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POSSIBILITIES TO IMPROVE THE SHARE OF MATERIAL RECOVERY OF MUNICIPAL SOLID WASTE IN FINLAND

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Abstract

EU's landfill directive and waste framework directive sets challenges and targets to Finnish waste management system. Biodegradable waste going to landfill must be decreased and simultaneously material recovery increased. Energy recovery in Finland has expanded fast and 42 % of the municipal solid waste (MSW) was incinerated in 2013. Same time disposal on landfill has been decreasing to 25 %. Material recovery has been problematic as it has remained in the same level of 33 % for several years while the target is set at 50 %.

From all the MSW about 37 % is source separated. Separated paper, cardboard, biowaste, glass and metal are most often used as material while wood and plastic is usually utilized as energy. Producers are moving towards wider responsibility and from the beginning of 2016 packaging industry will be responsible for the package collection. Waste incineration is done in 9 operating waste-to-energy plants and in several co-combustion plants which mainly use waste derived fuels.

Potential improvements for material recovery were first looked through source separation. Separate collected fractions could be source separated more effectively from mixed waste. Mixed waste still includes large shares of biowaste, paper, cardboards and plastics. More efficient biowaste separation would have a great potential on improving material recovery as on average 35 % of mixed waste is biowaste. Including garden waste home composting to material recycling could potentially increase recycling rate by 6 percentage point. To get the collection more efficient obligation for small properties could be tightened and new collection models developed. Separate collection could also be improved with multi-compartment collection on single family properties. The recycling rate could potentially be increased by 3 percentage point assuming that source separated cardboard, metal and glass mass could be doubled, as trials with multi compartment collection indicate.

In Finland there are at least nine mechanical treatment plants. From MSW the existing plants are settled to produce solid recovered fuels rather than materials for recycling. With more efficient mechanical treatment also material recovery could be complemented. In UPM Shotton plant in UK, different materials are recovered from separately collected recyclables fraction. Recovering fibers from mixed waste hasn't showed great potential as fiber gets dirty when mixed with biowaste. Ekokem is planning a new Ecorefinery where plastics and biowaste are separated from biowaste and used as a material. This is first of its kind plant in Finland and it has a potential to lead the way in Finnish recycling industry.

Possibilities of material recovery were gathered with questionnaire targeted to waste management companies. Questions were asked about separate collected waste going to elsewhere than material recovery, what could be the most potential ways to increase material recovery and do the respondents see mechanical treatment as a solution for the problem. Answers ranged from company to another. Sometimes separate collected fractions end up in incineration or on landfills because of the poor quality or purity rate of the separate collected material. Sometimes problems occurring in logistical chain can cause spoiling of the waste.

For plastic collection the problems was thought to be the variety of different plastic type. At the same time plastic was seen as a potential resource to increase material recovery. For wood waste

energy recovery was mainly seen as a best practice. Also promoting favorable environment for material recovery with different legislative instruments was seen as one likely solution to increase recycling. Attitudes towards mechanical treatment among respondents were inconsistent. The challenges related were recognized but also the fast changing operating environment which will have its effect on relevance of mechanical treatment in waste management system.

In the end it was concluded that to increase material recovery biowaste and plastics are maybe the most efficient fractions in volume. Still improvements can be made to several objects with different kind of techniques and also the operational environment must be favorable for material recovery. Co-operation and flexibility between different sectors is needed sometimes beyond the actors own interests.

Foreword

This report and work related to it was conducted in ARVI (Material Value chains) – research program managed by CLIC Innovation Ltd. Funding for the program was received from Tekes (the Finnish Funding Agency for Innovation), industry and research institutes. The aim of ARVI – program is to create understanding of business opportunities related to recycling of materials and required knowhow and abilities for utilization. This is achieved by creating knowledge, methods and concepts related to the management of material flows and exploring the global demands.

This report is based on research related to the work package 4 which includes case studies on selected materials: plastic, WEEE, MSW and ashes. This is a report on the work conducted within task 4.3 concerning MSW in subtask 4.3.1 regarding optimization of MSW separation. Valuable information was received from regional waste management companies, Riikinvoima Oy, Statistics Finland and Erkki Salminen Oy. The authors would wish to thank for their contribution to the report.

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1. Introduction

The waste management sector in European region is going through a transition to a more sustainable future. The goal is to increase the amount of material recycling of municipal solid waste (MSW) and further reduce disposal into landfills. The biodegradable MSW disposed into landfill is reduced by landfill directive (1999/31/EC), which states that the amount of biodegradable waste going to landfills must be reduced to 35% of biodegradable MSW produced in 1995. Furthermore, the waste framework directive (2008/98/EC) states that the re-use and recycling of MSW waste materials such as at least paper, plastic and glass should be 50% by 2020.

In Finland, similarly the aim is to reduce the amount of MSW disposed into landfill and increase recycling. The government decree on landfills (331/2013) forbids the disposal of organic MSW into landfill starting from beginning of 2016 if the share of organic carbon is higher than 10%. The disposal of untreated MSW into landfills is also prohibited. In addition, the government decree on waste (179/2012) requires that 50% of the MSW is recycled not later than 1st of January 2016.

In Finland, reaching the landfill ban on organic MSW and reaching the MSW recycling goal would further reduce the amount of MSW disposed into landfills and also could mean that available untreated waste for incineration plants might be reduced in the future. The fact that material recovery has remained the same for quite long time would imply that it is quite hard to increase it merely by educating general public in recycling. Mechanical treatment of mixed MSW is also required in addition to the source separation that is done at the moment. To understand the problems MSW treatment scene in Finland is first introduced, after which the target in the report is to find means to increase the share of material recycling.

2. MSW treatment to date

Figure 1 describes the Finnish waste management system. Regional waste management regulation defines how the waste act's responsibilities are taken into practice and practices may differ from region to another. Waste act defines the possibility to arrange the collection system where the transportation is invited to tender by the municipalities' authority or property owner. Waste should still be delivered into collection place defined by municipality.

As producer responsibility is expanding so is the drop-off collections organized by producer organizations. Municipalities often supplement separate collection with their own regional collection and household collection. Due to Waste act municipal waste management companies are still responsible to supply the material under producer responsibility to producer's terminals from where the collected waste is further treated. Simplified MSW scene includes three kinds of actors private, municipal and producers, Figure 1.

The treatment option are material recovery, incineration and landfill. Incineration plants are most often local energy companies from which the municipalities or their service companies can own a share. Landfills are most often managed by municipalities, but also industrial plants may have their own disposal sites. Material recovery is the hardest recovery option to track as for different materials exist several mostly private owned pretreatment and recycling plants.

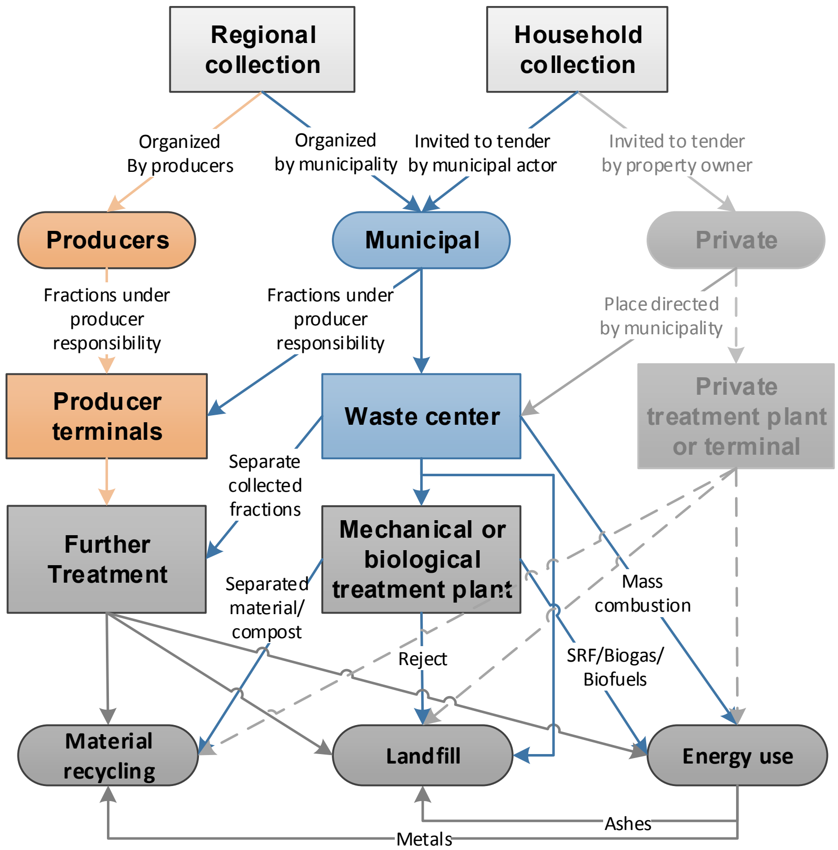

Figure 1. Simplified view of Finnish waste management system.

European commission has given decision (2011/753/EU) about rules and calculation methods for verification of the recycling targets. During the recent years, the mass of MSW directed to material recycling has remained quite the same in Finland, Figure 2. The share of energy recovery from MSW has increased by the expense of MSW disposal into landfills. In 2013, the share of material recovery was 33%, the share of energy recovery 42% and 25% was disposed of into landfills (Tilastokeskus 2014). A more detailed description of the MSW treatment in 2013 is summarized to table 1. In the year 2030 amount of MSW is estimated to be about 3 million tons per years. (Salmenperä et al. 2015)

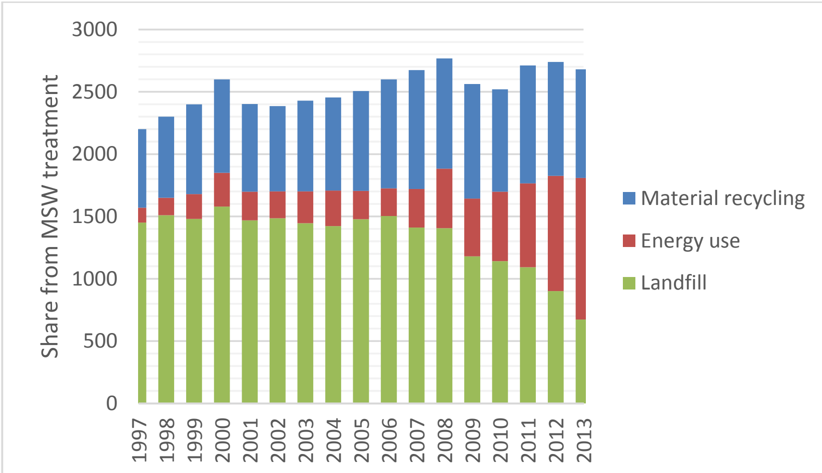

Figure 2. The mass and treatment of MSW in Finland (Tilastokeskus 2014, Pirkanmaa 2014)

Table 1. The amount and treatment of MSW in Finland in 2013 (Tilastokeskus 2014).

	Amount t/a	**Treatment t/a**		
		Material re-cycling	**Energy re-covery**	**Landfill disposal**
Mixed MSW	1 400 000	19 000	740 000	620 000
Source separation	1 200 000	840 000	270 000	36 000
Paper and cardboard	410 000	350 000	41 000	21 000
Biowaste	370 000	350 000	18 000	7 200
Glass	34 000	34 000	10	130
Metal	57 000	57 000	36	110
Wood	44 000	3 700	39 000	650
Plastic	41 000	8 900	32 000	33
WEEE	40 000	40 000	47	-
Other source separated	160 000	7 300	140 000	7 000
Others and miscellaneous	160 000	11 000	130 000	21 000
Total	**2 700 000**	**870 000**	**1 100 000**	**670 000**

The MSW is mainly composed of biowaste and paper and cardboard, which can be seen from the left pie chart in Figure 3. These two fractions comprise almost 60% of the estimated MSW in year 2012. When plastic is included, these three fractions make up almost three quarters of the whole MSW. The right pie chart in Figure 2 depicts the composition of mixed MSW and when comparing to the total MSW composition, it can be seen that the shares of biowaste, plastic and other waste are higher whereas the share of paper and cardboard waste is smaller due to source separation. However these three fractions still make up for 70% of the whole.

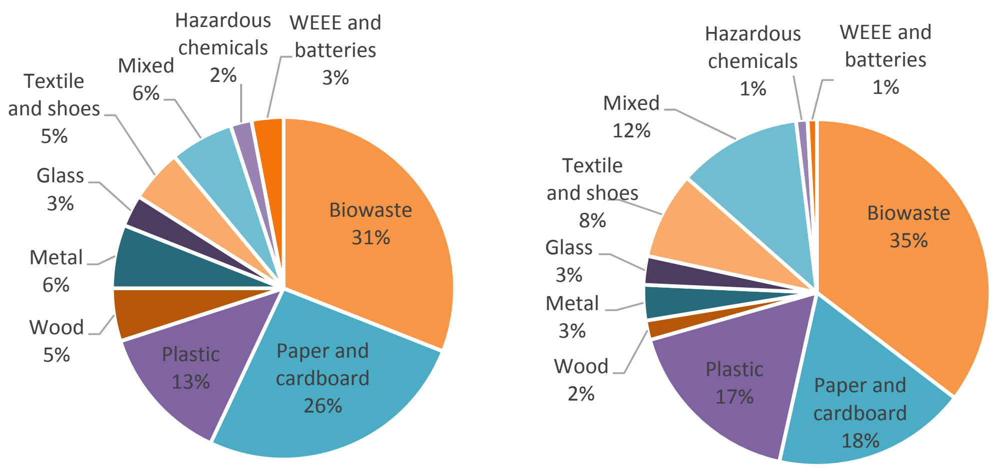

Figure 3. The composition of whole MSW, left pie chart (Salo 2014), and mixed MSW right pie chart (JLY 2015a).

2.1. Source separation and collection

The source separated fractions include: paper and cardboard, biowaste, glass, metal, wood, plastic, WEEE and other source separated waste (usually energy waste) (Table 1). The source separation in households has increased during the past few years according to the consumer behavior questionary. The increase in number of households which regularly separate biowaste was 23% between 2006 and 2012 (Table 2). The increase in households separating cardboard was even greater since the increase in source separating milk and other cardboard was 74% and in packaging cardboard also 43%. The paper waste was already in 2006 well separated so the increase could not be as significant.

Table 2. The share of households regularly source separating different wastes according population density in 2006 and 2012 (Tilastokeskus 2012a).

Waste fraction	Year	Population type			
		Urban %	Dense population %	Agricultural %	Together %
Biowaste	2006	50	44	45	48
	2012	58	59	65	59
Magazine and other newspapers	2006	94	84	75	89
	2012	94	89	94	93
Milk and other cardboard	2006	43	26	14	35
	2012	63	56	59	61
Packaging cardboard	2006	65	49	33	56
	2012	83	73	81	80
Glass jars[1]	2006	65	70	67	66
	2012	78	78	77	78
Metal waste[1]	2006	48	60	56	51
	2012	68	69	69	68
Hazardous waste	2006	72	79	78	74
	2012	83	80	81	82

[1] Excluding glass bottles and cans with deposit

Table 3 presents the composition of MSW by Salo (2014) and the mass amounts of different waste fractions of MSW in year 2013 as well as the share of source separation for separated paper and cardboad, biowaste, glass, metal, wood, plastic and WEEE waste.

Table 3. The composition of MSW (Salo 2014), MSW amount and source separated fractions in 2013 (Tilastokeskus 2014) as well as calculated shares of source separation.

	Share	Mass	Source separated	
	%	t/a	t/a	%
Biowaste	31 %	831 000	371 000	45 %
Paper and cardboard	26 %	697 000	407 000	58 %
Plastic	13 %	349 000	41 000	12 %
Wood	5 %	134 000	44 000	33 %
Metal	6 %	161 000	57 000	35 %
Glass	3 %	80 000	34 000	43 %
Textile and shoes	5 %	134 000	-	-
Mixed	6 %	161 000	-	-
Hazardous chemicals	2 %	54 000	-	-
WEEE and batteries	3 %	80 000	40 000	50 %
Total	**100 %**	**2 682 000**	**994 000**	**37 %**

The treatment of all MSW fractions between 2008 and 2013 are presented in Figure 4, Figure 5 and Figure 6 to demonstrate in which treatment the source separated and other collected waste is directed. The Figure 7 summarizes the utilization of source separated paper and cardboad, biowaste, glass, metal, wood, plastic and weee waste. The majority of source separated waste is directed to material recovery excluding wood and plastic which are almost entirely directed to energy recovery. The share of energy recovery was high also for the other source separated waste of which 90 % was directed to energy recovery in 2013. The other source separated waste was recorded separately for the first time in MSW statistic for the year 2013.

