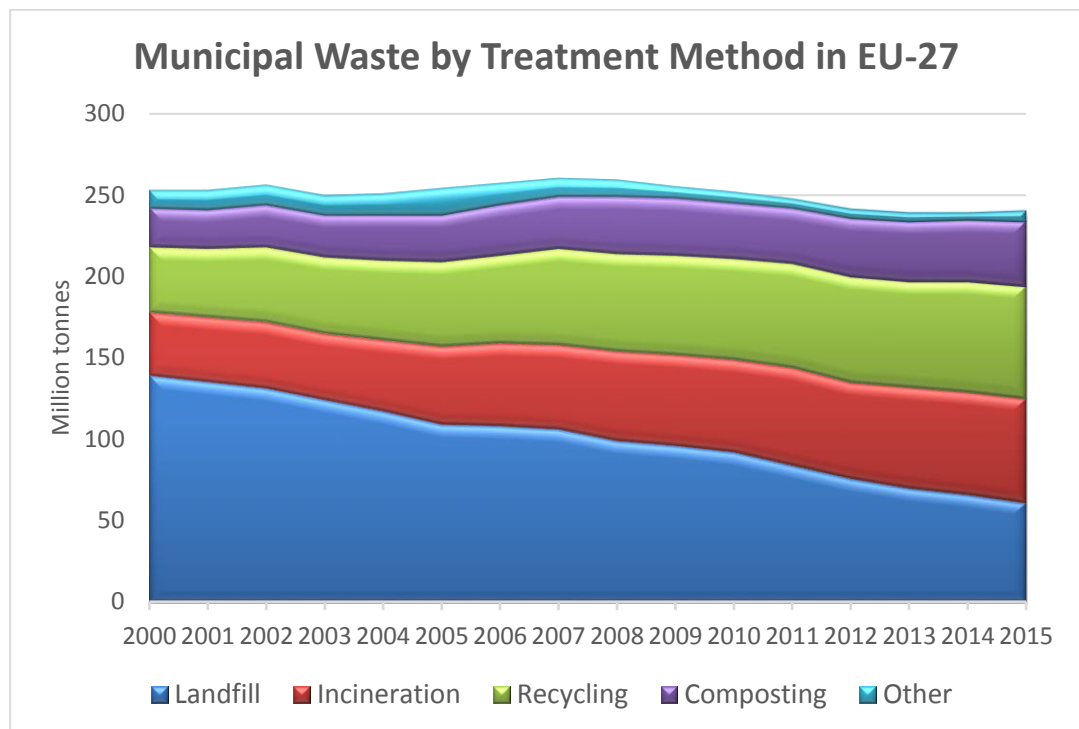


Figure 8 Municipal Waste by Treatment Method from 2000 to 2015 in EU-27 (adapted from Eurostat 2017.)

As can be seen on Figure 8 above landfilling rate is on EU level rather high but steadily decreasing. This is due to 1999/31/EY Directive which obliged Member States to reduce amounts of landfilled waste. (Eurostat 2017.) In year 2015 total amount of waste was nearly 250 million tonnes and landfilling a bit over 50 million tonnes. This means percentage of 20-25 of all the waste. Percentage share for Finland during the same year is considerably smaller, only about 10 percentages (Figure 6). Another difference between the graphs is that in Finland composting isn't separated from recycling. In 2015 recycling is around 45 percentages on EU level and in Finland around 40 percentages.

4.3 Innovations

Innovations such as the ones presented on this chapter are crucial for developing plastic recycling. Recycling through any other method than energy recovery isn't eco-

nomically sustainable if there aren't processes which can utilize the recycled materials. And since plastics usage doesn't seem to be diminishing new ways for reclaiming have to be innovated.

Saperatec GmbH

Saperatec operating in chemical industry is offering its customers high-technology solutions for recycling composite materials. It is one of the leaders in separating laminated structures. It has developed an efficient separating process with the help of high quality micro-emulsion. Saperatec is aiming with its technology the development of closed material cycles with added value. (Technology)

Waste materials containing multiple different substances are difficult to recycle and though they can be disposed to collecting of separated waste – collecting bin is chosen according to which material majority of the piece is – they are rejected in refining processes and end up to incineration. (Usein kysytyä kierrätyksestä [Frequently asked questions on recycling])

CADEL DEINKING

Cadel Deinking has developed unique, patented technology which removes ink from plastic waste surfaces. Deinking the plastics improves exploiting possibilities since colourings tends to limit the usage of secondary raw materials. In addition to ink removing Cadel Deinking is constantly improving water treatment in plastic refining processes in order to achieve environmentally and economically more sustainable process. Deinking is suitable for several different plastics types. (The Company)

Platio

Platio is a Hungarian EU-funded project developing solar paving for sidewalks. The paving is made of recycled plastics. (PLATIO Solar Paving)

Agilyx Inc.

Agilyx is an energy company located in the US. It refines difficult-to-recycle waste plastics into crude oil through environmentally friendly processes. Agilyx has invented the first technology which can recycle disposed polystyrene back to polystyrene in a full circle. Polystyrene waste is broken in the process into styrene monomers. (Our Polystyrene-to-Styrene Monomer (PSM) Technology 2016.)

