MATERIAL IDENTIFICATION AT CASE COMPANY

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ABSTRACT

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Title	Material Identification at Case Company	
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TIIVISTELMÄ

Opinnäytetyön tavoitteena on saada parempi kuva materiaalien tunnistamisesta. Mitä tapoja on tunnistaa jätteiden koostumusta, mitä arvoa tunnistaminen tuo sekä mitä tapoja voisi tulevaisuudessa olla tunnistamiseen. Toimeksiantajana toimiva yritys korostaa strategian mukaan materiaaliosaamistaan, kestävää kehitystä ja tahtoaan olla johtavassa asemassa toimialallaan Pohjoismaissa. Työn teoriaosassa esitellään arvoketju, materiaalin arvoa, digitaalista kehitystä, jätteiden hallintaa ja kiertotaloutta. Tutkimus keskittyy tämänhetkisiin tunnistusmenetelmiin sekä siihen, mitä arvoa tunnistaminen tuo. Tulevaisuudessa on mahdollista saada digitaalisen kehityksen avulla materiaalien tunnistamiseen sekä arvon tuottamiseen keinoja arvoketjussa niin yritykselle kuin asiakkaillekin. Yritys haluaa jatkuvasti kehittää materiaalien tunnistamismenetelmiä tehokkaammiksi, nopeammiksi ja luotettavammiksi, jätteiden laajemman hyödyntämisen ja kierrättämisen mahdollistamiseksi. Teknologioiden kehittyminen ja on-line menetelmät tarjoavat uusia keinoja materiaalien tunnistamiseen. Toimeksiantajana tässä työssä on ollut Fortum Waste Solutions Oy.

Avainsanat Materiaalien tunnistaminen, jätteiden hallinta, digitalisaatio, kiertotalous, arvoketju

Sivut 55 sivua

HAMK
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ABSTRACT

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The aim of the study is to get more clear understanding of material identification. What ways there are used for identifying different contents of waste, what value the identification gives and to find new methods for identification in the future. Case company's strategy emphasises knowledge in understanding materials, sustainable development and being leader within its scope in the Nordic countries. In this study theoretical background about value chain, material value, digital development, waste management and circular economy are presented. Research concentrates on current ways of identifying materials and on what value identification gives. Future holds a lot of opportunities within digital development in material identification and value adding possibilities in the value chain to both case company and their customers. Company has desire to continuously develop identification methods to be more effective, quicker and reliable, and in this way to be able to utilise and recycle materials more efficiently. Developing technologies and on-line analysis offer new methods for material identification. Commissioning party of this thesis has been Fortum Waste Solutions Oy.

Keywords Material identification, waste management, digitalisation, circular economy, value chain

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1 INTRODUCTION

Looking at the trends that shape the future of business, the case company is a leading actor regarding sustainable environmental development. Circular economy, green energy and sustainable solutions that add value, not only to the case company but also to customers, are essential part of the business. This research studies the ways that are currently used to identify materials and how to get more value with material identification of waste generated at customer's site. Identifying brings value to whole chain from customer to production and environment. Value can be achieved with correct pricing, production planning, circular economy in material efficiency, and in choosing and finding correct recovery or treatment. Research done by interviews with theoretical background will enlighten the possibilities to find new, efficient, and sustainable ways to enhance the value chain.

1.1 Research questions and aims of the study

There are not many ways to analyse or measure harmful substances on the spot. When handling materials to be recycled, one should be prepared that there are substances among, that do not belong there. In circular economy these additional substances can cause problems in process or be even harmful, causing dangerous situations like fires or explosions. (Rautiainen, 2019, p. 4-5)

Fortum's vision is "For a cleaner world". This the company wants to achieve with four step strategy. First is to drive productivity and industry transformation. Fortum's priority is consolidation of generation business in Europe. Second is to create solutions for sustainable cities. Third target is to grow in solar and wind. Fourth is to build new energy ventures, this includes investments in digitalisation, which will enable productivity improvements in the existing businesses and development of new customer offerings. Fortum's goal is to be in the forefront of energy technology and application development. (Fortum, 2017)

Fortum recognises four megatrends that shape the energy sector. These megatrends are climate change and resource efficiency, urbanisation, new technologies and digitalisation, and active customers. Fortum sees that megatrends will bring changes to how energy is produced and sold to customers and also to how energy is consumed. There is a need to maximise the value of resources, such as waste and biomass. (Fortum, 2017)

To achieve its vision, Fortum wants beside to reduce use of fossil fuels, to enhance circular economy and material efficiency. According to Kalle

Saarimaa, Vice President for Business Area Recycling and Waste Solutions at Fortum, focus is on recycling of plastics, waste electrical and electronic equipment (WEEE) and batteries. Saarimaa sees that there will be enough energy produced by renewable energy sources in the future, but it is important to ensure adequacy of materials. There is a need for battery recycling as society turns more electric, in plastic recycling motivation is to reduce impacts on climate and WEEE has similar issues as plastics. Fortum wants to be in forefront to develop solutions for challenges of today and in the future. (Motiva, 2020)

Fortum has as a goal to grow the value of material streams. With assisting customers to sort waste efficiently and safely, this adds value to customers in cost savings. By recycling materials, waste can have new life. There is need for more co-operation with customers to solve development needs they might face regarding materials and waste, and there Fortum can help customers to be more responsible. Aim of this research is to find out the ways that are now used to identify materials and what value does identification have especially for company. Researcher has a desire to learn more about the company and topical issues at workplace and to develop the company to be more competitive in waste management. Expected contribution of the research is to find out the current ways in material identification and possible needs regarding identification and new ways for identifying materials. Commissioning party wants with these research questions to find ways to bring more value to company's processes by material identification.

The main research question is:
What value does material identification give?

Sub-questions are:
1) What methods are currently used to identify materials?
2) What methods could be used for material identification in the future?

Research concentrates on waste treated at Fortum Recycling and Waste Solutions, especially industrial hazardous waste. Radioactive and explosive waste have been left out of the research, as these are not accepted for treatment in case company.

1.2 Definitions and key concepts

RWS: Fortum Recycling and Waste Solutions
IoT: Internet of Things
AI: Artificial Intelligence
ADR: Accord Dangereux Routier is European regulations concerning the international transport of dangerous goods by road
UN number: a four-digit number that identifies dangerous goods, hazardous substances and articles (such as explosives, flammable liquids, toxic substances)

Key concepts
Material identification, waste management, digitalisation, circular economy, value chain

1.3 Structure of the study

In introduction need for this study is described with some background information about the case company. Theory part enlightens the trends in work life like digitalisation, sustainability and circular economy. In theory value chain, material value and some waste sorting methods are described. Methodology for research is presented and the results of the research are shown and analysed. Discussion about the research results with recommendations for further research are represented before conclusions of the study.

2 CASE COMPANY AND VALUE CHAIN

Sustainability is at the core of Fortum's strategy and values. Values are curiosity, responsibility, integrity and respect that form the foundation of all activities. Fortum does assess company's impact and considers sustainability throughout the value chain. Sustainable energy and circular economy solutions are a competitive advantage and prerequisite for business growth and success. (Fortum, 2020a)

Value is the embedded worth of a product as seen by the customer and reflected in products selling price and market demand. The value in a typical product is created by the producer through a combination of actions, some of which produce value that the customer sees and some of which are only necessary given the current configuration of the design and production process. (Lean Enterprise Institute, 2020) Delivering value is seen as the single most important differentiator in today's marketplace and is essential to an organisation's success. Learning how to add value in a highly efficient way can be a key distinctive mark. (Martin, 2013) Value-adding can be seen any activity, which from customer's perspective is of value, so that the customer is willing to pay for that activity, or that activity is a possibility of doing business with that customer. (TKMG, 2020)

2.1 Short history of Fortum Waste Solutions Finland

Formerly known as Ekokem, originally Oy Suomen Ongelmajäte – Finlands problemavfall Ab, was founded in 1979. Company was established for the public good, to treat, store, recycle and transport hazardous waste, to cooperate with other actors, and to carry out research and consultancy in the industry. (Wastesolutions, n.d.)

Waste treatment was launched in Finland, in Kuuloja, Riihimäki in 1984. The plant had then a high-temperature kiln, a physicochemical plant and a landfill site for hazardous waste. In 1985 company changed its name to Ekokem Oy Ab. In 1995 remediation of contaminated soil and water was started. In 2007 a grate incineration plant was started up to utilise household waste from neighbouring towns and municipalities to provide district heating and electricity. (Wastesolutions, n.d.)

In June 2016 Ekokem opened a set of refineries, the Circular Economy Village, in Riihimäki, for separating raw materials from municipal waste for recycling and reuse. Ekokem had expanded to be a Nordic company and had waste treatment facilities in Finland, Sweden and Denmark and a sales office in Norway. In August 2016, the Finnish energy company Fortum acquired Ekokem Group. (Wastesolutions, n.d.) Ekokem is now part of Fortum Group and integrated as a business area "Recycling and Waste Solutions" into Fortum's City Solutions division.