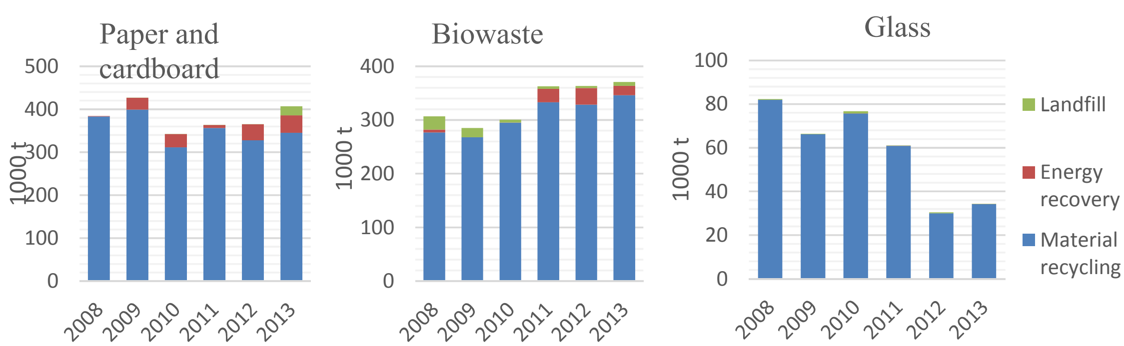

Figure 4. Treatment of source separated paper and cardboard, biowaste and glass (Tilastokeskus 2009, Tilastokeskus 2010, Tilastokeskus 2011, Tilastokeskus 2012b, Tilastokeskus 2013, Tilastokeskus 2014).

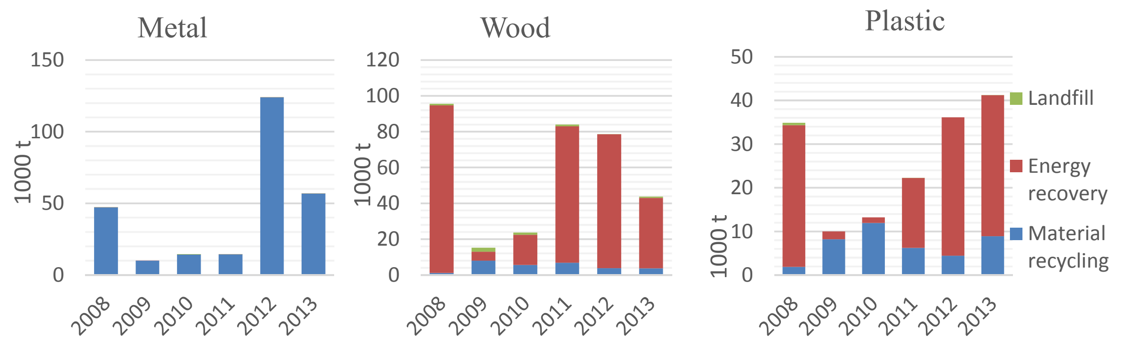

Figure 5. Treatment of source separated metal, wood and plastic (Tilastokeskus 2009, Tilastokeskus 2010, Tilastokeskus 2011, Tilastokeskus 2012b, Tilastokeskus 2013, Tilastokeskus 2014).

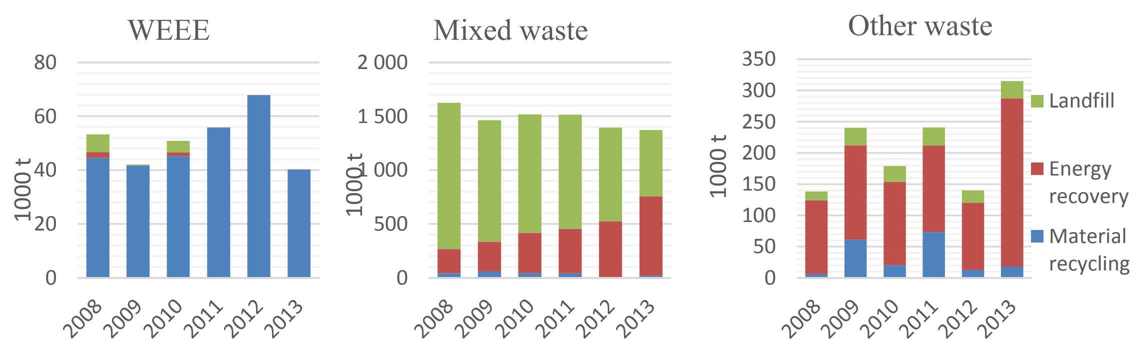

Figure 6. Treatment of source separated WEEE, mixed waste and treatment of other waste (in the year 2013 the other waste also includeds source separated other waste) (Tilastokeskus 2009, Tilastokeskus 2010, Tilastokeskus 2011, Tilastokeskus 2012b, Tilastokeskus 2013, Tilastokeskus 2014).

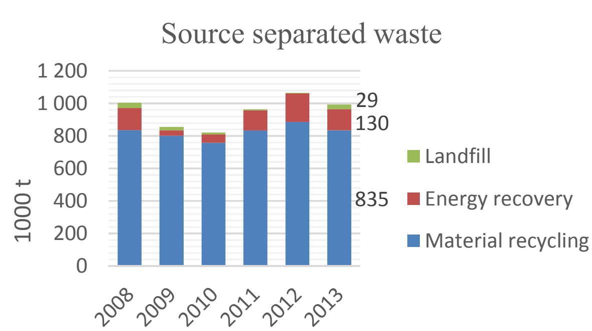

Figure 7. Treatment of sum of source separated paper and cardboad, biowaste, glass, metal, wood, plastic and weee waste showing the mass amount for year 2013. (Tilastokeskus 2009, Tilastokeskus 2010, Tilastokeskus 2011, Tilastokeskus 2012b, Tilastokeskus 2013, Tilastokeskus 2014).

The effective National Waste Plan contains a description of measures and targets of Finnish waste sector until 2016. In the follow-up reports the status and development of the waste management are monitored. Some indicators are determined to examine the fulfilment of the targets. For MSW the amount of waste, the amount of waste per citizen, shares of utilization options and landfilling, landfilling of biodegradable waste and production of biogas has been monitored. In Figure 8 the amount of biodegradable solid waste to landfill is presented as well as the targets set in the waste plan. In practise targets have later been set even stricter. Landfill

Degree (331/2013) forbids disposal of waste containing more than 10 % of organic waste on landfills from the beginning of 2016. This, in practise stops the disposal of biodegradable MSW as well.

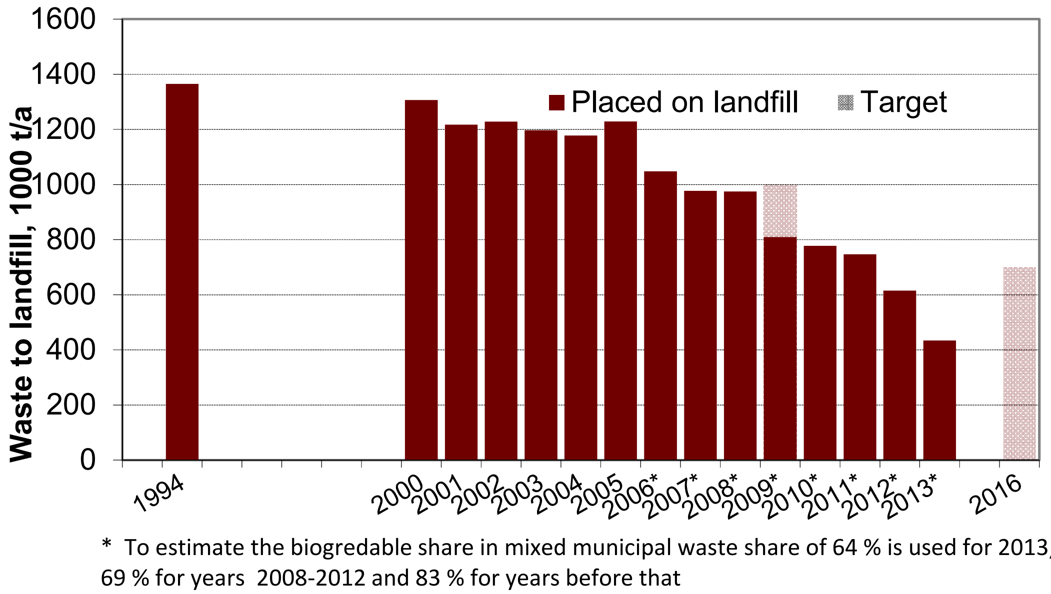

Figure 8. Biodegradable solid waste placed on landfills in years 1994-2013 and target values for 2009 and 2016 (Modified from SYKE 2015).

New waste plan is in planning and it will be outlining Finnish waste management from the beginning of the 2017 until the year 2022. Advance information report for the waste plan has already been published. (Ministry of the Environment 2015)

2.2. Producer responsibility

Producer responsibility obligates companies handling the waste of products they have imported or manufactured. (Waste Act 646/2011) Producer can fulfil the responsibility by joining a producer association or organizing their own collection, recycling and waste management. The producer responsibility pertains to vehicles, tires, electronics and electrical appliances, batteries and accumulators, printing paper and packaging. (Pirkanmaa ELY centre 2015a)

For packaging a new wider producer responsibility becomes operative 1.1.2016 after transition periods. This means after this date producers are in charge of national consumer packaging collection (in addition to the packaging of commerce and industry which has already earlier been covered by extended producer responsibility) and some changes to the source separation scheme is made. It may also affect in recycling rates. From the beginning of 2016 producers organize collection points for glass, metal, fiber and plastic packages. (PYR 2015a) There are six packaging producers associations in Finland and they all have common service company, Finnish Packaging Recycling RINKI Ltd (previously The Environmental Register of Packaging PYR Ltd). (Pirkanmaa ELY centre 2015a) It takes care of the collection and also maintain packaging waste statistics. The amount of packaging waste is assumed to be equal to the packages sent to the market per year according to companies having packaging producer responsibilities. (PYR 2015b) In Table 4 statistics from 2013 for packaging waste are presented.

Table 4. Packaging waste statistics from 2013. (Pirkanmaa ELY centre 2015b)

	Packaging waste t/a	Material recycling t/a	Recov-ered t/a	Recycling rate %	Recov-ery rate %	Reuse t/a	Reuse rate %	Target re-cycling rate %
Glass	82 153	63 122	63 122	77	77	28 747	26	60
Plastic	117 750	26 751	63 751	23	54	235 804	67	23
Paper, cardboard, carton	258 674	252 399	292 399	98	113	19 510	7	60
Metals	51 490	42 135	42 135	82	82	519 431	91	50
Wood	206 619	31 029	206 299	15	100	250 706	55	15

(1) The amount of packaging waste is assumed to be equal to the amount of packages sent to the market
(2) Recycled material includes material recycled as material in Finland and abroad
(3) Recovered includes both utilization as material and energy
(4) Recycling rate is recycled packages divided by the amount of packages sent to market
(5) Recovery rate is the amount of recovered packages divided by packages sent to the market
(6) When package is sent to market it becomes waste after that each time it is used again (refilled or used) it is calculated as being reused and marked in reuse column. These kind of packages in-clude bottles, and pallets.
(7) Reuse rate reused packages divided by total use of packages (packaging waste + reused)

2.3. Material recovery

For material recycling to be worthwhile, good markets and applications for the recycled materials are needed. This problem came out also from the questionnaire to the waste management companies presented later in the report. To understand the production chains from waste to new materials the different utilization options used in Finland are presented for source separated waste fractions.

2.3.1. Biowaste

The material recovery of biowaste means to date mainly composting (Figure 9). Anaerobic digestion has a share equivalent to home composting. Biowaste is often treated along with other biodegradable waste fractions.

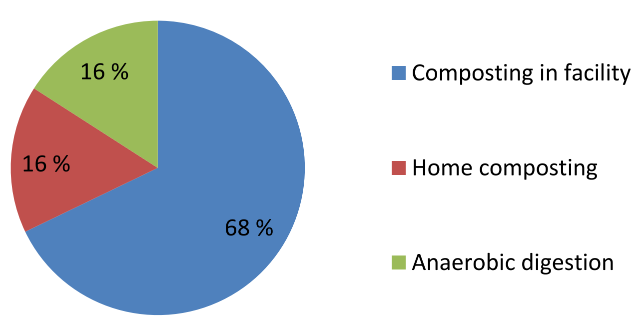

Figure 9. Material recovery of biowaste in 2011 (Espo 2013).

There are few different composting types used in Finland but the basic idea stays same: microorganisms decompose organic matter into soil matter. The product is then used as a soil enrichment material or growth medium. In Finland there is about 240 operating composting facilities. (Pirkkamaa 2014)

In digestion plants biogas and digested substrate products or soil enrichment material are produced. The gas is used to produce electricity, heat or mechanical energy. The organic matter is decomposed in anaerobic conditions and methane is produced in the process. (Pirkkamaa 2014) Biowaste is often used in biogas plants mixed to other organic waste like garden waste, other biomass or sewage sludge and manures. In 2013 there were 13 operating co-digestion plants and 19 under consideration. The biogas production of existing plants is presented in Table 5 and fertilizer products use (including following type designations: fertilizers, soil enrichment products, growth mediums and microbe product) in Table 6.

Table 5. Co-digestion plants in Finland and their biogas production and utilization. (Pirkkamaa 2014)

Plant	**Production 1 000 m^3**	**Utilized 1 000 m^3**	**Electricity MWh**	**Heat MWh**	**CH_4 %**
BioKymppi Oy, Kitee	1 824	1 824	1 574	7 954	60
Biovakka Suomi Oy, Turku	4 600	4 555	1 207	17 753	67
Biovakka Suomi Oy, Vehmaa	4 682	4 654	7 981	18 247	66
Envor Biotech Oy, Forssa[1]	5 240 *	4 968	7 339	20 352	65
Kymen Bioenergia Oy, Kouvola	1 886	1 870	1 224	1 749	66
Laihian kunta	144	47	0	252	60
Lakeuden Etappi, Ilmajoki	2 619	2 009	0	11 635	65
Oy Pohjanmaan Biokaasu, Kokkola	360	322	680	972	61
Satakierto Oy, Säkylä[2]	270 *	270	0	1 516	63
Ab Stormossen Oy, Koivulahti[4]	1 738	1 166	2 254	3 764	61
VamBio Oy, Vampula[3] (now Biotehdas Oy)	3 694 *	2 324	2 347	7 062	70
Total	27 057	24 009	24 606	91 256	64

[1] Information from year 2012, [2–3] Information from year 2011, [4] In 2013 Stormossen's gas production was 25 % smaller than normally due to second reactor's maintenance work

Table 6. Fertilizer product's use (including following type designations: fertilizers, soil enrichment products, growth mediums and microbe product) in Finland. (Pirkkamaa 2014)

Soil enrichment material m³							
Year	**Arable area and garden**	**Landscaping**	**Upgraded products**	**Forest**	**Export**	**Other**	**Total**
2008	275 370	100 982	275 114	127	17	23 654	675 264
2009	452 087	109 605	172 670	1 238	78	12 206	747 884
2010	445 816	146 467	283 742	966	3 302	4 613	884 906
2011	493 148	125 866	292 747	60	48	1 070	912 940
2012	544 625	148 028	305 751	1 797	15	2 448	1 002 664
Growth medium m³							
Year	**Arable area and garden**	**Landscaping**	**Upgraded products**	**Forest**	**Export**	**Other**	**Total**
2008	511 150	1 083 120	2 926	0	168 110	5 609	1 770 915
2009	610 544	1 106 246	5 168	0	169 154	22 096	1 913 209
2010	620 954	563 007	1 599	0	123 776	2 749	1 312 084
2011	1 118 646	827 348	0	0	89 519	7 915	2 043 427
2012	973 163	895 126	4 294	0	135 811	1 031	2 009 424

2.3.2. WEEE

Waste Management of Electrical and Electronic Equipment (WEEE) is regulated by law and manufacturers must take responsibility of the recycling process. The actions are mainly organized by manufacturer associations which for WEEE exist several. (Pirkanmaa ELY centre 2015c)

Consumers can return WEEE free of charge to WEEE collection spots. (SER-kierrätys 2015) From the collection point the equipment are brought to treatment plants and treated mainly in Finland to recover materials for industry to produce new equipment. (SER-kierrätys 2015) At the treatment place the equipment is first sorted according to the treatment demands. Often some hazardous or problematic parts needs to be safely removed. In the manual pretreatment state components for reuse or separate treatment are picked away. The equipment are disassembled partly or entirely into different materials according to the type of the equipment. The further treatment is usually mechanical processing which may include crushing, mechanical separation and other treatment processes. The materials, mainly metals, are then used as recycled material for industry in Finland or abroad, most often in the Far East. Plastics are in most cases incinerated. (Ignatius et al. 2009) Table **7** shows the treatment options for WEEE and different equipment categories commonly used.

Table 7. WEEE reuse and utilization in 2012 (Pirkanmaa ELY centre 2015c)

(t/a)	Reuse t	Reuse and recycling t	Reuse and recycling rate %	Utilization (energy + recycling + reuse) t	Utilization rate %
Large domestic appliance (1)	286	23 860	90	24 492	92
Small domestic appliance (2)	47	1 622	88	1 687	92
Teleinformatic equipment (3)	62	6 791	90	6 876	91
Consumer electronics (4)	139	12 951	92	13 172	94
Lighting equipment (5)	17	237	95	239	95
Lamps not including filament lamps (5a)	0	766	90	817	96
Electric- and electronic tools (6)	3	638	94	642	94
Toys, leisure and sport gear (7)	1	71	87	72	88
Health care equipment (8)	0	19	87	21	92
Control and monitoring equipment (9)	0	83	85	85	87
Automatic dispenser (10)	2	329	84	390	99
Total	**557**	**47 368**	**90**	**48 492**	**93**

2.3.3. Glass

Glass is recycled into new product, material or matter. The separate collected waste glass from Finland is used to produce new packages, glass wool or foam glass (Suomen keräyslasiyhdistys ry.). Glass wool is used as insulating material in constructing and foam glass as insulator or relief material when constructing roads or buildings. Glass wool and foam glass are produced in Finland but waste glass going to production of new packaging glass is shipped away. All the glass treated in Finland is taken in by Uusioaines Oy. They produce foam glass by themselves and pretreat glass to be used in other purposes. (Uusioaines Oy).