Polystyrene is as a material difficult to reclaim due to its fragile and porous texture. Most common recycling method for it is energy recovery. (Usein kysytyä kierrätyksestä [Frequently asked questions on recycling])

5 Circular Economy

Circular economy addresses the unbearable development in use of resources and provides totally opposite model for global economy and business-making. Transformation towards circular economy requires changes in whole value chain and so it is truly a substantial alteration.

What is to learn from circular economy from plastic waste management point of view is that disposed plastics aren't a burden, they are an investment. Plastic waste is an opportunity and an asset. As a secondary material plastic is valuable and reclaiming technologies decrease substantially the need of virgin raw materials. Recycling of plastics fulfills one of the core principles in circular economy.

This chapter explains the need for circular economy from historical and global economics standpoint, tackles the very core of the matter and gives examples of companies already operating in circular business.

5.1 Linear Economy

The increase of gross domestic product and rise of resource usage goes hand in hand. On average 0,4 % rise on resource usage is resulted from 1 % increase in GDP. Economic growth as it occurs nowadays is unsustainable. It uses approximately one and a half planets' worth of resources every year which is untenable in long term. This current trend in economy is so-called "take make waste" -model. Its linear cradle to grave flow has historically been seen as the only way to boost global economics and general well-being. (Lacy, Rutqvist 2015, 3-5.)

Not only the usage of scarce resources but also massive amounts of waste generated but not recovered is why linear economy is such an unbearable economy model. It is estimated that just one fourth of all waste globally is recovered and returned back to material circulation. Low recycling rates result in massive losses in annual value. (ibid., 8-9.) Hence, waste is more than just an environmental issue.

5.2 Basic Principles of Circular Economy

Circular economy is commonly mixed up with recycling which is concentrated merely on finding usage for already existing waste. Opposed to this belief circular economy is actually course of action with aims to preserve resources in the circulation at the end of product's useful life. Principally the aim is to design the product so that it remains in circulation as long as possible either on use or as a material. (Kiertotalous [Circular Economy] 2017.)

Constitutive idea in circular economy is planning sustainable ways to use resources. Target is to not to wear out materials and products but to recycle them. In practice products should be designed so that materials are easily separated at the end of products' lifecycles and when manufacturing the product no substances that rule out recycling of materials should be used. There are three fundamental ways to increase and sustain value in the circulation:

- I Material efficiency of manufacturing
- II Acknowledging reuse and raw material value

III Recycling through high-value circle

Fulfilling all three factors will lead to more economically efficient and resource-wise sustainable society. (Kiertotalouden mahdollisuudet Suomelle [Possibilities of circular economy for Finland] 2014, 4.)

By keeping in mind that *“preventing waste in the first place by refurbishing and reusing products and components instead of recycling makes much more economic sense”* (Lacy, Rutqvist 2015, 9.) fundamentals of circular economy can be followed with ease.

Follow-up is needed to confirm achievements of circular economy. Effectiveness of the actions can be assessed through environmental, economical and social impacts. Tools for the follow-up are life cycle assessment, socio-economic methods and multiple different indicators. Good circular economy indicators are for example usage of materials and resources, amount of different waste sections and their recycling rates. Indicators may also take into account gross domestic growth, employment or appreciation. Indicators can be defined to countries, regions, companies, organizations or branches. (Seuranta [Follow-up] 2017.)

5.3 Circular Businesses

On this chapter is presented companies operating through five main circular economy business models, which are:

- Product life-extension
- Product as a service
- Sharing platform
- Renewability
- Resource effectiveness & recycling.

Tractor manufacturer **Valtra** has created profitable product life-extension business from factory-refurbished used gearboxes. Product's life cycle becomes longer and energy and materials are saved comparing to manufacturing of new products.

(Tehdaskunnostetut traktoreiden vaihdelaatikot [Factory-refurbished tractor gear-boxes] 2017.)

Enevo is a software provider selling sensors to waste bins. The sensors follow up on bins' fill-up rates and the software optimizes emptying of the bins based on information received from the sensors. Enevo's product as a service –business helps to reduce carbon dioxide emissions and waste companies' logistic costs. (Jätekuljetusten optimointia datan avulla [Optimizing waste transports through data] 2017.)

Sharetribe is “platform of the platforms”. It offers a platform for marketplace-websites to individuals and companies without special skills in information technology. The platform is designed to increase sharing and selling of underutilized goods. This sharing platform helps to save scarce resources. (Helppo tapa perustaa vajaan käytettyjen tavaroiden markkinapaikka [Easy way to establish marketplace for underutilized goods] 2017.)

Kotkamills has invented coating which enables biodegrading of cardboard cups and –packaging. Cardboard products can be reused which reduces need of virgin raw materials. Kotkamills' renewability advancing business is in addition benefit brand- and image-wise. (Helposti kierrätettävät ja biohajoavat kartonkikupit ja –pakkaukset [Easily recyclable and biodegradable cardboard cups and –packaging] 2017.)

