LAPPEENRANTA–LAHTI UNIVERSITY OF TECHNOLOGY LUT
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Master’s thesis 2020

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GUIDANCE TOWARDS SUSTAINABLE WASTE MANAGEMENT IN MACHINERY INDUSTRY CASE STUDY

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TIIVISTELMÄ

Lappeenrannan–Lahden teknillinen yliopisto LUT
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Guidance towards sustainable waste management in machinery industry case study

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Tässä diplomityössä tutkittiin teoriaosuudessa, mitkä ovat EU:n ja Suomen tavoitteet jätepolitiikassa vuodelle 2030 ja miten jätehuoltoa ohjataan jätelainsäädännön ja -politiikan avulla. Teoriaosuudessa tutkittiin myös, miten 3 teollisuuden yritystä ovat huomioineet heidän ympäristöstrategiassansa jätehuoltoon liittyvät tulevaisuuden muutokset ja visiot.

Empiirisessä tutkimuksessa tutkittiin, miten erään teollisuuden yrityksen tehtaalla voitaisiin tehostaa jätehuoltoa vastaamaan paremmin tulevaisuuden muutoksiin, tehostamalla tehtaalla syntyneiden jätteiden kierrätystä materiaalina ja vähentämällä jätteistä aiheutuneita kustannuksia. Jätehuollon tehokkuuden analysoinnissa hyödynnettiin tehtaan antamia tietoja vuosittaisista jätemääristä, miten ne on käsitelty ja kuinka suuria kustannuksia tuotetut jätteet aiheuttavat tehtaalle. Tulosten perusteella tehtaalla tuotetaan paljon polttoon menevää jätettä, joka soveltuisi myös kierrätettäviksi materiaalina. Kustannusanalyysien ja teoriaosuuden perusteella, tehtaalla syntyneiden jätteiden kierrättäminen olisi tulevaisuudessa taloudellisesti tehokkaampi vaihtoehto kuin jätteiden poltto. Tehtaan jätehuoltoa analysoitiin myös työntekijöille tehdyn kyselyn perusteella. Kyselyn tarkoituksena oli selvittää, kuinka tehokas jätteiden kierrätys oli tehtaalla tällä hetkellä työntekijöiden mielestä. Empiirisen tutkimuksen lopussa teoreettinen osuus sekä tulokset analyyseista ja kyselystä hyödynnettiin SWOT analyysissa. SWOT analyysin tarkoituksena oli löytää tehtaan jätehuollon sisäiset vahvuudet ja heikkoudet sekä jätehuoltoon liittyvät ulkoiset mahdollisuudet ja uhat. SWOT analyysistä saatujen tulosten perusteella, tehtaalle annettiin kehitysideoita, joiden avulla he voivat saavuttaa tavoitteen tehokkaammasta ja kestävämmästä jätehuollosta.

ABSTRACT

Lappeenranta–Lahti University of Technology LUT
LUT School of Energy Systems
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Sustainability Science and Solutions

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Guidance towards sustainable waste management in machinery industry case study

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In this master's thesis theoretical research part was researched, what are the goals of the EU and Finland in waste policy for year 2030 and how waste management is guided by waste legislation and policy. The theoretical research part also researched how 3 industrial companies have considered in their environmental strategy future changes and visions related to waste management.

In empirical research was researched how a factory of a certain industrial company could improve waste management for better respond to future changes in waste management by improving material recovery from generated and reducing the costs from generated waste at the factory. In analysis of waste management efficiency was utilised data provided by factory about annual waste generation, how they are treated, and costs generated from them. Based on analyses' results, factory generates a lot of energy waste what could also be suitable for material recovery. Based on cost analyses and theoretical research, recycling generated waste would be more environmentally and economically efficient option than waste incineration in the future. Factory's waste management was also analysed via questionnaire for employees, what was made for finding out how efficient waste recycling was currently in factory according to employees. At the end of empirical research, the theoretical research and results from analyses and questionnaire were utilised in SWOT analysis. Purpose of SWOT analysis was to find internal strengths and weaknesses in factory's waste management as well as external opportunities and threats related to waste management in factory. Based on results given from SWOT analysis, for factory was given development ideas to help them achieve the goal of more efficient and sustainable waste management.

ACKNOWLEDGEMENTS

While working at cartonboard mill in Eastern-Finland I had this crazy idea that someday I'll graduate with master's degree in environmental technology. Back then the idea sounded so crazy in my head that if it would happen, I'd buy myself TAG Heuer Monaco wristwatch. Well the idea was not so crazy after all and now I guess I should go shopping...not really.

I want to thank Mika and Jenni for guiding me during this research and writing process. You gave me good ideas for the thesis when my mind was empty from ideas. Also, I want to thank everyone who have supported me during these two years in LUT. It has been wonderful and fast years. I'm grateful for all the skills and knowledges I've got, but more importantly for all the memories I've got from these two years in LUT. Now it is time to head towards new challenges in the future.

In Lappeenranta, 3rd day of December 2020

Juho Vakkilainen

TABLE OF CONTENTS

1 INTRODUCTION

The master's thesis topic is given by case-company in spring 2020, where theoretical research is made in spring and empirical research in autumn. Under empirical research is waste management in Factory A what operates in machinery technology industry. Main goal is to find development targets and develop Factory A's waste management towards more sustainable waste management along with their own long-term goal towards zero waste to landfill.

First chapter introduces to different type of waste generated and background information about waste development on global-, European Union- and on national level in Finland. It is important to knowledge the impact of proper waste management against climate change and what affects does inefficient waste management have. Given numbers on first chapter, are found from multiple resources. The research years varies between 2010 to 2018 and hence given numbers are not absolute truth about current situation in 2020. Given numbers from years 2010-2018 can instead be seen as development path for forecasting development of waste generation and how generated waste are treated.

Second chapter defines main waste legislations and policies. Idea is to give summary of current waste management legislation and policies and describe future changes in waste management legislations and policies. Based on current waste legislation and policy development, main waste management concepts are explained as they guide development of waste management. Introduced concepts in second chapter are concepts, what companies and industries should adapt into their own waste management as efficient as possible.

Third chapter describes definition for concept zero waste to landfill and zero waste. What is the difference between these two concepts? Have three example companies implemented into their sustainability strategy either of these concepts and what are their environmental strategy with waste management in overall? Also, how their waste management have developed during years 2015-2019. Development of these companies' waste management and in general what is their strategy in waste management is defined by annual reports published by the companies themselves.

Fourth chapter is beginning of empirical study about machinery technology company under research in this master's thesis. First under study is environmental strategy and waste management development inside case study company in overall. It is important to analyse first waste management development and strategy in the company in general as big vision and strategies, guide each factory operating in the company. On next step empirical research is narrowed into a factory operating inside the company. Factory A's waste management development is analysed further with internal data provided by the company to analyse waste treatment- and cost performance.

In fifth chapter, empirical research of Factory A's waste management is analysed further via questionnaire created for employees working in Factory A. Questionnaire defines further empirical research where scope in study is narrowed down to small research. Scope and goal of the questionnaire is to analyse how efficient is waste management in daily operations in Factory A and how employees review quality of Factory A's waste management?

In sixth chapter waste management in Factory A is analysed in SWOT analysis to evaluate performance of waste management in Factory A. Goal is to define main strengths, weaknesses, opportunities and threats of Factory A's waste management development towards more sustainable waste management along with zero waste to landfill-goal. Findings from theoretical and empirical research are utilised in SWOT analysis.

Final seventh chapter summarises current situation in Factory A's waste management by summarising research findings and analyses. Final chapter gives few recommendations with what kind of development steps Factory A can move forward towards more sustainable waste management by also increasing cost performance.

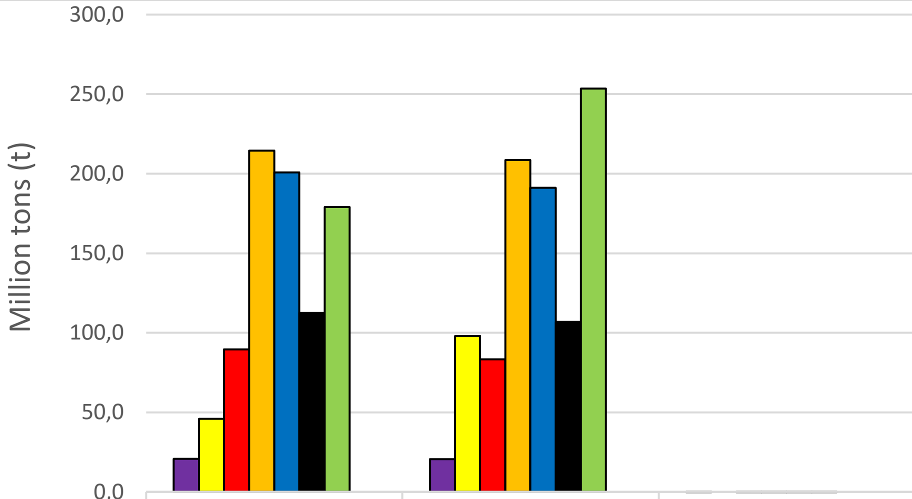
1.1 Global waste development

What is waste? Waste is defined by Cambridge dictionary as useless material or matter of any kind what is unused after all useful parts or substances have been collected. (Cambridge, 2020). European Union defines in waste framework directive 2008/98/EC waste as object or substance which the owner intends to discard or is instructed to discard. Hence in general, waste can be defined as a material or a product, what is no longer needed and needs to be disposed. Waste is generated throughout product's whole lifecycle from collecting raw materials to disposal of the product. Waste does not mean natural organic matter in biological cycle, where disposed organic material becomes a resource for new material. For example, decomposing animal is a natural energy source for microbes. Therefore, waste is something what is generated by humans and needs to be managed in waste management process.

Linear economy, where raw materials are needed to produce new products and at the end of the product's lifecycle some of the materials are recovered, has led to a situation that world's population consume way over the Earth's annual raw material generation. It is estimated that from global annual municipal solid waste generation only 30% is not disposed to landfills and only 19% of the total municipal solid waste is recycled as a material. To make the situation even worse, population is estimated to grow the most, where they lack proper waste management for material recovery from generated waste. Hence, needs and at the same time lack of natural resources will increase in the future. (Waste atlas, 2013). Research from 2018 by World bank estimates that humans produce globally in total 2,01 billion tons of municipal waste in a year and average waste production daily per person is over 0,7 kilograms. As population grows drastically every year, the total amount of municipal waste generated annually in 2050 is expected to rise from 2,01 to 3,4 billion tons. The amount of municipal waste per person varies between countries and average income and it is estimated that 16% of the world's wealthier population generate 34% of the total annual municipal waste. (Kaza, 2018, 3-6)

European Union what includes wealthier countries, the latest development calculations in waste production has been made by European Environment Agency for years between 2010-2016. Calculations includes annual waste generation from households and companies.

Increasing development of more complex waste treatment methods and at the same time increasing amount of waste streams from landfills to recycling and waste incineration, have increased the amount of secondary waste. (EEA, 2019) In figure 1 below is shown the development of waste generation from different sectors. Waste generation has grown by 10% from 2010 level. Secondary waste streams are included in total waste generation development and therefore waste from waste and water sector has grown in 2016 nearly 30%. Meanwhile waste generation from households and manufacturing has been slightly decreasing. In 2016 households generates 208,7 million tons of waste and manufactures generated 200,9 million tons of waste. From 2010 level households generates nearly 3% less waste and manufactures bit over 5% less waste in 2016.



	2010	2016	Change %
Agriculture, forestry and fishing (t)	20,7	20,5	-0,98%
Construction (t)	46,0	98,0	53,06%
Energy and extraction (t)	89,5	83,3	-7,44%
Households (t)	214,4	208,7	-2,73%
Manufacturing (t)	200,9	191,2	-5,07%
Services (t)	112,5	106,9	-5,24%
Water and waste sector (t)	179,1	253,5	29,35%
Total	863,1	962,1	10,29%

Figure 1: 2010-2016 waste generation in EU excluding major mineral waste (Modified EEA,2019)

1.2 Waste management definition

Waste management process according to Finnish Waste Act 646/2011 incudes waste collection, waste transportation, waste recovery and waste disposal. General definition for waste management is a process for managing disposed waste from human activities. Waste management follows waste hierarchy, where generated waste is primarily recycled as material or secondly utilised for energy. Waste management's purpose is to minimise waste's negative impact to environment and human health. Whether waste is solid or liquid, hazardous or non-hazardous, industrial or municipal, all waste must be processed with suitable method depending on waste type and quality. Industries are responsible for controlling non-hazardous and hazardous manufacturing waste generated from their actions. (Pongrácz, 2002, 18,104-105) Volume of non-hazardous waste is usually greater than hazardous waste generated in manufacturing. Waste management process can be divided like shown on figure 2.

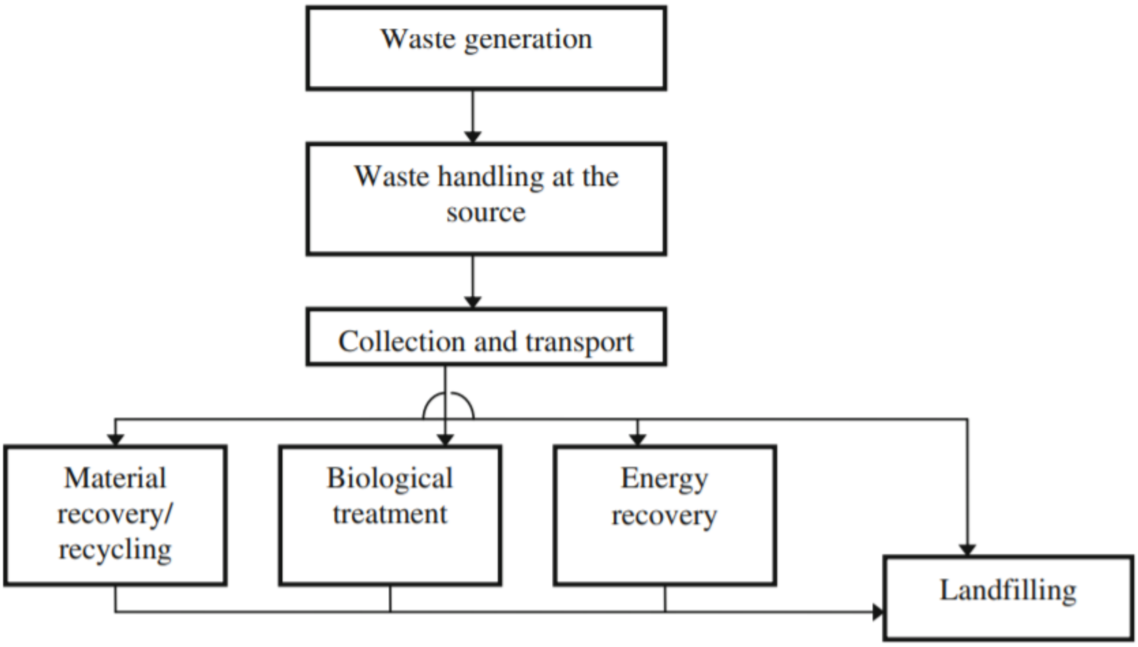


Figure 2: Waste management process (Martínez G. 2012, 2)

First step in waste management is monitoring for identifying the needs for waste management and quality of generated waste By identifying quality and volume of different waste types, the potential for waste utilisation can be maximised in accordance to waste hierarchy. Volume of different waste types and their quality varies in different industries. Some industries produce waste with high recyclable potential, where on the other hand other industries produces waste with low quality due to hazardous substances. Therefore, it is important and also mandatory by waste regulations for industries to analyse and monitor generated waste quality and volume and aim for maximising material recovery from generated waste. Based on volumes and quality of different waste types, industries develop separate waste handling and collection processes on production site for hazardous and non-hazardous waste. Hazardous waste must always be collected and handled separately from non-hazardous waste. When knowing waste streams from production and from where hazardous waste is generated, industries can create efficient waste collection for separate waste types by providing collecting possibilities near to locations, where waste is produced, minimising material and economical losses from wrong kind of waste sorting. After waste is collected and transported from production site, they are either recycled as material, used as a source for energy or disposed to landfill. Liquid hazardous waste can be also treated by evaporating or physicochemical treatment. (Shammas, 2008, 386) Waste utilisation as material or energy depends on quality of generated waste, but also because of development on waste management trends. Hence, are current waste management trends in Finland favoring waste utilisation as source for energy or is trend towards material recovery?

1.3 Waste development in Finland

In Finland methods for waste treatment have developed quite a lot. Finnish waste management has developed from disposing waste to landfills, towards energy recovery from waste by waste incineration. Latest stats created on June 2020 from research year 2018 reveals that level of municipal waste is around 3,041 million tons and grew by 6% from year 2017. From total municipal solid waste 57% is used for producing electricity and district heating by waste incineration and 42% of waste is recycled as material. Waste management development towards high level of energy recovery by waste incineration does not follow well waste hierarchy but benefits of waste to energy and reduction of waste disposal to landfill have kept waste incineration as popular method for waste treatment. As it can been seen from figure 3, development of municipal waste by treatment methods, from 2002 to 2018, the waste incineration has replaced nearly totally disposal to landfill. Development has been fast as bit over 10 years ago half of the municipal waste was still disposed to landfill and only 15% of total municipal waste was used as a source for energy.