2.2 Michael Porter's Value Chain

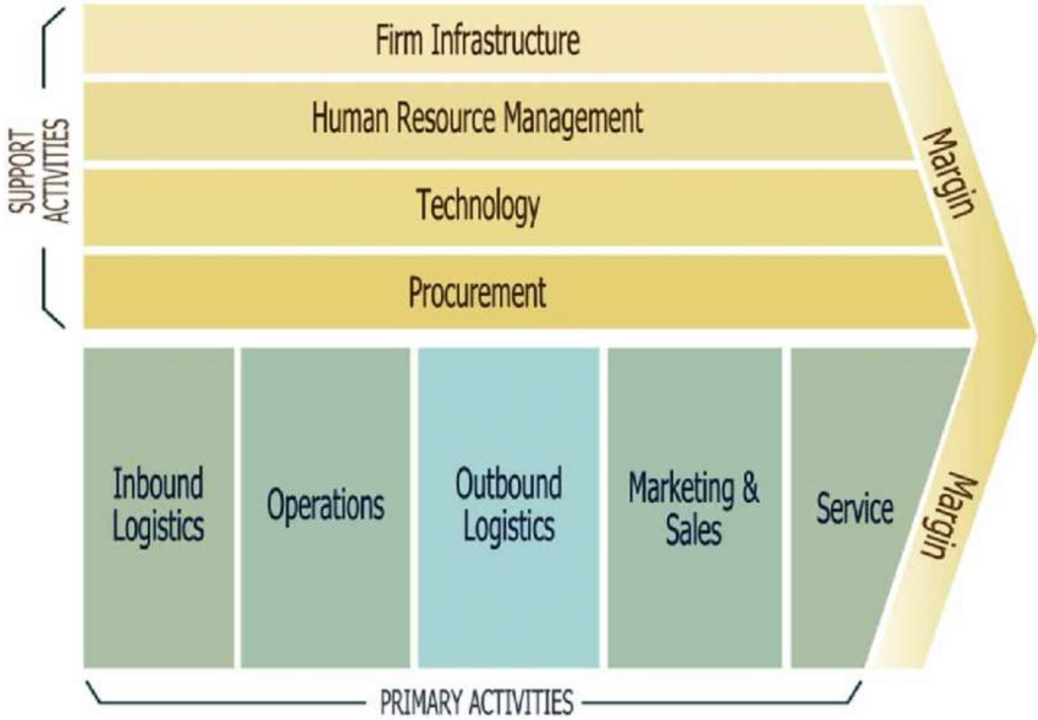

Figure 1. Porter's Value Chain Model. (ResearchGate, 2020)

Porter's value chain introduces four support activities and five primary activities, as described in Figure 1. The support activities include a company's infrastructure, human resource management, technology development and procurement. The primary activities include inbound logistics, operations, outbound logistics, marketing and sales, and customer service. A company needs to define a margin from the activities it undertakes to deliver the product or service to customer. (Presutti & Mawhinney, 2013, p. 2)

In retail market, their value chain model includes following aspects. In Primary Activities Inbound logistics can be real-time inbound inventory data, location of distribution facilities, trucks, material handling or warehouse. In Operations belong standardized model and access to real-time sales and inventory system. Outbound logistics are order processing and full delivery trucks. Marketing and Sales consist of pricing, communication, promotion, products based on community needs and low prices. Service is delivery, installation, repair, greeters, and customer service focus. Support activities have Company Infrastructure with management, finance, legal and planning. Human Resource Management concentrates on professional development, employee relations, performance appraisals, recruiting, competitive wages and training programs. Technology Development is about integrated supply chain system and real-time sales information. Procurement means real-time inventory, communication with suppliers and purchase supplies and materials. (Smartsheet, 2020)

The value chain should be able to deliver sustainable competitive advantage leading to sustained profitability. (Presutti & Mawhinney, 2013, p. 27) An effectively and efficiently managed value chain is a major key to competitive success. There are four core dimensions by which companies may choose to compete – cost, quality, response time and flexibility. (Presutti & Mawhinney, 2013, p. 28)

Value is created for the customer when a company's value chain can lower a buyer's cost or raise the buyer's performance or, ideally, do both simultaneously. (Presutti & Mawhinney, 2013, p. 29) Economic Value Added (EVA) elements are revenue, cost and assets. These EVA activities help to drive value creation. (Presutti & Mawhinney, 2013, p. 34) A company can meet its corporate social responsibilities through the effective management of the value chain. The way the activities in the value chain are managed will impact the greater society, while societal factors impact the performance of those activities. (Presutti & Mawhinney, 2013, p. 113)

2.3 Value Chain at Fortum Recycling and Waste Solutions

Value chain at RWS differs a bit from traditional manufacturing industry. Materials for production are waste, that customer pays for to get treatment in environmentally sound manner. Also product like district heating is not a traditional output. Company has mainly separated organisations for different processes.

Inbound Logistics at Fortum Recycling and Waste Solutions handles waste receiving from customers. Waste is typically collected from customers premises, but some customers organise own delivery to treatment. Normally customer pays for the waste treatment service. Only for few components, like some metals, where material is valuable, customer gets a refund.

Operations are the waste treatment processes, where waste is treated for example by incineration or recycling it. Operations are planned upon pre-information from customer about the waste. Already beforehand has sales acquired as much information about the waste as possible. Also laboratory analysis or treatment tests are possible before accepting the waste for treatment. After reception of waste, depending on the waste stream, different kind of identification is done. Often content is visually examined or if agreed or needed laboratory testing is done. Waste is either processed immediately or put in warehouse for later processing. There are several pre-treatment processes in use. Waste can be sorted, crushed, washed, separated or compounded. This way waste can be utilised as well as possible and refined into recyclable materials.

Outbound Logistics process is selling the products from operations. District heating is sold to Riihimäki and Hyvinkää area, and electricity to the national grid. Recyclable or recycled materials like metals and plastic granulates are sold to the market for further processing or as raw materials for new products. In Lithium-ion battery solutions mechanical treatment separates plastics, aluminium and copper to their own recycling processes and returns scarce metals like nickel, manganese and cobalt back into circulation for reuse in producing new batteries. Ready products are profiles made of recycled plastic. These plastic profiles can be used especially in conditions that are moist or require wear resistance like quays or fences.

Marketing and Sales is taking care of the customers and reasonable pricing by offering correct services, training, communication and promotion. Sales happens in two ways, sourcing waste for treatment and on selling products like plastic granulates. With idea of the whole service sale, all different waste compositions are defined to be able to offer comprehensive waste management services to customer.

Service has customer service who receives and handles the orders and gives instructions to customers about waste sorting, labelling and packaging. Customer service department is taking care of invoicing and reporting waste deliveries to customers.

Support Activities contains Company Infrastructure which has general management, finance, legal and public relations procedures. These are responsible for ensuring that company’s procedures follow strategic guidelines. Human Resource Management takes care of the recruiting, professional development, work rotation and performance appraisals. Technology includes maintenance, investments, IT and research and development. Procurement is negotiating and making contracts with vendors. They handle purchases of substances needed in production and indirect purchasing like maintenance of the production equipment.

3 DIGITAL FUTURE

Rapid changes in competition, demand, technology and regulations have made it more important than ever for organisations to be able to respond and adapt quickly (Ahlbäck, Fahrbach, Murarka, Salo, 2017). For Nordic companies to become winners in the ongoing wave of digitisation, they need to change the current course. It is time to move from planning to execution. It is time to make bigger and bolder digital investments and execute them faster, while funding the journey with short-term wins. (Kirvelä, Heikkilä, Lind, 2017, p. 24)

Malnight proposed a two-directional thinking model that involves looking into the long term to define the company's major strategic foundation while focusing on the short term to adapt the strategy to the current reality. While no one can predict the future with certainty, developing an informed point of view of how the future might look and what it will take to be successful is the critical foundation for leaders today. (Cordon, 2016)

SITRA (2017) sums up megatrends to be three in Nordic countries. First megatrend is the riddle of work and income. It's not known what will happen to work because of automation, robotization, artificial intelligence and digital platforms. These are changing all areas of work, including traditional industrial work, white-collar jobs and healthcare. Second megatrend is democracy fatigued. This means that to have working democracy, it needs to be strengthened by finding new ways of working and generating more incorporation. Third one is the economy at a crossroads. According to this economic growth based on overconsumption of natural resources is not sustainable. That is why we should learn how to explore and combine a lot of information, data and knowledge which will help us to reach our goals and start using the circular economy.