Finlayson has takeback-system for old sheets. Customers can bring their old sheets to Finlayson-stores and get a discount coupon in return. Sheets are sorted according to condition. Finlayson's partner in cooperation receives the most worn out ones for further processing and sheets in good condition are used to produce rag rugs. Finlayson's resource effectiveness and recycling –business saves scarce resources and helps to keep textile manufacturing in home country. (Eläköityneistä lakanoista räsymatoiksi [From retired sheets to rag rug] 2017.)

5.4 Circular Economy in Finland

One of the focus points on navigating Finland towards circular economy is acknowledging improvement possibilities in citizens' personal lives and especially citizens'

consuming habits. Households' consumption has from circular economy point of view three main factors: sharing economy, second-hand markets, and recycling of waste and dispensable goods. First two factors help to avoid the last one. Evaluating these factors is beneficial because majority of commodities are produced elsewhere and their reuse-value is significant if remanufacturing isn't required. In addition evaluating helps to understand value chains created by services and products that have notable possibilities in sharing economy. (Kiertotalouden mahdollisuudet Suomelle [Possibilities of circular economy for Finland] 2014, 4.)

Today up to two thirds of Finland's gross domestic growth comes from services. In circular economy this number should be even higher. Instead of selling a product companies should sell usufruct to the product, extend its lifecycle by updating and repairing, and refurbish the product into new ones once it reaches its end of life. Value should be created by sharing and optimizing resources more efficiently. If planned and executed wisely environmental load will diminish. Circular economy has the chance to create demand for wholly new kind of services, for example the importance of logistic services will increase in a country of long distances such as Finland. Circular economy is at the same time both local and global. Efficient material flow management will emphasize. (Talous kasvuun uusin ajatuksin: Kiertotalouden keinovalikoima käyttöön [Economy towards growth with new ideas: Means of circular economy into practice] 2016, 3.)

5.5 Circwaste

As briefly mentioned on chapter 1 *Introduction* this thesis's experimental research rests on Circwaste-project. Circwaste is a project coordinated by Finnish Environmental Institute and the objective of the project is to guide Finland towards circular economy. The project is largely funded by EU LIFE programme, but also e.g. Ministry of the Environment and regional waste companies Mustankorkea Ltd and Sammakkokangas Ltd are funders. (CIRCWASTE – Towards Circular Economy in Finland 2017.)

The project is situated in 5 geographical areas, Central-Finland being one of them. The whole project consists of 19 cases which focus on various different topics on

waste management, food economy, soil contamination etc.. More defined themes consist for example surplus food and nutrient cycle, biogas production, digital systems etc.. All the geographical areas have co-operational groups which will generate roadmaps with specific goals for smaller topic entities which all aim for the greater goal – circular economy with improved material flow management, waste prevention and efficient resource management. (ibid.)

Circwaste will enhance Finland's possibilities to profile itself as one of the global leaders in circular economy know-how. There is a constant need for new solutions in waste management and -business and Finland will gain with Circwaste not only the opportunity to meet the requirements stated by legislation but also develop waste management even further. Finland will benefit from Circwaste also by gaining perseverance to the development process. Goal is to establish new projects promoting circular economy all around Finland through which competitiveness in Finnish society will strengthen in the future. (SYKE: EU:lta merkittävä rahoitus Suomelle... [SYKE: EU gives significant funding to Finland...] 2016.)

Total budget for Circwaste is nearly 19 million euros of which EU funding is about 11,2 million. The rest comes from companies and other small financiers. The project covers 20 % of Finland in acreage and 24 % of the population. Duration for the whole project is seven years, it started in October 2016 and ends in December 2023. (Pitkänen 2017, 4-6.) As a comparison the research this thesis studies lasts only two months.

6 Research Results

In this chapter is presented results of the experimental research of household packaging plastic collecting.

6.1 Questionnaire

There are 194 apartments on the houses taking part in the research. From that number 20,1 % responded to the questionnaire concerning tenants' experience. 87,18 % of respondents were women and the rest 12,82 % men. Respondents' age range was following:

- 18-30 years: 2,6 %
- 31-45 years: 30,8 %
- 46-63 years: 35,9 %
- 64- years: 30,8 %

Three most controversial statements on the questionnaire were:

I have sorted out plastic waste and taken to areal collecting points even before the research begun.

There was right amount of both plastic and mixed waste bins during the research.

I didn't know before the experiment that plastic waste can also be recycled.

Answers to these statements varied from fully disagree to fully agree the most. They are gone through more detailed on chapter 7.1 *Tenants' Experience*. On the next page is Figure 9 presenting average answers to all of the statements in the questionnaire.