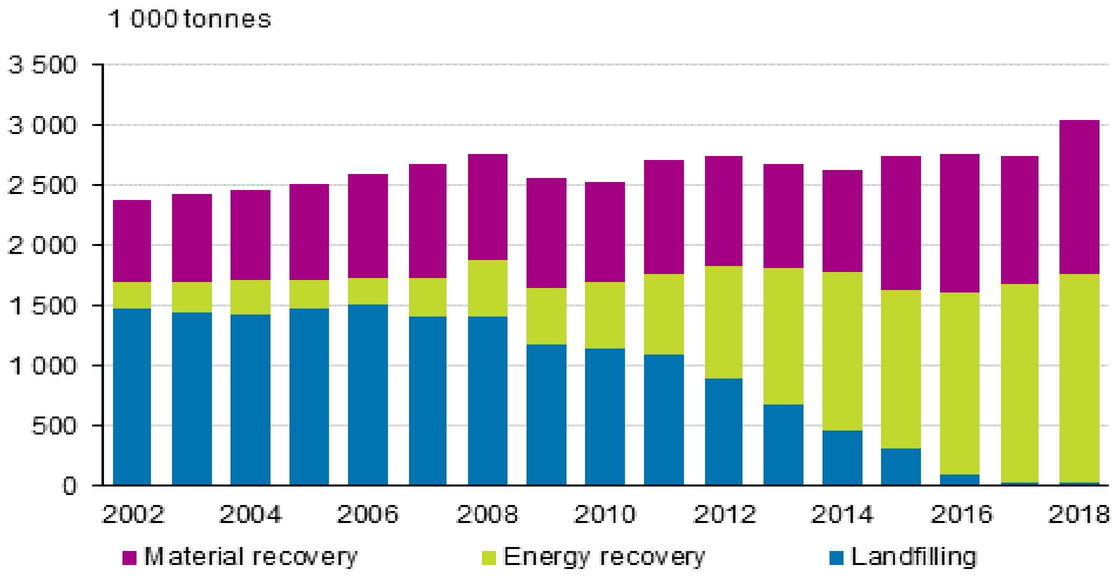


Figure 3:2002-2018 Municipal waste treatment development in Finland (Statistic Finland, 2020a)

1.3.1 Industrial waste development

Industrial waste is non-hazardous or hazardous waste generated in manufacturing. Generated industrial hazardous and non-hazardous waste needs to be treated properly as industrial waste can cause major damage to environment or human health if not treated right. (De Vroom, 2019) In manufacturing industry waste is mostly used as a source for energy. Price development of raw materials and increasing demand for material recovery via regulations will develop waste management of generated industrial waste from energy recovery towards material recovery. The challenge in movement towards material recovery will be with hazardous waste. Quality of hazardous waste should be improved by decreasing amount of hazardous substances in hazardous waste for better material recovery. (Salmenperä, 2015, 12-13; Laaksonen, 2017, 36)

In table 1 below are latest information given in June 2020 by Finnish authorities about industrial waste production in metal- and in paper- cardboard industry. From table it can be seen that different industries have different volume of specific more complicated waste types. Metal industry has high level of hazardous waste due to production of finished products need a lot of chemicals. Paper- cardboard industry produce high level of wood waste due to usage of wood as raw material. The table does not include side streams from production, what are utilised either in own production or in other companies' production according to report.

Table 1: Different waste types generated 2018 in metal. and paper and cardboard industry, 1000t (Modified, Statistics Finland, 2020b)

Different industrial waste types generated 2018, 1000t	Metal industry	Paper and Cardboard industry
Chemical (t)	52	191
Metal (t)	131	16
Paper and Cardboard (t)	5	68
Wood (t)	6	1 904
Sludge (t)	101	583
Mineral (t)	975	161
Total (t)	**1 270**	**2 923**
Hazardous waste from generated waste (t)	**565**	**6**

2 POLICIES, TRENDS AND LEGISLATIONS RELATED TO WASTE MANAGEMENT

Different industries are obligated follow multiple trends, policies and regulations to maintain their competitiveness among competitors and find acceptance for their business operations from society. Therefore, it is important to introduce few main environmental legislations and concepts what industries and other kind of companies should follow. Environmental aspects are increasing importance year by year and therefore it is not acceptable for industries to bypass such trends as sustainability if they want to maintain competitiveness. Industries who manages environmental aspects efficiently will be more competitive in future business markets. Among sustainability, waste management and waste prevention play important role in companies' development towards sustainable business operations.

One of the most important programs towards more sustainable living is United Nations 2030 Agenda for Sustainable Development, what is launched in 2015. This program includes 17 sustainable development goals what should be achieved by year 2030 to have environmentally, socially and economically sustainable world. Sustainable development goal number 12, responsible consumption and production has an impact to waste management by including multiple targets for 2030, where most important ones are:

1. Efficient use of natural resources by sustainable management
2. Waste management efficiently preventing waste generation by preventing waste production and increasing level of reuse and recycling.
3. Achieve sustainable management of waste and chemicals throughout whole life cycle by reducing production on waste including hazardous chemicals or material.

2.1 Circular economy

Movement toward circular economy is one of key elements for competitiveness development and at the same time reducing impact to environment. Circular economy concept aims for balance between society, environment and economy by moving from produce-use-dispose linear economy to closed loop economy. In circular economy materials and products are designed to be durable and easy to reuse to prevent waste generation and decrease usage of natural raw materials. (Ellen Macarthur Foundation, 2017; Kohvakka, 2019, 130)

Ideology of circular economy is not only in durable and reusable products. It is a new business model where digitalization opens news possibilities for non-material services. Hence, customer habits are moved from buying and owning physical products to buying non-material services and sharing instead of owning. Waste management’s part is reduced in circular economy. In linear economy waste management is for preventing disposing generated waste without utilisation by using waste as a source for material or energy. In circular economy waste incineration is seen as material loss and therefore the weighting on circular economy is on increasing the importance of proper product designs and production methods to prevent waste production. (Sahimaa, 2016, 13-15)

2.2 Waste hierarchy

Waste hierarchy is an important concept along with circular economy. Waste hierarchy included in Waste Framework Directive 98/2008 is a five-level pyramid (figure 4), what gives guidance for households and industries to primarily prevent waste generation and minimize waste disposal to landfills. Waste hierarchy introduced in the waste framework guides primarily to prevent waste generation by preparing disposed product to be suitable for reusage as a product again. If this is not possible, then usable materials from the product should be separated and recycled for producing new products. Waste what can't be reused as a material should be used as a source for energy. This means incineration of waste to produce electricity and heat energy or digesting organic matter in anaerobic digestion process. Waste not suitable for energy production are disposed to landfills or incinerated without energy production. Therefore, the importance of waste prevention by better product and production process designing is very high. (Kohvakka, 2019, 96)

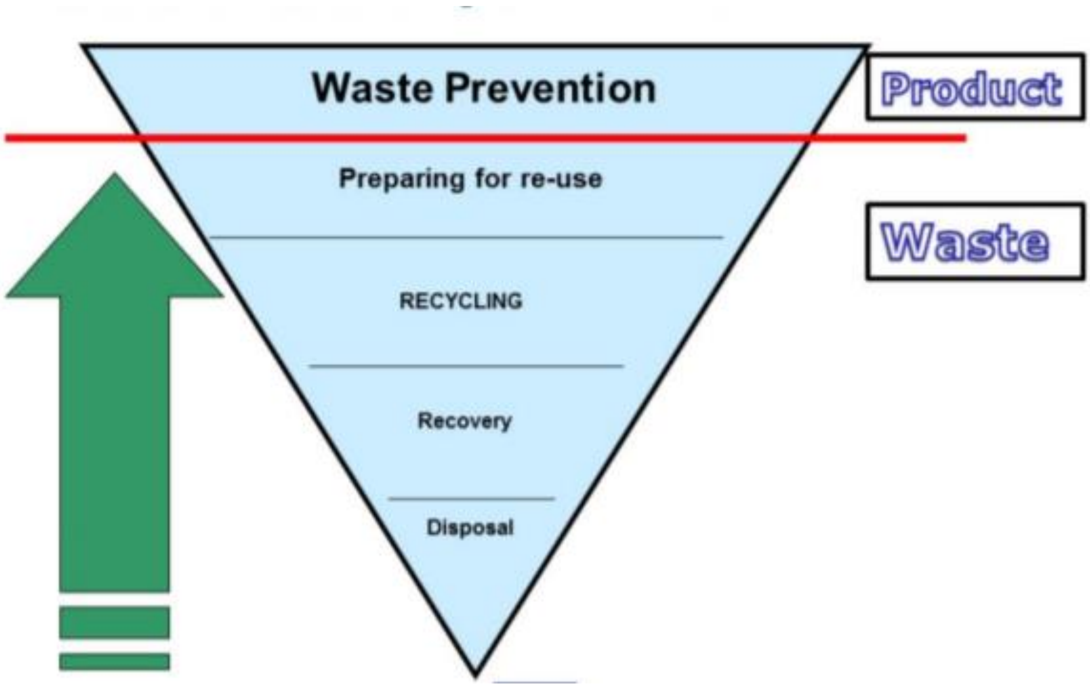


Figure 4: Waste hierarchy in Waste Framework Directive 2008/98/EC (European Commission, 2020a)

Joan Simon, director of Zero Waste Europe has developed the waste hierarchy even further, describing that waste hierarchy demonstrated in Waste Framework Directive 2008/98 can be extended by adding two more levels to the pyramid and chancing goals of the levels.

(figure 5) He states that extended waste hierarchy, zero waste hierarchy pyramid support more efficiently movement from linear economy to circular economy than commonly accepted waste hierarchy from directive 2008/98. Zero waste hierarchy increases the importance of products durability and material recovery efficiency by excluding waste management levels, where material is not recovered such as waste incineration. Zero waste hierarchy includes not only environmental aspects, but also increases importance of social, economic and logistical aspects in waste management. This is made by supporting only products and services, what supports more environmentally friendly customer habits and prevent usage of single use or low-quality products. Third level, preparation for reuse is same as in first level in of basic waste hierarchy. Waste generation should be primarily prevented. Generated waste should be recycled as material and organic biodegradable waste used as a source for energy. From generated mixed waste should be efficiently separated chemical, organic and other useful materials to prevent resource leakage. Leftover residues from mixed waste separation should be only organic residues and therefore they should be biologically stabilized and disposed to landfill. The lowest level in extended waste hierarchy includes methods what should not be used. (Simon, 2019)

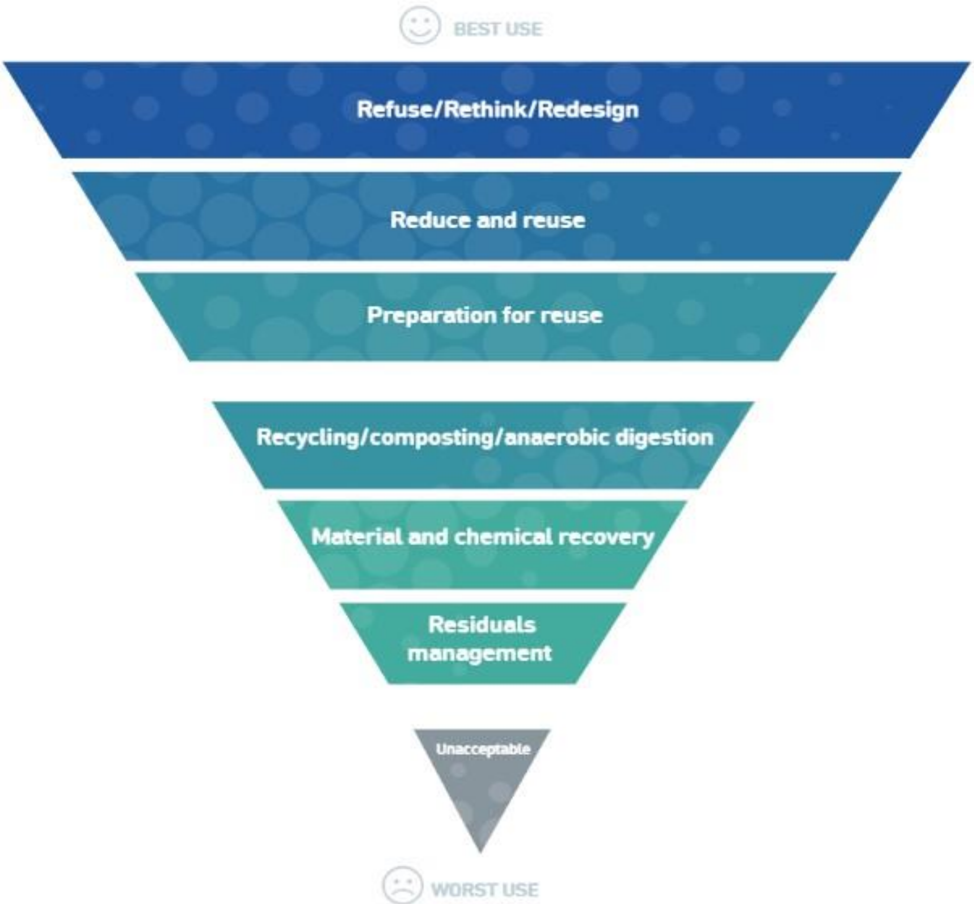


Figure 5: Zero waste hierarchy (Simon, 2019)

2.3 Waste management action plans

Waste management in European Union is based on earlier mentioned waste framework directive 2008/98/EC what supports movement towards circular economy. Decided on November 2008 Waste Framework directive 2008/98 gives guidance for other EU and national waste legislations, what EU member countries must follow. The directive introduces main definitions and concepts for EU-member countries related to waste management, such as definition of end-of-waste criteria and previously defined waste hierarchy. Directive 2008/98/EC require that all generated waste from homes as well as from production must be managed without harming or endangering environment or human health. In Finland main waste management concepts and guidance is presented in Waste Act 646/2011.

2.3.1 European Union Environment Action Programs

For guidance towards 2050 long-term vision, EU has developed multiple environment action programs, where latest active seventh action program is adopted in decision 1386 in year 2013. Long-term vision for year 2050 includes vision for zero waste society, where natural resources are managed on sustainable level. Seventh Action Program 2020 includes 3 priority actions guiding EU member countries for more sustainable business and living towards year 2050. Material efficiency should be increased by increasing the importance of waste regulations based on article 191 of the treaty of EU. (European Commission, 2019b, 2-4) This article defines that all member countries should implement similar policy for sustainable development with goal for higher environmental quality protection and improvement. In waste management this means that most of municipal waste to be recycled by 2050 and less than 1% of waste should end in landfill.

Latest developments in Eu's environmental policy towards goals presented in UN 2030 were made in Action plan towards circular economy decided on March 2020 and on October 2020 in proposal for 8th Environmental action program for years 2021-2030. Circular economy action program decided on March 2020 as part of EU industrial strategy suggest new legislation for making sustainable products a new norm in European Union market area. Products must be designed to last longer and be usable more than once. Avoidance of waste generation is top priority and most of generated waste should be turned into usable and profitable material. In production usage of raw materials should be reduced and products and materials no longer needed should be designed to be easy to reuse, repair or recycle. One smaller development topic given in action plan affecting waste management is to standardize waste collection labeling in EU. Action plan focuses specially into specific waste types such as packaging material waste, plastic waste and electronic equipment and electrical waste. New regulations and strategies for the specific waste types should be developed in national level.

European Union's 8th environmental action program towards long-term goals 2030 and 2050 revealed in 14th day of October, should replace 7th environmental action program in first day of January 2021. Upcoming, yet non-active 8th environmental action program follows 2050 20 vision and main objectives from 7th environmental action program, with goal to accelerate transition to resource efficient, biodiverse and zero polluting society. New 8th environmental action plan will implement Eu's Green Deal- action program with new objectives until 9th environmental action program 2030. Green Deal-action program guides investments towards environmentally friendly solutions by example investing in non-fossil fuel combustion engines and investing in new technologies and industrial innovations. (EU, 2020, 7-8) As given proposal about next action program is yet a draft, further strategies or decisions according to waste management has not been given.

2.3.2 National waste plan to 2023

Based on requirements given by Waste Framework Directive 2008/98 to have proper waste management for reducing quantity and hazardousness of waste, Finland has developed own national strategic waste plan. From recycling to circular economy- waste plan to 2023, decided in 2017 and last time developed in 2020, aims for preventing waste generation and improving quality of generated waste. In long-term vision for 2030 Finnish waste management will be:

1. Sustainable waste management with high standards supporting circular economy
2. Production and consumption are material efficient.
3. Waste generation have decreased from present level.
4. Level of reuse and recycling have increased, and the recycling markets are working and creating jobs.
5. Valuable raw materials even in low concentration are collected from recyclable material and reused.
6. Usage of hazardous substances in production are reduced enabling harmless material cycles.