To speed up Europe's digital shift, business leaders, national and European policy makers and individuals, they all can influence. Companies must estimate to what extent digital matters to them and how it might change their business models. Also, they need to adapt their organisations, digitise their operations and promote open innovation simultaneously. Governments should be active on three areas: allowing investment and access to capital, opening up data flows and recognising issues surrounding skills and the labour market. The social and economic transition brought by digitisation, including to ease its impact on job displacement needs to be handled. Finally, individuals need to develop their skills and understand the flexibility and new opportunities that digitisation offers them. (Bughin et al., 2016)

According to survey on Finnish company technology managers, industrial companies are moving in digitalisation towards new business activities and search for value for customers, instead of only saving costs by digitalisation. The most important new development and investment objects according to this survey were cloud services, data analytics and big data, internet of things solutions (IoT) and artificial intelligence (AI) (Keränen, 2017). Results for businesses from automating and digitalising tasks and processes are reduced labour costs, also increased reliability and lower maintenance costs, new quality levels with fewer human errors and higher productivity and efficiency (PWC, 2017, p. 11).

Satell (2018) finds three reasons why digital age is ending. First is that the technology is not becoming more powerful year after year, advancement is not so easy anymore. To maximize performance, technology needs to be optimised for a specific task. Secondly the ability to work with digital technology is increasingly becoming a midlevel skill, where the technical skill required to create digital technology has dramatically decreased. Third issue is that the devices have not much new features, digital applications are becoming quite mature.

3.1 Digital strategy

"Kids don't make the distinction between the digital and the non-digital like those of us who weren't brought up in the digital age. For them it's all just one experience." John Goodwin, CFO of LEGO in 2014 (Cordon 2016, p. 2)

A digital strategy provides direction, enabling managers to lead digital initiatives, measure their progress and then redirect those efforts as needed (Ross, Sebastian & Beath, 2017, p. 8). According to Ross et al. (2017, p. 9) to succeed in the digital economy, companies must offer a unique value proposition that is difficult for both established competitors and start-ups to replicate. This kind of value proposition comes from a digital strategy that is focused on either a set of digitised, integrated offerings or a relationship that engages customers in ways that competitors cannot match.

According to Mark McDonald (2015) digital is more than a set of technologies bought. Digital is the abilities those technologies create. McDonald defines digital to be the application of information and technology to raise human performance. He sees that digital becomes just another technology when digital investments do not call for changing what people do in ways that enhance their ability to achieve their goals.

Peppard and Ward (2016, p. 32) define Digital Strategy as combined IS and IT strategy. Information Systems Strategy offers the demand, it is a business led, agreed list of prioritized initiatives to be undertaken in the organisation's planning horizon. Information Technology Strategy is the supply, statement of the IT components required to satisfy the IS strategy and the ways in which these are to be supplied to the business. Business strategy essentially defines where the business is going and why. IS strategy determines what is required in terms of IS applications and information to support business strategy execution. IT strategy specifies how what is required can be delivered using technology. IS/IT can both enable and shape the business strategy.

3.2 The pillars of digitisation

Peppard and Ward divide digitisation in four pillars that characterise digital disruption and the shifts those building IS/IT strategy must be aware of. (2016, p. 12) From marketplace to marketspace is the business moving from being conducted in the physical marketplace to the virtual marketspace on Internet. Online environment has many original characteristics as it is all over, directly reaching end-customers, facilitating the conduct of business directly with them. Compared with physical world, online more information can be changed and more customers can be reached. It is interactive human and machine-to-machine (M2M) communication, data gathering, collaborative problem solving and negotiation are moving from physical place with fixed locations, inventories and products to an information-defined 'virtual' transaction space.

Second pillar is Blurring of physical/digital divide. This means that physical products are becoming increasingly digitised, blurring the traditional distinction between physical and virtual products. That there are so many connected devices, opens up possibilities for proactive, remote or 'touchless' servicing and new business models quite unlike traditional 'fee-for-service'. (Peppard & Ward, 2016, p. 12)

Third one is Move from push to pull economy. As products, buildings, roads and assets of all types are 'instrumented' and able to gather data on their conditions and become even more connected, machine intelligence will be able to make decisions, or at least suggest answers. For example, car software can detect when a component needs to be replaced and can automatically book an appointment with car service. The service can order right components to be delivered for maintenance. Also manufacturer can use data for new designs. (Peppard & Ward, 2016, p. 14)

Fourth pillar is Development of open standards. Adoption and innovation are accelerated by open standards, which make the interchange and flow of data both easy to achieve technically and seamless to users. (Peppard & Ward, 2016, p. 14)

3.3 Internet of Things (IoT) and IoT powered digital twins

The Internet of Things (IoT) is the global network of physical objects or 'things' embedded with electronics, software, sensors and connectivity to enable it to achieve greater value and service by exchanging data with the manufacturer, operator and/or other connected devices. Each thing is uniquely identifiable through its embedded computing system but is able to interoperate within the existing Internet infrastructure. In manufacturing, the focus is on automating inventory management, real-time monitoring and controlling of machine operations. Besides the huge amount of potential new application areas for Internet connected automation, the IoT is expected to generate large amounts of data from diverse locations, aggregated at a very high velocity, thereby increasing the need to better index, store and process such data. (Peppard & Ward, 2016, p. 11)

In 2010, the Internet of Things (IoT), which refers to the data generated by physical devices that are connected and accessed through the web, gained momentum and within a year was producing roughly as much data as all personal devices. Two ways in which these types of data could generate value for organisations are: 1) by enabling companies to gain a better understanding of their consumers and to target them more effectively and help to predict sales; and 2) in a more functional way, by helping to transform the business or improve business processes. (Cordon, 2016, p. 8)

Posti, Finnish Postal Service, is developing with Telia new type of intelligent post box. Intelligent post box will use new NB-IoT-technology. NB-IoT is an international network technology, which allows cost effectively to connect large number of devices on same network. Intelligent post box tells on real time how the box is used and even on possible vandalism. Posti is with this system looking for benefits on logistics. (Posti, 2018)

IoT has been used to forecast need for maintenance. Metso uses in their crusher for stones sensors that collect data in cloud and system assists to forecast need for maintenance, optimise performance and energy efficiency. Kemppi has in their welding machines small computer that adjust the arc flame, recognises deviations and simultaneously collects data. If it is noticed that time goes for other things than actual welding, can preparation work be done by someone else than professional welder. Machine can also give instructions what to do next and how the work should be done. It is possible to gain savings if with on time maintenance can device break downs and maintenance breaks be prevented. Process optimisation with IoT can bring substantial cost efficiency in industry. (Lappalainen, 2018a, p. 39-42)

Digital twin is a mathematical model of process, product or service based on data. It is a digital pair for physical machine, including data from real world, works in similar way like real machine and is in interaction with it. With digital twin designers can test different solutions and see the consequences quickly before physical prototype is made. It is possible to better understand and predict how machines work. Virtual design enables rapid technological product development. Machine use can be trained virtually. When customer uses actual machine, virtual twin can help to optimise and develop use. (Lappalainen, 2018b, p. 17)

By attaching Internet of Things (IoT) sensors to physical goods, organisations can create digital twins of their real-life products and assets. This way, companies get access to real-time data that enables them to gain greater visibility into their supply chain operations and make real-time business decisions to meet and even predict customer demand. Alibaba uses data, such as demographics and weather forecasts, to offer products that customers in certain areas are likely to purchase. (Thalbauer, 2018)

3.4 Artificial Intelligence

Artificial Intelligence (AI) can be defined as the science and engineering of imitating, extending and broadening human intelligence through artificial means and techniques to make intelligent machines (Shi, 2014, p. 1). Artificial intelligence is a branch of computer science. In AI is machine intelligence studied, to use artificial methods and techniques, developing intelligent machines or intelligent systems to imitate, extension and expansion of human intelligence, realise intelligent behaviour. Artificial Intelligence can be divided into symbolic intelligence and computational intelligence. Symbolic intelligence is the basis of physical symbol system to study the knowledge representation, acquisition and reasoning process. Computational intelligence includes neural computation, fuzzy systems, genetic algorithms and evolutionary planning. (Shi, 2014, p. v)

AI refers to a broad field of science including not only computer science but also psychology, philosophy, linguistics and other areas. AI is involved in getting computers to do tasks that would normally require human intelligence. An AI system combines and utilises mainly machine learning and other types of data analytics methods to achieve artificial intelligence capabilities. Narrow AI can solve problems, that a specific algorithm is designed to do. General AI is a system that can learn and then solve any problem it is presented. (Van Duin & Bakhshi, 2017)

Chatbot is an example of AI. Finnish telecommunication company DNA uses chatbot on web pages to answer questions from customers. Chatbot recognises the questions with few key words and gives standard answers. If necessary, customer service person, “bot whisperer”, alters the answers and in complicated issues there is a person solving the problem. Terveystalo, a Finnish healthcare company, uses AI to analyse information about customer and to tell essential observations to doctor. Juha Juosila, Terveystalo Director of digitalisation, says that analyses made with machines offer possibility to develop health care that predicts and makes notes on risks for lifestyle illnesses. Valmet has developed an Expert-bot, that is a virtual assistant, whom can be asked help in using Valmet machines and equipment. (Sjöström, 2018, p. 6)