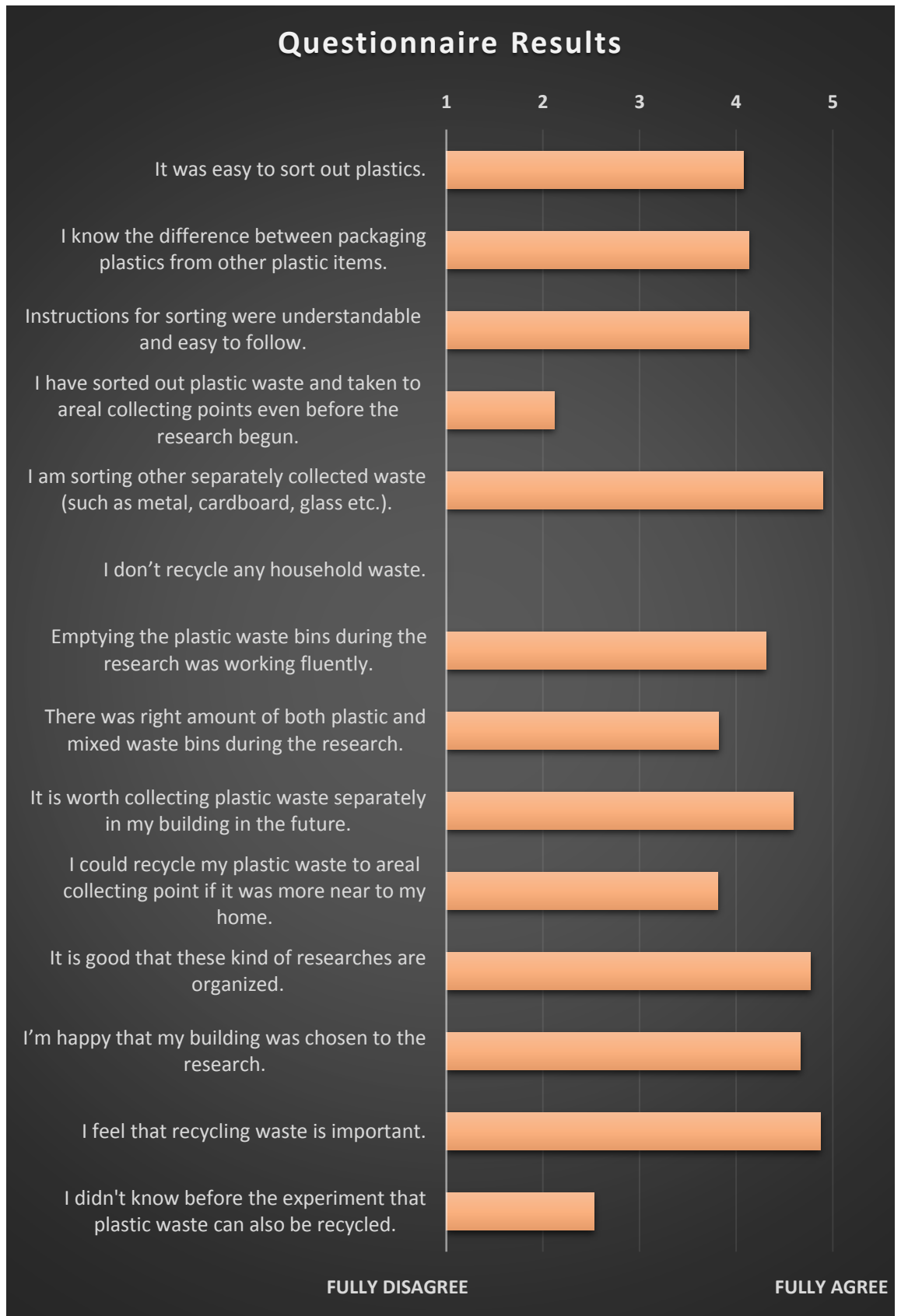


Figure 9 Results of The Questionnaire

6.2 Sorting

All sorted waste material was measured both by weight and volume. Materials were sorted to 10 litre -buckets which were weighted each time when filled. All the buckets were emptied between different buildings' waste samples. If a bucket didn't fill up from one waste sample its fill-up rate was assessed visually. Weighting was done with an ordinary household kitchen scales which had an accuracy of one gram. Results from the measurements were first wrote into forms by hand and later entered to spreadsheet.

Figure 10 shows an example of the measuring. Picture was taken on the first week of the research. Waste samples were rather small throughout the research but especially at the beginning. In this measuring as well as in many others the bucket didn't fill-up before the sample was sorted.



Figure 10 Weighing of The Batches

As mentioned on chapter 2.3.3 *Sorting of Collected Material* all collected waste was sorted firstly to three different sections from which two were divided further into two subsections. So, all together there was five different sections: reusable and recoverable plastics, contaminated and non-packaging plastics, and other waste.

The latest technology in Finland at Plastic Refinery at Riihimäki can treat PE-HD and -LD, PP and PET –plastics in a reusing process (Pohjoismaiden ensimmäinen Muovijalostamo tuottaa laadukasta uusiomateriaalia teollisuudelle [The first Scandinavian Plastic Refinery produces high-quality reclaimed raw materials for industry]). Ergo, on sorting division of packaging plastics to reusable and recoverable is done based on this. However, as the research proceeded it came out that reuse and recovery are difficult to distinguish from each other. Thus, sorting results on that part aren't probably too reliable.

Figures 11 and 12 present the results week by week for each of the buildings. On Figure 11 results are presented by weight and on Figure 12 by volume. On the figures slight improvement as the research proceeded can be seen but unfortunately on large-scale the improvements were merely just marginal.