For supporting long-term vision, four specific waste types are included in waste plan to 2023. Selections are made based on challenges Finnish waste management may face in the future with these specific waste types. The four specific waste types are municipal waste including packaging waste and excluding bio waste, electronic equipment and electrical waste 21

(WEEE), construction and demolition waste (CDW) and bio waste. National waste plan aims for positive effects for safe and sustainable resource usage and improvements in environmental protection. National waste plan guides for prevent waste generation and increase material recovery from generated waste. On long-term National waste plan aims for circular economy by highlighting environmental awareness related to waste generation.

For industries, the most important waste types under research in National waste plan are specially packaging waste, municipal waste in general, CDW and WEEE. By year 2030 recycling rate of municipal waste should be 55%, where specific recycling goals for packaging waste is given on packaging waste directive 2018/852. Material recycling rate for CDW should be 70% by year 2030. In WEEE reduction focus is in design of electrical and electronic products. Only electronic and electrical products with long life span should be produced. Also, they should not include hazardous substances and it should be easy to recover valuable materials from disposed electronic and electrical products.

2.3.3 Changes in national waste laws toward long-term goals

Based on changes made in EU directives about movement towards circular economy, Finnish Environmental Ministry created in year 2019 a work group for implementing EU environmental- and waste directives into national legislations and regulations. Main goal for developing current national waste legislations and regulations is to create waste management what responds better for future waste management trends by increasing demands for waste management and sharing responsibilities from product end users to product producers. (Government of Finland, 2020, 9) On September 2019, the national work group presented their results for how national waste legislations and regulations should be changed to meet new standards given by EU waste directives.

Based on National waste plan 2023 and findings and suggestions made by the work group, Finnish Government presented on spring 2020 new changes to national waste legislations and regulations, what will be implemented into national environmental legislation from year 2021 and onwards. National waste plan 2023 is planned to be valid until year 2027 with updated visions supporting recycling- and circular economy objectives towards 2030 main objective. In 2030 Finish waste management should meet waste recycling rates given by EU's waste regulations for each waste type. Updates to national waste plans should be ready during year 2021. (Levinen, 2020, 13)

New recycling goal for municipal waste generated by resident- and commercial buildings is created. By year 2035 recycling rate of municipal waste should be 65%. This means actions for more efficient separate waste collection systems are needed as plans for updating waste taxation is underway in Finnish government. At the same time demands for packaging material recycling rates increases for each packaging material. (Environmental Ministry of Finland, 2019). In addition, new waste regulations specify e.g. waste definitions and monitoring and traceability of hazardous waste and other wastes. Hazardous content of materials and products should be minimised, and hazardous substances should be reported for authorities via REACH database.

Due to opinions given by different stakeholders and tight time schedule, current time schedule for new waste acts to be implemented to national waste regulations must be rearranged according to Riitta Levinen, Senior Ministerial Adviser in Environmental Ministry. She is manager in team responsible for developing new national waste regulations. On Waste Day 2020-webinar held on 6th day of October, she mentioned that there will be delays in time schedule and updates made for new waste regulations. Reasons for delays and changes are due to challenges finding solution among different participants involved in waste management and in general current situation in Finland. For example, waste regulation MARA for utilisation of waste in civil engineering should have been followed by MASA waste regulation. This regulation would have given possibility for specific ground soil waste, to be utilised in similar civil engineering targets as specific waste in MARA-regulation. However, stakeholders' opinions were mostly against MASA-regulation and thus, MASA waste regulation is dropped.

2.4 Waste taxation law 1126/2010

In previous chapter is described how waste disposal to landfill has decreased from 2015 and onwards in Finland. Main reasons for that has been Government Decree 331/2013 on landfills, banning organic material disposal to landfills since 2016. Other, an economical reason has been waste taxation legislation 1126/2010. Waste taxation legislation 1126/2010 is created to reduce waste disposal to landfill by making it less desirable option for waste producers and – receivers. The taxable disposal of waste is an activity that requires an environmental permit for a landfill in accordance with environmental legislation. Each ton on waste disposed to landfill without utilisation costs 70€/ton of waste and this tax is for the owner of public or private landfill. Waste taxation is only for waste, what can be seen to be possible to utilise otherwise according to waste hierarchy. Therefore, waste what is disposed to landfill for to be used as building material at the landfill is excluded from disposable taxable waste. (Finnish taxation office, 2020)

Among other changes to be made in national waste legislations, Finnish government has made plans for updating and chancing waste taxation and expanding waste taxation possible to also include waste incineration. If waste taxation is expanded to include waste incineration, amount of waste taxes depends on energy production and CO2 emissions from waste incineration. Reason for including waste incineration to waste taxation is based on future visions towards circular economy. Waste taxation update would also mean increase of disposed waste to landfill taxation and updated definition for taxable disposable waste.

Updates for waste taxations are yet undecided by the Finnish government and work group working under Environmental ministry have still not made decisions and thus clear vision for future of waste incineration and waste disposal to landfill are hard to predict. Goal for new waste taxation is set for spring 2021. (Finnish government, 2020, 127) Also, possibility for adding taxes for packaging material made from nonrenewable materials, is under research together with other possible changes in waste taxation.

2.5 Packaging waste

By new 2021 national waste regulations, demands for separate packaging waste recycling rates increases. Active national packaging waste regulation 518/2014 involves companies with annual revenue of one million euro or more, operating in Finland to be responsible for packaging waste produced by their operations. Separate packaging material recovery and collection must be done and produced packaging waste must be treated in Finland. Cost from processing packaging waste is covered by waste producer mostly. By new packaging regulation, what includes goal of national waste action plan to 2023, increases demands for packaging waste producers. New waste regulation for packaging waste follows directive 852/2018.

The main goals of packaging and packaging waste production are ensuring high quality of environment by reducing amount of waste produced thus decrease usage of raw materials. On 2015 adopted EU’s strategy towards circular economy, it includes legislative proposals to increase quality of waste management towards material recovery. Waste directive 852/2018 is created to set clear recycling targets for different materials used in packaging. Recyclability of packages should be 90% and by of end of year 2025 minimum 65% of all packaging waste created inside EU market area, should be recycled, by improving environmental performance of packaging. At the end of year 2030 the total recycling rate demand is increased to 70%. Recycling targets for 2025 and 2030 (table 2) are calculated by dividing total weight of recycled packaging waste by total packaging waste generated.

Plastic as a packaging material is one of the key materials in movement towards circular economy. In 2018 created EU strategy for plastic aims for increasing profitability of recycling plastic waste and increasing quality of reusable plastic materials. Quality of reusage plastic materials is made by increasing funding for innovating solutions and developing knowledge of plastic materials through whole plastic material’s life cycle. Plastic packages are problematic due to their short lifecycle and single usage. Most of plastic materials are incinerated for energy or disposed to landfill, leading to loses of potential recyclable plastic materials.

Table 2: Packaging material recycling targets for years 2025 and 2030 (Modified. Kauppila, 2020, 6.)

Packaging material	2025	2030
Plastic	50 %	55 %
Wood	25 %	30 %
Ferrous metal	70 %	75 %
Aluminium	70 %	80 %
Glass	70 %	80 %
Paper and cardboard	75 %	80 %

2.6 End of waste criteria

End of waste-criteria is defined in Waste Framework Directive 98 article 6. Disposed waste with low impact on environment and human health, which has market value and is fulfilling technical standards and legislation requirements compared to raw materials, may cease to be waste and become a secondary material or a product (European Union, 2008, 6). Idea of EoW is to develop recyclable material usage in production by promoting environmental and economic benefits from material recovery and on long-term create recyclable material markets. (Hjelmar, 2016, 23). There is yet no wide range of standardized measurement and limits set in EoW for different waste types, what defines when waste cease to be waste. At the moment EoW- criteria have been specified for glass cullet and for iron, steel aluminum and copper scrap. Importance of low impact on environment and human health should play important role in assessment of EoW- criteria to increase development of material recycling. The quality- and control regulations for possible recyclable materials should always be measured from point of impact to environment and human health to remove extra barriers from recyclable waste and thus decrease raw material intensity in production. (Turunen, 2017). Products what use to be waste are obligated to be included in REACH system for measuring their quality and hazardousness.

2.7 Hazardous substances registration

To support more sustainable and safer production and development of secondary material markets, Registration, Evaluation, Authorisation and Restriction of Chemicals is created. REACH is a database created by European Chemical Agency based on regulation 1907/2006. REACH database is developed to collect information of different kind of substances used in EU market area to protect environment and human health from hazardous substances. If substance is suspected to be harmful for environment or human health, it is identified as substance of very high concern (SVHC) and should be added to REACH candidate list. Substances added to candidate list are evaluated by authorities who may restrict or ban usage of evaluated substance. REACH database's goal is to reduce usage of hazardous substances in production and therefore the whole lifecycle impact of hazardous substance in a product is not measured. (Calder, 2020)

On July 2018 new goal was added into Waste Framework Directive 98 for reducing hazardous substances in waste. This goal is achieved by demanding companies producing, importing or distributing products including over 0,1% of SVHC weight by weight in EU market area to submit information of the product to SCIP database starting from beginning of year 2021. Substances of Concern in Products (SCIP) is advanced version of REACH database because the data is more specific to create clear picture of products whole life cycle. More specific information is used to primarily to replace hazardous substances with less hazardous substances and help companies in sorting and recycling waste including hazardous substances. (Vogt, 2020) Where in REACH database it is enough to give information about hazardous substance on parent product level, on SCIP database data from hazardous substance must be given from whole supply chain. Products including hazardous substance must be informed from each level of manufacturing, where given information must include reference substances and information about the manufacturing and about product itself. (Calder, 2020) Movement from REACH to more advanced SCIP database supports creation and development of secondary material and product markets by giving accurate data of material and products lifecycle and what do they include or may include.

2.8 The possibilities for utilizing waste in civil engineering

Movement towards secondary material usage, act 843/2017 better known as MARA regulation came into effect in beginning of year 2018. As a part of movement towards circular economy, MARA regulation gives possibilities for specific waste materials listed in regulation's appendix I, to be utilised as earth construction. In the core of this regulations has been ensuring high-level of waste management by developing usage possibilities and quality criteria for waste, planned to be utilised in earth construction. Specially for industry the development is beneficial as it gives them more possibilities for utilizing side streams from production. (SYKE, 2019) If waste material fulfills demands given on MARA regulation they can be used as earth construction without requirement for environmental permit.

If environmental permit is needed it is done in accordance with Environmental protection Act 527/2014. Official notification for local authority is done for them to evaluate quality of waste and planned utilisation target. Official MARA notification needs to have clear information about utilisation site and who are responsible in the utilisation process. Quality of waste must be tested according to MARA regulation where for each waste is specific guidance for how and what should be tested. For example, foundry sand, what can be utilised in industrial and warehouse buildings, should be tested for solubility of sulfate, nickel etc. and concentration of PAH and BTEX. Strategy for sampling from waste materials should be planned according to standard SFS-EN 14899 or technical standards by The European Committee for Standardization (CEN). (Government of Finland, 2018, 28-29)

Previously mentioned and now canceled MASA waste regulation, will be utilised in updating environmental protection legislation 527/2014. Possible new chapter 14 in environmental protection legislation 527/2014, will give guidance for reporting standards and limitations for hazardous substances in ground soil and how and where such ground soil can be utilised. Former MASA environmental protection update is estimated to be decided in Finnish government in spring 2021. (Levinen, 2020, 17)

3 WASTE MANAGEMENT STRATEGY DEVELOPMENT

As previous chapter shows waste management policies and legislations are not easy to read and they seem very complex from functional perspective. How big visions created in European Union and national level are actually achieved in basic everyday waste management? There are a lot of regulations and concepts what individual companies and organisations should follow. Efficient and clear waste management strategy is needed to visualize what is the strategic long-term goal in waste management for example for a car manufacture operating in European Union market area?

For most of companies around the world, sustainability is the most important concept in their environmental strategy. Sustainability can be divided to social, economic and environmental sustainability what together share common goal. People and businesses should live and operate inside natural ecosystem's capacity, where business generates environmentally and socially healthy environment for the people. Sustainability creates long-term value by increasing the importance of what kind of social- economical- and environmental impacts do business operations have. Over half of industry executives sees sustainability as an important tool for improving competitiveness and reducing negative impact in public image in front of important stakeholders, such as local raw material producers and local nongovernmental organisations. Ideal environmental strategy in waste management part aims for achieving goals presented in UN 2030 for material efficient production by preventing waste production and making waste less hazardous for environment and human health. Ideal environmental strategy includes also own strategic action programs for achieving those environmental goals what are important especially for the company. In waste management company's own strategic goal can be preventing waste generation due to clear economic benefits the company will achieve by doing so. Waste prevention reduces environmental impact and increases availability of materials, hence decreasing material costs. (Haanaes, 2016, 2-3. Heinberg, 2010, 7)

3.1 Zero waste and zero waste to landfill

Companies are creating own zero waste to landfill and zero waste strategies to achieve long-term benefits and maintaining competitiveness and positive image among their important stakeholders. Definition of zero waste and zero waste to landfill are commonly mixed and therefore it is important to understand the differences between these two strategies. What is their long-term goal and with what methods to achieve them?

Zero waste aims for redesigning whole lifecycle of a product. Waste generation should be minimised. Generated waste is utilised as materials and waste disposal to landfills or usage as a source for energy by incineration are not recommended. Zero waste is therefore close to circular economy and to extended waste hierarchy concept defined by Joan Simon in previous chapter. However, zero waste is still more of an ideology than an actual achievable long-term goal. Product designs, production methods and in general business environment are not yet build towards circular economy what zero waste supports. Zero waste demands continuous assessment of materials used for production for preventing waste generation and efforts for this are still quite limited for reasons mentioned before.

Zero waste to landfill, aiming for minimizing waste disposal to landfill is more suitable for companies to achieve long-term goal of less than 1% of waste disposed to landfill. Goal created to achieve long-term goal of zero waste to landfill increases the importance of waste hierarchy. Successfully achieving zero waste to landfill goal means that waste generation decreases, and generated waste is mostly recycled as material. Yet not all materials are recovered or are not recoverable due to hazardousness or in general due to low quality of waste. Therefore, unrecyclable waste should be used as source for energy by waste incineration what generates inert ashes. Goal for zero waste to landfill can be to recover and recycle all nonhazardous waste (Jones, 2017; Lombardi, 2016).

3.2 Zero waste to landfill- strategy

Strategy for zero waste to landfill is implemented often in companies' environmental strategy. Strategy for long-term goals include vision, mission, strategy and value, what directs companies towards their long-term goals. The most important steps are to define clear long-term targets towards zero waste to landfill. With what kind of actions zero waste to landfill will be achieved. Does the company aim for decreasing waste disposal to landfill to be maximum 1% or must every waste type generated to be either recovered as material or used as source for energy? (Cheeseman, 2017) To make it more complicated, some companies define them to achieve zero waste- goal when they do not dispose waste to landfill and instead incinerate all unusable waste. (Lombardi, 2016) This is why clear guiding and motivating waste management related goals for employees towards achieving zero waste to landfill through continuous improvements should be created.

3.2.1 Vision, mission, values

Creating strategy for zero waste to landfill starts from creating vision, clear picture of where company sees itself in the future waste management and what they want to achieve with their zero waste to landfill strategy? When vision is defined, company needs to create missions for how they'll achieve their vision. What needs to be done, how they are done and by whom? For guiding principles values are created to justify and guide company's actions towards long-term vision. An important motivating aspect for achieving long-term goals is to plan suitable time schedule together with time scheduled smaller goals, benchmarking development towards main goal. (Hardyment, 2015, 4-10)

3.2.2 Identifying important issues

For efficient strategy towards zero waste to landfill it is vital to find and understand internal and external weaknesses and strengths effecting possibility on achieving strategic goals. Are productions processes material efficient? What is the quality of generated waste? Does waste incineration for energy recovery have better cost performance than material recovery?

There are a lot of different kind of analysis frameworks, where SWOT analysis is one of the best known and widely used for analysing strategy. SWOT stands for strength, weakness, opportunities and threats and it is commonly used as framework for evaluating company's strategic planning by analysing company's competitiveness against rival companies. (Grant, 2020).

SWOT analysis is suitable for finding and evaluating quality of waste management. Company can find methods to improve given goals in strategy by evaluating internal strengths and weaknesses of current waste management and comparing external possibilities and incapabilities towards generated goals. Internal strengths and weaknesses in waste management are identified by researching material and information from inside company's environment. This can be done through researching first company's overall internal data. How much waste is generated and how generated waste is treated? Based on findings the quality of waste can be defined by further data analysis on specific waste types or waste treatment methods. After needed data and information are collected, zero waste to landfill strategy is discussed together with company's employees and partners involved in waste management. In discussions goal is to find strengths and weakness from current waste management process what are supported by data investigated before.

External opportunities and threats can be evaluated based on internal findings and implementing external data such as national regulations and costs from different waste management methods. Based on SWOT analysis made for waste management, different developing chances can be done as supporting actions towards long-term goals. These supporting actions and their estimated impacts for waste management can be seen as benchmarks for long-term goal by giving guidance, how much difference does multiple supporting changes have towards long-term goal.