3.5 **Machine learning**

Machine learning uses analytics and algorithms to find patterns in data, predict outcomes and automate processes, making it possible for companies to effectively forecast and plan for future (Thalbauer, 2018). Machine learning is the process in which a computer sorts out regularities from training data. Machine learning can be applied to various problems and data sets. Depending on the technique used, an algorithm can improve itself by adding a feedback loop that tells it in which cases it made mistakes. Difference with AI is that machine learning algorithm will never understand what it was trained to do. As an example, it may be able to identify spam, but it will not know what spam is or understand why it needs to be identified. Also if there is a new sort of spam showing, it will probably not be able to identify it unless someone re-trains the algorithm. (Van Duin & Bakhshi, 2017)

With machine learning it is possible to foresee what could go wrong and prevent or correct in advance. This reduces downtime, avoids unnecessary costs and increases customer satisfaction. Machine learning can reduce time spent on repetitive tasks, increasing efficiency and productivity and helping companies optimise their supply chain operations. (Thalbauer, 2018)

3.6 **Robotics and Robotic Process Automation**

A simple form of robot is a machine that is programmed to perform a simple task by following step-by-step instructions. More intelligent shapes of robotics are like unmanned autonomous vehicles, drones, smart vacuum cleaners and smart assistants. Robotics combine hardware-mechanical parts, sensors, screens – with intelligent software and data to perform a task for which certain level of intelligence is required, like orientation, motion or interaction. (Van Duin & Bakhshi, 2017)

Traditional industrial robots are part of automated production chain. Co-operation robots, cobots, work alongside with workers, not replacing them. Cobots are designed to work as colleagues with humans; as their right hand where issues like quality of work, conditions, safety or productivity are in high demand. Difference between robot and cobot is, that worker can easily and quickly program cobot even without being automation engineer. Cobots can also do different kind of work at workplace instead of only one. (Saastamoinen, 2018)

Robotic Process Automation (RPA) is about a computer program that imitates manual work done on computers step by step and click by click. RPA conducts time consuming repeatable routines of administrative work. RPA is one tool among others, purpose of RPA is to have business processes automatized, reduce costs and improve efficiency. Also quality control, shorter lead-time and faster customer service are known benefits for RPA. (Azets, 2020)

4 MATERIAL VALUE

According to Ashby (2012, p. 21) most of the energy produced goes into three big sectors: transportation, buildings (heating, cooling, lighting) and industry, which includes the production of materials. Ashby estimates that making materials consumes about 21 % of global energy.

Ashby (2012, p. 80) states that when a product reaches the end of its life it's no longer valued. Resources are lost with real waste, when waste cannot be replaced, and resource is weakened when put away. Waste can also be seen as resource as it contains energy and materials. Since most products still work when they reach the end of their first life, waste contains components or products that can still be useful. Product can be treated in many ways at the end of its first life: extract the energy via combustion, extract the materials and reprocess them, replace the bits that are worn and sell it again or put it on sale as it is. (Ashby 2012, p. 93)

To create value with emerging technologies it is important to identify sources and mechanisms that enable monitoring and evaluation of the technologies. Their potential value and use within customers and organisation and products can be found. (Connor 2015, p. 210)

4.1 Material flow accounting

Material Flow Accounting and Analysis (MFA) is one of the key methods for measuring the material use of countries and economic sectors and provides an empirical basis for evaluating resource use policies. MFA describes the material inputs to a system of concern, the material outputs from that system, and the material throughputs throughout the system. (Materialflows, 2018)

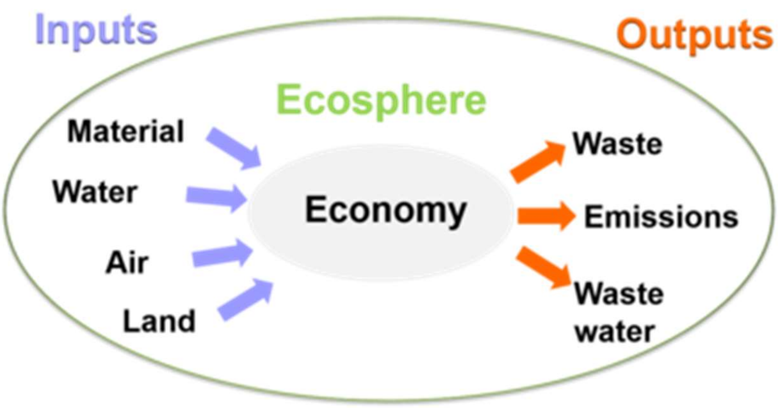

Figure 2. Material flow accounting (Materialflows, 2018)

In Figure 2 Material flow accounting is described. There raw materials, water and air are extracted from the natural system as inputs, transformed into products and finally re-transferred to the natural system as outputs – waste and emissions. Reduction in the use of materials for instance by means of increasing resource efficiency could provide a successful strategy to combat global environmental problems. (Materialflows, 2018)

4.2 Material efficiency

Finland's waste plan includes a national waste prevention programme. Waste prevention is promoted by the use of new instruments to increase material efficiency in production processes, construction and consumption, and by making the enforcement of current legislation more effective. (Nordiska Ministerråd 2009, p. 19) According to Motiva (2020) large companies can save up to million euros yearly with material efficiency inspection. Savings depend on the turnover, but 3-5 % yearly savings of turnover are typical. Cost for material loss can be over 25 times higher than the cost for waste handling.

There are policy instruments for waste prevention and material efficiency. Administrative instruments are mandated by law and cover for example the use of bans, prohibitions and standards. Product policy should be further developed and used for enhancing material efficiency. Producing sustainable and repairable products is important, and the price of a product should reflect its environmental burden. Producers responsibility obliges producers to organise the reuse, recovery or suitable treatment or disposal of their products and the wastes derived from them, and to cover the related costs. Economic instruments in the Nordic countries are different taxes and charges, deposit-refund schemes, and producer responsibility. (Nordiska Ministerråd 2009, 22-25)

Rational selection of materials to meet environmental objectives starts by identifying the phase of product life that causes greatest concern: production, manufacturing, transportation, use or disposal. Dealing with all of these requires data not only for the obvious eco-attributes (energy, emissions, toxicity, ability to be recycled, and the like), but also data for mechanical, thermal, electrical, and chemical properties. (Ashby 2012, p 312) Motives for increasing material efficiency are to minimize the decrease of non-renewable material resources; to reduce dependence on imports, particularly of materials already in short supply; to reduce the demand on other resources, particularly energy; and to reduce unwanted emissions generated by material production and use. (Ashby 2012, p. 418)

Steel and nonferrous metal industries are among those sectors with the highest energy intensities and recycling saves up to 95 % of the energy consumption expended in the production of the primary metal. The most commonly used Nonferrous metals are aluminium, copper, brass, zinc and lead. Because of their limited availability, their high value and the considerable energy saved if recycled, large quantities of these NF metals are reclaimed and recycled. (Pretz & Julius, 2011, p. 89-90)

According to Pretz and Julius (2011, p. 91) about 40 % of the world's steel output originates from scrap iron and steel. The energy saved from using recycled steel scrap amounts to approximately 75 % of the energy that would have been spent to generate the steel from primary mineral raw materials, and the CO2 emissions are reduced by 58 %. Also the recycling process results in an 86 % reduction in air pollutants and a 97 % reduction in mining waste. Metal can be recycled indefinitely. Metals have a high market value, supply and demand are the determining factors that affect the market prices.

4.3 Material handling and identification

Material handling includes keeping track of the materials being moved and stored. Usually label is attached to the item, package or unit load to uniquely identify it. (Groover and Jayaprakash, 2016, p. 288) Automatic identification and data capture (AIDC) refers to technologies that provide direct entry of data into a computer or other microprocessor-controlled system without using a keyboard. (Groover and Jayaprakash, 2016, p. 353)

Groover and Jayaprakash (2016, p. 355) divide AIDC technologies into six categories.

1. Optical. Most of these technologies use high-contrast graphical symbols that can be interpreted by an optical scanner. These can be one-dimensional and two-dimensional bar codes, optical character recognition and machine vision.
2. Electromagnetic. Radio frequency identification (RFID), which uses a small electronic tag capable of holding more data than a bar code.
3. Magnetic. These technologies encode data magnetically, similar to recording tape. Two important techniques are magnetic stripe, used in plastic credit cards and magnetic ink character recognition, used in banking industry for check processing.
4. Smart card. Refers to small plastic cards imbedded with microchips capable of containing large amounts of information. Other terms used are chip card and integrated circuit card.
5. Touch techniques. These include touch screens and button memory.
6. Biometric. Used to identify humans or to interpret vocal commands of humans. Include voice recognition, fingerprint analysis and retinal eye scans.