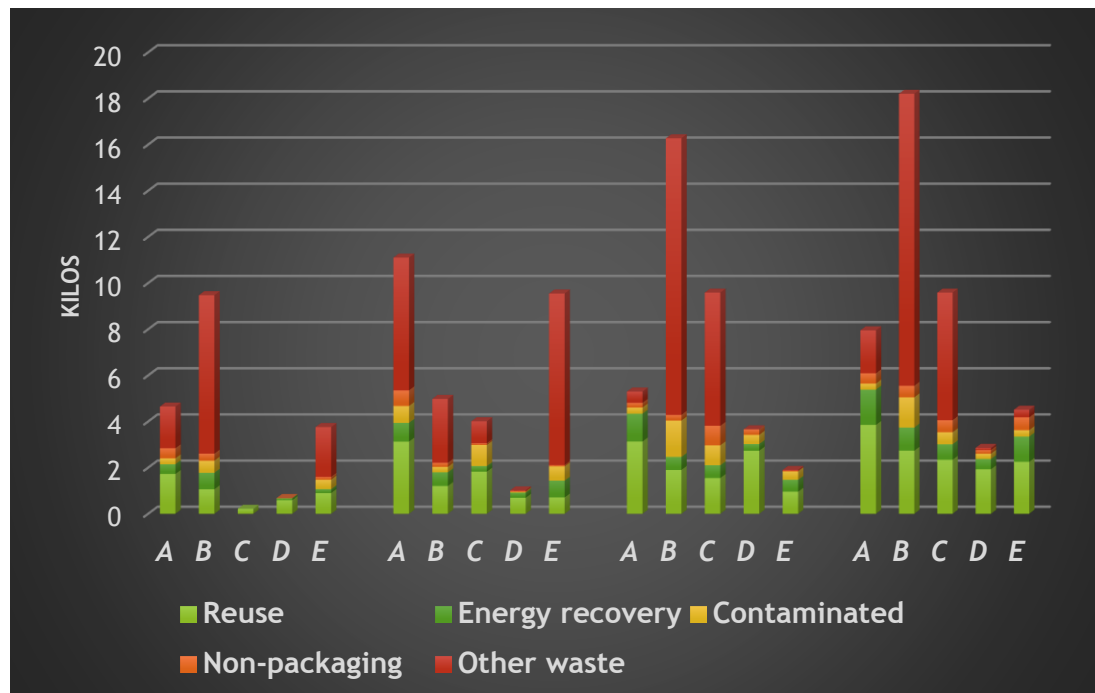


Figure 11 Results of The Sorting by Weight

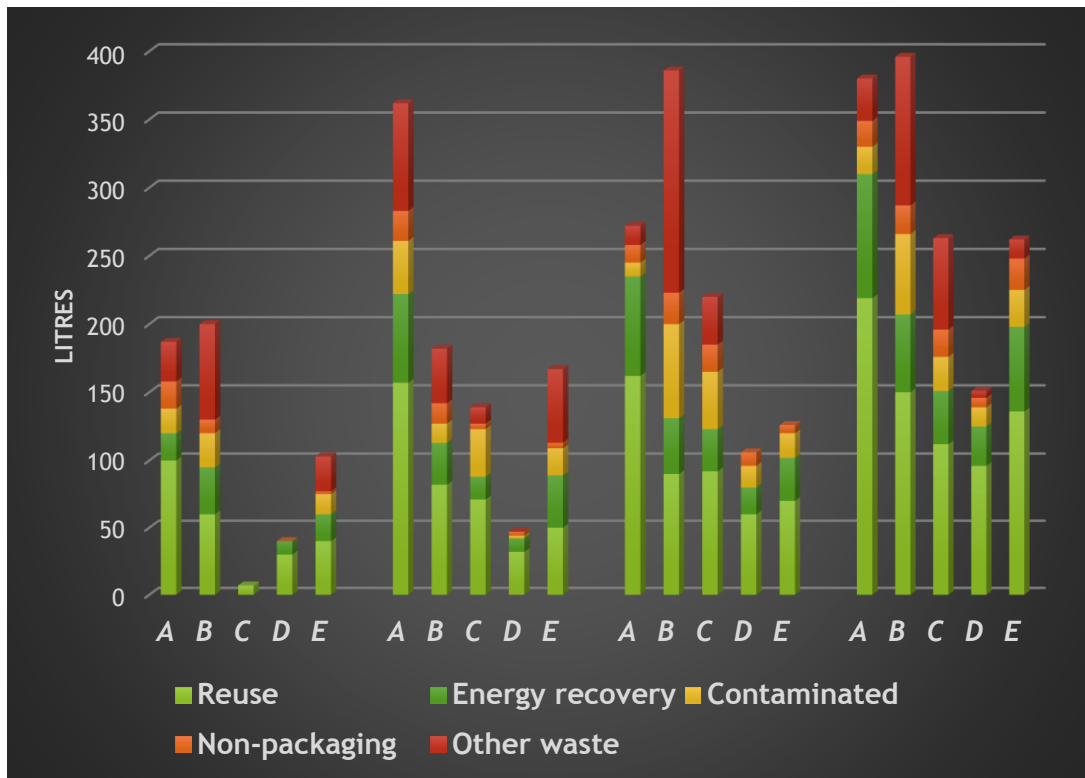


Figure 12 Results of The Sorting by Volume

During the research total of ~130 kilos of plastic and other waste was collected of which ~47 kilos was recyclable plastic (reuse + recovery). The amount of not acceptable plastics –section was only 15,4 kilos. Other waste, such as bio, metals and cardboard, was collected in total ~67 kilos. When measured in volume approximately 4000 litres of waste was collected. Share of recyclables was 2538 litres. There was only 748 litres of other waste.