3.3 Waste management in three machinery companies

It is interesting to review how three machinery companies implement and manage in their environmental strategy their waste management. Three machinery companies used as example companies are KONE, Wärtsilä and Andritz. Information about environmental policies and waste management development inside these companies are gathered from companies' annual sustainability reports or annual financial reports. Specific information about companies' waste management and how generated waste is treated are minimal or not available from external sources. Therefore, information about waste management gathered from annual sustainability- and financial reports can't be seen as 100% neutral information. Information can be used for estimations for how well these three companies have developed their waste management towards long-term goal of zero waste to landfill, zero waste or other long-term environmental goal.

3.3.1 KONE

KONE is a Finnish elevator, escalator and automatic building door manufacturing company, who also provides maintenance services for their products. According to them, their vision is to deliver best customer experience by improving the life in urban areas. On strategic level they want to be leader in sustainability. From environmental sustainability aspect, KONE has four focus areas including innovation and improving resource efficiency. KONE has ambitious long-term goal for meeting UN 2030 goals and have fully working circular economy model by year 2030. As a part of environmental policy KONE's waste management strategy aims for 0% waste disposal to landfill. Zero waste to landfill is achieved by allowing some of the waste to be incinerated for energy recovery.

They aim for efficient material usage by improving recyclability and durability of materials and reducing usage of hazardous substances in their products. As an example of material efficiency in Netherlands they have replaced single use packaging with recyclable plastic containers for spare part deliveries to their service technicians. Idea of reusable plastic containers is to deliver spare parts to the site and work as waste container for damaged parts and packaging waste produced on site. Plastic containers with tracking codes are later on collected and transported to centralized internal waste handling unit, where generated waste is mostly recycled. (KONE, 2019; KONE, 2020, 6,10)

3.3.2 Andritz

Andritz is Austrian globally operating equipment supplier for factories in four business markets, where 50% of annual orders comes from pulp- and paper sector, 22% from metal sector, 18% from hydro sector and rest 10% from separation sector. Biggest market area by region is Europe with 33% from total order intake in 2019. According to Andritz, their vision is become global leader in innovating engineering by providing quality and sustainable technical solutions for their shareholders and customers. (Andritz, 2020)

Environmental sustainability for Andritz is to develop environmental protection and maintain natural resources by developing their own operations in general and their products to meet better environmental demands and regulations. As an example, 45% of Andritz products are using renewable energy. Andritz does not give examples in their annual reports, how they'll actually decrease their environmental impact from their own daily operations. Nor they give long-term goals implemented to UN 2030, circular economy or zero waste to landfill. Therefore, information about waste management and waste management strategy inside Andritz's operations is mainly based on annual waste generation presented in annual financial reports.

3.3.3 Wärtsilä

Wärtsilä is a Finnish machinery company specialized in marine and energy markets by providing power plants and energy storage solutions to their customers, who are mainly from European and Asian region. Their strategy is to provide solutions for sustainable societies by developing innovating technology solutions for renewable energy. As a part of their strategy, environmental sustainability for Wärtsilä means reducing emissions from their customers operations. This goal is achieved by maintaining high level of research and development to provide best available technology solutions for customers to decrease energy and material consumption. (Wärtsilä, 2020, 15-16)

Wärtsilä has implemented UN 2030 goals for their strategy with short-term goals benchmarking the development of their environmental development. Yet focus is on reducing environmental impact from their customers operations. Clear long-term strategy for zero waste or zero waste to landfill can’t be find from their reports. Wärtsilä describes that they aim for reducing waste generation and increase using generated waste as secondary material or source for energy. Therefore, it can be assumed that Wärtsilä is aiming for zero waste to landfill in the future. Assumption of possible zero waste to landfill- strategy can be supported by annual sustainability reports where are reported, how many presentences of annually generated waste are recycled, disposed to landfill or incinerated for energy production.

3.3.4 Waste management development in 2016-2019

Waste management data collected from annual reports are displayed on table 3. In table 3 annually generated waste is displayed in tons as well as how much from annually generated waste goes to material recovery, energy recovery or disposal without utilisation. Annual waste generation data includes both, hazardous and non-hazardous waste. Four-year development is selected due to changes in companies reporting methods. Andritz has different reporting method before year 2016 in their annual report. Before they only reported total annual generation of different waste types without treatment methods. In table 3 is also described annual development and 4-year development of each category in presentences. Short-term analysis from gathered data reveals that the three example companies are in different situations with their waste management. Hence, the three example companies can be placed on three different development levels, when waste management is compared to previously described waste policies and trends in chapter 2 and to zero waste or zero waste to landfill-strategy.

Table 3: 2016-2019 waste management development in 3 machinery companies

Andritz	2016	2017	2018	2019	2017 vs 2016	2018 vs 2017	2019 vs 2018	2019 vs 2016
Disposal (t)	7 800	8 100	6 100	7 600	4 %	-25 %	25 %	-3 %
Material recovery (t)	28 400	30 700	28 800	30 300	8 %	-6 %	5 %	7 %
Energy recovery (t)	4 900	6 300	5 700	6 700	29 %	-10 %	18 %	37 %
Total (t)	41 100	45 100	40 600	44 600	10 %	-10 %	10 %	9 %
KONE	**2016**	**2017**	**2018**	**2019**	**2017 vs 2016**	**2018 vs 2017**	**2019 vs 2018**	**2019 vs 2016**
Disposal (t)	1 900	2 200	1 800	1 400	16 %	-18 %	-22 %	-26 %
Material recovery (t)	24 300	33 700	39 500	34 700	39 %	17 %	-12 %	43 %
Energy recovery (t)	2 800	4 000	3 900	5 600	43 %	-3 %	44 %	100 %
Total (t)	29 000	39 900	45 200	41 700	38 %	13 %	-8 %	44 %
Wärtsilä	**2016**	**2017**	**2018**	**2019**	**2017 vs 2016**	**2018 vs 2017**	**2019 vs 2018**	**2019 vs 2016**
Disposal (t)	10 926	3 746	4 630	2 340	-66 %	24 %	-49 %	-79 %
Material recovery (t)	36 165	25 760	27 854	24 394	-29 %	8 %	-12 %	-33 %
Energy recovery (t)	2 812	2 980	3 538	3 483	6 %	19 %	-34 %	-17 %
Total (t)	49 903	32 486	36 022	30 217	-35 %	11 %	-16 %	-39 %

Andritz has not yet implemented strategy for zero waste or zero waste to landfill. From short-term analysis it can be seen that Andritz's waste management has not changed much during past 4 years. Annual waste generation have increased every other year from 40 000 tons to 45 000 tons and vice versa every other year annual waste generation decreases back to 40 000 tons. Interesting is that level of waste disposal to landfill and material recovery from waste has not changed.

KONE and Wärtsilä have implemented future environmental trends and policies into their waste management strategy. Latest sustainability report from 2020 by KONE reveals development of waste management inside the company to be towards zero waste to landfill by reducing waste disposal to landfill and increasing level of energy recovery by waste incineration. For 4 years waste recovered as energy has increased by 100% from 2016 level while amount of annual waste generation has increased by 44%. In KONE's year 2020 sustainability report is mentioned that annual waste generation reporting from 2019 includes three new countries under waste data collection scope.

Information in table describes that Wärstilä's waste management development can be assumed to follow same path as KONE, but their waste management development is few years back from KONE. This assumption can be made by comparing numbers reported in KONE's and Wärstilä's annual reports. Year 2017-2019 average material usage is compared into 2017-2019 average waste generation and how much waste is disposed to landfill. Year 2016 is excluded because reporting for material usage has changed in KONE's latest report and it does not include annual material usage from year 2016. KONE's previous years' annual reports include different numbers in annual waste generation and -treatment. Between years 2017-2019 Wärtsilä used in average 87 000 tons of materials in production according to latest annual report. During these years KONE used annually in average 1 408 000 tons of material in production. When comparing average annual material to how much waste is generated and disposed to landfill, it can be seen that KONE is more efficient in waste prevention.

4 WASTE MANAGEMENT ANALYSIS 2015-2019

Case study company under empirical study is first studied in same method as before in previous chapter. How the company is currently dealing with generated waste from producing goods? As waste management strategy guides waste management development inside each production unit, it is important to analyse company in big picture before narrowing research to one of the case study company's production units. How a production unit inside the company perform with waste management in comparison to big picture vision? The production unit under research in case study company is defined as Factory A in this research. The case study company is producing products for multiple different customer sectors, where Factory A's annual revenue from overall annual revenue is approximately 1/3. In Finland 30% of the company's employees are working in Factory A directly.

Next will be analysed how in overall the case study company perform in comparison to previously analysed companies. In waste management strategy, the case study company is aiming for zero waste to landfill by 2030.

4.1 Overall strategic development in waste management

Case study company's annual sustainability reports reveal that company includes in their sustainability strategy 4 main goals from the UN's 17 Sustainable development goals. The 4 UN's Sustainability development goals are:

1. Clear water and sanitation
2. Affordable and clear energy
3. Responsible production and consumption
4. Decent work and economic growth.

Performance towards these goals are annually reported in annual sustainability reports. Goal of responsible production and consumption has impact to waste management. In company's environmental efficiency strategy, the UN goal of responsible production and consumption is achieved by reducing waste generation and minimizing waste disposal to landfills. In numbers by year 2030 company aims for decreasing level of waste disposal to landfill by 80% by year 2030, when baseline reference is average waste disposal to landfill between years 2010-2012.

Waste management development analysis from years 2015-2019 is made to analyse current development towards long-term goal for year 2030. In table 4 is data about annual waste generation, treatment methods and how waste management has developed from year 2015 to year 2019. Data is collected from annual sustainability reports. Numbers shown on this table include hazardous and non-hazardous waste what are combined together based on waste treatment method. In case study company annual waste disposal has decreased by 48% from year 2015 level to year 2019 and level of material recovery has grown stable by each year in comparison to annually generated waste. From year 2015 level the case study company has managed to decrease waste disposal to landfill by 48% in year 2019, hence goal towards zero waste to landfill needs further development in case study company according to short-term analysis.

Case study company	2015	2016	2017	2018	2019	2017 vs 2016	2018 vs 2017	2019 vs 2018
Disposal (t)	22 000	19 980	12 810	13 460	11 500	-9 %	5 %	-15 %
Material recovery (t)	13 100	14 780	18 200	20 870	15 610	13 %	15 %	-25 %
Energy recovery (t)	2 820	4 020	3 600	4 300	4 730	43 %	19 %	10 %
Other (t)	580	410	810	440	910	-29 %	-46 %	107 %
Annually generated waste (t)	38 500	39 190	35 420	39 070	32 750	2 %	10 %	-16 %

Table 4: 2015-2019 total annually generated waste divided by waste treatment method in case study company

When case study company is put in comparison with previously described companies, the comparison shows that case study company is in overall on same development level with Andritz (table 5). At the beginning case study company is behind Andritz in waste management development. Comparing annual waste generation to how much waste is disposed and how much is recovered as material, Andritz is ahead in waste management development. Andritz generates annually more waste but manages to utilise waste more efficiently than case study company. Yet, in case study company by each year the amount of waste disposed to landfill have decreased quite a lot while Andritz waste disposal to landfill development has been quite minimal.

Table 5: Waste management development comparison between case study company and Andritz

Case study company	2016	2017	2018	2019	2019 vs 2015
Disposal (t)	20 000	12 800	13 500	11 500	-43 %
Material recovery (t)	14 800	18 200	20 900	15 600	5 %
Energy recovery (t)	4 000	3 600	4 300	4 700	18 %
Total (t)	38 800	34 600	38 700	31 800	-18 %
Andritz	**2016**	**2017**	**2018**	**2019**	**2019 vs 2016**
Disposal (t)	7 800	8 100	6 100	7 600	-3 %
Material recovery (t)	28 400	30 700	28 800	30 300	7 %
Energy recovery (t)	4 900	6 300	5 700	6 700	37 %
Total (t)	41 100	45 100	40 600	44 600	9 %

4.2 Waste management in Factory A between years 2015-2019

In Factory A like in any other factory waste is generated from production, offices and canteens. Yet, most of different waste is generated in production processes. Production data from years between 2015-2019 are provided by the case company. Factory A’s production is divided into two production units, where other production process produces materials and other production process produces finished products. Annual production numbers are therefore reported in two different measurement units. Production of materials is reported in tons and produced finished products in number of finished products. To consider production of materials reported in tons gives more accurate estimation than number of productions of finished products. Production of finished products includes different kind of products where each produced finished product is unique.

On figure 6 below is shown annual production from years 2015-2019. Due to differences in numbers of annual material and finished products production, chart with two y-axes is used where number of materials in tons follow y-axis on right side and number of finished products follow y-axis n left side. The figure describing development of production shows that during last five years the production has increased by each year. Production peak is on year 2018, when number of finished products and tons of materials increased by 21% and 23%, when compared to previous 2017 year.

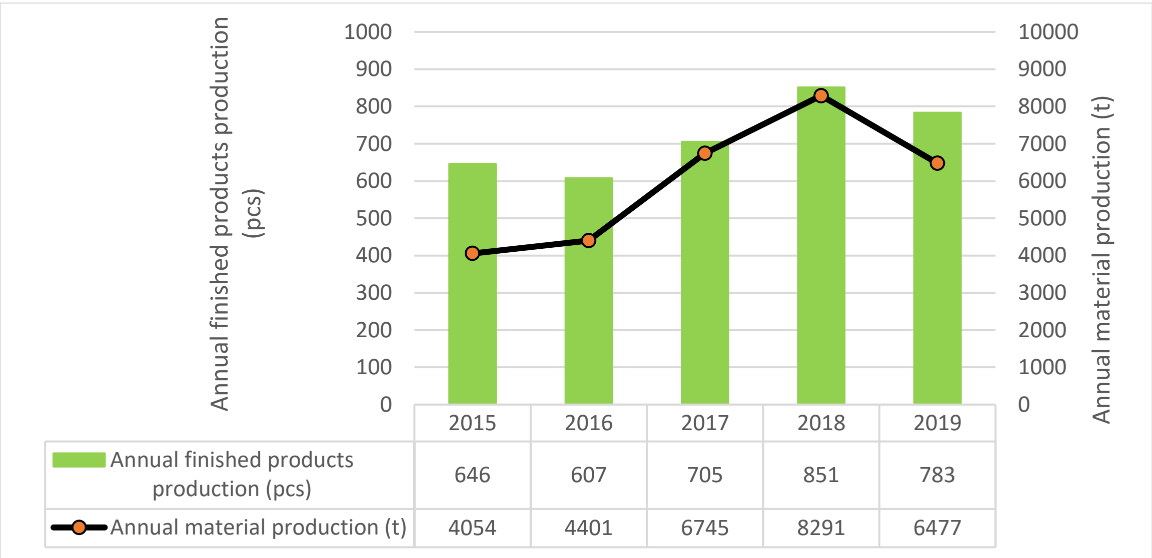


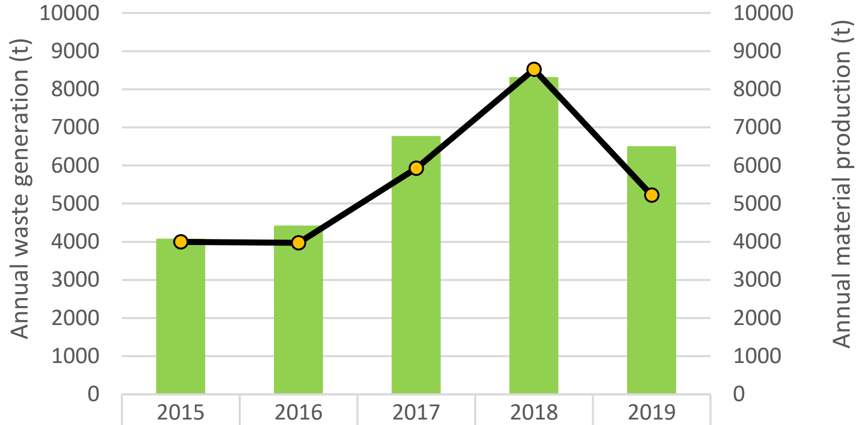
Figure 6: 2015-2019 production of finished products and materials in Factory A

4.2.1 Waste generation development in Factory A

As annual productions are divided into two different measurement units, annual waste generation and -treatment methods are analysed separately for material production and for production of finished products. Given data about annually generated waste- and treatment methods from years 2015-2019 are same numbers what Factory A uses in reporting for authorities.