The glass recycling scene is going through changes due to package production responsibility taking place. In spring 2015 PYR invited to tender different treatment options for separate collected package glass as the wider producer responsibility was taking effect. As a result since May 2015 the glass material is shipped to England to Berryman glass recovery plant to the production of packaging material. (PYR 2015c.)

2.3.4. Metal

Metal recycling works effectively because recycled metals have high economical value and metals can be recycled several times without losing the desired properties of the material. In Finland the collection is concentrated to few companies biggest of them Kuusakoski Oy and Stena Recycling Oy, also Eurajoen Romu Oy and Kajaanin Romu Oy have few terminals. (Mepak-Kierrätys Oy 2015) These companies might also purchase metal waste from smaller collectors and treat metal waste from WEEE fraction and used cars. Companies separate metals to fractions like steel, iron, aluminum and color metals. Exact share of how much different fractions goes through the different processes are hard to come by because streams are so diffused. It is also unknown how big share of the metals is exported to be used in other countries than Finland. Some streams may also go through unofficial channels which don't fulfill all the legislative requirements.

2.3.5. Fiber materials

Recycled paper is used as a material to produce newspaper, directory or soft papers. (Suomen Keräystuote ry.) All the paper collected is used in paper making process in Finland. Large amount of it later leaves Finland as 90 % of paper products are produced for export. (Metsäteollisuus 2015) The fiber from cardboard or carton is used for example in production of corrugated board, packages or core stock. (Suomen Kuitukierrätys Oy 2015)

2.3.6. Plastic

Plastic recycling is still relatively small compared to energy recovery. Recycling is hard because separate plastic collection doesn't exist widely. Some trials for MSW has been done but biggest share of recycled plastics still comes from commercial or industrial sources rather than municipal. (Suomen Uusiomuovi Oy 2015a) Recycled plastic can be used for plastic products such as plastic profiles, plastic bags, transportation boxes and other consumer goods. (Suomen Uusiomuovi Oy 2015b.) PET-plastic bottles are widely used goods and a large share of them are recycled trough Palpa which manages a return systems of beverage packages in Finland. Finnish Packaging Recycling RINKI Ltd. is starting a plastic collection with 500 consumer points to fulfill producer responsibility of consumer collection for packaging. (PYR info 2015)

2.3.7. Wood

From the statistics presented in Table 3 it is easy to see that wood recycling isn't favored in Finland. Separate collected wood is most often utilized as energy. From packaging waste statistics on the other hand can be seen that wood used in packaging is reused with over hundred percent recycling rate. Most probably this is because the same wood packages go through the process multiple times.

2.4. Incineration

The capacity of waste-to-energy plants operating in 2014 or decided to be built are summarized to table 8. The total capacity of plants amounts to 52% of the total MSW amount in 2013. Till the end of 2013 there was also one waste incineration plant operating in Turku. The six plants existing in 2013 combusted 659 000 t waste, which is 60% of the total mass of MSW directed to energy recovery. (Espo 2015) Rest of the waste was combusted in waste co-incineration plants.

Table 8. The capacity of operating and coming waste-to-energy plants.

Location	Powerplant	Capacity (t/a)	Starting	Slag (t/a)
Riihimäki	Ekokem waste-to-energy plant I	150 000	2007	29 000
Kotka	Kotkan Energy waste-to-energy power plant	100 000	2008	16 000
Oulu	Oulun Energy eco power plant	120 000	2012	22 000
Mustasaari	Westenergy waste-to-energy plant	180 000	2012	30 000
Riihimäki	Ekokem waste-to-energy plant II	120 000	2013	21 000
Lahti	Lahti Energia Oy, Kymijärvi II	141 000	2013	15 000
Vantaa	Vantaan Energy waste-to-energy power plant	340 000	2014	42 000
Tampere	Tammervoima waste-to-energy power plant	150 000	2016	-
Leppävirta	Riikinvoima waste-to-energy power plant	133 000	2016	-
Salo*	Ekokem Korvenmäki plant	110 000	2018	-
Total		**1 544 000**		**175 000**

* The implementation in this form is uncertain

There is also some material recycling included in incineration. The metals which can be separated from ashes are directed to material recycling but they are not included in statistics as material recycling since the waste is already accounted for as directed to incineration and including the metals in recycling would mean partial double counting.

In the end of 2016 new waste-to-energy plant will start operating in Varkaus. This plant differs from other plants as it utilizes circulating fluidized bed technology. Plant will have capacity to take in approximately 145 000 t/a of mixed solid waste (Riikinvoima 2015) Unlike in grate firing the waste must be pre-treated before fed into the boiler. In Riikinvoima plant in Varkaus the incoming waste is source separated and in the plant it will be crushed and sieved to achieve the optimal particle size. Metals are separated before incineration with magnetic and eddy current separator. (Holopainen 25.5.2015)

In addition to waste-to energy plants there are some power plants that use pretreated waste as a fuel. The amount used can vary greatly in different plants according to SRF (solid recovered fuel) price and availability. In Table 9 are presented the plants in Finland using MSW derived fuels. The capacity is from the Environmental Permit and doesn't necessarily present the amount actually used.

Table 9. Operating co-firing plants in Finland REF capacity according to environmental permits. (ELY centres 2015)

Location	Powerplant	Capacity (t/a)
Pietarsaari	Oy Alholmens Kraft Ab	40 000–80 000
Kotka	Kotkan Energia Oy, Hovinsaari power plant	13 500
Kouvola	Stora Enso Oyj, Anjalankoski power plant	135 000
Äänekoski	Äänevoima Oy	18 500
Eura	Adven Oy Kauttua power plant	58 000
Pori	Porin Prosessivoima Oy	50 000
Rauma	Rauman Biovoima Oy	90 000 ja from 2017 69 600
Kajaani	Kainuun Voima	7 % of fuel energy content
Parainen	Finnsementti	25 000
Lappeenranta	Finnsementti	30 000
Total		**640 000–800 000**

Lahti Kymijärvi II plant presented in Table 9 has special features as it is an only plant in Finland using gasification of waste. The plant started operating in 2012. Plant uses solid recovered fuels prepared from energy waste. In the plant fuel is gasified, the gas is cleaned and the gas in burned in a boiler. (Lahti Energia 2015)

3. The potential of source separation

To increase the share of material recycling it would require increasing the source separation since 97 % of the material recycling is done with source separated material. This might proof to be a difficult task. The main source separated fractions are biowaste with 31 % share and paper and cardboard with 34 % share. Increasing the source separation of biowaste could be efficient way to increase material recycling since 95 % of the source separated biowaste was directed to material recovery. Similarly from paper and cardboard waste 85 % was directed to material recovery.

The main potential for source separation is in the mixed MSW that is currently disposed of into landfills (620 kt in year 2013). The ban on directing organic waste into landfills might increase the interest to look for measures to improve source separation of biowaste and direct them to biological treatment. On the other hand the landfill ban on organic waste increases interest on incineration of waste.

It might be possible to recover recyclable fibers from the fraction named others and miscellaneous which is mainly directed to incineration. For example in 2013, from the other and miscellaneous waste directed to incineration (130 kt), mixed packages comprised 66 % (Espo 2015). The mixed packages might be suitable also for material recycling.

3.1. The potential of increased separate collection for biowaste

For biowaste the separate collection is regulated differently in different areas (**Table 10**). Areal waste management regulation defines the size of the property which is obligated to have separate collection for biowaste. Most often properties with more than 5 apartments need to have separate bin for biowaste or alternatively biowaste can be composted on the property. The obligation may in some waste management regions only cover the population centers while sparsely populated areas are only recommended to home compost.

Table 10. Waste management companies biowaste collection obligations according to regional waste management regulation.

Waste management company	Separate collection obligation; minimum amount of apartments per property
Ekorosk Ab Oy, Etelä-Karjalan Jätehuolto Oy, Jyväskylän kaupunki, Jämsän jätehuolto liikelaitos, Kainuun jätehuollon kuntayhtymä (Eko-Kymppi), Metsäsairila Oy, Millespakka Oy, Mustankorkea Oy, Puhas Oy, Sammakkokangas Oy, Savonlinnan Seudun Jätehuolto Oy	1
Kymenlaakson Jäte Oy	3
Oulun Jätehuolto, Perämeren Jätehuolto Oy	4
Itä-Uudenmaan jätehuolto Oy, Keski-Savon Jätehuolto, Loimi-Hämeen Jätehuolto Oy, Napapiirin Residuum Oy, Nurmijärven kunta, Pirkanmaan Jätehuolto Oy, Pohjois-Satakunnan Jätteidenkäsittely Oy, Porin kaupunki/tekninen palvelukeskus/ Jätehuolto, Rauman seudun jätehuoltolaitos, Rouskis Oy, Satakierto Oy, Stormossen Ab Oy	5
HSY Jätehuolto, Jätekukko Oy, Kiertokapula Oy, Lakeuden Etappi Oy, Päijät-Hämeen Jätehuolto Oy, Vestia Oy, Ylä-Savon Jätehuolto Oy, Uudenkaupungin Jätehuolto	10
Rosk'n Roll Oy Ab, Turun Seudun Jätehuolto Oy	20
Botnia Rosk Oy Ab, Lapin Jätehuolto kuntayhtymä, Outokummun kaupunki	No collection/No data

Finnish environmental management together with couple waste management companies and waste management companies association financed a project to discover how the biowaste collection for small properties could be implemented. Some small trials were done with shared biowaste bin of 5 to 10 one-family-houses and biowaste collection as a part of district waste collection. Shared bins served well but creating the group and finding volunteers was found to be very difficult. Experiences from district collection of biowaste were not encouraging. Theoretically the project showed that about one third of Finnish 480 000 one-family-households could voluntarily have potential for separate collection of biowaste as approximately one third or even two thirds is already composting. (Runsten 2014)

3.2. The potential of multi-compartment bins

Multi-compartment collection could offer one solution to improve recycling on small properties, where no separate collection of recyclable fractions exists on the property. A trial on multi compartment bin collection for small properties was performed by Itä-Uudenmaan jätehuolto - company. The trial period was provided free of charge for the customers. As a result, they found some pros and cons about the system. The system works so that private properties can purchase a multi-compartment bin where to place their recyclable waste fractions. The bin is then collected with truck having multiple compartments. The fractions collected to the multi-compartment bin during the trial were metals, glass, mixed waste and cardboard. (Korhonen et al. 2013)

Multi compartment collection showed a lot of potential because during the trial the gain of material recovered fractions doubled. At the same time the people found that service of waste management was better and source separation easier. (Korhonen et al. 2013)

Some development work was still needed. Customers found that the bin sizes were not optimal because compartments for different fractions filled up at different times. Also the time needed to empty the waste bin was longer which leads to higher collection fees. Not all customers would like to pay more for the service. The compartments in the bin were also limited and not all fraction traditionally source separated could be collected, paper was still only collected at the recycling point. (Korhonen et al. 2013)

Also some private waste management companies offer their service for multi-compartment collection on a property. This is only possible in areas where the local waste regulation allows it. Municipal actors have criticized that they are not in the same position to offer the services because private business can operate on cost-effective areas and make use of the valuable material by themselves, while municipal actors are obligated to bring it to producer collection. Also some problems can come from customers because they still have to pay eco bill, part of which, covers the maintenance of recycling points. (Kuningaskuluttaja 7.5.2015)

3.3. Source separation of textiles

As the amount of textiles produced is increasing in the world, it could be reasonable to think whether textiles could be recycled. Material recycling has a minor role in textile treatment as majority of the textiles no longer fit for use are incinerated or disposed on landfill with mixed waste. Reuse would be the ideal solution but as the quality of the clothes and other textiles is decreasing so is the potential for it. (Dahlbo et al. 2015)

The main problems with separate collection are connected to too small batches and heterogeneous quality of the textiles. The potential for recycling of textiles and its environmental effects were examined in Ministry of the Environment's TEXJÄTE project (2015). The project also concluded proposals for action. Conclusions included actions to promote textiles reuse and recycling to decrease the caused environmental effects. Chemical recycling was proposed as one recycling technique that should be increased alongside with domestic reuse. (Dahlbo et al. 2015)

4. Existing mechanical treatment facilities in Finland

Finnish Solid Waste Association (Jätelaitosyhdistys) did a survey on Finnish REF-plants in 2005. That day waste scene looked different but a lot of the same technology was in use as nowadays. Few plants to produce REF from mixed waste or separate collected energy waste existed. (Jätelaitosyhdistys 2005) Since then grate firing has taken over the waste incineration industry but some production of REF still exists. Now when aims of the waste management are shifting more towards recycling, existing REF production plants could be exploited to support material recycling.

4.1. Loimi-Häme waste management company REF facility

Loimi-Häme waste management company directs mixed household waste to Ekokem waste power plant and processes energy waste further to REF in mechanical processing facility (Figure 10). REF facility started in 1999 in Forssa (LHJ 2014). The facility has a capacity of 50 000 t/a and it can process household waste, energy waste as well as wood waste (JLY 2015b). The main waste fractions that are directed through the facility are household waste, energy waste and WEEE metal. (Sundqvist 2014)

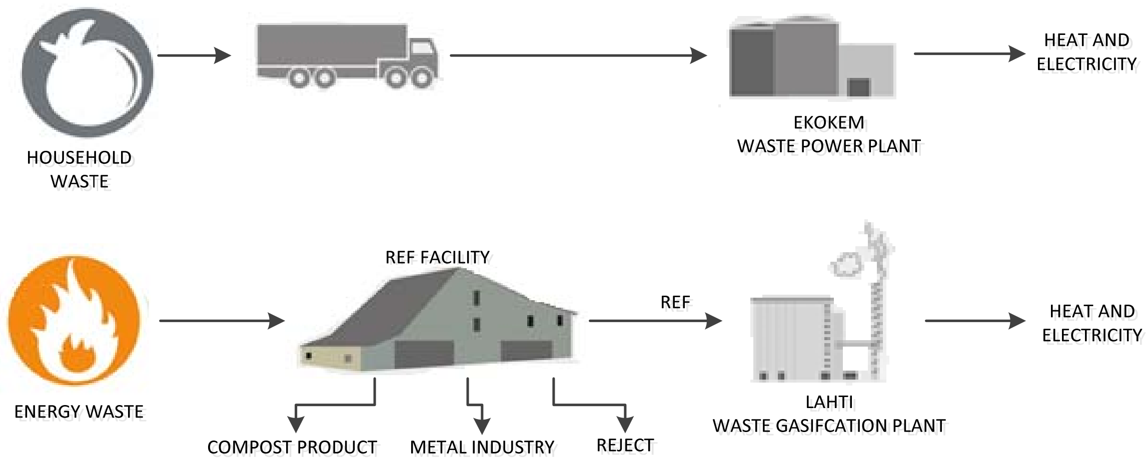

Figure 10. Energy recovery from waste in Loimi-Häme waste management (Modified from LHJ)

The incoming waste is crushed and then materials unsuitable for combustion are mechanically removed. From the energy waste, mainly metals are removed. The household waste requires more separation. The separated fractions from waste with magnets, screens and wind separation are: biodegradable material and small scale mineral material, magnetic and non-magnetic metals, heavy incombustible material. The REF fuel is directed to Lahti Energy waste gasification power plant. The metals are directed for raw material to metal industry. Biodegradable waste and minerals are composted or utilized in landfill construction. The big objects such as stones are directed to landfill (LHJ 2014). The energy use of REF facility has varied in 2004-2009 from 42 kWh/t to 68 kWh/t being on average 55 kWh/t. (LHJ Group 2009, LHJ Group 2010)

The household waste is fed with grab bucket to apron conveyor. Before the primary shredding, the waste goes through sack opener and vibration screening. Waste also passes through sorting line where harmful large objects may be manually removed. The primary shredding reduces the particle size to 200 mm. After the primary shredding, metals are removed with magnetic separation belt and biowaste containing fraction with drum screening (50 mm). Wind separation is used to remove material suitable for combustion. The separated fraction is directed to secondary shredding which reduces the particle size to 50 mm. Additional metal is removed with magnets and eddy current separator. The energy waste is fed with grab bucket directly to primary shredding and it goes the same route as the household waste but bypasses drum screening and wind separation, Figure 11. (Jaakko Pöyry 2005, Ajanko et al. 2005).