7 Analysis

7.1 Tenants' Experience

Response percentage is one indicator for research reliability. It expresses how many participants filled in and returned the questionnaire. If response percentage is very low survey's representativeness might be arguable. For reliability reasons survey's

results should always include the percentage of responses as well an estimation of how many percentage of the responses were inadequate. (Vehkalahti 2008, 44.)

Response percentage of the questionnaire was only slightly over 20 %. Due to this results aren't reliable. Nevertheless, there are some interesting observations that should be analyzed. Three statements were raised on chapter 6.1 *Questionnaire* as most controversial ones. All other statements had only little if any variation on answers. First one of the three

"I have sorted out plastic waste and taken to areal collecting points even before the research begun."

is interesting for many reasons. Questionnaire didn't find out respondents' place of residence. If it had the statement could indicate how far the areal collecting point can be so that people are still prepared to take their separated waste sections there. On the other hand, to be actually reliable result in any way this would definitely need higher number of responses.

The statement in addition tells about tenants' interest on recycling. Those tenants whose answer was fully agreeing have more positive attitude towards recycling than fully disagreeing tenants and have some knowhow concerning it.

"There was right amount of both plastic and mixed waste bins during the research."

Some tenants disagreed this strongly whereas other were satisfied with the situation. The result shows that in some buildings estimation of needed number of bins was wrong and so if the research is repeated estimation needs some extra attention.

I didn't know before the experiment that plastic waste can also be recycled.

This statement tells the most about tenants' knowhow. For some recycling of plastics is a new thing.

Respondents' age-range was quite constant. Only responses from youngest age-group were almost non-existing. It is difficult to say any reasons for this. Is it because the youngest just weren't interested in the research? Or could it be that they don't feel paper forms and sending of traditional mail comfortable? Or maybe they had lack of time? This research is unable to answer to these questions.

7.2 Quality and Quantity of Collected Waste Materials

7.2.1 Quality

As mentioned on chapter 6.2 *Sorting* there were difficulties on identifying reusable and recoverable plastics. Both are excellent materials for recycling and therefore inaccuracy on this part of sorting results doesn't compromise the results as a whole. In fact, accurate sorting on these two wouldn't have even given much more content to the research.

The most interesting waste section in the sorting was perhaps 'contaminated plastic'. With only a little effort at households this section could have been useless and all the waste materials on the section would had been sorted to reusable and recoverable plastics –sections.

One elderly person who contacted Mustankorkea's customer service was convinced that plastic strawberry packaging was PVC-plastic and was confused whether it can be recycled since the instructions they got before research begun said that PVC is not acceptable material to recycling but foodstuff packaging is. Below is Figure 13 showing what material marking of PVC looks like.



Figure 13 PVC-marking

Problems related to material quality as described above were reoccurring during the research. If tenants' knowledge is poor too high-quality cannot be expected. As from results can be seen quality varied a lot between buildings and weeks but on average was unexpectedly low. Below however is an example of exemplary sorting of household waste (Figure 14).



Figure 14 High-quality Plastic Waste

7.2.2 Quantity

A clear difference between the amounts of different waste sections can be seen when comparing Figures 15 and 16. On the figures is presented percentage shares of all collected waste by using different measuring techniques. Plastic waste is light-weight whereas mixed waste is often rather heavy. For that reason it seems that the amount of mixed waste – or ‘other waste’ - is very high on Figure 15. Mixed waste is also often quite dense and plastic waste isn’t. This explains the totally different shares of amounts on Figure 16.