Reason to use automatic identification and data collection techniques are data accuracy, timeliness and labour reduction. The error rate in bar code technology is approximately 10000 times lower than in manual keyboard data entry. The speed of data entry for handwritten documents is approximately 5-7 characters/sec and it is 10-15 characters/sec for keyboard entry as automatic identification methods are capable of reading hundreds of characters per second. (Groover, 2016, p. 355)

4.4 Waste sorting methods

Mechanical treatment of waste is often used in recovering valuable materials from waste streams or in association with biological or thermal waste treatment. The purpose, for example, may be to remove contaminating items, to separate one waste stream into more streams or to homogenize the waste in order to optimise other processes. Mechanical treatment may be categorised into: Size reduction, separation when waste is sorted according to single or combined characteristic and compaction where bulk density is increased. (Bilitewski, 2011, p. 321)

Bilitewski (2011, p.327) describes that the separation refers to the process of separating one waste stream into two or more waste streams according to a single characteristic or to a combination of characteristics. A high recovery of a specific material fraction in a waste stream is usually associated with less purity of the recovered material. The most common types of separation equipment are:

- screens
- air classifiers
- ballistic separators
- magnets
- eddy current separators
- optical sorters
- flotation/deinking
- density separators, including float-sink units and hydrocyclones
- manual separation

Screening separates material of various sizes into specific particle size ranges. If a specific particle size is characteristic for a specific material fractions, screening may also be used for separation of materials. Screening is performed by separating particles based on the size of the openings on a screened surface. (Bilitewski, 2011, p. 327)

Air classifiers separate according to the particle’s falling velocity in an air stream. The falling velocity of a particle depends on its form and its specific gravity. The basic idea is that the less dense materials (paper, plastics, dry and light organics) are caught in the upward current of the air and carried away by the air, while the more dense material (metals, stones, tiles, wet organic matter) drop to the bottom unable to be supported by the air current. (Bilitewski, 2011, p. 332)

Ballistic separator uses several particle characteristics simultaneously: size, density and rigidness. The ballistic separator was developed for the separation of residential and commercial waste into three fractions: heavy, light and fine. (Bilitewski, 2011, p. 337)

Magnetic separators attract magnetic ferrous metals. Technology usually involves an overhead separation system that attracts ferrous material and moves it away either upright or parallel to the waste transport direction. (Bilitewski, 2011, p. 338)

Eddy current separators rely on the induction of eddy currents in nonmagnetic metal objects in response to an electromagnetic field. This allows for the separation of metallic aluminium and copper. Eddy current separators provide mechanism for sorting a waste mixture of similar density grades. (Bilitewski, 2011, p. 339)

Optical sorting uses colour sensitive cameras, near-infrared spectroscopy and UV sensors to identify different types of plastics, composites, paper, batteries, etc. and their position on the conveyor belt is determined. Based on the information recorded, air jets are activated which sort the identified items into the corresponding collection containers. (Bilitewski, 2011, p. 340)

Flotation is primarily used to remove impurities, in particular as part of the waste paper deinking process. (Bilitewski, 2011, p. 341)

The ore industry developed the technique for using a fluid medium for density sorting. Density sorting is most often used to separate plastics. There are two types of density sorting with fluid mediums: float-sink method and hydrocyclones. (Bilitewski, 2011, p. 341)

Despite all technological progress, manual sorting represents the single most reliable method to separate secondary products from a mixed waste stream. Sorting personnel can effectively separate residential and commercial waste into bins for wastepaper, colour specific or mixed glass and clear or coloured polyethylene foil, while at the same time remove contaminating materials. (Bilitewski, 2011, p. 343)

Chemical recycling is a general term used to describe technologies where post-consumer plastic waste is converted into valuable chemicals. These chemicals can be used as feedstock by the chemical industry. Chemical recycling technologies include pyrolysis, gasification, chemical depolymerization, catalytic cracking and reforming, and hydrogenation. Monomers, oligomers and higher hydrocarbons are feedstock that can be used to produce virgin-like polymers to create new plastic articles. (Plastics Recyclers, 2020) Chemical recycling makes possible of all types plastic waste to transform into its original chemical components. By creating a new, secondary raw material that offers the same quality as virgin feedstock, chemical recycling can help to close the loop and reduce the consumption of fossil fuels. (Chemical Recycling, 2020) Neste, a Finnish oil refining company, at their oil refineries produce a multitude of end products. Neste's existing refinery processes can turn the liquefied waste plastic into raw material for new plastics and chemicals. Chemical recycling enables recycling of a wider range of waste plastics than traditional mechanical recycling. Through chemical recycling, also coloured, multilayer and mixed-material plastic waste can be liquefied in a thermochemical liquefaction process, which turns them into a material similar to crude oil. (Neste, 2020)

4.5 Digital supply chain

Roblek, Mesko and Krapez (2016, p. 7) present the digital supply chain (DSC). Industry 4.0, digitisation, is about companies aiming themselves to the customer through e-commerce, digital marketing, social media, and the customer experience. Business will change through integration of research and development, manufacturing, marketing and sales, and other internal operations, and new business models based on these advances. The fourth industrial revolution develops towards the digital ecosystem. The digital supply chain broadens the vertical integration of all corporate functions to the horizontal dimension. All actors are involved, like the suppliers of raw materials and parts, the production process itself, warehouse and distributor of finished products and the customer. With a network of sensors and social technologies, controlled by a central control hub and managed through a connecting data analytics engine. Table 1 describes the long road to Industry 4.0.

The long road to Industry 4.0, the digitisation of every aspect of business				
			Today	
1800	**1900**	**1970s**	**2015+**	**2030+**
Industry 1.0	**Industry 2.0**	**Industry 3.0**	**Industry 4.0**	**Digital ecosystem**
The invention of mechanical production powered by water and steam started the first industrial revolution	Mass production, with machines powered by electricity and combustion engines	Electronics, IT, and industrial robotics for advanced automation of production processes	Digital supply chain	Flexible and integrated value chain networks
	Introduction of assembly lines	Electronics and IT (such as computers) and the Internet constitute the beginning of the information age	Smart manufacturing	Virtualized processes
			Digital products, services, and business models	Virtualized customer interface
			Data analytics and action as a core competency	Industry collaboration as a key value driver

Table 1. The long road to Industry 4.0 (According to Roblek et al., 2016)

Digital supply chains advantage is not only greater efficiency. Real goals are the new business models and revenue streams it will make possible. (Roblek et al., 2016, p. 31)

5 CIRCULAR ECONOMY

According to Sitra (2018) in circular economy consuming will be based instead of ownership on using services. It is not only about recycling, but also about production of raw materials, processing materials, product manufacturing, distribution, trade and perfection. Walter R. Stahel (2016) compares circular economy to be like a lake as a system. The reprocessing of goods and materials generates jobs and saves energy while reducing resource consumption and waste. Circular economy turns goods that are at the end of their service life into resources for others, closing loops in industrial ecosystems and minimizing waste.

Purpose of Finnish waste law is to prevent danger and harm caused by waste and waste management to health and environment in addition to reduce the amount of waste and harmfulness, promote sustainable use of natural resources, ensure functioning waste management and prevent littering. (Finlex, 2011)

5.1 Difference between linear and circular economy

Linear economic system is based on consuming materials and discarding them after use and this is about to be replaced by circular economy. Circular economy involves a reduction in the consumption of virgin raw-materials and environmental impacts and another aim is to generate positive economic impacts. (SYKE, 2018) Circular economy means new type of resource wise business model, where economical value is created, and environmental impact reduced by keeping materials in use as long as possible and by reducing loss of natural resources. By 2030 some of these circular economy actions are expected to increase GDB by 1,7 billion euros and create 5000 new jobs in Finland. At the same time, it is expected reduction in greenhouse emission from consumption (-2,6 %) and use of raw materials (-0,6 %). (SYKE KIVIKI, 2018)

In Figure 3 SYKE describes how the chemical and material cycles are managed. In sustainable circular economy it is important to reduce the use of hazardous substances throughout entire product’s life cycle: from design to production, use, maintenance, reuse and recycling (SYKE, 2018). Three general objectives of circular economy are: 1. sustainable use of natural resources, 2. keeping products in the circulation for as long as possible and 3. recycling side-streams and waste into raw materials (Tikkanen, Antikainen, Kautto, Salmenperä, 2018, p. 4).