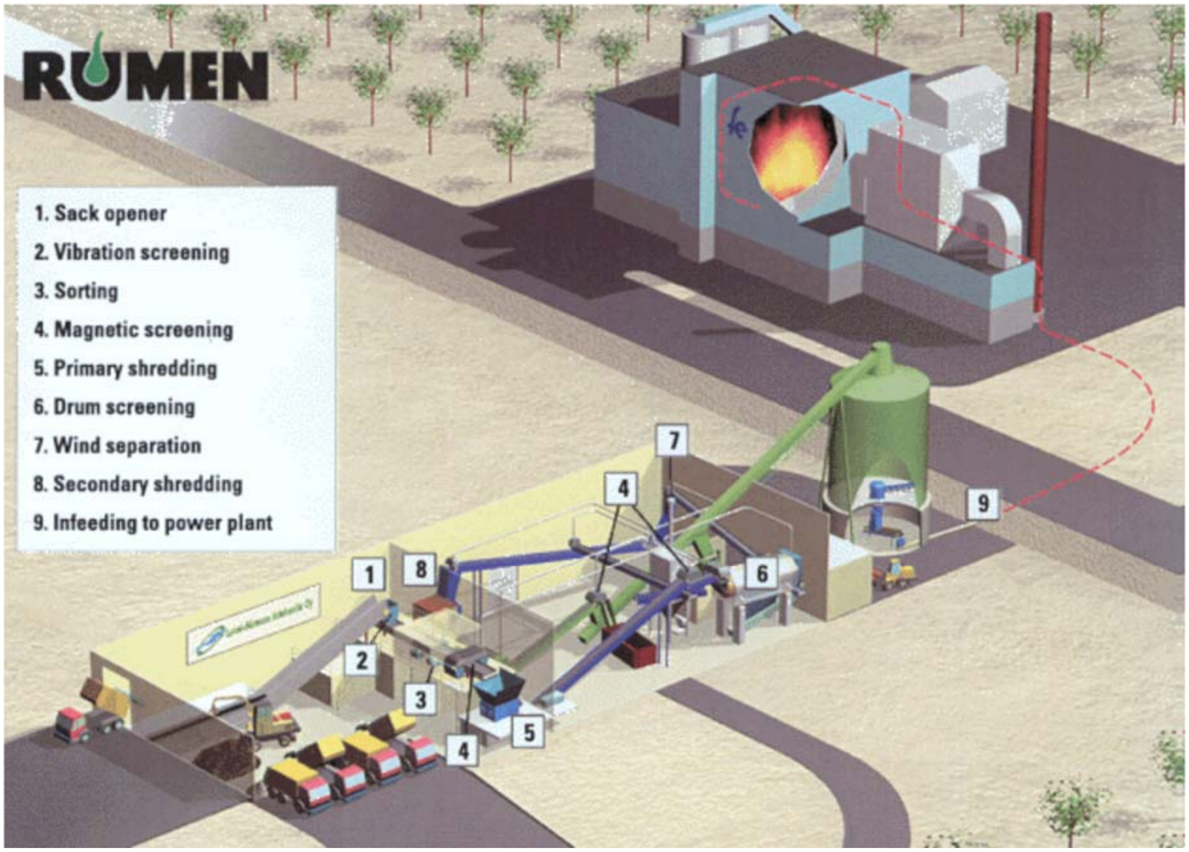

Figure 11. REF facility of Loimi-Häme waste management company (Ekholm 2005).

Composting of biowaste containing fraction from Loimi-Häme waste management company REF facility in compost drum and subsequent disposal into landfill was studied in Kaatopro project. The methane potential of this fraction was before composting 259 m^3/t_{TS} and after the composting 52 m^3/t_{TS}, which means that composting reduced methane potential by 80 %. The suitability of composted fraction as landfill cover was examined according to German regulation and suitability as growing medium for grass according Finnish regulation. The composted fraction was not suitable for either use according the examined regulations. (Sormunen et al. 2005). According to Wahlström et al. (2004) criteria given for contaminated soil can be used in estimating suitability of landmass use in landfill cover. The threshold values and guiding values are given in Government Decree on the Assessment of Soil Contamination and Remediation Needs (214/2007).

There has been some test using energy waste and household waste in Loimi-Häme waste management company REF facility, located in Forssa, in study conducted by Ajanko et al. (2005). The energy waste was collected from Lahti and household waste from Jyväskylä and Pietarsaari municipalities. In the study waste composition studies were conducted for the selected regions and similar waste was directed trough the REF facility. The composition studies were conducted in Jyväskylä. The results of energy waste composition study and fractions from using energy waste in REF facility are presented in Figure 12, 13 and 14. The LHV of RDF was 19-23 MJ/kg from waste from Lahti, 17-21 MJ/kg from waste from Jyväskylä and 13-22 MJ/kg from waste from Pietarsaari (Ajanko et al. 2005).

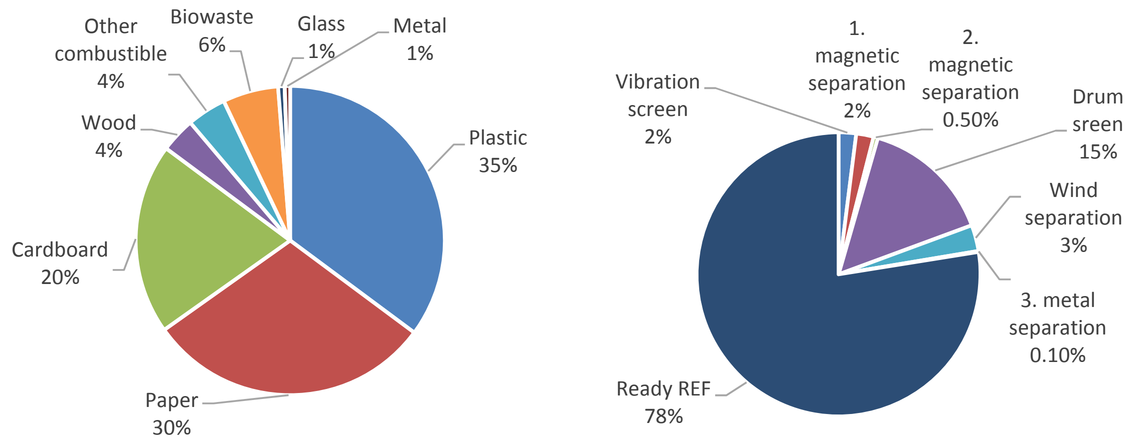

Figure 12. Energy waste composition in Lahti (left pie chart) and fractions from REF facility using energy waste from Lahti (right pie chart) (Ajanko et al. 2005).

Production of REF from energy waste produced significant reject fraction from drum screen, 15%. This was due to large mesh size which was 50 mm. However, this fraction was also good quality fraction suitable for combustion with mainly plastic and paper. (Ajanko et al. 2005)

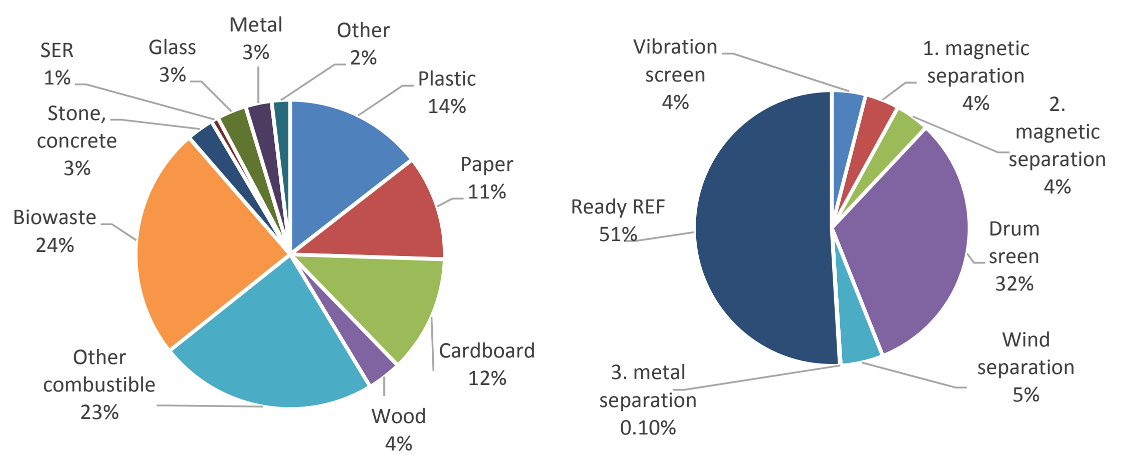

Figure 13. Household waste composition from Jyväskylä (left pie chart) and fractions from REF facility using household waste from Jyväskylä (right pie chart) (Ajanko et al. 2005).

The fraction separated with drum screen from household waste from Jyväskylä was mainly composed of plastic and paper with some amount of biowaste. The fraction from 1st magnetic separation contained big plastic rags and car spare parts and iron tubes. The fraction from 2nd magnetic separation contained electric wire, cans but also light fraction. Reject from vibration screen contained fine heavy dirt and small metal pieces. (Ajanko et al. 2005.)

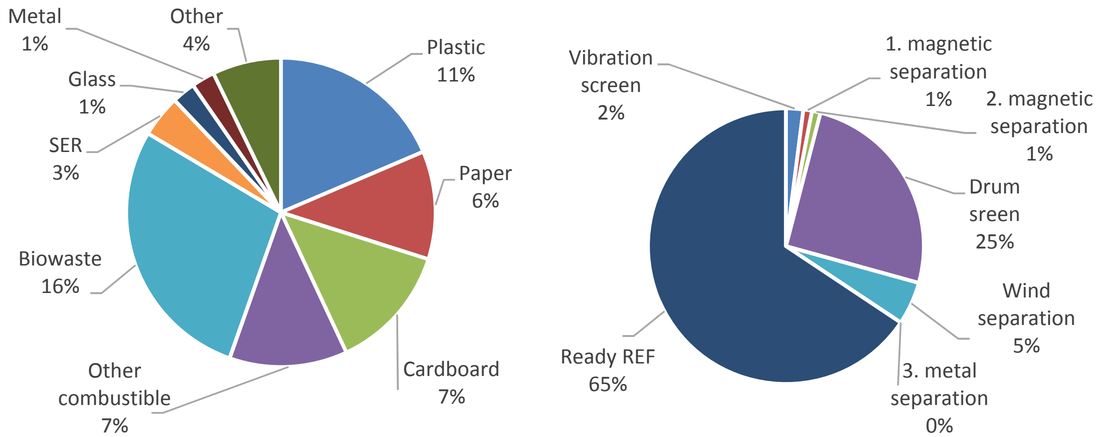

Figure 14. Household waste composition from Pietarsaari (left pie chart) and fractions from REF facility using household waste from Pietarsaari (right pie chart) (Ajanko et al. 2005).

The fraction from drum screen separation of shredded household waste from Pietarsaari contained also mainly light fraction which is plastic and paper. The reject fraction from wind separation was mainly biowaste containing small amounts of cardboard. (Ajanko et al. 2005)

4.2. Pirkanmaa waste management company - Ressu waste treatment facility

Pirkanmaa waste management company has a Ressu waste treatment facility in Tampere which was built in 1997. The facility has two lines which utilize wood waste and energy waste from companies to produce REF. In 2012 the facility received 10 800 t waste. The metals are removed from the waste by magnets. (Pirkanmaan Jätehuolto). Originally the capacity was 72 000 t/a and the facility also utilized household solid waste. Household waste was not used after 2005. (JLY 2015c).

The household waste was fed with wheel loader to apron conveyor which directed the waste to pre shredding. The magnetic separation was used to separate metals before shredding to reduce wear of the shredder. Magnetic separation belt removed additional metals from the waste after pre shredding. Then the biowaste containing fraction was separated with drum screen and the waste was directed to vibration screening to remove inert material. Secondary shredding reduced the particle size to 50 mm and magnetic separation belt removed metals left in the waste. The ready REF was stored in fuel storage or was baled and wrapped in plastic to be stored in storage field. The separated fraction containing biowaste was composted and used in covering and landscaping landfills. (Jaakko Pöyry 2005).

4.3. Ewapower Oy

Ewapower Oy is located near Ekorosk Oy waste management company in Pietarsaari (JLY 2015d). The company started to produce pellets from waste in 1998 and the production capacity is 30 000 – 40 000 t/a ready pellets. The facility uses commercial and industrial waste as well as household waste. In Ekorosk's operational area the municipal waste is collected in black bio- and colored energy waste bags. The bags are separated with optical sorter. The energy waste is moved with conveyors to Ewapower plant and biowaste to digestion plant. (LSSAVI 2010)

The uncrushed waste going to Ewapower's plant is directed to pre-treatment (shredding) after which it is directed, along with material which has arrived as shredded, to drum screen. Metals are then removed with magnetic separation belt. After the drum screen is the wind separation which separates heavy impurities. The next phase is further crushing of the material. After this the material is dried and directed to second wind separation device. Then the waste is ready to be fed to one of the three pellet machines (Ajanko et al. 2005). The investment and production costs are significantly higher than those of regular SRF production lines. The drying and pelletizing requires a lot of energy and energy consumption is approximately 15% of the energy content of waste (Mroueh et al. 2007). Figure 15 describes the process.

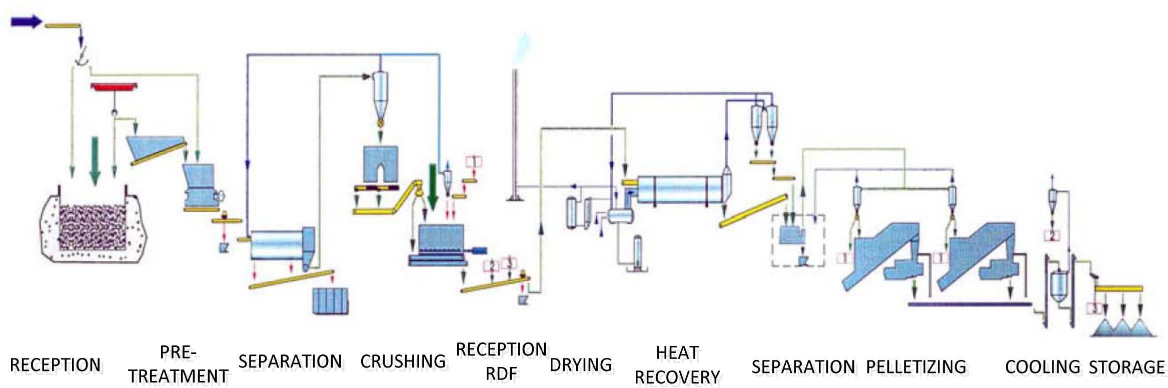

Figure 15. Ewapower waste pelletizing process chart (Ajanko et al. 2005).

4.4. Päijät-Häme waste management company

LATE sorting terminal in Lahti, operated by Päijät-Häme waste management company, sorts mixed household waste and construction waste for material and energy recovery using excavator with crab bucket. The capacity of the terminal is 50 000 t/a waste. Primarily it is used to separate wood, plastic, metal, hazardous waste and WEEE. Main part of the waste 35 000 t/a is directed to waste power plants and one fourth is directed to mechanical separation. Less than 5% is disposed into landfill. (PHJ 2014). In Figure 16 different streams entering and leaving the process are presented.

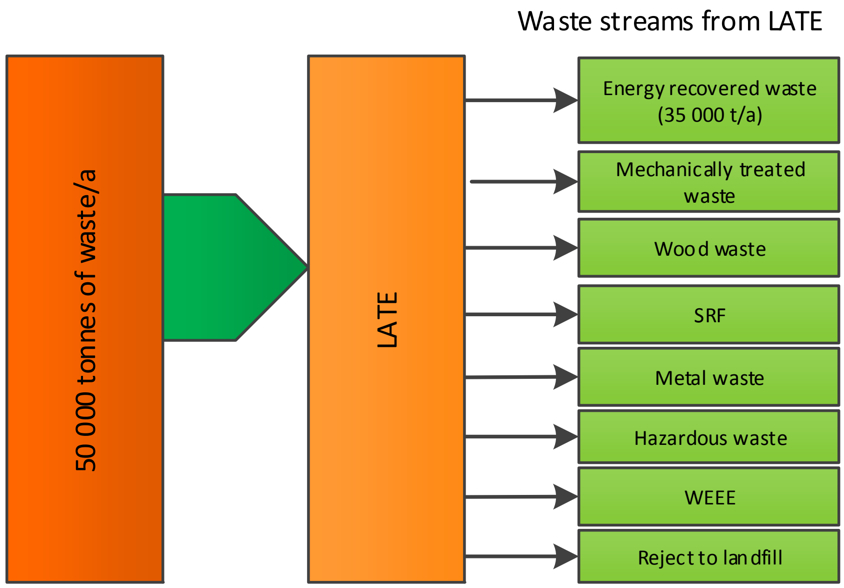

Figure 16. Flowchart from LATE-terminal. (Modified from PHJ 2014.)

Päijät Häme waste management company also has another plant doing mechanical treatment. In the MURRE plant RDF is produced from energy waste. The capacity of the facility is 60 000 t/a waste which includes energy waste from households, industrial and commercial sources. The waste is feed into crushing with material handling device. In MURRE the waste is first crushed and then metals are removed with magnetic separator and eddy current separator. The crushed waste is then dropped into concrete bunker and from there to the intermediate storage or straight to the power plant. The waste can be wood, plastics, textile, paper or cardboard. (PHJ 2015)

4.5. Huurinainen Oy

Huurinainen is a contractor for Ekokymppi waste management company and it treats mixed and energy waste from Kainuu region in a treatment plant that refines the waste into SRF. In this treatment plant the mixed and energy waste is processed to SRF which is then energy recovered in Kainuun Voima heating plant. The treatment facility is located in Kajaani in Majasaari waste treatment center. 2013 treatment facility received 16 000 tons of mixed and energy waste. (Ekokymppi 2014)

In the treatment plant waste load is unloaded on the treatment plants floor from where visible metals and inconvenient pieces are removed. From the floor the waste is fed into the treatment device. The waste is crushed with two crushers. The first pre-crusher crushes the waste to 20 cm pieces which is then sieved with drum screen to separate the compost material. Energy waste goes on to the wind separation from where the reject is landfilled and usable fractions continues to post-crushing. Magnetic metals are separated with magnetic separator. (Sillanpää 2012) After treatment 69 % of the input waste is recovered as REF fuel, 2 % as metals and 25 % as compostable material. 2013 only 3 % of the input waste was landfilled. (Ekokymppi 2014)

4.6. Lakeuden ympäristöhuolto Oy

Lakeuden Ympäristöhuolto is a waste management and recycling company that provides services for enterprises, commercial, industrial and construction waste producers. Company produces REF from either source or mechanically separated waste material. The mixed waste is sorted and sieved in Ylistaro in Teräsmäki sorting facility. The production line includes crushers, separators and screens. (Lakeuden ympäristöhuolto 2014)

In Teräsmäki the REF-facility is made for Finnish circumstances. The line includes pre-crusher, three magnet separators, wind separation, drum screen and post-crusher working by cutting technology. The facility processes waste from industry, construction and commercial sources. (Saarinen 2011) The REF material inconvenient for material for material recovery includes then fractions like different plastics, wood, paper and cardboard. From fuel refining the REF is transported to energy production plants.