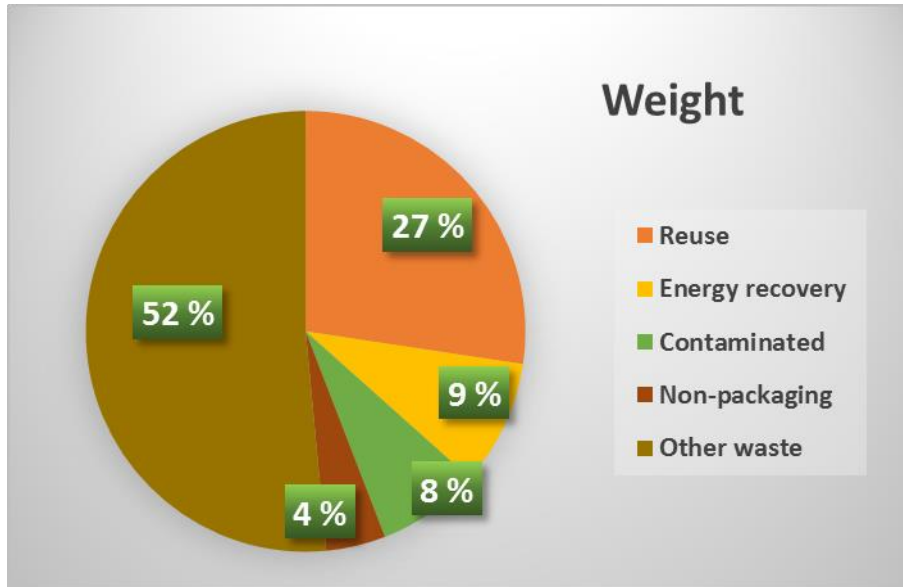


Figure 15 Weight Percentages of The Sorted Waste

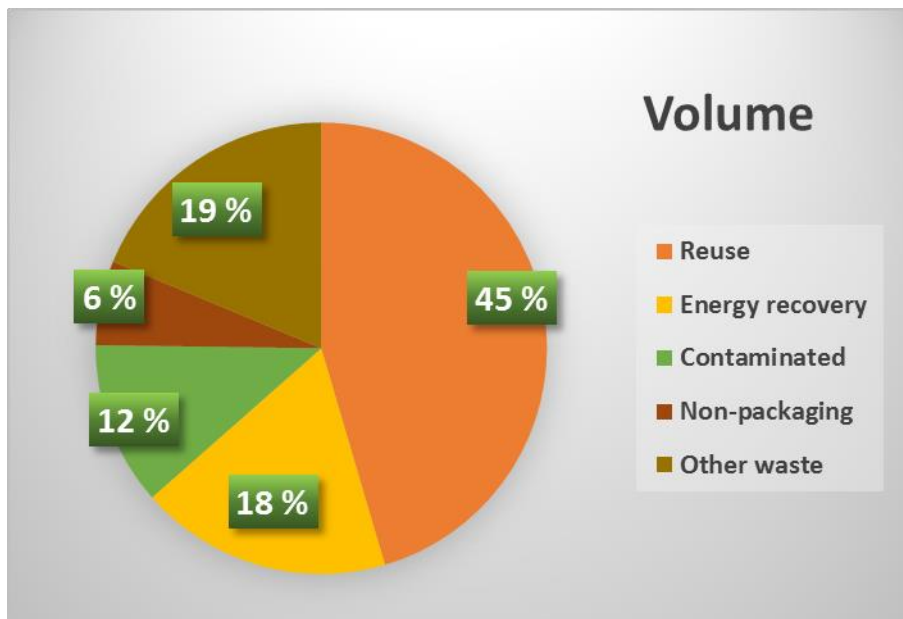


Figure 16 Volume Percentages of The Sorted Waste

On chapter 6.1 *Questionnaire* was told that approximately every fifth tenant replied to the questionnaire. If assuming that about the same number of tenants recycled their plastic waste as there was responses and taking into account that household plastic recycling is quite a new “thing” in waste management can be stated that number of participants was rather moderate. This is, however, only speculating not definite fact.

7.3 Collecting of Plastic Waste in Jyväskylä

If municipal regulations were to change in Jyväskylä results might look similar to results in this research. One suggestion on why tenants didn't take part on the recycling more enthusiastically is that they weren't informed well enough. But if (and when) the regulations would come into force, Jyväskylä city nor Mustankorkea wouldn't have the time and resources to promote the change any more than on this thesis research. In fact promoting would probably be even lesser. Promoting changes in waste management due to new municipal regulations to all citizens by delivering a notice to each household twice wouldn't be very cost effective. More likely ways for informing would be social and other media which aren't as efficient as home-delivered notification.

One down-fall in the research this thesis studied was that "the guinea pigs" of the research i.e. tenants didn't get to choose on their participation. Expectation for the signatory was that sorting results would be excellent and amount of recycled packaging plastic much higher. This presumption was way too positive. On the other hand the results are truthful and show the situation from the offset of participants being with different perspectives and habits. Some of them doesn't recycle their waste at all, some recycle everything they can. Some of them might have recycled plastics before, majority probably hasn't.

Plastic is a very lightweight material. For it being cost effective to transport the loads have to be rather heavy relative to volumes of the loads, i.e. it has to be packaged tightly or transported as minimum distances as possible. Therefore it should be calculated carefully if collecting and transporting packaging plastic waste from all housing corporations is economically and environmentally profitable. According to this thesis' research it's evident it is not. But despite of this fact recycling of households packaging plastics should be advanced way or another.

8 Conclusions

8.1 Suggestions for The Host Company

As mentioned on chapter 1 *Introduction* there is growing interest in plastic recycling in Jyväskylä. However it didn't show too clearly during the research. Reasons for this can only be guessed. One reason might be that the research time was too short. Changes take time. People are accustomed to do their household waste management in a certain way and changing it doesn't always come naturally. Another reason might be that participants just were "wrong". These tenants didn't ask their participation, they were chosen whether they liked it or not.