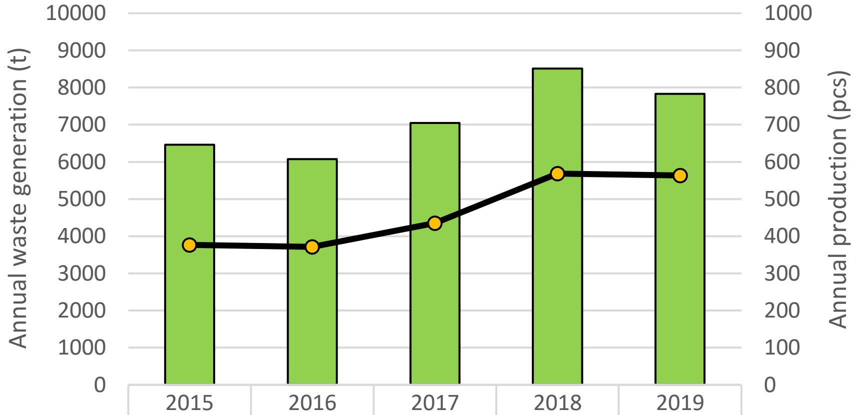
Development of annually generated waste per number of finished products or tons of materials are described on figures 7 and 8 below. In theory is calculated estimation for how many tons of waste is generated in producing a ton of material or a finished product. Theoretical estimation is made by dividing annual waste generation by annual production of either material or finished products. Results from calculations are shown on figures 7 and 8. Furthermore, there are huge variety of different kind of waste types generated annually in the production of materials and finished products what are found to be impossible to show in annual waste management development figures.

Before creating figures describing waste generation from producing materials and finished goods, estimation was that amount of waste generated from producing finished goods is far greater than waste generation from material production. From figures 7 and 8, it can be seen that the estimation is correct. During 5-year development span, ton of material generates waste in ratio 1:1 and thus development of generated waste is in near linear line with development of production development. Producing single finished product generates quite a lot more waste. In year 2015 a single produced finished product generates 5,85 tons of waste and in 2019 waste generation per a single finished product produced has increased to 7,2. Therefore waste generation per a single finished product has increased by nearly 24% from 2015 level.



	2015	2016	2017	2018	2019
Annual material production (t)	4054	4401	6745	8291	6477
Annual waste generation from material production (t)	3997	3973	5926	8519	5220
Amount of waste generated from producing a ton of material	1,01	1,11	1,14	0,97	1,24

Figure 7: 2015-2019 annual waste generation from material production in Factory A

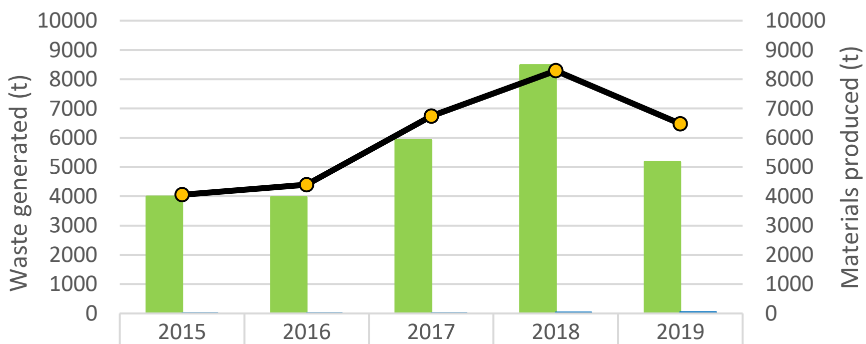


	2015	2016	2017	2018	2019
Annual production of finished prodcuts	646	607	705	851	783
Annual waste generation from finished product production	3762	3713	4350	5684	5637
Amount of waste generated from producing a finished product	5,82	6,12	6,17	6,68	7,20

Figure 8: 2015-2019 annual waste generation from finished products production in Factory A

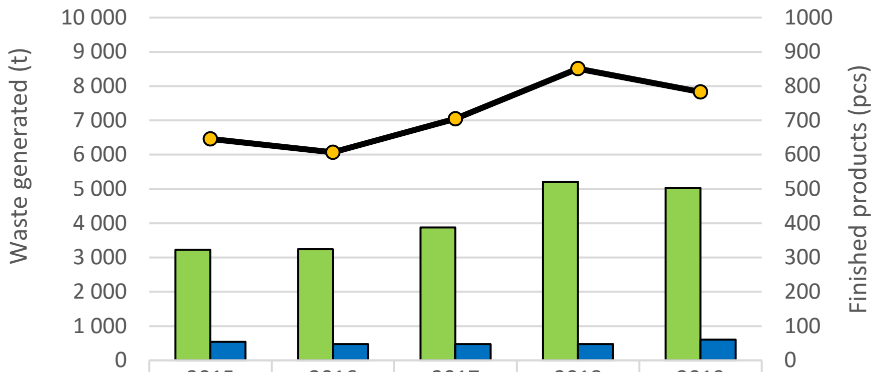
4.2.2 Development of hazardous and non-hazardous waste in Factory A

Previous figures describe development of annual waste generation in comparison to annual production development. Next is researched development of annually generated hazardous and non-hazardous waste. Separating hazardous waste from non-hazardous waste is utilised for evaluating quality of waste. Generated hazardous waste due to its hazardous substances needs further treatment to meet standards for possible material recovery. In general, hazardous waste generation does not support sustainable production of materials or finished products. In figures 9 and 10 annually generated waste from each production line is divided into hazardous and non-hazardous waste. Annual production of finished products and materials are displayed in linear chart and hazardous and non-hazardous waste are displayed in bar charts. Figures describing amount of hazardous and non-hazardous waste generated from material and finished products production follow y-axis on the left side in figures 9 and 10. Annual production of materials and finished products follow y-axis on right side.



	2015	2016	2017	2018	2019
Annual non-hazardous waste generation from material production (t)	3995	3969	5923	8483	5175
Annual hazardous waste generation from material production (t)	2	4	3	36	45
Annual material production (t)	4054	4401	6745	8291	6477

Figure 9: 2015-2019 annual hazardous- and non-hazardous waste development from material production in Factory A



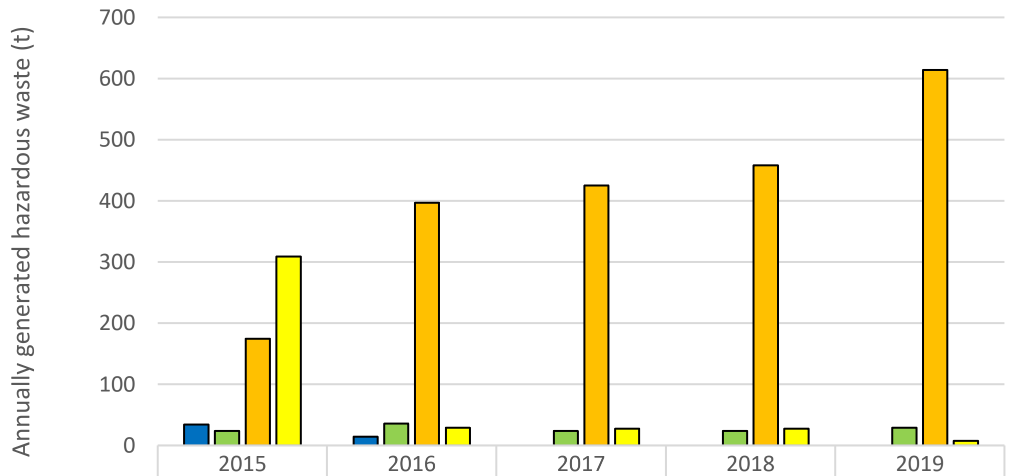
	2015	2016	2017	2018	2019
Annual non-hazardous waste generation from finished product production (t)	3 222	3 241	3 879	5 212	5 031
Annual hazardous waste generation from finished product production (t)	540	472	473	473	606
Annual finished product production (pcs)	646	607	705	851	783

Figure 10: 2015-2019 annual hazardous- and non-hazardous waste development from finished product production in Factory A

From figures can be seen that annual hazardous and non-hazardous waste generation have increased from year 2015. Most of the waste is non-hazardous waste, but amount of annually generated hazardous waste have increased in comparison with annual production. Such development in interesting because level of annual hazardous waste generation has increased also while level of annual production has decreased to previous year's level. Especially latest data from year 2019 shows major increase in annual generation of hazardous waste in both production processes. In material production level of generated hazardous waste has increased enormously in comparison from year 2017 to year 2019, when production of materials has increased by bit over 1000 tons. Clear explanation for such development can't be made but in theory the explanation could be the size of finished products. Most of hazardous waste is generated from finished product production as it uses a lot of chemicals. Hence, when annual production of finished products decreases from previous year in year 2019, it could mean that during this year is produced bigger finished products, what leads to greater number of annual hazardous waste generation in year 2019.

4.2.3 Development of waste treatment methods for generated waste in Factory A

From production, offices and canteens most of the waste generated are non-hazardous. Nonhazardous waste has greater potential for being recycled as material and thus material recovery from annually generated non-hazardous waste is estimated to be high. In next analyses are analysed how annually generated hazardous and non-hazardous waste from Factory A are treated. Annually produced waste, hazardous and non-hazardous waste are treated by the common methods used generally in waste treatment. Most of the waste are either recycled as material, incinerated for energy or disposed to landfill. Other methods used for only liquid hazardous waste treatment are evaporation and physicochemical treatment. Usage of these two waste treatment methods for hazardous waste treatment are low therefore, “Other” in figure 11 is combination of these two rather rarely used treatment methods. Treatment of annually generated hazardous waste, what is more difficult to recover as material due to hazardous substances, is estimated to be mostly incinerated for energy production and figure 11 shows such development. In year 2015 some of the waste is disposed, but after year 2016 all of annually generated hazardous waste is utilised for energy production. As seen from previous figures most of the hazardous waste is annually generated in finished product production.

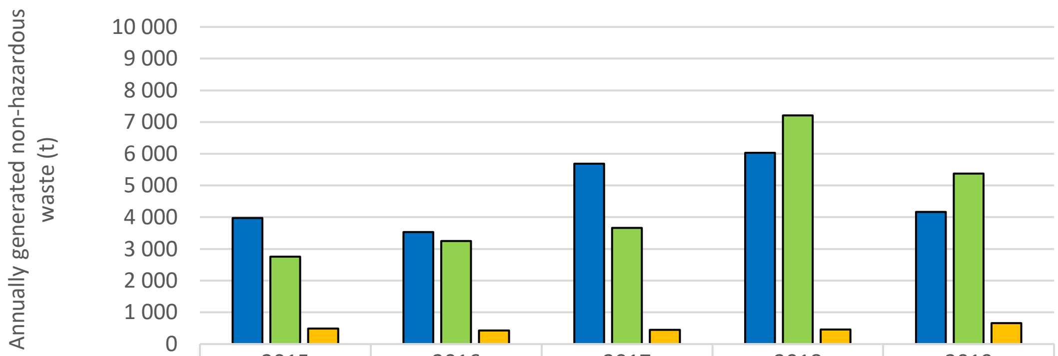


	2015	2016	2017	2018	2019
Disposal (t)	34	14	0	0	0
Material recovery (t)	24	36	24	24	29
Energy production (t)	174	397	425	458	614
Other (t)	309	29	27	27	7

Figure 11: 2015-2019 waste treatment of annually generated hazardous waste in Factory A

From figure 12 describing treatment of annually generated non-hazardous waste shows results what are surprising. Where does such high level of non-hazardous waste going to landfill comes from? Information in table 6 reveals that such development numbers comes from material production. In material production most of annually generated non-hazardous waste is reported to be disposed to landfill. Analysing further Factory A's waste management data about what kind of waste is disposed annually to landfill it reveals that huge amount of annually disposed waste from material production is such waste what can be utilised as earth construction according to waste legislation 843/2017, MARA. Therefore, estimation is that waste suitable for earth construction is reported as disposed to landfill in Factory A as waste is not utilised at Factory A, but the waste receiving company actually utilised this waste in their own operations.

Table 6 also shows that most of the non-hazardous is recovered as material in Factory A. Waste utilised as energy includes waste to energy, wood waste and municipal mixed waste incinerated for energy recovery. Bio waste, what is utilised partly as energy and partly as material is included in material recovery. Bio waste comes from canteens and offices in Factory A. Latest year shows slight increase in energy recovery, while material recovery has decreased. Table 7 included development of hazardous waste treatment in Factory A, where can be seen how difficult it is to recover material from hazardous waste. Nearly all hazardous waste is incinerated for energy since 2017.



	2015	2016	2017	2018	2019
Disposal (t)	3 979	3 535	5 689	6 030	4 164
Material recovery (t)	2 754	3 245	3 666	7 209	5 378
Energy recovery (t)	484	430	447	456	664

Figure 12: 2015-2019 waste treatment of annually generated non-hazardous waste in Factory A

Table 6: 2015-2019 Annually generated non-hazardous waste from each production unit in Factory A

Production unit	Method	2015	2016	2017	2018	2019	2019 vs 2015
Material production	Disposal (t)	3689	3392	5351	5681	3920	6 %
Material production	Material recovery (t)	306	577	572	2802	1255	310 %
Material production	Energy recovery (t)	0	0	0	0	0	0 %
Total (t)		**3995**	**3969**	**5923**	**8483**	**5175**	**30 %**
Finished products production	Disposal (t)	290	143	338	349	244	-16 %
Finished products production	Material recovery (t)	2448	2668	3094	4407	4123	68 %
Finished products production	Energy recovery (t)	484	430	447	456	664	37 %
Total (t)		**3222**	**3241**	**3879**	**5212**	**5031**	**56 %**

Table 7: 2015-2019 Annually generated hazardous waste from each production unit in Factory A

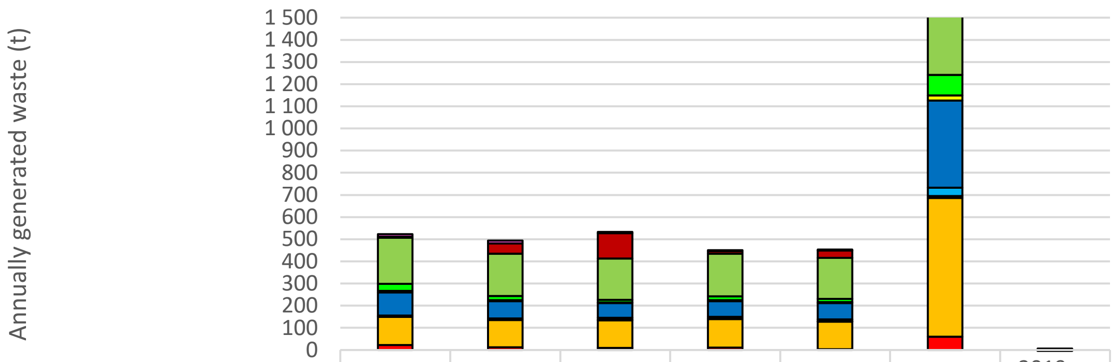
Production unit	Method	2015	2016	2017	2018	2019	2019 vs 2015
Material production	Disposal (t)	0	0	0	0	0	0 %
Material production	Material recovery (t)	0	0	0	0	0	0 %
Material production	Energy recovery (t)	2	4	3	36	45	2150 %
Total		**2**	**4**	**3**	**36**	**45**	**2150 %**
Finished products production	Disposal (t)	34	14	0	0	0	-100 %
Finished products production	Material recovery (t)	24	36	24	24	29	21 %
Finished products production	Energy recovery (t)	172	393	422	422	569	231 %
Total		**230**	**443**	**446**	**446**	**598**	**160 %**

4.2.4 Generated waste in Factory A highlighted in National waste plan

In chapter 2 presented National waste plan presents 4 goals which should be achieved by year 2030. By year 2030 60% of bio waste, 65% of municipal waste and 70% of construction waste should be recycled. Waste of electrical and electronic equipment (WEEE) should decrease by increasing the importance of waste prevention by increasing lifetime and quality of electrical and electronic equipment. Generated WEEE from electrical and electronic equipment should be made easy to separate and recycle as materials

Most non-hazardous waste produced in Factory A is comparable to waste produced in households such as recyclable paper or waste to energy. Municipal waste has usually good recycling potential and therefore recycling rate of different types of municipal waste describes well waste management performance and quality of waste generated in Factory A.

When analysing amount of annually generated municipal waste and bio waste the main goal is to assess the separate collection of different waste types in comparison to the generated waste for energy recovery. If in Factory A recycling level of different type of municipal waste are low and level of waste disposal to landfill or now more commonly waste incineration for energy recovery are high, it indicates low waste sorting or low quality of generated waste in Factory A. Construction and demolition waste (CDW) and waste electrical & electronic equipment (WEEE) are excluded from the comparison and instead compared to given goals in National waste plan. In figure 13 below based on given data is described level of different municipal solid waste, WEEE and construction waste generated in Factory A. From total annually generated waste under research is calculated annual material- and energy recovery or disposal rate. Annually generated waste and from this calculated amount of waste going to material- energy recovery or disposal to landfill are described in tons.