Figure 3. Managing chemicals and material cycles (SYKE, 2018)

From linear to circular economy, which is an economic system where material and substance cycles are closed as much as possible. Companies should plan and offer products and services that match principles of circular economy. Business models that support circular economy can be found in material and energy input sustainable circulation promotion, optimising production process, service sector and leasing, sharing platforms for services and products, increasing the lifetime of products and material recycling. Consumers should choose these products and services and participate in producing through sharing economy solutions. Political decision makers have a role in creating operational environment that supports moving into circular economy with different policy instruments. (Tikkanen et al. 2018, p. 8)

5.2 Fortum Waste Solutions Circular Economy Village

Figure 4. Fortum Waste Solutions Circular Economy Village at Riihimäki (Fortum, 2018)

Since 2016 Circular Economy Village has operated in Riihimäki, Finland, to reduce the amount of waste going to incineration and to increase the amount of materials being recycled. In Figure 4 process of the Village is described. Mixed waste received from society is sorted at Eco Refinery. At Eco Refinery metals, plastics, bio waste and energy waste are separated. Metals go to metal recycling. Plastics are directed to Plastic refinery where recycled plastic and for example construction materials are produced. 75 % of the plastic is recycled to recyclates and rest is utilised in Waste-To-Energy plant. Recycling of plastic requires only 15 % of the energy compared to production of new plastic. Bio waste is treated at Bio Refinery, operated by an external actor, there biogas and fertilisers are produced. Energy waste goes to Waste-To-Energy plant, which produces district heating and electricity. (Fortum, 2018)

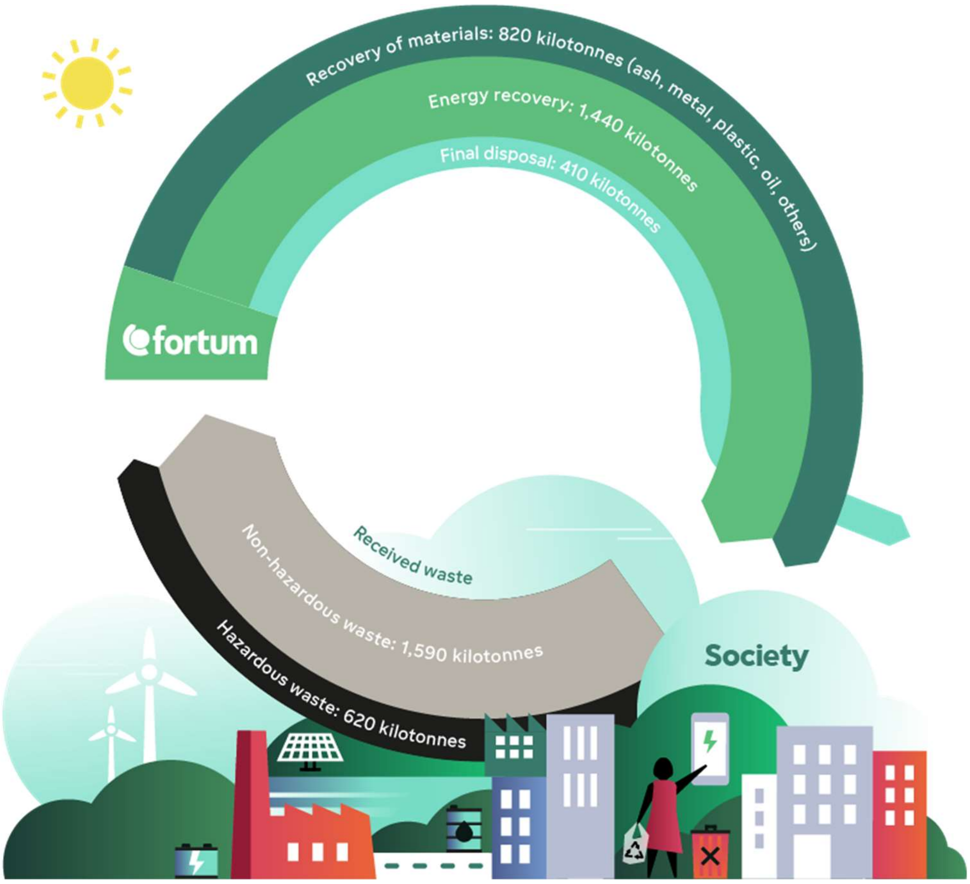

Figure 5. Received and treated waste from customers in 2019 (Fortum, 2020)

Reliable waste management and resource efficiency are important in a sustainable society. Fortum aims to promote the transition towards a more comprehensive circular economy and resource efficiency. Here circular economy means that materials are utilised as efficiently as possible and hazardous materials are removed from circulation. The aim is to make new raw material from waste whenever possible and to keep valuable materials in circulation. These amounts in Figure 5 are total received and treated waste at whole Fortum Waste Solutions in 2019. In Finland was received 633 kt of Non-hazardous waste and 241 kt of Hazardous waste in 2019. From this recovery of materials was 223 kt, energy recovery 375 kt and final disposal 188 kt. Final disposal includes received waste from customers and also ash from waste incineration. (Fortum sustainability, 2020, p. 33-34)

5.3 Waste types and amounts

Williams (2005, p. 63-64) defines waste according to EU Waste Framework to be any substance or object which the holder discards or intends to discard. Definition of waste is subjective, as others waste can be to someone else valuable resource. Waste must have strict legal definition to comply with the law, because definitions of waste have financial and legal implications for business, local authorities and government. Agreement on definitions and classifications of waste are required to enable accurate formulation of local, regional and national waste management planning.

Characterization of solid waste is usually a difficult task because the waste varies a lot, is heterogeneous, but also in quantity and temporal variations. Characterization can be costly if good and reliable data is needed. Therefore, a waste characterization is often concentrated to meet specific need for information. (Lagerkvist, Ecke & Christensen, 2011, p. 63)

For the design of a waste incineration plant, the best available data on amount and composition of each waste type is needed, and the effect of expected future changes in the waste management system should be taken into consideration, like the introduction of source sorting or pre-treatment. Three key variables in characterizing waste as a fuel are caloric value, moisture content and ash content. (Christensen, 2011, p. 366-367)

Hazardous waste stems from industry, manufacturing, maintenance and services (Christensen, 2011, p. 983). The aim of all hazardous waste treatment is to treat the waste in such a way that the hazards of the waste are removed, neutralized and/or reduced (Christensen, 2011, p. 987).

Municipal waste contains waste from companies, institutions and households. Term household waste is used for waste produced at home like biowaste, cardboard, paper, glass, metal and plastic. (Ymparisto.fi, 2018)

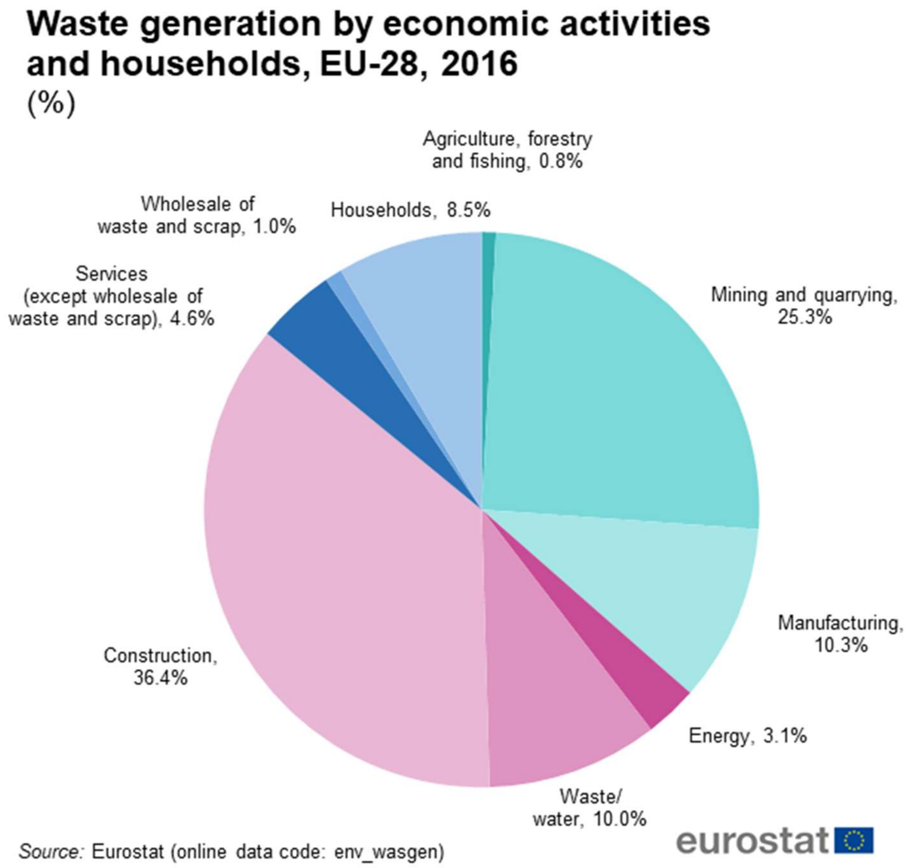

Figure 6: Waste generation by economic activities and households, EU-28, 2016 (%) (Eurostat, 2019)