4.7. Pohjanmaan Hyötyjätekuljetus

Pohjanmaan hyötyjätekuljetus owns a REF production and dry waste mechanical separation plant which is located in Laihia. The plant has a capacity to treat 25 000 t/a waste. It receives waste from households. (Länsi-Suomen ympäristökeskus 2009) The waste material is fed into operation line from the storage. First process is pre-crushing after which magnetic metals are separated. From the separator waste goes on to separator which separates PVC-plastics and small heavy particles. The REF is separated from the waste flow and it goes through eddy current separator. The crusher in the end of the line crushes the REF into smaller particles which can then be placed in storage or transporting containers. (Länsi-Suomen ympäristökeskus 2009)

4.8. Kuusakoski Oy Lahti waste treatment line

Kuusakoski Oy has built waste treatment line to Lahti which supplies refuse derived fuel (RDF) to Lahti Energy waste gasification plant, Figure 16. The environmental permit states that the mass of treated construction and demolition waste (C&D waste) is 200 – 250 kt/a and energy and packaging waste from industry 100-150 kt/a. The maximum amount of waste treated in the facility is 350 000 t/a and the amount of RDF is approximately 126 000 t/a. The incoming waste includes among others plastic, cardboard, wood, wool, metal and concrete. In addition to RDF, the waste treatment line outputs include mineral material, wood, plastic, metals and other recyclable materials. (ESAVI 2012). At the moment (year 2015) the received C&D waste mass is 350 t/d and 100-150 t/d energy waste from which 250-300 t/d SRF is produced.

The main products from treating C&D waste are RDF, stones and minerals. The byproducts also include magnetic and non-magnetic metals. The pre-sorting is done mainly manually with grabbing bucket or by hands to that metals, minerals, combustible fraction, wood fraction and fraction for landfill is separated. The combustible fraction is then further processed with the treatment line. The main process phases after pre-sorting are (ESAVI 2012):

- Crushing (pre-crushing and main crushing)
- Magnetic separation (in several phases of the process
- Screening (in several phases of the process)
- Wind separation (own wind separation for overflow and underflow of screen
- Density separation with water

- Manual separation
- Removing residual metals (inductive separation and eddy current separation)

The energy waste (plastic from industry, cardboard and wood packaging material) is treated when needed on waste treatment line after pre-sorting (ESAVI 2012). These fractions are fed as a side stream to the end of the treatment line as shown in Figure 17.

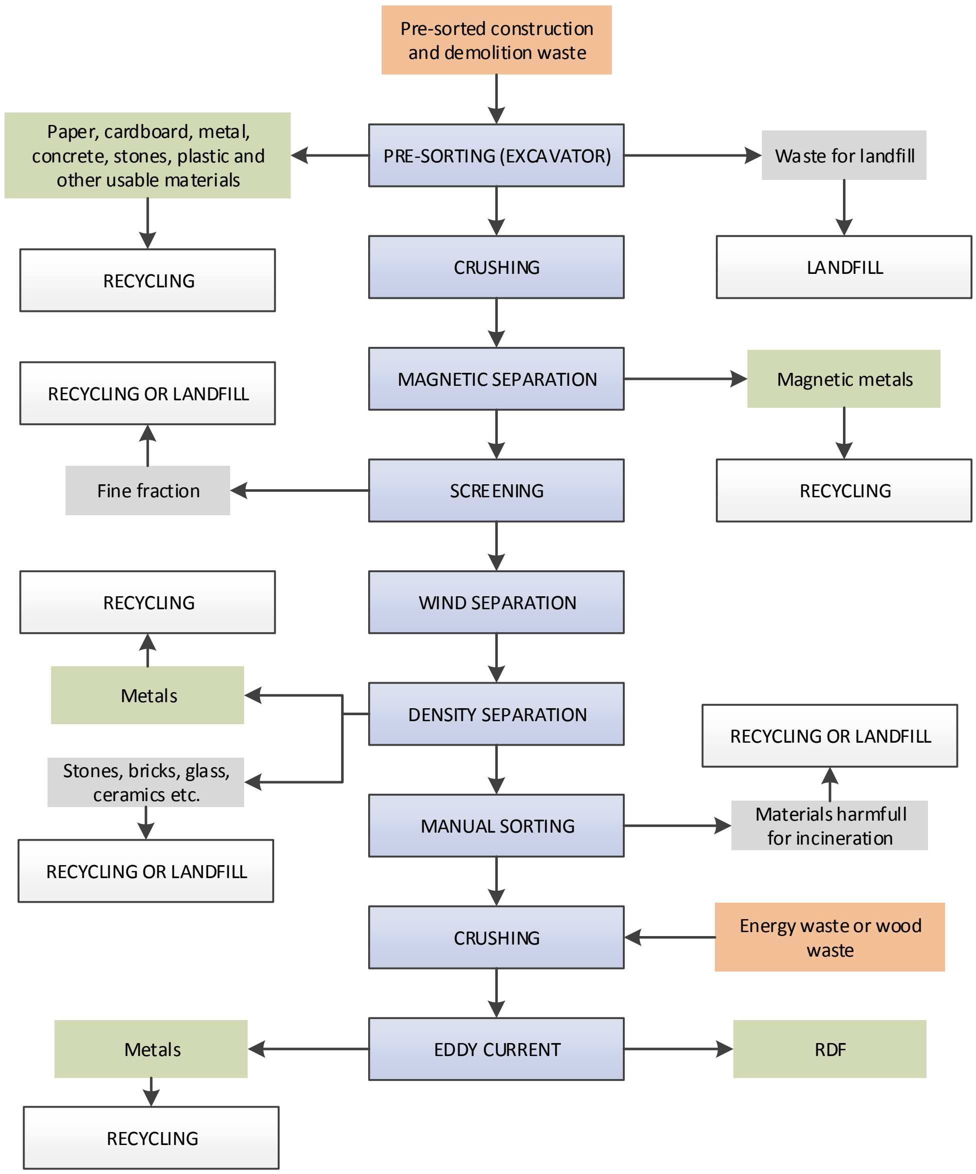

Figure 17. Mechanical waste treatment line utilizing C&D waste and energy waste from industry (ESAVI 2012).

4.9. Kymeenlaakso Jäte Oy waste treatment line

The waste treatment line in Kymenlaakso Jäte Oy treats mixed MSW in Kouvola. (Figure 18) The treatment line was built in 2013 with a capacity of 25 000 t/a comprising of Komptech Terminator 5000 S, Komptech Ballistor 6400, Mastermagh belt magnet, Mastermagh drum magnet and Cityequip AirBasic 1600 wind separator. (Kymenlaakson jäte 2013a, Kymenlaakson jäte 2013b) The investment cost for the line was 1.9 million € from which 0.4 million € was received from Ministry of Employment and the Economy as energy support (Kymenlaakson jäte 2014). The waste is first directed to pre-shredding where the difficult materials are transformed into a form that is easier to process further. After this the ballistic separation equipment separates flat and soft energy fraction, 2D fraction and hard, rolling or bouncing materials, 3D fraction. The ballistic separation equipment also separates fractions having particle sizes of 0-30 mm and 30-80 mm. The magnetic drum separation is used to remove metals from 0-30 mm fraction and overband magnetic separator for removing metals from the 3D fraction. Wind shifter is then used to remove light combustible fraction and heavy fraction containing stone and other inorganic materials. The old shredding line is used to crush the separated energy fraction to particle size suitable for fuel use. At the end of the processing line eddy current separator removes non-magnetic metals from the energy fraction. (Vimelco 2013) In the best case from the incoming waste 45% has been separated for energy recovery, 30% for use in landfill structures and 15% metals which leaves 10% to be disposed of into landfill (Ritvanen 2014).

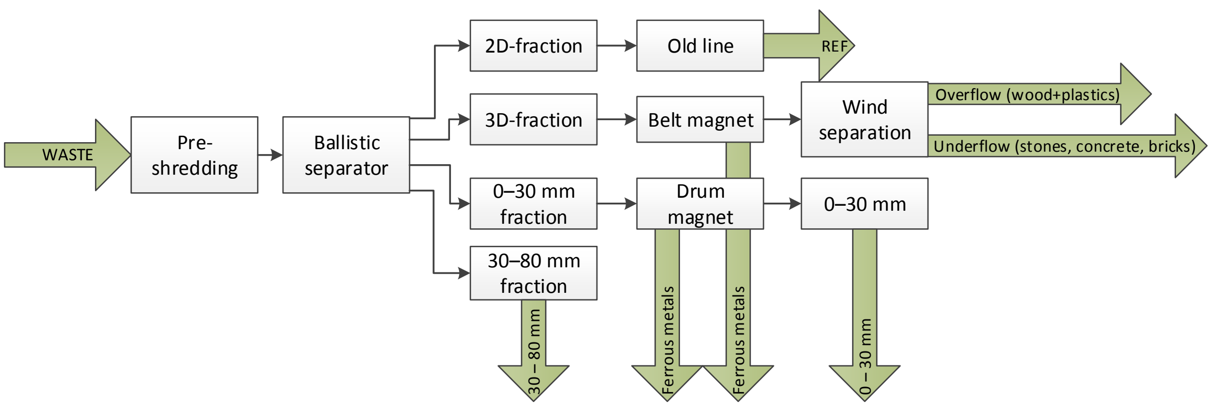

Figure 18. Flowchart from Kymenlaakso waste management companies mechanical treatment process. (Modified from Ritvanen 2014)

5. Mechanical treatment facilities recycling fibers

5.1. UPM Shotton

UPM has a material recycling facility in Shotton UK next to paper mill in order to provide recycled fiber materials for the process. Process chart is shown in Appendix II in Figure 1. The processing capacity of the facility is 270 000 t/a equal to 42 t/h. The waste is single stream collected and includes containers, cardboard, plastic bags and wraps, plastic, metal and glass. (UPM 2011)

The material is loaded into feeder which offers a constant load of materials into the process. The waste is then manually pre-sorted and plastic bags and big objects are removed. From pre-sorting the material is send to OCC (Old Corrugated Cardboard) screen to recover cardboards. Glass containers break and debris with other fines falls between the disks. Manual quality control is used to verify the cardboard quality. Rest of the material is send to further processing. The assembly of three disk screens first remove fine particles of 4 inches or less. Fibers going through the screen are send trough optical sorting unit to remove cartons from the newspapers. Another optical unit and manual sorting ensures the quality. (Machinex 2011)

The final fibers are removed from the containers with 3D finishing disk screen that separates material into three flows. Containers (cans) fall off to the side, while mixed paper stick to rubber-sheathed disks and the rest of glass falls between disks. Mixed paper from disk screen goes under an optical sorting with injection to separate containers and cardboard. Another disk screen and a manual quality control is used to achieve the desired quality for mixed papers. (Machinex 2011)

Containers falling from the sides of the 3D disk screen are moved to light and flat separator to remove paper and plastic wraps. Manual sorting ensures the recovery of a papers. Containers continue on to magnetic separator and disk screen to transfer the containers of six inch or less which then go through eddy current separator. After that containers go through three level optical sorting until which separates the plastics into three categories: PET, HDPE and mixed plastics. Plastics are further divided into transparent and colored plastics. Plastic fractions like all the other fractions finally go through manual quality control. (Machinex 2011)

Fines and glass obtained from the earlier steps pass under a magnet and are send to glass clean-up system. The clean-up system extracts light particles by suction and oversized particles are removed. It is possible to divide glass into three categories according to their size. All the materials sorted by category are finally moved to baler conveyor. (Machinex 2011)

5.2. Fiber fraction from mixed waste

The recycling rate for fiber materials is high but availability of recycled fibers is decreasing year by year. The industry is facing a lack of recycled fiber materials and higher material fees. That's why master's thesis study about mechanical separation of fiber materials from mixed MSW was performed by Ojala (2014). The biggest challenges for using recycled fiber are material availability, fiber quality and strength properties of the product. Additionally the fiber is microbe contaminated when it is in contact with biowaste, which makes it unusable for some applications. The recovery of fibers could be done by sorting the waste either optically or mechanically. (Ojala 2014)

In the study it was revealed that the darkness of the fiber is too much for many applications of paper industry. Also the strength properties were discovered to be weaker than traditional source separated recycled fiber. Tensile, bursting and tearing strength were all measured with reference to recycled fiber. Microbiological decomposition might be the reason for poor strength properties. The fiber can only be used mixed with virgin fiber in applications demanding strength properties. (Ojala 2014) Many affairs limit the applications of fiber separated from MSW. Ojala (2014) presents that biorefinery or biocomposite materials could be potential applications. Still the matter should be further examined. (Ojala 2014)

Fibers could still be used in other application than where they nowadays most often are. One option could be insulating purposes. Also building boards are potential recycling option and these products are already on market. Ethanol or biogas production from MSW have also been studied. In MSW the fiber is in more easily exploitable form than in lignocellulose biomass. This property could make fiber in MSW an economically feasible raw material for bioethanol production. (Ojala 2014)

6. Planned mechanical treatment facilities

6.1. Erkki Salminen Oy waste treatment facility

Erkki Salminen Oy started in 1956. The main function at the operation done at the moment is sorting, baling and storing waste paper, sorting, crushing and temporary storing of material for energy recovery as well as sorting and treatment of construction waste. The maximum capacity at the moment is 35 000 t/a. Erkki Salminen Oy has also environmental permit for mechanical treatment of household waste. The investment for the required equipment is done in 2015 (Konttila, 2015). The planned capacity is according to environmental permit 12 000 t/a (Keski-Suomen Ympäristökeskus 2008).

The planned treatment for household waste includes receiving the waste in covered space with concrete walls. Crab bucket is used to remove big pieces which would make the sorting difficult. Thereafter the waste is directed to hammer shredding. The metals are then separated with magnetic separation and eddy current separation. Then the fine fraction, containing among others biowaste and glass is screened away. After the screen light fraction is removed with wind separation. The fine fraction containing biowaste is then screened to remove glass and composted. The recycled fuel is supplied to power plants. (Keski-Suomen Ympäristökeskus 2008) The composted fine fraction can be used in construction of green areas and road shoulders (Konttila 2005).

6.2. Ekokem Riihimäki mechanical treatment plant, Ecorefinery

Ekokem company is investing 25 million € to build mechanical treatment plant for MSW (Uusiouutiset 2015). The aim is to separate organic material (35%) as well as plastic (10%) and metals (3%) before energy recovery from waste (52%). The capacity of the plant is planned to be 100 000 t/a and approximately half of the waste would be recycled as material. (Ekokem 2014a, Ekokem 2014b) The plastic will be used in recycled plastic products and biorefinery treats the biowaste into biogas, fertilizers and ammonia water. (Ekokem Group 2015). The investment cost is approximately 11 million € and the building has been started in spring 2015 (Ekokem 2014b).

Ekokem has informed that their process will be adjusted to fit in Finnish circumstances and work as reference plant. The process will have different kinds of sorters, sieves and crushers. Ekokem will need from five to ten NIR-separators in the process. (Uusiouutiset 7/2014) In 2013 Ekokem performed trial runs with NIR-equipment (ESAVI Ekokem-Palvelu Oy 2013).

7. Possibilities of mechanical treatment for improving material recovery rate

7.1. Questionnaire for waste management companies about material recycling

A questionnaire was performed to get insight of the situation of material recovery in waste management companies. Five different waste management companies replied to the questionnaire. The results may reflect the operational environment of the company or express opinions of an individual. The respondents represented different positions in companies (for example Service manager, chief executive officer, development engineer). Though, some valuable information and new ideas for material recovery could be obtained from the study. To get an accurate information of a support for a single idea a wider survey is needed. Sometimes the respondents could have quite opposite views to the raised question. The questionnaire is attached as an Appendix I.

7.1.1. Reasons for landfilling or energy recovery of separate collected waste

First question was concerning the reasons for landfilling or energy recovery of separate collected waste fractions. Main reasons for such was that the purity rate wasn't good enough for material recovery because of disregard towards source separation. Also the volume of the fraction could be too small for an effective further treatment. Some fractions were also spoiled, got dirty or mixed with other fractions during storing. The components not belonging in the treated fraction like packages in biowaste or glass waste were sometimes either used for energy recovery or landfilled. The volumes of these separate collected waste streams going to energy recovery or landfill were not quantified in answer so the magnitudes of the problems are hard to reach. Some companies determined that for them the subject is not a big issue.