	2015	2016	2017	2018	2019	Total	2019 vs 2015
Disposal (t)	104	6	0	0	0	110	-100 %
Energy recovery (t)	212	265	252	264	258	1 251	21 %
Material recovery (t)	211	223	282	187	196	1 098	-7 %
Waste electrical & electronic equipment (t)	12	12	6	5	4	39	-67 %
Construction waste (t)	5	46	115	11	34	211	580 %
Waste to energy (t)	208	192	185	193	184	963	-12 %
Confidential paper (t)	31	17	12	18	15	93	-52 %
Recyclable white paper (t)	7	5	4	3	4	23	-46 %
Mixed municipal waste (t)	104	79	66	72	74	394	-29 %
Metals (t)	5	5	9	9	9	38	73 %
Other confidential material (t)	1	2	3	1	1	8	0 %
Bio waste (t)	127	122	124	129	125	627	-2 %
Recyclable paper (t)	22	13	10	11	4	60	-84 %

Figure 13: 2015-2019 development in Factory A of non-hazardous waste included in National waste plan

During past 5 years in Factory A non-hazardous waste disposal to landfill have decreased to zero and waste management have moved towards waste incineration for energy recovery. In total half of waste is recovered as material and other half is utilised as energy. Therefore, if all waste types under analysis are included in calculations, quality of waste management and quality of non-hazardous waste are on good level in Factory A. In further analysis, where CDW and WEE are excluded from analysis, Factory A has recycled 40% of generated municipal waste as material from years 2015-2019. When recycling goal for municipal waste is 65% by year 2030, it means Factory A should decrease amount of waste utilised as energy.

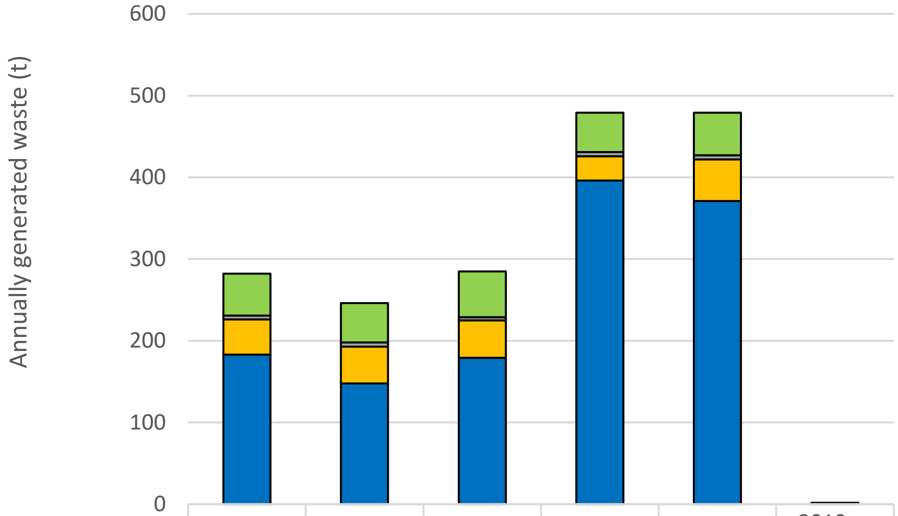
If only municipal waste without biowaste is compared to waste incinerated for energy recovery, the situation is completely different. Nearly 74% of municipal waste recovered as material is biowaste and thus without biowaste, the annual material recovery rate of municipal waste is quite low and goal for 65% material recovery is not achieved in comparison to amount of energy recovery from municipal waste. In numbers during last 5 years, the amount of material recovered from generated municipal waste without biowaste is 221 tons while energy recovery from generated municipal waste is 1251 tons.

Level of waste electrical and electronic equipment has decreased by 2/3, but it does not tell much from equipment quality as level of WEEE has been low during the reported years. Level of construction waste, what changes annually quite a lot in Factory A is mainly recycled as material and only 3 tons of construction waste is incinerated for energy according to given data. Therefore, factory A achieves recycling goal of construction waste as only a presentence of total construction waste is not recycled. On the other hand, what kind of waste generated construction waste types includes can't be defined from data.

4.2.5 Packaging waste development in Factory A

Based on packaging regulation 518/2014 and packaging directive 852/2018, development of annually generated packaging waste is calculated and described in figure 14. As recycling rates for each material are different, but rather high it is interesting to see development of each packaging waste. In Factory A, most of packaging waste is unprocessed wooden packaging, where data about how many wooden packages are reused is unavailable. Cardboard- and glass packaging waste combined together generates less than quarter of total annually generated packaging waste.

From data about packaging waste is excluded metallic containers including hazardous solid. Hence, only non-hazardous packaging waste is included in calculation for annually generated and treated packaging waste. Most of the packaging waste should be recycled by 2025 and by year 2030 overall packaging recycling rate should be 70% or more. On figure 14 is displayed information, how annually generated packaging waste are treated. From figure can be seen that nearly all of the annually generated packaging waste in utilised for energy and only little amounts are recycled as material. Results about packaging waste treatment describes, that Factory A has in overall low efficiency in recycling packaging waste as material, when reusage of packages is excluded from analysis. Reason for why only cardboard- and glass packaging are recovered as material could be find from costs generated from waste treatment. At the moment recycling wood waste as energy waste is free or cost is very little for Factory A. Therefore, it is important to analyse cost performance of Factory A's waste management



	2015	2016	2017	2018	2019	2019 vs 2015
Cartonboard packaging (t)	51	48	56	48	52	2 %
Glass packaging (t)	5	5	4	5	5	0 %
Wooden packaging (processed) (t)	43	45	46	30	51	19 %
Wooden packaging (unprocessed) (t)	183	148	179	396	371	103 %
Material recovery (t)	56	53	60	53	57	2 %
Energy recovery (t)	226	193	225	426	422	87 %
Disposal (t)	0	0	0	0	0	0 %

Figure 14: 2015-2019 annually generated packaging waste in Factory A

4.3 Factory A waste management's annual cost development

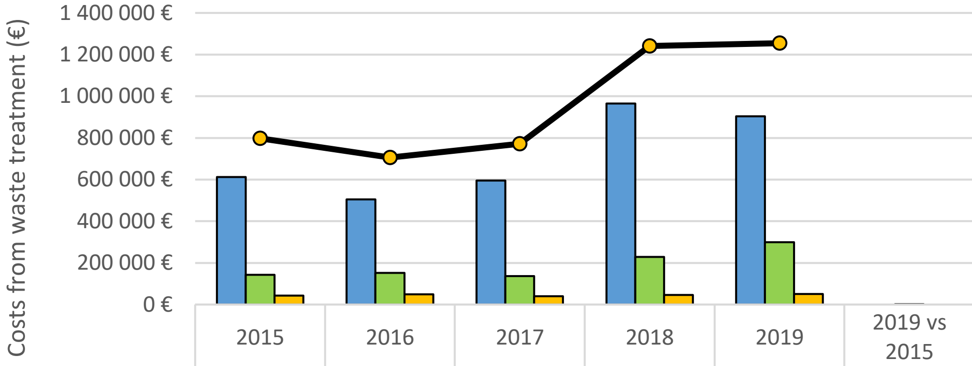
Cost performance of waste management is an important indicator as costs generated from different waste types and how they are treated, configure the development of waste management. Usually price of different waste types and how they are treated guide the direction in waste management development. If for example recovering waste as energy by incineration is cheaper than material recovery, the amount of waste to energy and mixed municipal waste is most likely high in comparison to material recovery from waste. Thereby, costs from annually generated hazardous and non-hazardous waste are analysed after volume of different kind of waste and how they are treated are known.

Cost of different kind of waste types are given by companies responsible for transporting and treating annually generated waste from Factory A. Reporting method by responsible companies varies between euros/ ton of waste or total costs per annually generated waste type. Specific cost structure data is not available, or it is very limited. For example, expenses generated from waste transportation cannot be evaluated separately from other expenses. Given data about annual price development of different kind of waste types includes costs from waste transportation, reception of waste etc. Costs from annually treated waste are generated by multiple responsible company in waste treatment. Thus, in further inspection most of annually generated waste is received and treated by few companies. For example, annually generated hazardous waste in Factory A is recovered and treated by one company.

4.4 Cost development from annually treated waste

In first figure 15 is described annual cost development of hazardous and non-hazardous waste from each production, production of materials and -finished goods. Euro is used as a currency to follow reporting standard. All companies receiving waste from the Factory A, reports costs in euros. In figure 15 “Other costs from annually treated waste”, includes additional costs generated from hazardous and non-hazardous waste. Other costs are mainly costing from hazardous waste such as renting waste containers and cleaning them.

From figure 15 it can be seen that costs from waste management have increased from year 2015 level. Increase in annual costs has happened especially during past two years when the annual costs have increased a lot. Annual costs development can be explained partly by looking at previous figures about annual waste generation. Such development where annual waste generation and annual costs from waste management have increased, is not ideal for Factory A. Hence, development towards zero waste to landfill and better material efficiency is not just an environmental improvement, but also an economical improvement.



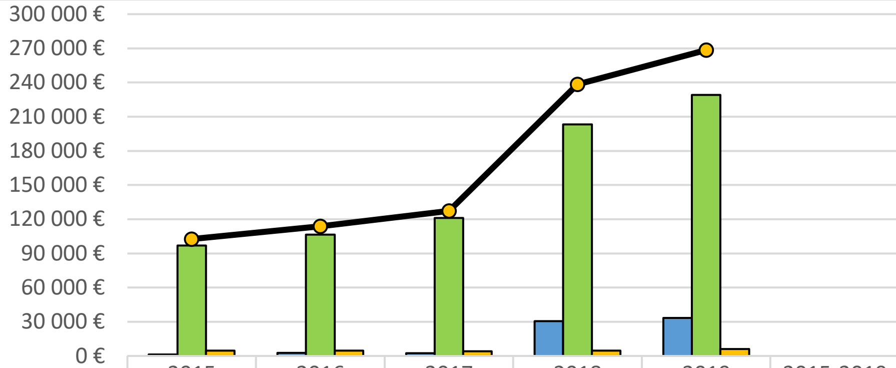
	2015	2016	2017	2018	2019	2019 vs 2015
Cost of annually treated non-hazardous waste	612 110 €	505 022 €	595 347 €	965 461 €	904 047 €	48 %
Cost of annually treated hazardous waste	143 094 €	151 629 €	136 621 €	228 439 €	299 411 €	109 %
Other costs from annually treated waste	42 881 €	49 448 €	39 790 €	46 786 €	51 181 €	19 %
Annual costs from generated waste	798 084 €	706 100 €	771 758 €	1 240 686 €	1 254 639 €	57 %

Figure 15: 2015-2019 cost development of annually generated waste

4.4.1 Cost performance of production processes

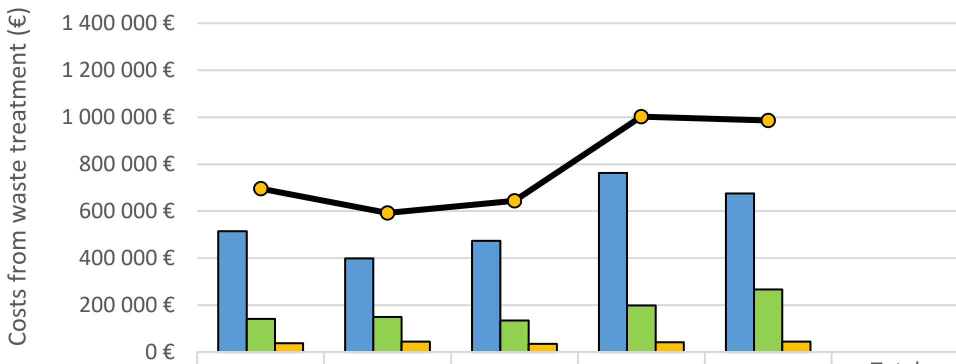
When total costs from annually generated hazardous and non-hazardous waste are calculated, next will be calculated annual costs from generated waste in material- and finished products units. Figures 16 and 17 describe annual price development of hazardous and non-hazardous waste together with other annual costs from each production unit. Other costs are defined same as before in total costs from annually treated waste. Figures include also total costs generated from all the waste treated during past 5 years. Total price from 5-years defines that it is important to have efficient cost performance in waste management.

Figure 16 describes cost development of annual waste treatment in material production unit. This figure shows massive increase in costs from treating non-hazardous waste. Such development can be explained by looking at previous tables 6 and 7 describing annual development of non-hazardous and hazardous waste generation and how they’re treated. High annual waste management costs from finished products production can be explained by huge amount of recyclable metal waste generated from producing finished products. In general, if looking at table 8, where are compared waste treatment costs from year 2019 to year 2015 level, annual costs have increased a lot during past 5 years.



	2015	2016	2017	2018	2019	2015-2019
Cost of annually treated hazardous waste	1 208 €	2 579 €	2 270 €	30 516 €	33 427 €	70 000 €
Cost of annually treated non-hazardous waste	96 894 €	106 360 €	120 975 €	203 281 €	229 043 €	756 553 €
Other costs from annually treated waste	4 520 €	4 732 €	4 115 €	4 726 €	6 131 €	24 224 €
Total costs from annually treated waste	102 621 €	113 671 €	127 360 €	238 523 €	268 602 €	850 777 €

Figure 16: 2015-2019 cost development of annually generated waste from materials production unit



	2015	2016	2017	2018	2019	Total 2015-2019
Cost of annually treated non-hazardous waste	515 216 €	398 662 €	474 371 €	762 180 €	675 003 €	2 825 433 €
Cost of annually treated hazardous waste	141 886 €	149 050 €	134 351 €	197 923 €	265 984 €	889 194 €
Other costs from annually treated waste	38 361 €	44 716 €	35 675 €	42 060 €	45 050 €	205 862 €
Total cost of annually treated waste	695 463 €	592 428 €	644 397 €	1 002 163 €	986 037 €	3 920 489 €

Figure 17: 2015-2019 cost development of annually generated waste from finished products production unit

Annual costs from hazardous waste have increased also during past 5 years, where most of the costs from hazardous waste is generated from producing finished products. (table 8) In 2015 from generated hazardous waste only 2 tons are generated from material production. In 2019 hazardous waste generation in material production has grown to 45 tons, while costs from hazardous waste treatment in material recovery has grown enormously. Generated hazardous waste is mostly received and treated by one company and thus annual cost development of hazardous waste from each production process reveals how this company have changed their costs for hazardous waste treatment.

Table 8: Cost development of Factory A's waste management between years 2019 and 2015

2019 vs 2015	Costs non-hazardous waste	Costs hazardous waste	Other costs	Total costs
Material production unit (€)	132 150 €	32 219 €	1 611 €	165 981 €
Finished product production unit (€)	159 787 €	124 098 €	6 689 €	290 574 €
Material production unit (%)	136 %	2667 %	36 %	162 %
Finished product production unit (%)	31 %	87 %	17 %	42 %

4.4.2 Cost development of waste under national waste plan scope

Based on national waste plan it is interesting to estimate, how does this effect to costs generated from annually treated waste mentioned in national waste plan. Since 2015 most of the municipal waste has been either utilised as energy or material instead of disposing waste to landfill. Disposing waste without utilisation is not only made hard by legislation, but it is also quite expensive. In 2015 Factory A generated 104 tons of mixed waste what was disposed to landfill. This cost approximately 15 800 €. During same year Factory A generated 208 tons of waste to energy and this costed approximately 13 900 €.

Movement from waste disposal to energy recovery has been going for a while and next step is moving from energy recovery to material recovery in waste treatment. Which treatment method is financially more efficient for the Factory A at the moment? In table 9 is described cost development of municipal waste, what is recovered as material in comparison to cost development of municipal waste going for incineration to recover energy from it. Annually generated bio waste is excluded from this comparison. By combining annually generated municipal waste types together based on treatment method and dividing with these annual costs from material- and energy recovery from municipal waste, given euro/ton prices are surprising. Waste management trend have been towards reducing waste generation by preventing waste generation and recycling generated waste as material. Yet based on calculations it is still cheaper to incinerate waste for energy than recycle it as material. If annually generated municipal waste from year 2017 would have been completely incinerated for energy, it would have cost 56 800 €, while 100% material recovery would have cost 70 400 €. However, it can be seen from table 10 that each year the cost per ton for material recovery in average is decreasing while cost per ton of energy recovery is increasing. In 2015 price for waste to energy and mixed waste per ton are 67 €/t and 157€/ t and in year 2019 172 € and 173€.

Table 9: 2015-2019 cost development of treating municipal waste generated in Factory A

	2015	2016	2017	2018	2019
Energy recovery (€)	13 860 €	37 722 €	33 691 €	43 542 €	44 522 €
Material recovery (€)	23 517 €	23 099 €	17 675 €	18 322 €	15 199 €
Energy recovery (t)	208	271	252	264	258
Material recovery (t)	84	101	158	58	71
Energy recovery (€/t)	67	139	134	165	173
Material recovery (€/t)	279	230	112	318	214

Table 10 describes difference of annual costs of each waste type, what can be implemented into national waste plan scope. It can be seen that at the moment Factory A is paying quite a lot for recycling paper or confidential material. Cost of confidential materials could be true, but cost from recycling paper seems very high. Forest industry use recycled paper and cardboard as raw material for production and thus such high prices for material recovery seems odd and question rises if waste containers including paper waste are emptied too often, leading to overpriced paper waste treatment. Annual costs of waste to energy and mixed waste seems to be bit high as well as it could be. Estimation for actual cost per ton of waste incinerated for energy could be around 150 €/ t. Such estimation is made based on prices given by different companies receiving waste to energy and municipal mixed waste from companies.