This figure 6 shows waste generation by economic activities and households in 28 member countries of the European Union in year 2016. Over 60 % of the waste is generated in construction and mining and quarrying industries. High amount of waste generated in Finland, in relation to population size, see Figure 7, comes from mining and quarrying. Elsewhere construction and demolition often contributed to high shares. (Eurostat, 2019)

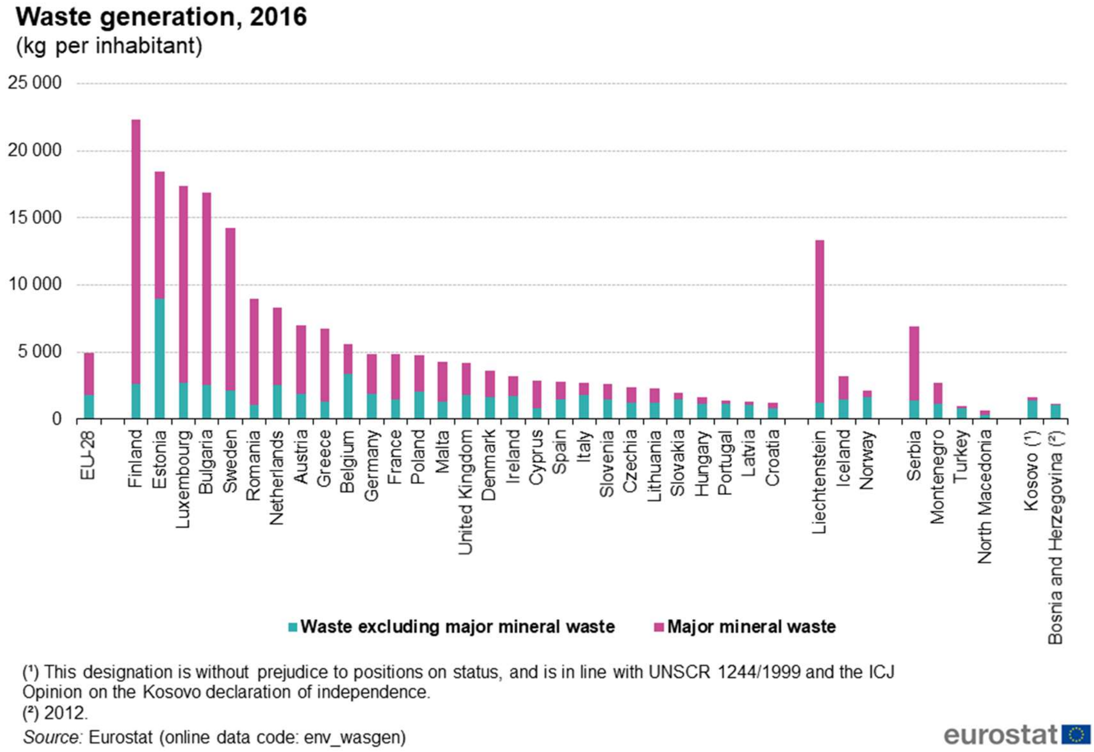

Figure 7. Waste generation, 2016 (kg per inhabitant) (Eurostat, 2019)

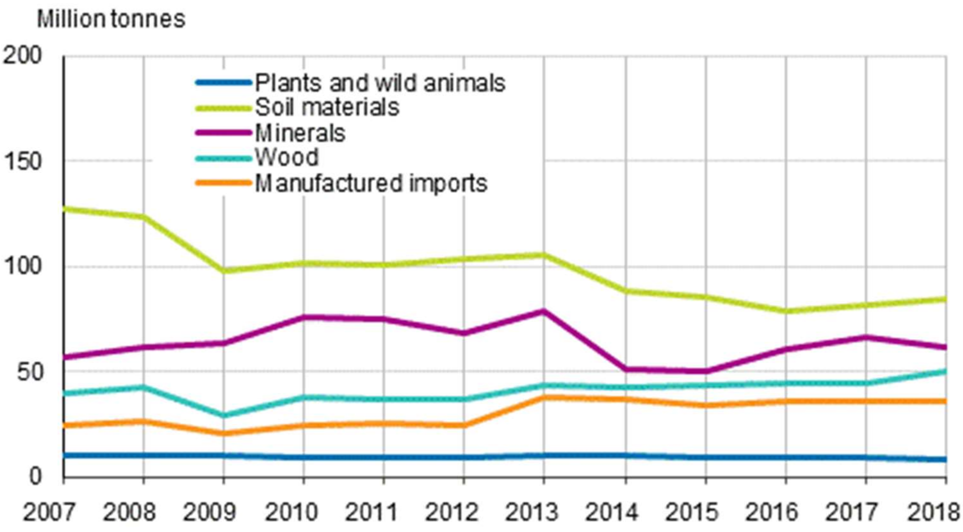

Figure 8. Use of direct inputs by material group 2007 to 2018, million tonnes (Tilastokeskus, 2019)

In 2018, altogether 642 million tonnes of natural resources were used in Finland. The use of direct inputs by material group is shown in Figure 8. Direct inputs include domestic direct inputs and imports. (Tilastokeskus, 2019)

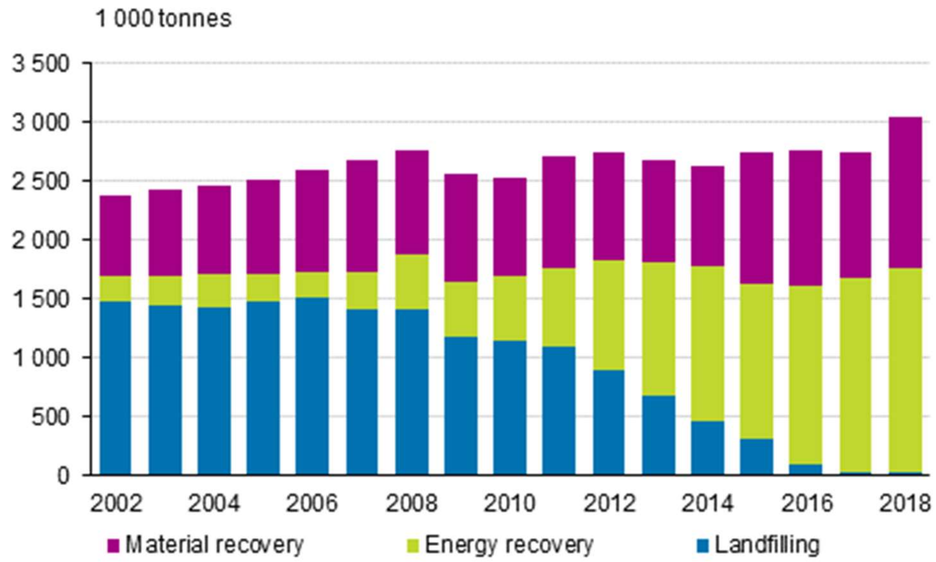

Figure 9. Municipal waste by treatment method in 2002 to 2018 (Tilastokeskus, 2020)

Figure 9 presents the amounts of municipal waste by treatment method in Finland. The share of material recovery of waste has grown. Landfill disposal of waste has ended almost completely, partly due to the landfill prohibition of organic waste that came into force in 2016. Energy recovery of waste is the most significant treatment method of municipal waste. Energy recovery is based on combined production of electricity and heat, and heat is particularly recovered in district heating networks. According to Statistics Finland, wood and plastic were recovered more than in previous years in 2018. Recycling of glass also increased. (Tilastokeskus, 2020)

5.4 **Sustainable Value Chain**

The value chain of a specific company that sells its products to consumers, or intermediate products to other companies, in the traditional sense starts at the extraction (or harvest) of resources and ends at the company. This can also be referred to as the supply chain, or upstream value chain of a company. When considering sustainability aspects of the value chain of a product, the downstream value chain should also be considered. This includes the distribution of products to customers, final consumers and end-of-life options, like waste disposal, recycling and reuse of a product. By including both upstream and downstream, the value chain covers the complete life cycle of a product. (Ugarte & Swinkels, 2015, p. 3-4)

Companies can have several reasons, why they feel the need to manage and improve sustainability aspects and these reasons can be either risk based or improvement based. Risk based reasons include Image, Continuity of supply and Transparency. About Image, in the public opinion companies that put their brand name on a product are hold responsible for bad practices, mistakes or accidents that take place in the value chain. Continuity of supply can be affected by bad practices, mistakes or accidents that take place in the upstream value chain and can lead into interruption of supply of raw materials or intermediate products. A similar risk exists downstream if a certain disposal route is closed or under discussion due to bad practices or accidents. Transparency is about building trust and providing insight in possible risks with stakeholders such as consumers and investors. (Ugarte & Swinkels 2015, p. 8-9)