Not so many ideas for the follow up question, how the situation could be improved, was gained. One respondent clarified that the logistical chain from customer to the end use should be complete. Also when choosing the process for waste treatment the quality demands may differ.

7.1.2. Increasing material recycling

Some ideas were given when asked how the material recovery rate could be raised. Plastic and wood were specified in the question. For plastics, better product specification was needed as well as market channels and organization of material and treatment chains. If plastic would be collected, also collection spots would have to be installed and some informing for consumers done. Also informing customers more about problematic fractions in source separation was seen as one solution for improving recycling rates. One respondent mentioned that even if good material recovery options could be found their environmental impacts should be examined and proved to be better than the existing ones and also economical profitability and purity of the material was seen as a problem.

For wood waste some opposite views existed. One company presented clearly that energy recovery is a good practice for waste wood and second one that material recovery of waste wood is unprofitable. It was said that for example use of waste wood in composite materials is problematic because of the further recycling of these materials. Few other thought some solutions for material recovery of wood could be found. One material recovery application could be chipboards. It was also written that material efficiency must be kept in mind when constructing and waste wood could also be categorized so that good quality wood is used as material and the rest energy recovered.

When asking if other factions separate collected or miscellaneous waste could also somehow be material recovered, textiles and plasterboards were mentioned. About plastics separation it was written that it could be separated mechanically but the costs and energy usage of separation plant would be too high for it to be profitable. Companies and commercial waste was thought as potential source of plastic material for efficient material recycling. One company stated that ash and slag and material recovery of metals from them are also important and significant material recovery possibilities.

7.1.3. Joint collection of different fractions

Fourth question was about collecting different waste fraction at the same time. On respondent thought packaging materials: glass, metal and plastic, could quite easily be separated mechanically and the volumes would be large enough for profitable operations. But still producers would have to take responsibility on this. MSW going to energy recovery includes a lot of biowaste and respondent thought it could be separated for anaerobic digestion and at the same time heating value of the waste going to incineration improves. One company had gone through a trial of collecting glass and metal together and afterwards mechanically separating them but it was proven to be unprofitable. Also improvement in the system were thought to be relevant: different actors in the system like producer associations, privately arranged waste collection and municipality arranged waste collection should cooperate more when organizing the collections.

7.1.4. Likely options for increasing material recycling in Finland

The likely options for improving material recycling in Finland were mentioned to be such as: recycling points for plastic and cardboard, guidance on recycling plastics for companies and offering good price for the recycled plastics. Some legislative solutions were also presented: responsibility for public services with large waste volumes should be kept within waste management companies' responsibility to ensure a large enough material streams into the system to implement development projects. Also financial support for investment to new facilities using the obtained recycled materials was suggested as well as other legislative control means for reutilization of a product or material. Cooperation between private and public sector was expected for new innovative solutions for waste treatment to be found. The basis for recycling system, markets for recycled materials, should also be arranged. Producer responsibility covering packaging waste collection was seen as one solution.

7.1.5. Mechanical treatment facilities in Finland

Question about possibilities of mechanical treatment facilities operating in Finland bisected the respondents. One thought that the already existing operations will continue and expand fast. How fast, depends of the capacity of the waste incineration plants which affect the RDF market price. Mechanical treatment was also seen as good options for treatment of stream left after separate collection if required market for the materials exists. Other were less optimistic saying that these operations include challenges but on the other hand the operating environment is changing fast. When choosing the right operations, regional functionality and systematic solutions must be kept in mind. One respondent thought it is possible to treat mixed waste in mechanical treatment facility but the treatment consumes energy and increases costs.

7.2. SRF from MSW using mechanical treatment

Nasrullah et al. (2014c) made experiments to produce SRF from MSW in Finland in existing mechanical separation facility (energy waste collected from households). The composition of the waste used is presented in Figure 19. The waste was separated with shredding, screening and sorting to fractions presented in Figure 20. The in plant electricity consumption of SRF facility was 70 kWh/t waste, which included the mechanical treatment devices, conveyer belts, dust extraction system and material handling machinery (such as wheel loaders and excavators).

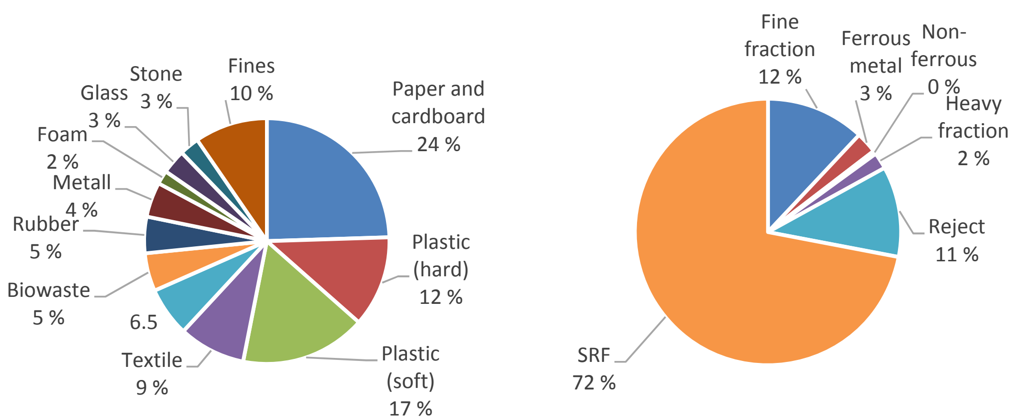

Figure 19. The composition of MSW (energy waste from households) used in SRF production study (left pie chart) and the resulting products (right pie chart) (Nasrullah et al. 2014a).

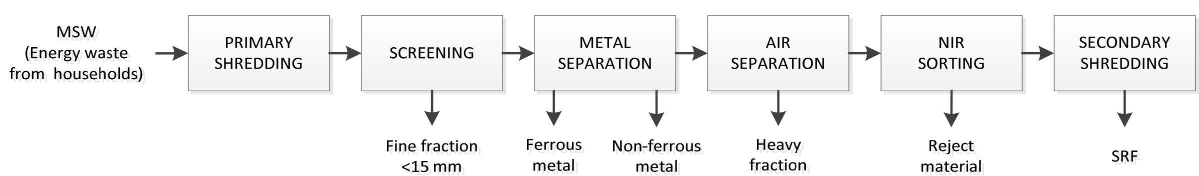

Figure 20. SRF production from MSW with mechanical treatment.

Primary shredding was used to reduce the particle size (nominal top size D_{95} 150 mm). The objective was to homogenize, deal with large and hard particles and open plastic bags. (Nasrullah et al. 2014a). The composition of the waste after screening can be seen from Figure 21. After shredding, jigging and drum screens were used to separate fine fraction (particle size <15 mm), large particles > 300 mm particle size back for shredding and material with particle size in between those was send for further treatment. Then ferrous and non-ferrous metals were separated using several magnetic and eddy current separators (Figure 22 and 23). The wind separation was then used to separate lightweight components (plastic, wood, paper and cardboard, textile, foam etc.) from heavy and middle weight fractions. The lightweight material was put into SRF stream. After wind separation, NIR was used to separate combustibles (paper, cardboard, non-PVC plastic etc.), which were not separated in wind separation, to the SRF stream and rest of material (inert, PVC plastic and other) ended to reject stream. (Nasrullah et al. 2014a) The heavy fraction and rejects composition is depicted in Figure 24.

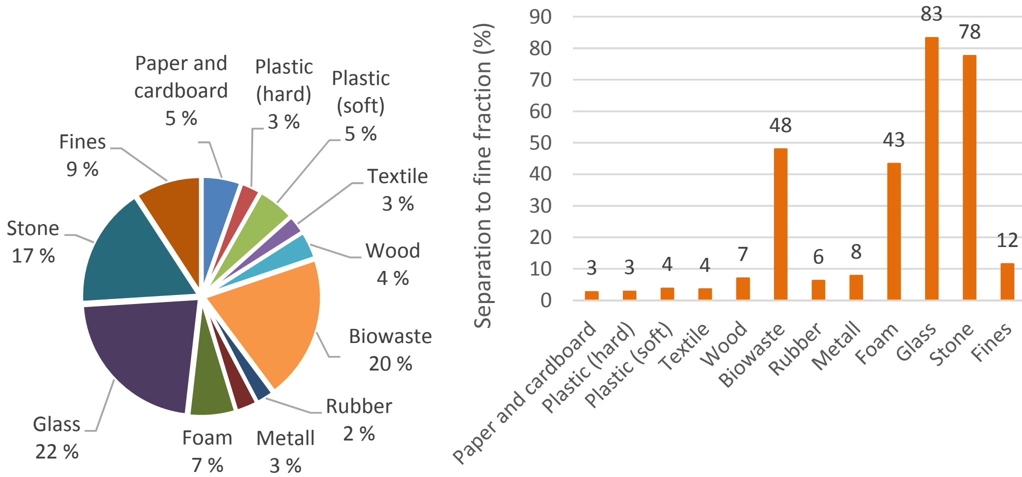

Figure 21. The fine fraction composition coming from screening (pie chart) and column chart presenting recovery rate of different materials from screening (percentage of each material from the input of that material) (Nasrullah et al. 2014a).

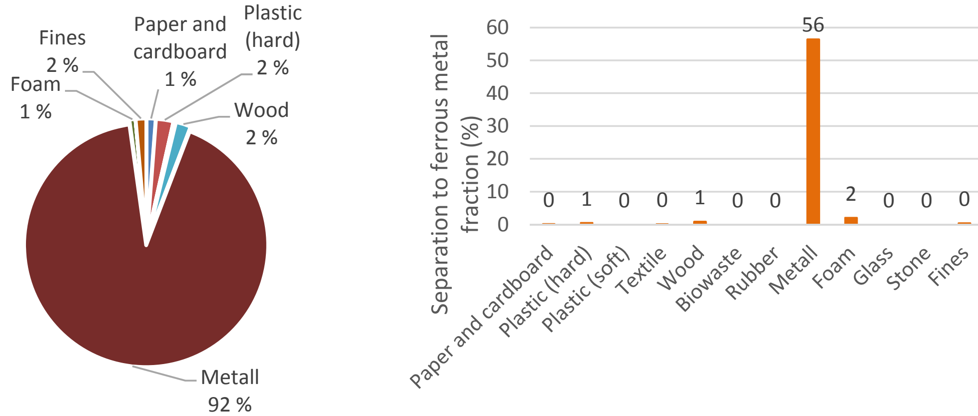

Figure 22. The ferrous metal fraction composition (pie chart) and column chart presenting recovery rate of separation to ferrous metal fraction (Nasrullah et al. 2014a).

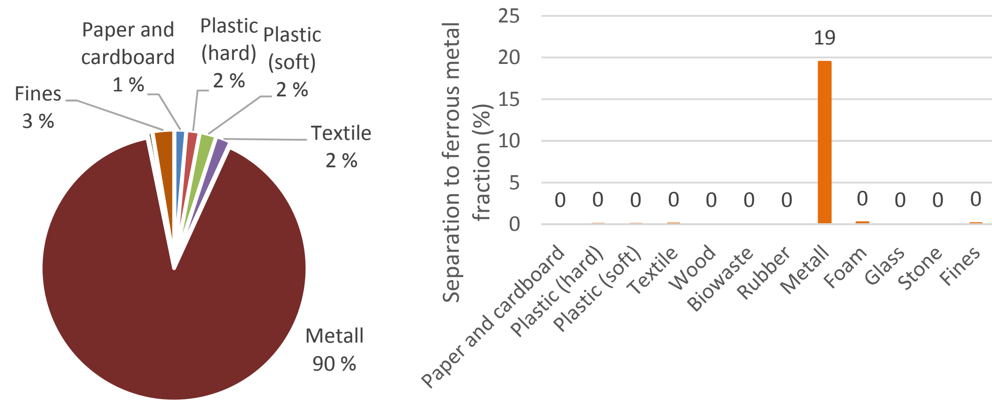

Figure 23. The non-ferrous metal fraction composition (pie chart) and column chart presenting recovery rate of separation to non-ferrous metal fraction (Nasrullah et al. 2014a).

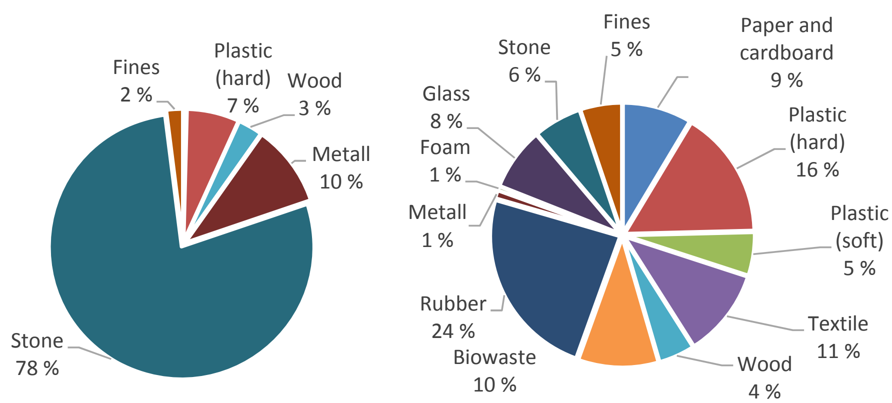

Figure 24. The composition of heavy fraction (left pie chart) and composition of reject (right pie chart) (Nasrullah et al. 2014a).

8. Possibilities for improving material recovery rate

Possibilities for increasing recycling rate were calculated using estimations on MSW amounts and treatment. Basic idea of the estimations was that the 50 % recycling target should be achieved (33 % in 2013) and the calculations was conducted for the known MSW mass in 2013 and the estimated MSW mass in 2020. The estimate for MSW mass in 2020 was based on predictions made by Finnish Environment Institute (Salmenperä et al. 2015). The composition of mixed MSW in 2013 and in 2020 was assumed to be as presented in Figure 3.

Two scenarios were formed to estimate the possibility to reach 50% recycling target using the total MSW mass generated in 2013 in calculations. In Figure 25, the first bar presents the MSW amount in 2013. Next bars present only the recycled masses. The source separated fractions are highlighted with pattern fill and solid fill is used for the fractions in mixed MSW. Recycling target of 50 % is calculated from total mass of MSW in 2013. In the first scenario it was assumed that all the already source separated fractions are directed to recycling, meaning that no spoiling of the separately collected fractions happens and all could be used for material recovery. The resulting recycling rate would be 49% which means that by only this method the recycling target cannot quite be achieved. It should also be noticed that some of these fractions might only be collected for energy recovery and so material recovery of them would need separation of the fractions or using the materials e.g. for composite products.

The second scenario takes in the possibility of increased mechanical separation with similar recycling efficiency as the scheme of Ekokem's Eco refinery (37% biodegradable, 10% plastic and 3% metals for recycling) (Ekokem 2015b). In this scenario it was also assumed that the source separated MSW to material recycling does not decrease. The calculation shows that approximately 70% of the mixed MSW generated in 2013 (940 000 t/a) would have to be treated in mechanical treatment plant to achieve the recycling target.

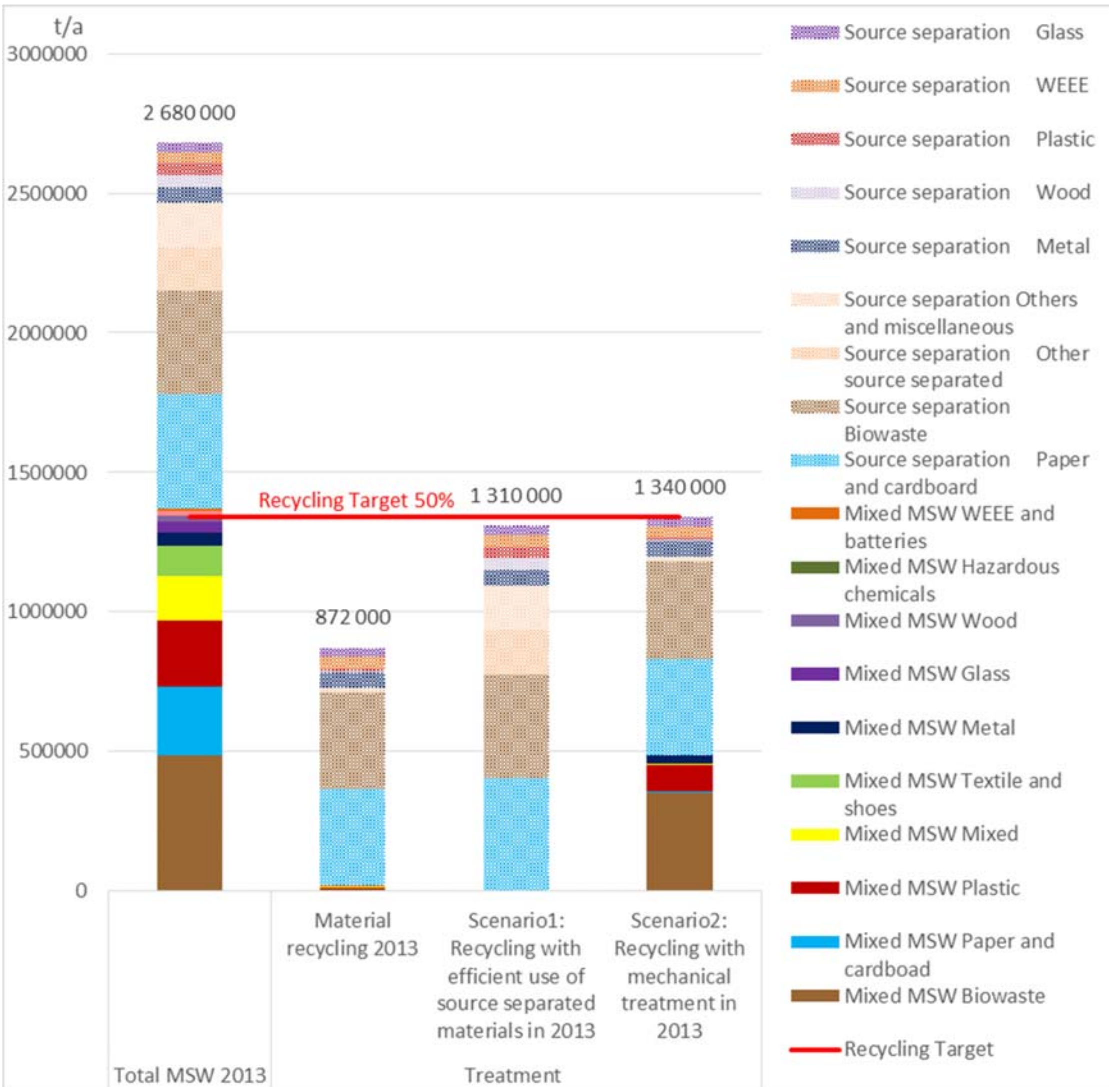

Figure 25. Total MSW mass in 2013, MSW mass directed to recycling in 2013 and in scenarios 1 and 2 (source separated fractions with pattern fill and mixed waste with solid fill).