Table 10: 2015-2019 further cost analyses of different municipal waste types generated in Factory A

Waste fraction	2015	2016	2017	2018	2019
Recycable paper (€/t)	42	79	99	91	357
Biodegradable waste (€/t)	94	95	94	95	100
Other confidential material (€/t)	755	736	767	741	756
Metals (€/t)	63	62	101	81	85
Mixed municipal waste (€/t)	152	153	156	167	173
Recycable white paper (€/t)	201	227	221	235	236
Confedential paper (€/t)	509	648	823	637	704
Waste to energy (€/t)	67	134	126	164	172
Construction waste (€/t)	86	130	31	382	87
Waste electrical & electronic equipment (€/t)	303	181	156	347	32

4.5 Analysis of given data

In overall, created estimations can be found to be useful and estimating quite accurate the development of waste management inside Factory A. Given data about generated waste and costs created by them are collected from multiple sources. Factory A creates each year separate data report about annually generated waste and how they are treated. Separate report about annual waste generation and waste treatment are created separately for material production and finished product production unit. Data in these reports are summary from reports given by companies receiving waste from Factory A during each year.

Quality and reporting style between two different processes varies and thus specially data about annually generated waste from material production and how they are treated, are found to be difficult utilise for accurate analyses. Waste treatment data given from material production process are found to be too simplified. It is not clear what actually happens to different waste types in waste treatment.

Inaccuracy appeared in both annual waste management reports and therefore further data from each company receiving waste from Factory A is used to either support or correct data provided by Factory A in each waste management report. Given data by companies receiving waste are found to be suitable for support volume of each individual waste type generated annually from both production units. However, the method how they report received waste varies and some of waste type are missing their waste treatment method. Yet quality of data about annually generated waste and how they are treated, described in previous figures can be used for estimating development of waste management between year 2015-2019 in Factory A. Data from 2018 seems to be unfinished as data given from this year by the Factory A about generated waste and treatment methods did not match with reports given by waste receiving companies.

Costs from annually generated waste are not reported in same method as annually generated waste in Factory A and thus cost analyse data, are mostly directly from waste receiving companies. There are different variations how companies report generated costs and therefore costs from actual waste treatment are left very simple. Only two of the waste receiving companies report separately their cost structure from transporting or renting waste containers. Possible inaccuracy in cost estimations follows possible inaccuracy made in analysing annually generated waste and how they are treated.

5 CURRENT STATUS OF WASTE MANAGEMENT ACCORDING TO EMPLOYEES

Previous chapters data gives answers about big picture development. Therefore, it is important to narrow empirical research to daily waste management inside Factory A. A questionnaire is created for Factory A’s employees. Online Google Forms questionnaire is created for employees and the link for the questionnaire is spread to employee via email. Answering for the questionnaire is estimated to take 5-10 min. Questionnaire is open for a month. Reason for questionnaire is to estimate efficiency and quality of separate waste recycling in each production unit and in offices. Goal is to find strengths and weaknesses of waste management inside Factory A. The questionnaire’s questions are developed based on previous chapter’s data analyses about waste management and on theory presented previously in chapter 2 about future development of waste management in Finland and in European Union.

5.1 Questionnaire for Factory A employees

Questionnaire includes three categories with each category including 3 questions. Each category is linked into each other and thus answers given in category 1 are analysed further from different angle in category 2 and again further from different angle in category 3. Each categories' questions are answered in rate scale 1-5, where 5 defines excellent and 1 very poor. After each category employees attending to questionnaire are given possibility to give short answer, if they'd like to give feedback about status of waste management or development ideas for better waste management in Factory A. As there has been a lot of talking about separate plastic packaging waste collecting and recycling, a question for employees about, if separated waste sorting for plastic packaging waste is needed or not. Question defines how important employees see separate plastic packaging waste sorting or should plastic waste be utilised for energy in waste incineration? At the end of the questionnaire employees are given possibility to give in general development ideas or feedback related to waste management in Factory A.

5.1.1 Category 1: Quality and quantity of waste containers in Factory A

First category in questionnaire is about finding out what kind of effect do Factory A's waste containers have to waste collecting. Do lack of waste containers prevent employees from recycling different waste types separately from each other? Are there enough high-quality waste containers for each waste type, what are generated at working place? Category 1 questions related to the quality of waste containers seeks to determine how the quality and quantity of waste containers affects the efficiency of waste sorting. Questions in first category of the questionnaire are the following in accurate order:

1. Amount of waste containers in my working area?
2. Waste containers quality in my working area?
3. Location of waste containers in my working area?

5.1.2 Category 2: Waste sorting efficiency in Factory A

Second category following questions about quality and amount of waste containers, includes questions about waste sorting efficiency. As quality and quantity of waste containers are known it is interesting to know, how important waste sorting and furthermore waste recycling is for employees. Is separate waste collecting important for employees or is it enough to only have waste containers for few waste types, such as metal and paper and rest of the generated non-hazardous waste generated in Factory A can be collected as waste to energy or municipal mixed waste? Questions in category 2 are the following in accurate order:

1. Generated waste in my working area are sorted?
2. Generated wastes are possible to sort separately in my working area?
3. Correct waste sorting is important in my opinion?

5.1.3 Category 3: Waste management related information and guidance in Factory A

Second category following questions about quality and amount of waste containers, includes questions about waste sorting efficiency. As quality and quantity of waste containers are known it is interesting to know, how important waste sorting and furthermore waste recycling is for employees. Is separate waste collecting important for employees or is it enough to only have waste containers for few waste types, such as metal and paper and rest of the generated non-hazardous waste generated in Factory A can be collected as waste to energy or municipal mixed waste? Questions in category 2 are the following in accurate order:

1. Generated waste in my working area are sorted?
2. Generated wastes are possible to sort separately in my working area?
3. Correct waste sorting is important in my opinion?

5.1.4 Separate waste collecting for plastic packaging waste in Factory A

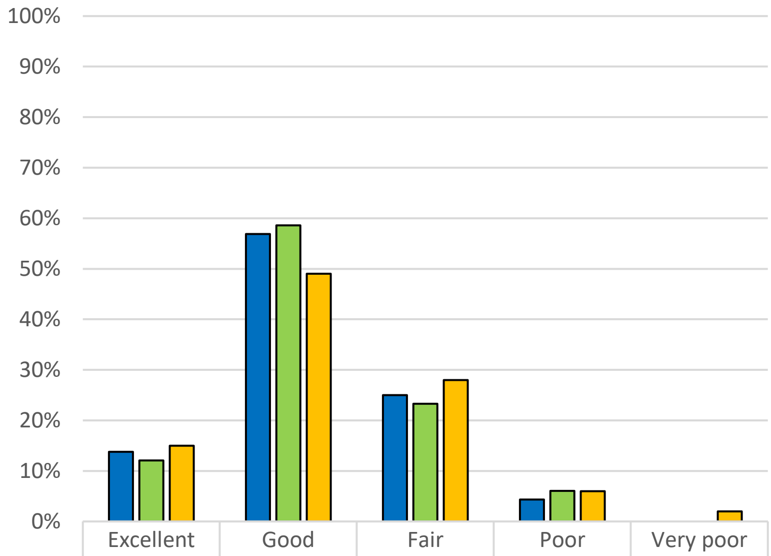
Based on current waste management trends and how it is getting more and more important to recycle plastic packaging waste, a single question about separate plastic packaging waste collecting is asked from employees. Factory A has tried before collecting separately small plastic packages generated in offices and production, but results have been low. For plastic packaging waste generated in producing finished products, Factory A provides a waste compactor. Therefore, the question, “Should plastic waste be collected separately in Factory A”, aims specially for providing answer for, if Factory A should expand separate plastic waste collecting to also include collecting plastic packaging waste from outside production processes in Factory A?

5.2 Category 1: Quality and quantity of waste containers in Factory A

Results Figure 18 describes answers given by employees working in Factory A. Most of the answers in general defines quality and quantity of waste containers to be on good level. Few answers even give excellent score for quality and quantity of waste containers in their own working area. Yet a quarter of employees answering to questionnaire defines quality and quantity of waste containers on their own working area to be fair, but not good.

Amount of waste containers are on good level among office- and production working areas based on given answers. On open feedback about them reveals that employees in offices lack possibilities for waste sorting due to lack of waste containers for metal-, glass- and plastic waste in the offices. Yet they find current level of mostly waste to energy-, bio- and white paper waste containers to be enough in the offices. High amount of waste to energy- waste containers is seen as decreasing factor in separate waste sorting efficiency. In production similar problem is not found based on given answers by production employees. Hence quantity of waste containers in production is defined to be on good level.

In offices the quality of existing waste containers is found to be on good level and therefore low quality of existing waste containers do not have an effect to waste sorting in the offices. In production in general quality of waste containers is seen to be on good level, but small size of waste containers for different waste types are seen as a problem in production. Critique given to size of waste containers in production can be actually turned to be not about size of the waste containers in production, but more about how waste containers are located in production. Open feedback given by office- and especially by production employees criticise locations of waste containers to be either hard to access or difficult to find. This leads to incorrect waste sorting and increase in amount of waste to energy or municipal mixed waste generation. Based on this criticism, results on locations of waste containers can be seen to be the weakest link in category 1 questions. Employees working in production gives for locations of waste containers 3 as overall grade. Few employees from production gives also very poor or poor reviews about locations of waste containers in their own working area.



	Excellent	Good	Fair	Poor	Very poor
Amount of waste containers in your working area	14%	57%	25%	4%	0%
Quality of waste containers in your working area	12%	59%	23%	6%	0%
Location of waste containers in your working area	15%	49%	28%	6%	2%

Figure 18: Questionnaire results from Category 1: Quality and quantity of waste containers

5.3 Category 2: Waste sorting efficiency in Factory A-results

Previous category revealed that lack of waste containers in offices for few specific waste types and not best locations for waste containers in production and offices have negative effect for separate waste sorting. In figure 19 is collected answers in 1-5 scale by production and office employees, whose answers in category 2 gives category 2 the best overall grade.

Waste sorting is important for production and offices employees as it can be seen from presentences. Nearly everyone who answered to the questionnaire sees waste sorting as an important topic in efficient waste management. From 10% who didn't see separate waste sorting as an important topic, they explain their opinion in feedback. They remind that generated waste is good fuel for producing electricity and heat ad that waste incineration happens with low emissions due to good technology used in waste incineration. This is a good point, but as 90% of employees sees separate waste sorting as important topic, some sort of waste sorting must be provided for the employees. Important finding from question 3 is that the interest for separate waste sorting is very high among both, office and production workers. Question about how possible it is sort waste and how employees sees waste sorting happening in their own working area based on overall results seems to be between good and fair.

Based on results, how well employees think waste is sorted in their working area is according to feedback mostly linked to lack of waste containers for specific waste types such as plastic waste and inefficient container locations. Therefore, employees from production and offices estimate waste sorting possibilities and in general how efficiently waste are sorted to be on good level with a lot of potential if previously mentioned problems are fixed. Also, offices and production employees tell in feedback that due to lack of guidance and information, efficient waste sorting is not as possible as it could. In Category 3 questions is then interesting to find out, if guidance and information are on good level or is there going to be found issues, what partly leads to inefficient waste management.

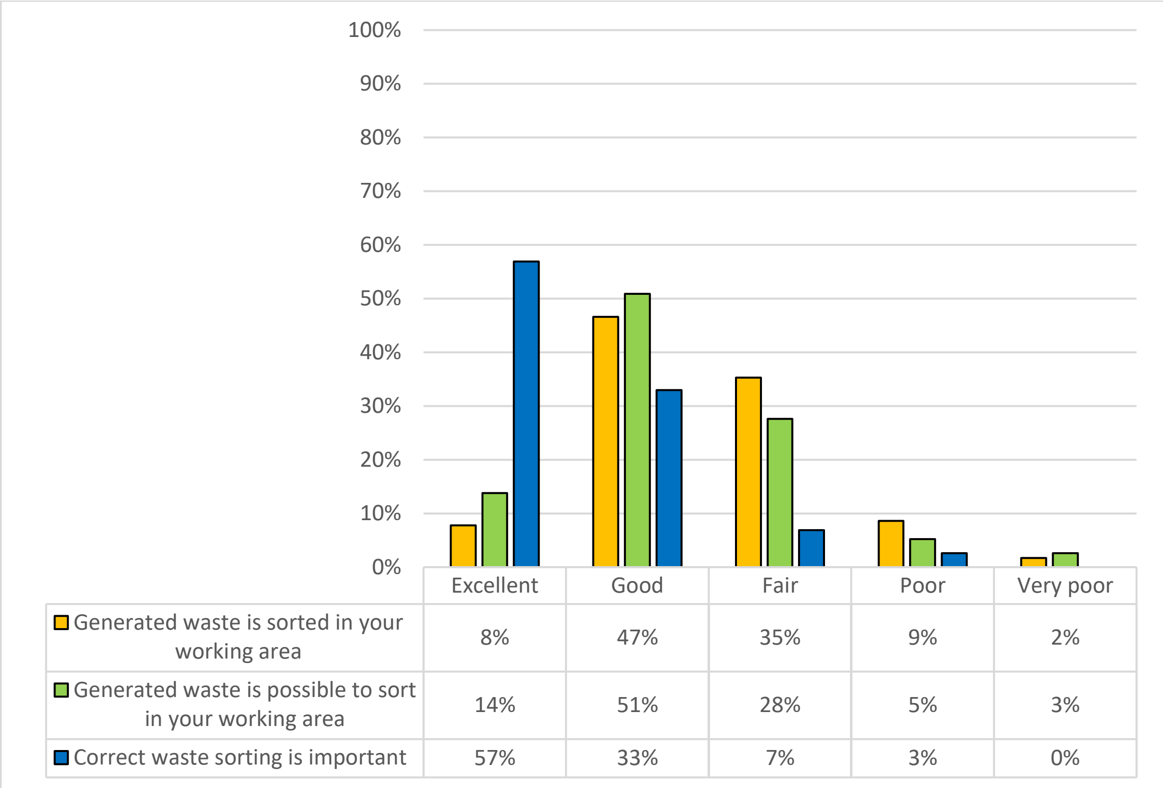


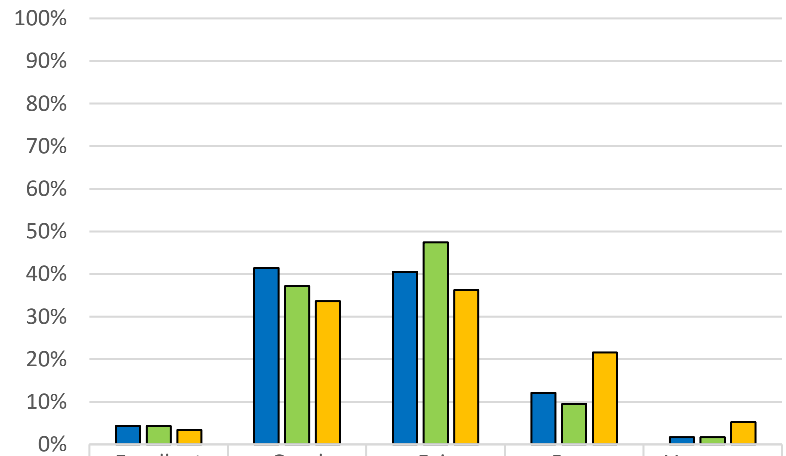
Figure 19: Questionnaire results from Category 2: Waste sorting efficiency

5.4 Category 3: Information and guidance related to waste management in Factory A-results

When reflecting answers from previous categories to results in category 3 (figure 20), it is clear that information and guidance could be better than what it is now in Factory A. In each category's feedback employees from offices and production have said lack of information and guidance to be the reason for inefficient waste sorting. Therefore, employees rate information and guidance related to waste management in Factory A to be on fair level. Employees working at office and production evaluate category 3 in similar rates and thus, lack of quality and quantity in information and guidance is can be found to be under need for development in offices and in production.

Information and guidance for employees is wanted to be more easily available. In feedback multiple employees from offices and production tell not only in category 3, but also in previous categories' open feedback that they wish more information about correct waste sorting and where waste containers are located in Factory A. They wish more clear information visible at the places where waste is disposed by employees. Lack of guidance and information is seen by employees from offices and production as main reason, why disposal to waste to energy or municipal mixed waste are seen easier solutions instead of separate waste sorting.

Results given on last question in category 3 about how employees see structure and responsibilities related to Factory A's waste management, suggest that unclear responsibilities and structure to be main reasons for incorrect waste sorting. Overall grade about waste management responsibilities and structure is on fair level, but amount of answers giving poor or very poor rate for this particular question is quite high compared to previous questions. Poor or very poor ratings are given by employees from production. Production employees give an 2,8-overall grade for from responsibilities and structure in waste management. In offices employees give bit higher rating and thus overall grade is 3 for this question. Therefore, especially employees, who answered from production, want to have more clear responsibilities about who does what and to whom to contact in case of a problem in daily waste management.