Since plastic recycling is interesting and important topic Mustankorkea should definitely continue studying it. Making repeats of the research with some alterations would probably give better insight on why this research didn't result too successful. Alterations could be for instance changing the time considerably longer, half a year or so should do. Time should be so long the participants would have had for sure adjusted their behavior if they're even going to do it. In a longer research participants would also have the time to increase their knowledge on recycling and therefore improve their results. Results could in addition be different if the research was conducted in owner-occupied apartment buildings. In this research all the houses were rental apartment buildings. When owning part of the property residents might feel differently in buildings' waste management. Another suggestion for research variation is to do a research so that only those who actually wish to participate would have the change.

If after studying the matter thoroughly results still don't look too complimentary, Mustankorkea should anyway add plastic recycling bins to areal waste collecting points. Business-wise there wouldn't be sense in collecting household packaging plastics separately but it's not all about making good business. Mustankorkea is municipality owned service-company whose main task is to provide basic waste management services to all citizens living in its region. Plastic recycling is one of them.

Survey showed that there are limitations in citizens' knowhow on recycling. Some tenants informed that they did not know before the research that packaging plastics

can also be collected separately and recycled. Mustankorkea should put effort on promoting this.

8.2 Future Trends

According to Laaksonen et al. recycling of plastics should be increased heavily. This is stated on waste legislation as targets for future and on EU's circular economy –plan. (2017, 21, 46-47.) As seen on this thesis' research it isn't easy. People don't recycle even if given a chance. In Finland is a take-back system for beverage bottles and cans. Customer pays a deposit when purchasing beverages and gets the deposit back when returning empty packages. Could one solution for increasing plastic recycling be adding deposit to other consumer packaging as well?

As presented on this thesis plastic recycling is a business field in which innovations are common and daily way of operating. Traditional measures don't work in world where changes are inevitable. Use of plastics cannot continue as it has until now. Companies that invest in innovation will grow and thrive.

8.3 Reflections on The Project

Project scheduling was working well. At first the schedule seemed a bit too loose but around halfway-done progress stopped for a while completely. I felt like I had lost the red line or wasn't sure if it ever even existed. After the break however I got hang of the project again and was able to finish this thesis.

Personally I'm a bit of a tree-hugger-kind-of-person. I value environmental protection and sustainable development very high. Still, I believe I was able to keep a systematic, professional tone on the thesis throughout and didn't fall down to any excesses or bigotry. I was also able to keep my focus on studying plastic recycling from packaging plastic collecting research point of view and didn't wander astray to any unessen-

tial information. Topic of this thesis was very close to my heart and could have written a lot irrelevant text – I found lots and lots interesting but in this case useless sources of information – but I managed to filter all that out.

The project was educative and interesting. I learned a great deal about waste management overall and specifically in Jyväskylä region. I feel my knowledge grew on this business field far beyond than what was needed to complete this thesis. But even though I am grateful of the things I've learned I found the subject and therefore the project difficult to complete. The subject is very different from common logistics engineering thesis subjects. There aren't a lot of literature available from the subject so I truly had some difficulties of finding good sources. I also feel that our studies prepare us only for more traditional logistics tasks.

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Appendices

Appendix 1.

Questionnaire



MUSTANKORKEA

Questionnaire / plastic recycling

Plastic recycling experiment organized by Jyväskylän Vuokra-asunnot and Mustankorkea Ltd is now ending. Plastic recycling bins will be removed from your building's waste collecting area during Monday 28th. Now it is time to gather tenants' opinions and experiences about the experimental research. It will take only a little time to answer this questionnaire. The answers are valuable information about the research. Please return the questionnaire form in an envelope send with the form until september 4th.

Thank you for your cooperation!

Choose the alternative most suitable to your opinions. You may also leave a question without an answer if you feel you don't know or wish to answer.

	Fully disagree	Not for nor against	Fully agree		
It was easy to sort out plastics.	1	2	3	4	5
I know the difference between packaging plastics from other plastic items.	1	2	3	4	5
Instructions for sorting were understandable and easy to follow.	1	2	3	4	5
I have sorted out plastic waste and taken to areal collecting points even before the research begun.	1	2	3	4	5
I am sorting other separately collected waste (such as metal, cardboard, glass etc.).	1	2	3	4	5
I don't recycle any household waste.	1	2	3	4	5
Emptying the plastic waste bins during the research was working fluently.	1	2	3	4	5
There was right amount of both plastic and mixed waste bins during the research.	1	2	3	4	5
It is worth collecting plastic waste separately in my building in the future.	1	2	3	4	5
I could recycle my plastic to waste areal collecting point if it was more near to my home.	1	2	3	4	5
It is good that these kinds of researches are organized.	1	2	3	4	5
I'm happy that my building was chosen to the research.	1	2	3	4	5
I feel that recycling waste is important.	1	2	3	4	5
I didn't know before the experiment that plastic waste can also be recycled.	1	2	3	4	5

Respondent's age: 18-30 31-45 46-63 64- Respondent's sex: male female

Size of the household: _____ person(s)

A small surprise is raffled between the respondents. If you wish to participate the lottery write your contact information here:|