The similar scenarios as for 2013 were formed for year 2020 to estimate the possibilities to reach 50% recycling target from the estimated amount of MSW with one additional scenario (Figure 26). The first and second scenario remain the same as for previously for year 2013. The third scenario is based on the increased material recycling rates (material recycling is assumed to increase by increased source separation rate and increased material recycling rate of source separated waste) estimated by Finnish Environment Institute (Salmenperä et al. 2015). The used material recycling rates for the main fractions are summarized to Table 11.

Table 11. Calculated material recycling rates for year 2013 and recycling rates for 2020 estimated by Salmenperä et al. (2015).

	2013	2020	Increase
Paper and cardboard	50 %	67 %	32 %
Biowaste	43 %	63 %	48 %
Glass	44 %	89 %	104 %
Metal	39 %	87 %	125 %
Plastic	4 %	27 %	532 %

The packaging waste source separation is increasing in the future along with increased extended producer responsibility and also plastic packaging waste recycling could be increased. Total plastic mass in MSW was assumed to be 365 000 t in year 2020 (Salmenperä et al. 2015). Part of the plastic waste is directed already to material recycling. In order to calculate potential of increasing plastic packaging waste material recycling, plastic packaging mass was assumed to be 81% of the total plastic mass, of which 66% was assumed to be source separated and 33% of source separated mass was assumed to be directed to material recycling (Gaia 2015). This leads to 22% recycling of plastic packaging waste as summarized to Table 12.

Table 12. Calculated MSW plastic packaging recycling with increased source separation.

	t/a	of total plastic
Total plastic mass	370 000	
Plastic packaging	300 000	
Source separated	43 000	
Material recycling	16 000	4 %
From mixed MSW	6 300	
From source separated	9 300	
Plastic packaging recycling	64 000	22 %
Plastic recycling total	80 000	

Another way to increase the material recycling of plastic would be directing all the source separated plastic (assuming 66% source separation) to mechanical separation where different plastic qualities can be separated and residual plastic could be utilized in composite manufacturing. In the Ekokem refinery following plastic polymers will be separated: LDPE, PP, PET and HDPE. The removal rate of plastics with NIR was assumed to be 90%. The share of different plastic polymers was obtained by plastic separation study made in ARVI program (Anderson & Poliakova 2015). Together with separating plastic polymers and composite manufacturing, the recycling rate of plastic packaging waste is 59% as summarized to Table 13.

Table 13. Calculated MSW plastic packaging recycling including plastic polymer recycling and composite manufacturing.

	Share	Removal rate	Mass (t/a)
LDPE	27 %	90 %	47 000
PP	20 %	90 %	35 000
PET	11 %	90 %	19 000
HDPE	6 %	90 %	11 000
PS	8 %		0
Other	28 %		0
Total			110 000
Other plastic	Composite manufacturing		83 000
To composite	75 %		62 000
Reject	25 %		21 000
Plastic packaging recycling	59 %		170 000

From the second bar in

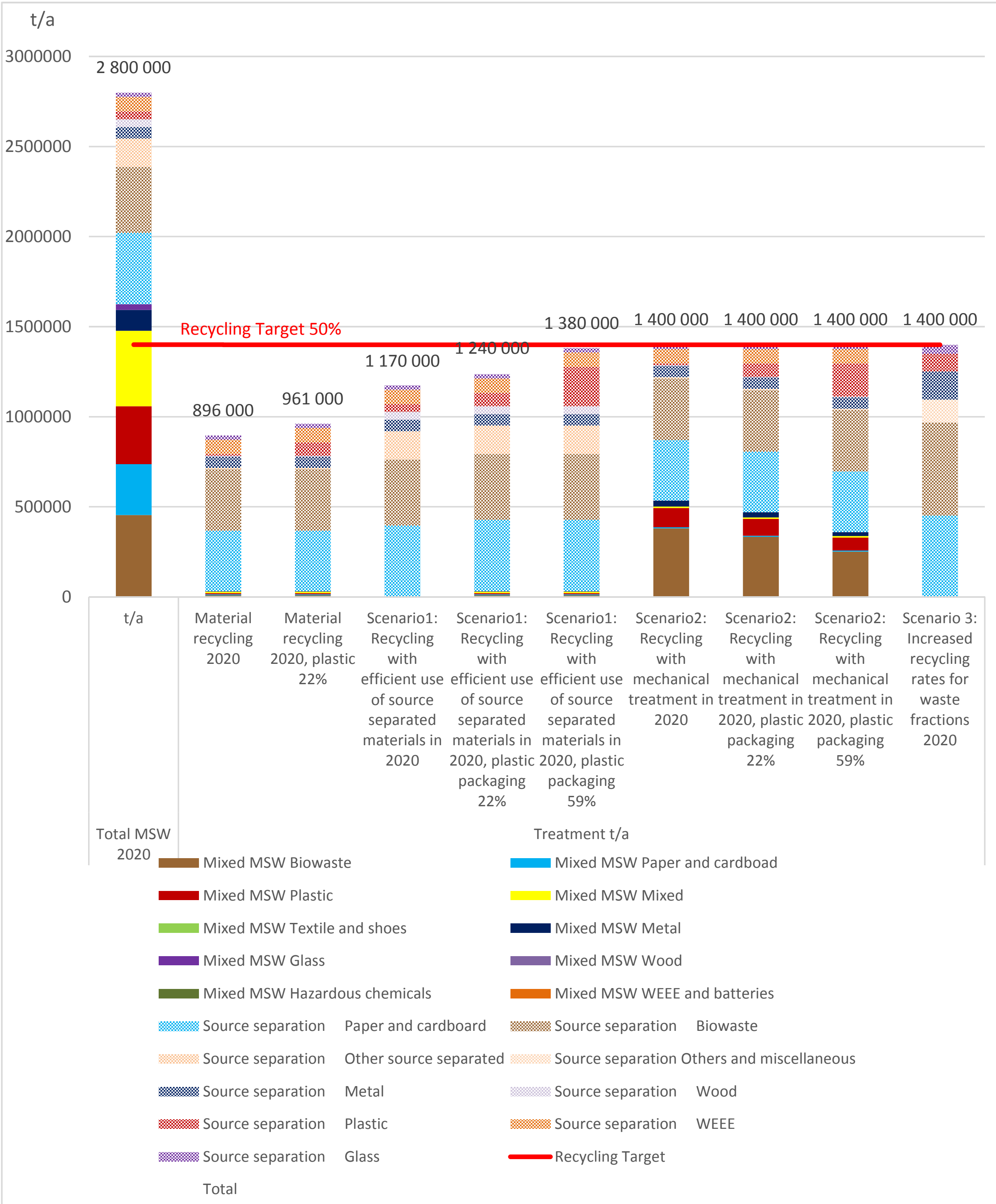

Figure 26can be seen that if recycling is not actively promoted, Finland will fall behind the recycling target with notable marginal. The recycling rate in 2020 was estimated to be 32%, which is slightly lower than achieved in 2013 because the share of paper, which is very actively recycled, is decreasing year by year due to decreasing usage. The result of Scenario 1 show that even by similar shares of source separation and directing all the source separated mass to recycling, the recycling rate would reach only 42% without increasing the source separation and material recycling of plastic packages. With 22% plastic packaging recycling, the recycling rate would be 44% and with 59% plastic packaging recycling, already 49%. The 50% recycling target could be achieved by directing 62% of the mixed MSW to mechanical treatment as calculated in scenario 2. The plastic packaging recycling would reduce the need for mechanical treatment of mixed waste. The 50% recycling target would be achieved by directing 54% of the mixed MSW to mechanical treatment if the plastic packaging recycling rate would be 22% and in case the plastic packaging recycling rate would be 59% only 40% of the mixed MSW would be needed to be directed to mechanical treatment. The recycling target of MSW can be also achieved by increasing material recycling of the waste fractions (by increasing separate collection and also directing more separate collected waste to material recycling) like in scenario 3. For this scenario to be achieved, it would require ambitious development work to boost the source separation efficiency (Table 11). Some means for the boost are presented in the same report by Salmenperä et al. (2015) but their effectiveness is not evaluated. The scenarios show that it is unlikely that the target can be achieved by depending on one solution.

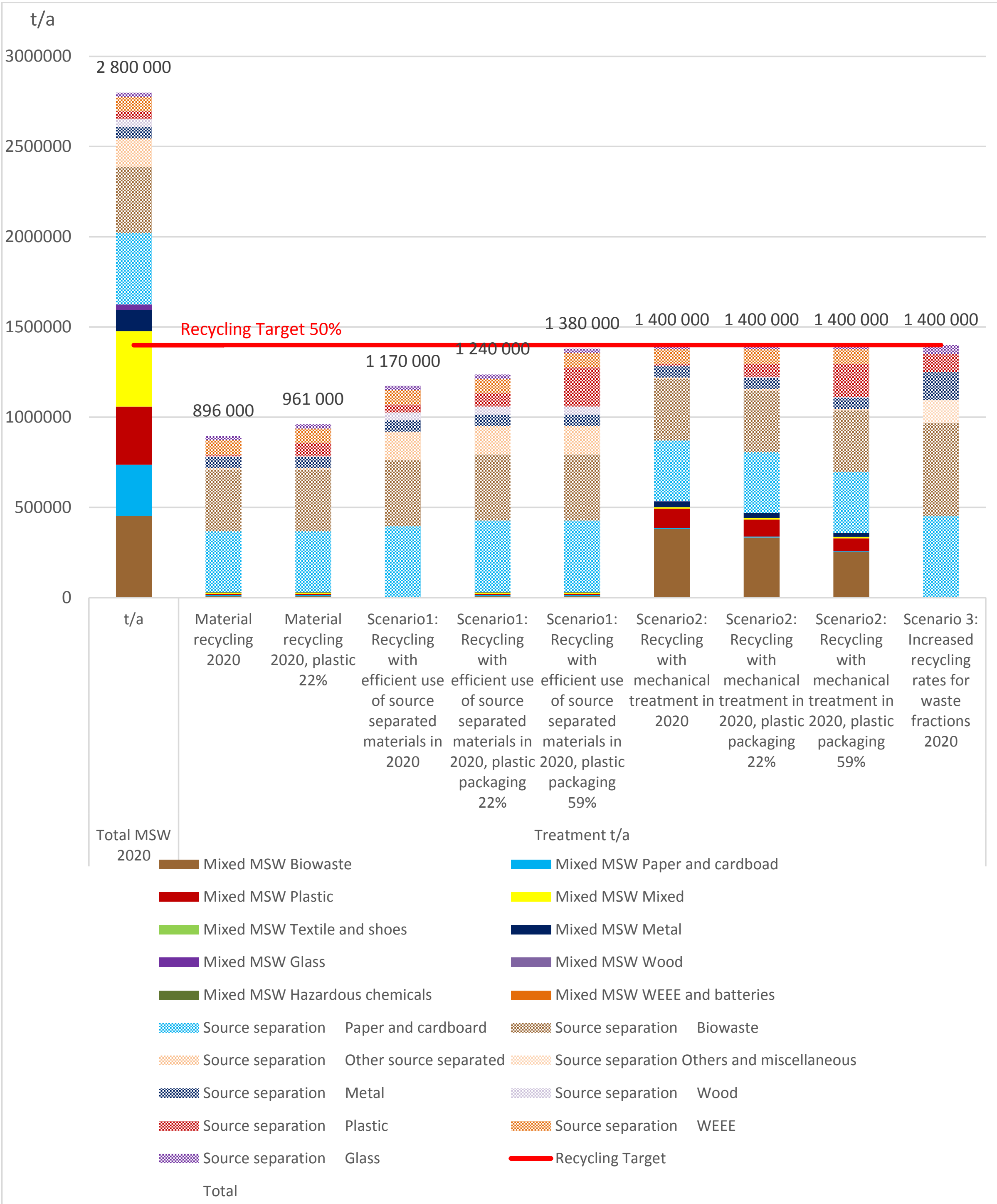

Figure 26. Total MSW mass estimated for 2020, MSW mass estimated to be directed to recycling in and in scenarios 1, 2 and 3 (source separated fractions with pattern fill and mixed waste with solid fill).

The presented scenarios try to depict an overall picture of the magnitude of the issue of increasing recycling rate but there are also issues such as increasing producer responsibility from packaging waste which will most likely affect recycling rates. Plastic package collection will start in the beginning of 2016. The collection targets are low and only 6 000 tons of plastic consumer packages are assumed to be collected per year, at least in the beginning. (Tekniikka & Talous 2015) Also Ekokem's new Eco refinery is supposed to be in operation during 2016. In the plans of Ekokem, it is stated that 50 % of the input will be recycled. With 100 000 t/a input it would mean 50 000 t/a. In addition Salmenperä et al. (2015) estimate that 14 800 t/a metals was recovered from combustions plants ashes in 2013 and estimated 170 000 t/a bio and garden waste was home-composted. If recycling rate calculation method would be modified to include these masses, recycling rate could be raised 6.6 percentage points. The amounts include a lot if uncertainties as trustworthy statistics don't exist. The slag from waste incineration (180 000 t/a, Table 8) can be utilized in construction and including this use as recycling could increase recycling rate by 6 percentage points.

In some areas energy waste is still separate collected, which leads to a situation where lot of recyclable material is incinerated. The other source separated waste mentioned in 2013 MSW statistic (Table 1) was assumed to be energy waste. By assuming that this energy waste collection would be stopped and instead energy waste would be directed to utilization along with other source separated fractions and mixed waste, about 2 percentage point increase in recycling rate could be achieved with the present recycling rates for source separated waste fractions. This calculation is done with energy waste composition according to Salmenperä et al. (2015) (Table 14).

Table 14. Composition of energy waste. (Salmenperä et al.2015)

Waste fraction	Average composition of energy waste [%]	Other source separated in 2013 [t/a]
Plastic	33 %	52 800
Paper/cardboard	46 %	73 600
Wood	4 %	6 400
Other combustible	2 %	3 200
Impurities	15 %	24 000
Total	100 %	160 000

Separate collection and recycling of textile waste was assessed exhaustively in TEXJÄTE – project (Dahlbo et al. 2015) and results were used to assess potential of increasing recycling rate of MSW. Increased recycling scenario with 40% separate collection and 22% material recycling of textile waste (22% recycling, 14% reuse, 64% energy use) (Dahlbo et al. 2015) was used as basis for calculation. This would mean that approximately 16 000 tons of textile waste could be yearly recycled. The amount could probably be even higher as the textile consumption is increasing.

Multi compartment collection could be done in single-family-houses in which lives about 2.69 million inhabitants in Finland. (Statistics Finland 2012) Per person 500 kg of waste is formed per year and 50% of this is assumed to form in households. (Statistics Finland 2013) Assumption is that the amount of cardboard, glass and metal collected could be doubled based on study on multi-compartment bins. With taking into account source separated cardboard, metal and glass about 71 000 tons more recyclable materials could be collected per year with present waste composition and source separation efficiency. (Korhonen et al. 2013)

The effect of above mentioned actions on MSW recycling rate are summarized to Table 15. The biggest increase to recycling rate from these actions comes from home composting. However, the estimate on garden waste home composting is quite rough and there is not really possibilities for collect any statistics about it. Uncertainties in assumptions are great also with multi-compartment collection since it is difficult to predict how people would react to change in waste collection practices. Some increase in recycling rate will take place since Ekokem Eco Refinery is already being built and eventually it will show how the recycling from the waste fraction coming from it will succeed.

Table 15. The effect of different actions on MSW recycling rate.