	Excellent	Good	Fair	Poor	Very poor
Quality of information and guidance relating to waste management	4%	41%	41%	12%	2%
Availability of information and guidance relating to waste management	4%	37%	47%	10%	2%
Responsibilities related to waste management are clear	3%	34%	36%	22%	5%

Figure 20: Results from questionnaire Category 3: Information and guidance

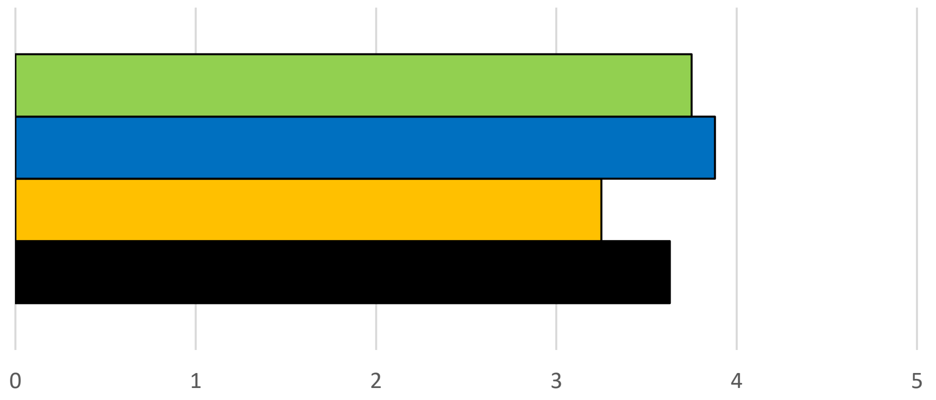
5.5 Separate plastic packaging waste sorting in Factory A-results

Answer given reveals that there is high interest among employees working in Factory A to have possibility for sort generated plastic waste separately from other waste types. From total answers 97% from support separate plastic waste sorting. In offices employees would like to have waste containers for plastic package among with metal- and glass waste containers as employees generate a lot of plastic packaging waste from food containers. According to answers given by office employees, they'd like to reduce amount of waste to energy. Therefore, disposing generated plastic packaging waste to waste to energy containers are seen as inefficient waste treating method.

Among answers given by production employees, separate waste sorting for plastic packaging waste is seen as important matter also. From employees working in offices, they've given 100% support, but in production also negative answers for plastic recycling are given, but yet 90% from production employees answers support separate plastic packaging waste sorting. Those who don't see important to separate plastic packaging waste from other waste explain in feedback that they see it less polluting and easier from logistic angle if generated plastic waste is utilised as waste to energy instead of collected separately.

5.6 Overall results

Overall results from questionnaire about quality and efficiency of waste management in Factory A based on employee's answers, is rather good. Employees working in offices and employees in production gives for Factory A waste management overall grade 4. On figure 18 is displayed overall grade from each category and it can be seen how results from each category varies from below overall grade to beyond overall grade. Therefore, it is important to also analyse more specifically each category, question by question and by dividing given answers to categories for employees working in offices and people working in production. In overall results there are no need to describe results separately from employees working in offices and answers given by office employees as individual overall grade from both are nearly equal to each other and on the other hand, separating overall grade to overall grade in production and offices, is not seen to give more value to the research.



	Overall grade given by employees
Category 1	3,75
Category 2	3,88
Category 3	3,25
Overall	3,63

Figure 21: Overall grade from questionnaire by each category and overall grade from whole questionnaire

5.7 Quality of questionnaire answers

To the questionnaire answered 116 employees working in the Factory A. Number of answers is decent and from answers can be created conclusions about what are the strengths and weaknesses of the Factory A’s waste management in daily operations in Factory A. From total number of employees working directly in Factory A, estimation is that approximately 10% from employees answered to the questionnaire during the month. From answers 57% are from employees working in offices and 43% from employees working in production and therefore, results from questionnaire can be seen supporting general opinion about waste management in Factory A among office- and production employees. However, the previous statement is relevant only with production of finished products. Involvement to questionnaire by employees working in material production unit are found to be low. This has minor impact on empirical research results in general, but as level of answers from material production unit is low, waste management development analysis in material production relies more on theory and previously done data analysis.

From questionnaire answers it is interesting to notice, how employees at the office and production seems to have similar opinion about what are the strengths and weaknesses of waste management and thus, SWOT analysis and results from research can be found to be more relevant, when adding together results from waste management data analysis, questionnaire and theory.

6 SWOT analysis about Factory A’s waste management

SWOT analysis is made for defining inner strengths and weaknesses and outer opportunities and threats the Factory A have in their waste management, when target is movement towards more sustainable waste management with goal towards less than 1% annually generated waste disposed to landfill. SWOT analysis is based on theoretical and empirical research made previously. In each category is presented the main found issues what furthermore have impact in movement towards long-term goals. On table 11 are presented in summary main found positive and negative impacts to Factory A’s waste management development, what are further explained in under each category.

Table 11: Factory A's waste management SWOT analysis

	Strengths	Weaknesses
Internal	- Employees support waste recycling as material> Separate plastic recycling - Quality of waste management equipment	-Unclear responsibilities and low communication in waste management - Amount of waste to energy recovery and disposal to landfill
	Opportunities	Threats
External	- Decreasing price development of material recovery in comparison to waste to energy and waste disposal - Long-term visions for year 2030 are clear on EU and on national level	- Increasing price development of hazardous waste and waste to incineration. - Unclear timetable and changes in waste legislation on national level.

6.1.1 Strengths

Questionnaire and analyses about waste management in Factory A reveals that there is high potential for increasing annual material recovery from generated non-hazardous waste. Questionnaire for employees measuring motivation and possibilities for proper waste sorting unveil that employees working in office and in production, have in general high motivation for waste sorting when it is possible. Employees want to increase possibilities for proper waste sorting, what will help recover material from waste instead of energy recovery. Nearly all from employees who answered to questionnaire also support separate plastic packaging waste collecting, instead of disposing plastic packaging waste as waste to energy.

Data analyses about annually generated waste in Factory A and cost performance of different waste treatment methods unveil that annual costs from material recovery have been decreasing each year. Estimation is that for Factory A material recovery from generated waste is in the future cheaper method than energy recovery. According to questionnaire it is estimated that there are enough waste containers for movement towards material recovery from energy recovery, if some of the waste to energy- and mixed municipal waste containers are utilised as waste containers for different waste types.

6.1.2 Weaknesses

The main weaknesses for Factory A towards more sustainable and efficient waste management is estimated to be lack of clear organizational structure and guidance in waste management. Employees give in questionnaire feedback that responsibilities in Factory A's waste management are unclear. Specially employees working in production want to have more clear responsibilities about who does what and to whom to contact in case of a problem in daily waste management. When organization structure and responsibilities in waste management are unclear, it leads to decrease in waste management performance and development. In questionnaire employees from offices and production give feedback that they'd like to have better guidance for correct waste sorting, better locations for waste containers and better possibilities for waste sorting. As responsibilities are unclear, the response to employees' feedback are limited and inefficient.

On cost performance side the lack of clear responsibilities can be seen in cost development of such waste types, what have been decreasing during the 5-year timespan. As an example, costs of different kind of recyclable paper waste have been increasing, when at the same time volume of generated paper waste have been decreasing. Question rises is there efficient monitor for waste collecting in Factory A at the moment or does companies providing waste services to Factory A collect half full waste containers?

Waste management analysis revealed that yet amount of waste disposal to landfill is high in comparison to long-term goal. Also, at the moment large amount of non-hazardous waste are incinerated for energy instead of material recovery. In near future the cost performance can be estimated to decrease if waste disposal to landfill can’t be decreased and most of nonhazardous waste potential for material recovery is still incinerated for energy. Based on cost performance analysis it is estimated that waste incineration for energy will be more expensive than material recovery from generated waste in near future and price of waste disposal will be high from current price. In estimation is included future changes in waste taxation legislation what will increase cost of waste disposal to landfill and waste incineration for energy.

6.1.3 Opportunities

Factory A’s waste management movement towards material recovery instead of waste disposal to landfill or waste incineration is supported by waste management legislations and policies created on European Union and on national level. Long-term vision in national and on European Union level is movement from linear economy to circular economy by increasing importance of waste hierarchy’s firsts top levels, waste prevention and recycling generated waste as material. Therefore even, when waste management legislation on EU and national level are partly unclear, long-term goals in waste management strategy are easier to recognize. Factory A’s waste management strategic goals are therefore possible to create and also measure in comparison to given targets on EU and national level. For example, National waste plan 2023 contains clear long-term recycling goals for specific waste types. By following in theoretical part presented waste management policies. As waste policies and legislations are towards waste prevention and improving material recovery from generated waste as part of long-term goal of circular economy, it also means positive price development in waste management for Factory A. If Factory A manages to improve waste prevention and increase material recovery from generated waste, it will increase cost performance of the waste management. Therefore, from cost performance angle it is important in waste management strategy to focus on improving waste prevention, increase material recovery, decrease waste disposal to landfill 1% and decrease amount of waste to energy recovery as efficiently as possible.

6.1.4 Threats

Current situation with waste management policies and legislations are under development, what creates opportunities, but also threats to Factory A's waste management development strategy. In general, at the moment there is not yet clear structure from national level, what kind of impacts do new upcoming changes in waste management policies and legislation have for waste producers and for waste treating companies. Therefore, it is not possible to prepare fully for major changes in waste management. In big picture the long-term goal is still that in 2030 EU-countries will be implementing circular economy and thus role of waste management changes.

At the moment waste treatment has moved from waste disposal to energy recovery, what is at the moment usually used waste treatment method used for utilising waste. In Factory A movement towards material recovery have increased annually, but at the same time waste to energy recovery by incineration is high. In national waste management changes is mentioned changes in waste taxation. Waste taxation would increase price of waste disposed to landfill and also incinerated waste. Price of municipal mixed waste and waste to energy, what both are incinerated for energy recovery have increased annually and calculations made in empirical study shows that energy recovery by ton of waste cost nearly the same amount as ton of waste recovered as material.

If waste taxation is included also into waste incineration, in estimation it could mean that price of a ton of waste to energy and mixed municipal waste for Factory A would increase from 172€/ t to 242-243 €/t if latest prices from 2019 are used in calculation and waste taxation price per ton is 70€/t, what is current tax for waste disposed to landfill. Yet biggest threat from cost performance angle, is changes made in waste disposal to landfill taxation.

7 CONCLUSION

Raw materials are limited and legislations and policies towards waste generation are annually increasing importance of waste prevention and material recovery from generated waste. Therefore, waste management is recommended to be included in long-term environmental strategies as zero waste or zero waste to landfill- strategy, where vision is not only diminishing negative environmental impact from company's actions, but also to generate better image for stakeholders as environmentally aware and responsible company. Movement towards more sustainable waste management for the company should be also economically wise as previously mentioned. Changes towards more sustainable waste management should also include improvements to cost performance.

Empirical study and SWOT analysis define where Factory A is performing well and where they need to improve towards more sustainable waste management and achieving long-term goal of zero waste to landfill. Factory A's waste management is estimated to have potential for improving waste management towards better material recovery from generated waste, if they can increase amount of possibilities for separate waste sorting and decrease waste going to energy recovery. In empirical research one of main issues is found to be lack of responsibilities in waste management, what leads to wrong kind of waste sorting, inefficient waste management development and feedback from employees not to be recognized as efficient as they could be.

Cost performance of waste management is estimated to be improving as well if movement towards material recovery from waste can be made. Costs from treating non-hazardous and hazardous waste have been increasing each year and therefore it is vital to improve cost performance also together with achievable environmental improvements in waste management. Cost performance and material recovery improvements are easier for nonhazardous waste, what on positive side are generated annually a lot more than hazardous waste. Yet, on other hand annual costs from hazardous waste treatment has increased more rapidly than costs from treating non-hazardous waste, leading to a challenge to improve cost performance of hazardous waste treatment, especially when hazardous waste treatment is mainly covered by single company not in Factory A, but in general in Finland.

7.1 Development ideas

Achieving long-term goal towards more sustainable waste management and less than 1% of waste disposed to landfill will need a lot of effort from Factory A and thus further development projects in waste management are needed. Based on case study company's overall long-term vision in waste management, theoretical suggestion is that Factory A generate their own long-term goal for hazardous and non-hazardous waste towards 2030 where base level is year 2019. When year 2019 level is selected, goals towards long-term goal for 2030 could be the following:

1. Increase material recovery waste by 20% from 2019 level
2. Decrease energy recovery from waste by 30% from 2019 level
3. Limit generated waste disposal to landfill to only 1% from 2019 level

Development numbers are based on previous findings in other companies' waste management development and findings in waste management analysis in chapter 4. In table 12 below is shown what such development would mean in numbers. Main difference can be made, if disposed waste to landfill from material recovery could be utilised in earth construction based on secondary material usage act 843/2017. This would help Factory A decrease waste disposal to landfill. In Factory A, lot of non-hazardous suitable for material recovery is incinerated for energy. On hazardous waste the main development should be on decreasing usage of hazardous substances, thus leading to increase in possibilities of recovering some of hazardous waste as material and decreasing annual hazardous waste generation.

Table 12: Theoretical estimation for waste generation development from year 2019 to year 2030 in Factory A

Non- hazardous waste	2019	2030	Change %
Disposal (t)	4 164	42	-99 %
Material recovery (t)	5 378	6 454	20 %
Energy recovery (t)	664	531	-20 %
Annual non-hazardous waste generation (t)	10 206	7 026	-31 %
Hazardous waste	**2019**	**2030**	**Change %**
Disposal (t)	0	0	0 %
Material recovery (t)	29	35	20 %
Energy recovery (t)	643	514	-20 %
Annual hazardous waste generation (t)	672	549	-18 %

For achieving long-term goal, other more minor developments should be made to support long-term goal. First suggestion is to develop and include more specific waste management measurements. Based on data analyses in chapter 4, the quality of data reveals further development needs in waste management reporting. Reporting methods should be following one similar reporting method and reporting should include more detailed data than now. Current available data is found to be bit difficult to read and analyse due to lack of details in reports. Details in data about generated waste and how they're treated varies in annual reports between material- and finished product units, leading to inaccuracy in waste management analyses. In annual waste management reporting is suggested to include also summary about:

1. Annual costs from annually treated hazardous and non-hazardous waste
2. Annual waste prevention performance
3. Number of waste containers and how often they're emptied

Annual data about costs is utilised for measuring annual cost performance development of different treatment methods for hazardous and non-hazardous waste. Level of waste prevention can be used as benchmark for material efficiency in Factory A. Number of waste containers and how often they are emptied is utilised to help understand efficiency of waste sorting by reducing waste containers, what are not needed and remove them or replace them with waste containers what are needed. Each extra container causes unnecessary costs and each full container reduce efficiency of proper waste sorting. In general, with current measurements and especially if suggested measurements are added to annual reports, suggestion is that quality of waste management is measured in quarters for more accurate results and making it easier for making long-term analyses about waste management development in Factory A. Reporting in quarters would mean increasing need for workforce in managing and reporting waste management data.

Second thing what Factory A should do to improve waste management efficiency and further help develop waste management towards long-term goal, is to develop communication and responsibilities between different units operating inside Factory A. In SWOT analysis one of main weakness in Factory A's waste management towards long-term goal is defined to be unclear responsibilities between employees involved in waste management and inefficient communication between employees working in Factory A. Questionnaire reveals that employees from offices and production have multiple development suggestion for improving waste management towards more sustainable waste management.

Therefore, first is suggested to develop responsibilities and communication between different production units. Secondly is suggested to develop clear feedback system between responsible persons in waste management and employees to have better response for positive and negative development in waste management. Better communication also helps to improve guidance towards right waste sorting. Now at the moment incorrect waste sorting is found to be partly due to lack of knowledge for proper waste sorting or location for right waste containers in Factory A.

Third suggestion involves development of waste containers. At the moment Factory A collects energy waste as municipal mixed waste and waste to energy, what both are treated by waste incineration to energy. Therefore, based on quality and price of municipal mixed waste and waste to energy, municipal mixed waste containers are suggested to be either utilised as waste to energy containers or utilised for separate waste sorting. Second option is better option as Factory A should increase material recovery from generated waste by improving waste sorting possibilities in general and also include separate plastic packaging waste sorting. In production the level of waste containers for different waste types is found to be on good level, but in offices level of waste to energy containers and lack of waste containers for plastic packaging waste, cardboard waste and glass waste, are found to be a problem.

Other solution for improving waste sorting in the offices and also in production is to develop waste sorting guidance by adding more visual information about proper waste sorting and update location maps of different waste containers at the office and production buildings. QR-technology for better information at the waste container could be solution as well but use of visual pictures without need for reading QR-code with a phone is recommended. QR-code technology would fit better for scanning, how many times each container is emptied during a year. Also, QR-codes could be utilised for example in keeping track where different waste containers are. This could help finding out waste containers original location, when waste container includes unknown waste and waste container is moved from original location.

Lastly it is recommended that Factory A refresh their contracts with companies receiving waste from Factory A, because the contracts at the moment seems partly outdated, leading to overpriced services. For example, price of a ton of waste to energy and municipal waste are calculated to be in Factory A between 172-173 €/ton. This seems high because for example certain another company charge 140 € for ton of waste to energy and 155 € for ton of municipal mixed waste.

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