	Mass for recycling (t/a)	Recycling rate increase (%)
Ekokem Eco Refinery	50 000	2 %
Plastic packaging recycling	6 000	0.2 %
Stopping energy waste collection	43 000	2 %
Textile recycling (22% material recycling)	16 000	0.6 %
Multi-compartment collection	71 000	3 %
Changing calculation		
Slag recycling from waste incineration	175 000	6 %
Metal recovery from ash	15 000	0.6 %
Garden waste home composting	170 000	6 %
Total	371 000	14 %
Present MSW recycling rate		33 %
New MSW recycling rate		47 %

9. Discussion

Finnish waste management is in transformation and incineration has already occupied more ground while disposal into landfills has decreased. The system change will continue as wider producer responsibility is taking place and new ways to develop recycling are discussed. However, 50 % material recycling target by 2016 won't be achieved. Some actions have been done to promote the targets but the restrictions on the landfilling of biodegradable waste has led to cost-effective waste incineration taking over material recycling. Even if targets are not achieved, innovative ideas and solutions are needed as a new national waste plan is taking place from 2017 and recycling targets are set even higher than on previous one and EU's common target is 65% material recycling by 2030.

The overview on Finnish waste management scene has shown that improvements on recycling rates can be achieved through separate collection as well as with other means like mechanical separation or new service concepts. The average mixed MSW was earlier in report found to include significant shares of biowaste, paper, cardboard and plastics. Preventing these fractions from going to incineration or landfills with mixed MSW could be the most effective way to promote the recycling targets. Also more effective recycling of the already separate collected waste could offer improvements but this demands more regional solutions as problems seem to be multifold and small-scale.

Biowaste represents the biggest fraction in average MSW and separating it has been recognized as an important way to increase recycling. With tightening the regional waste regulation of biowaste even further, the separate collected biowaste volumes could be increased in some regions. Regional characteristics like long distances have to be taken into account when setting obligations. Solutions like shared bins between small properties could reduce the costs for biowaste collection.

Paper and cardboards comprise the second largest fraction in average MSW. Fortunately for these fractions good applications exist and problem is more in the lack of material than lack of markets as paper usage is decreasing. The source separation rate is already on good level for paper and cardboards. Still sometimes these separate collected batches may end up to incineration or landfill. Reasons may be poor purity rate, too small batch, spoiling, batch getting dirty or mixing with other fractions. Same problems may concern also other source separated fractions. In these cases better guidance or motivation for source separation, better planned storing and full control of the logistical chain are needed.

Plastics are third largest fraction in MSW. The difference with plastic compared to other fractions is that for now broad separate collection for it doesn't exist. From the beginning of 2016 separate collection for packages made of plastic will be organized by producer organizations as a wider producer responsibility takes place. First, only 500 collection points will be available. New collection network is together with Ekokem's plastic refinery a beginning towards material recycling of plastics.

Demands for collection of other fractions like cardboard, glass and metal on a property could also be raised. Also new service models like multi-compartment bins on properties could raise sorting rates on properties. Balancing the waste charges towards mixed waste could motivate customers to recycle more efficiently. New materials could also be source separated, for example textiles which make about 8 % of mixed MSW together with shoes and 5 % of the whole MSW. Textiles are often reused which doesn't show in statistics.

Mechanical treatment facilities operating in Finland are mainly producing solid recovered fuels. Existing mechanical treatment doesn't significantly increase recycling as most of the material ending up to mechanical treatment is either combusted or landfilled. For mechanical treatment plants increasing material separation may not be favorable, excluding fractions with low calorific value. Existing plants' processes could be improved to better support material recovery. This would require favorable operational environment for recycling and new investments for the plants. Treatment plants focused on material recovery like UPM Shotton do not yet exist in Finland and their effectiveness and suitability for Finnish waste management system is not well known.

The treatment plants using recycled materials should also be prepared and more adapted to use mechanically recycled materials as their purity rate may be lower than source separated fractions'. Sometimes too poor purity rates in mechanical treatment or source separation may be the reason for fractions ending up to secondary utilization or disposal. Ekokem's Ecorefinery is supposed to be in operation by the end of 2016 and hopefully it will illustrate if biowaste and plastics can be mechanically separated from mixed waste and used effectively afterwards.

Mechanical separation of fiber materials from mixed MSW cannot yet be recommended as the fibers were often too dirty for traditional recycled fibers applications. In Shotton plant mechanical separation of fibers is done, but realistic purity rates of the materials and effectiveness and costs of the process are hard to reach. Mechanical separation done from mixed recyclable fraction would require source separation system change. Change may not be preferable after all the education of customers to recycle into different bins, especially when there is only little information about effectiveness of the competing system.

Improvements can be done on multiple levels and also the operational environment should be more favorable for recycling. National authorities are responsible of the general guidance, monitoring and development. In the questionnaire made for waste management companies few legislative and other instruments were presented as a potential ways to promote material recycling. For example investment support, waste or incineration taxes and co-operation between private and public waste management was brought up. Development work could be even more actively directed towards product planning and material applications as through new markets material recovery could become more profitable and mechanical treatment processes developed.

10. Conclusions

Achieving recycling target of 50% is hardly possible to achieve by of 2016. The material recovery rate has remained around 30% quite long time which would imply that it is quite hard to increase it merely by educating general public in recycling. Even if this target is not achieved yet, innovative ideas and solutions are needed as a new national waste plan is taking place from 2017 and recycling targets are set even higher than on previous one. Improvements on recycling rates could be achieved through a combination of increasing separate collection as well as with other means like mechanical separation or new service concepts. Including garden waste home composting to material recycling (estimated 170 000 t/a) could increase the recycling rate by 6 percentage points (to 39% from the current 33%). Increasing source separation by using multi-compartment collection from single-family-houses (increasing 71 000 t/a cardboard, metal and glass going to recycling) could increase the recycling rate by 3 percentage point. Plastic packaging source separation by 66% and directing 33% to material recycling (64 000 t/a) could increase the material recycling by 2 percentage points. Including utilization of slag from waste incineration as material recycling would increase recycling rate by 6 percentage points. Present mechanical treatment plants for MSW plants are mainly focusing on making fuel out of MSW and not really for material recovery. Ekokem´s Ecorefinery could illustrate if biowaste and plastics can be mechanically separated from mixed waste and used effectively afterwards. It is clear that there is a need for increasing co-operation and flexibility between different sectors in waste management sometimes beyond the actors own interests.

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APPENDIX I

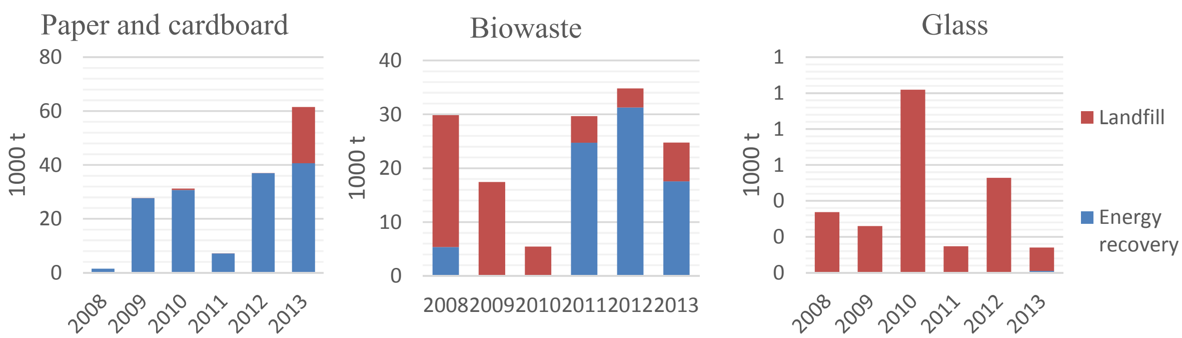


Figure 1. Treatment of source separated paper and cardboard, biowaste and glass (Tilastokeskus 2009, Tilastokeskus 2010, Tilastokeskus 2011, Tilastokeskus 2012b, Tilastokeskus 2013, Tilastokeskus 2014).

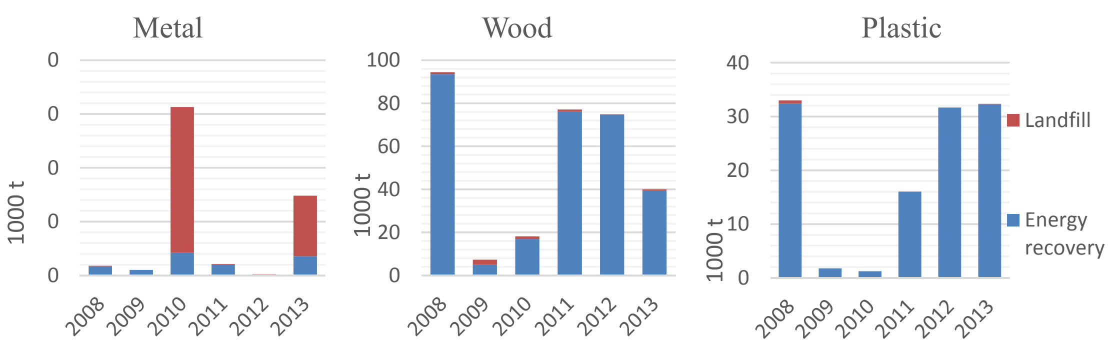


Figure 2. Treatment of source separated metal, wood and plastic (Tilastokeskus 2009, Tilastokeskus 2010, Tilastokeskus 2011, Tilastokeskus 2012b, Tilastokeskus 2013, Tilastokeskus 2014).

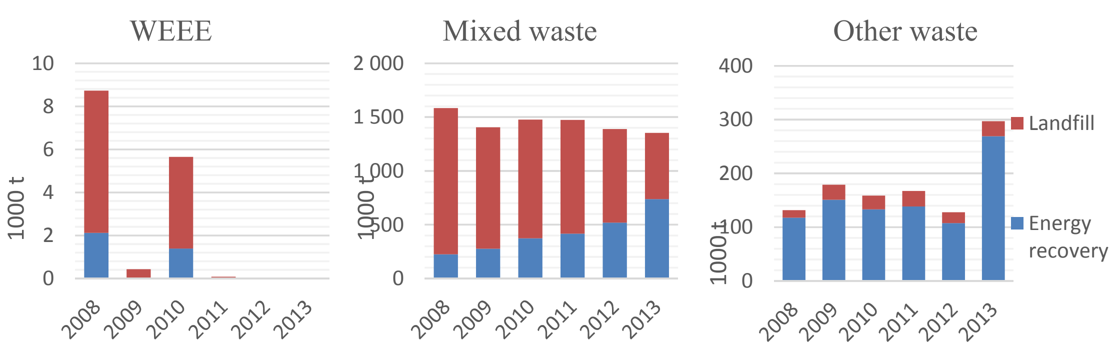


Figure 3. Treatment of source separated WEEE, mixed waste and treatment of other waste (in the year 2013 the other waste also includeds source separated other waste) (Tilastokeskus 2009, Tilastokeskus 2010, Tilastokeskus 2011, Tilastokeskus 2012b, Tilastokeskus 2013, Tilastokeskus 2014).

APPENDIX I

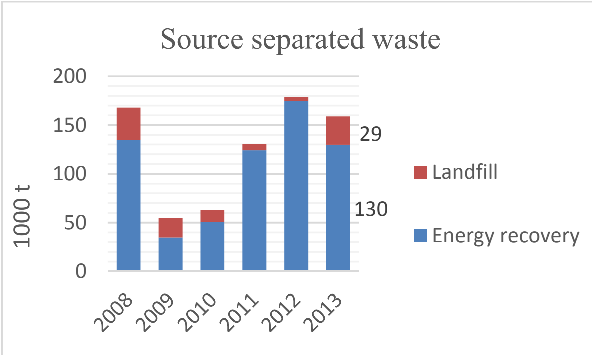


Figure 3. Treatment of sum of source separated paper and cardboad, biowaste, glass, metal, wood, plastic and WEEE waste showing the mass amount for year 2013. (Tilastokeskus 2009, Tilastokeskus 2010, Tilastokeskus 2011, Tilastokeskus 2012b, Tilastokeskus 2013, Tilastokeskus 2014).

APPENDIX II

JÄTTEEN MATERIAALIKIERRÄTYKSEN LISÄÄMINEN

Alla on muutama kysymys yhdyskuntajätteen erilliskeräykseen liittyen ja liitteenä kuvia ja taulukoita pohdinnan tueksi. Lisää rivejä voi laittaa jos käy tila liian ahtaaksi. Mikäli kysely herättää muita kysymyksiä materiaalikierrätykseen liittyen, voi niitä lisätä dokumentin loppuun.

1. Mitä syitä on siihen, että nykyisin erilliskerättyjä jakeita päätyy myös kaatopaikalle ja polttoon? Keräyksessä? Käsittelyssä? Kuinka niihin voisi puuttua?

2. Miten nykyisten erilliskerättyjen jakeiden materiaalikierrätystä saataisiin nostettua / onko se mahdollista/tavoiteltavaa? Lähinnä muovi ja puu, joista suuri osa menee polttoon.

3. Muu erilliskerätty ja sekalainen jäte (Taulukko 1) ovat pääosin sekalaisia pakkauksia ja palavaa jätettä polttoon. Olisiko sieltä mahdollisuutta saada lisää kierrätettävää ja millä tavoin?

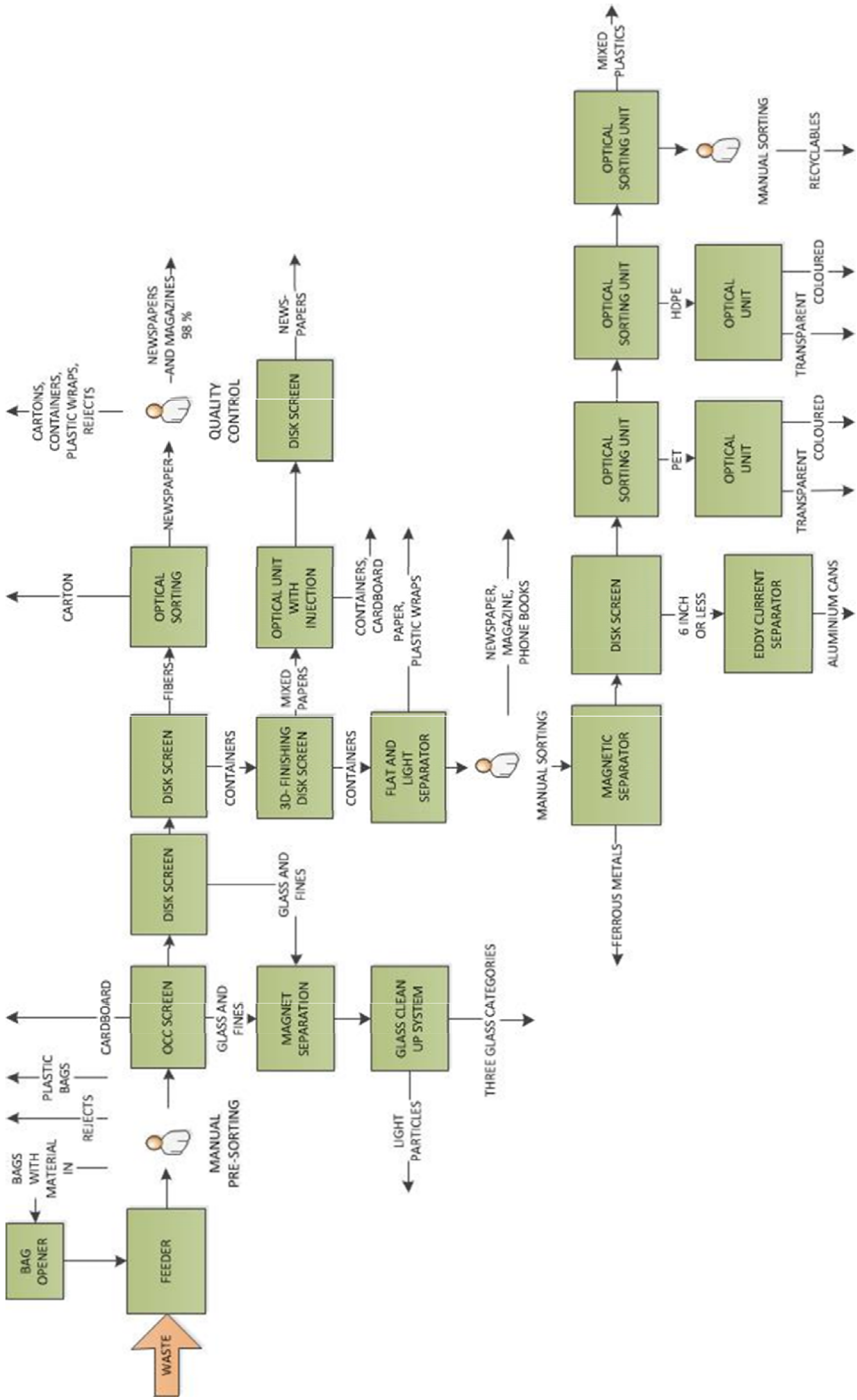
4. Mitä jakeita yhteiskeräämällä voitaisiin Suomessa lisätä materiaalikierrätystä? Arvioi myös toteuttamiskelpoisuutta.

5. Mikä on mielestäsi todennäköisin keino, jolla materiaalikierrätyksen lisäämistä Suomessa pyritään saamaan aikaan?

6. Millaiset mahdollisuudet arvelet olevan sekalaisen jätteen käsittelylle mekaanisissa käsittelylaitoksissa ja kuinka toteuttamiskelpoinen ratkaisu se olisi?

APPENDIX III

Figure 1. UPM Shotton process flow chart (Machinex 2011.)



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