Improvement based reasons include New market opportunities, Long-term product strategy and Long-term company sustainability strategy. New market opportunities can be offered if there is increasing attention for sustainability in the market for products that can show improved value chain sustainability, compared to other products in the market. Long-term product strategy can be affected as value chain sustainability issues can influence competitiveness or even acceptance of a product in the market. Long-term company sustainability strategy is executed by setting long-term goals and policies to improve sustainability aspects or remove certain sustainability aspects from its portfolio. This can include value chain measures such as selecting suppliers on their sustainability performance, applying pressure to certain supplier to improve their processes or working conditions or redesign products, making it possible to remove certain materials or suppliers completely from the value chain. (Ugarte & Swinkels, 2015, p. 9)

5.5 Waste Flow Mapping

The main purpose of the Waste Flow Mapping (WFM) is to provide a framework for identifying and analysing potentials for waste management and material efficiency in manufacturing industry, including residual material values of metals, combustible and inert waste, process fluids and other hazardous waste. Waste Flow Mapping combines lean and green principles and tools like Value Stream Mapping, Eco-mapping and a Waste composition analysis to include the business improvement potentials. WFM analyses the unwanted material output in order to find efficiency losses upstream, increase the value regained from residuals and ultimately reduce unnecessary input. (Kurdve, Shahbazi, Wendin, Bengtsson, Wiktorsson & Amprazis, 2017, p. 3)

Potential waste management process improvements on plant level can be found in subprocesses for example: underused bins; lack of bins for some waste fractions; lack of and poor quality of signs and instructions; inefficiencies in handling and internal logistics; poor quality of information management; container and equipment inefficiency; inefficiencies and unnecessary costs of external transports; inefficiencies in choice of final treatment. (Kurdve et al., 2017, p. 16)

Understanding the values of materials and costs for waste handling and treatment, gives a clear guidance to efficient operations. Waste Flow Mapping is a suitable framework, for analysing the waste management process and to efficiently identify sustainability improvement potentials. To group different waste fractions into segments and analyse these segments individually is necessary to identify Best Practice for the different segments. It is crucial to avoid mixed material with lower quality grade of that particular material. The proposed performance measurements support management control. (Kurdve et al., 2017, p. 18)

5.6 **Green Performance Map**

According to Kurdve and Wiktorsson (2013) creating economic sustainability by environmental sustainability has become a successful strategy for many businesses, bringing new revenue streams and improving cost control. To succeed with a cost-efficient environmental improvement work there is a need for operational management to take ownership of the environmental performance and for operators to get involved in the continuous improvement work also with regards to environment. The Green Performance Map (GPM) is intended to interlink environmental experts with improvement teams, and to introduce performance measures and non-expert tools to support operational engagement in environmental improvement.

6 METHODOLOGY

This thesis is a case study with current state analysis having qualitative approach. In the qualitative approach, case study refers to the in-depth analysis of a single or small number of units. Purpose of a case study research is to describe that particular case in detail and take learning from that and to develop theory from that approach. (libweb, n.d.) A case study enables to gain an in-depth understanding of a certain object or a defined group of objects. As a research strategy, case study has an unrestricted framework, which enables use of any suitable methods of analysis. (Lähdesmäki, Hurme, Koskimaa, Mikkola & Himberg, 2009) According to Eriksson and Koistinen (2014, p. 4) in a case study one or more cases are retrieved, and their definition, analysis and solution is the central goal. That is why it is never self-evident or insignificant in a case study how the case is selected, defined and validated. Defining the case is a process that continues throughout the research (Eriksson & Koistinen, 2014, p. 6).

Taylor et al. (2015, p. 17) describe qualitative methodology to be research that produces descriptive data, which means people's own written or spoken words and observable behaviour. Qualitative researchers are concerned with the meaning people attach to things in their lives (Taylor et al., 2015, p. 18.). They refer Corbin & Strauss (2008) that central to phenomenological perspective and hence qualitative research is understanding people from their own frames of reference and experiencing reality as they experience it. Qualitative research is inductive. Qualitative researchers develop concepts, insights, and understanding from patterns in the data rather than collecting data to assess preconceived models, hypotheses, or theories. (Taylor et al., 2015, p. 18) Qualitative research aims to understand reality with help of gathering and analysing qualitative data. Qualitative processing of research data is based on logical deduction and interpretation of the content, which aims to create of scattered information a meaningful, clear, concise and coherent unity of information which describes the studied phenomenon. (Lapin AMK, 2020)

Interview can be used for data collection, when the aim is to produce knowledge of opinions, ideas, observations, attitudes, values and experiences of living people. Basic structures for interview are unstructured or open, semi-structured and structured or form interview. (Lähdesmäki et al., 2009) This research has semi-structured interviews. All the respondents receive the same questions, but no given options to answer. Information required by research can be gathered through different kind of interviews. Examples of interviews are personal, e-mail, telephone, theme, open and group interviews. An interview is a flexible way to collect information, why it suits well for different kind of research goals. Interview techniques are suitable for collection of qualitative information. Interviews in person and with e-mail are suitable for interviewing specialists. With e-mail it is possible to interview experts in different countries or different parts of country. E-mail interview is inconvenient method for both interviewer and interviewee. (TUT, 2020)

Current state analysis or As-is process analysis is a process management strategy that identifies and evaluates a business's current processes. Current state analysis can focus on an entire business organisation or on one or more specific processes within a department or team. Current state analysis helps business to evaluate the current state of its processes and identify opportunities for improvement. (Lucidchart, 2020)

7 RESULTS OF THE STUDY

The study questions were sent to selected key personnel at RWS by email on March 17, 2020. Recipients work in management level at the case company in sales, production, planning, research and IT, and have enough insight and knowledge to answer these questions about material identification. Five answered the questions by email, one of them was combined from two of the attendees after their discussion, this is though considered as one response. Also one group interview with three respondents was conducted as well as one interview by phone. From eighteen emails sent, nine interviews were completed. The group interview was made on Microsoft Teams and recorded per permission of participants, to be able to complete the notes written during interview afterwards. For interview on phone were notes written. Transcription of notes and email responses was gathered to be able to compare and analyse the research material. All the responses were in Finnish and are freely translated by the researcher for this work. Research questions were formulated with case company to get a picture of the current state and how to get more value with material identification in the future.

Research questions:

1. What methods are currently used to identify materials?
   (e.g. pH measurement, sensors)
   Mitä keinoja käytetään tällä hetkellä materiaalien tunnistamiseen? (esim pH mittaus, sensorit)

2. What value does material identification give? How can this value be measured? (e.g. pricing, safety)
   Mitä arvoa materiaalien tunnistaminen tuottaa? Miten tätä arvoa voidaan mitata? (esim hinnoittelu, turvallisuus)

3. What methods could be used for material identification in the future? (e.g. AI)
   Mitä keinoja voitaisiin tulevaisuudessa mahdollisesti käyttää materiaalien tunnistamiseen? (esim tekoäly)

7.1 Main findings of interviews

After thorough familiarization of transcribed responses some main findings could be recognised. These main findings are described in Table 2. Answers were categorised in question 1 by identification method and if the identification is done manually or by machine. In question 2 it was considered if the value is value for customer or for company. Question 3 had responses that referred to possibilities that are already under construction, the ones that are available but not used and visions about possible new techniques for identification in the future.

Main findings of interviews

Question	**Answer**
1. Current methods	Pre-information from customer
	Laboratory analysis
	Visual examination
	Measurement of pH
	Magnet
	X-ray measurement of metals with handheld device
	Infrared for plastic waste
2. Value	Pricing
	Safety
	Production planning
3. Future methods	Sensors
	Monitoring device
	Connection device
	AR
	AI
	On-line methods
	Computer vision

Table 2. Main findings of interviews

1. Current methods

Pre-information from customer about the waste is highly important and was mentioned in every response. It is the basis for accepting the waste for treatment, pricing, packaging, transport, and production planning. As an Interviewee responded, customer or deliverer is responsible for giving correct pre-information already before transport. This is based on requirement from ADR legislation. Especially the UN-number indicating hazardous features, is important regarding production activities.

The most common way to identify materials is visual examination. Eight out of nine respondents named visual. Visual examination is used to complement the pre-information. If the state of the waste looks like it is described and how the labelling says and if no additional tests are required, process goes on as planned. By visual examination the characters of the waste are controlled. How the material looks like, if there are any bigger particles and what is the state of the content – gas, solid, liquid or paste. Also odour can tell a lot, even though from safety point of view smelling is not recommended.

Six interviewees mentioned the laboratory analysis. Analysis can be made before the waste is accepted or upon arrival as planned or to control if suspected variation in waste content. As an Interviewee explained, the whole variety of analysis methods are used. Chosen analysis method depends on the need, what kind of waste stream is and which process is used to handle the waste. These analysis methods can include organic or inorganic, microscope and optic methods, pH test, conductivity, moisture, dry matter and solubility. Especially in case of recyclable materials, physical, mechanical, structure and conditions can be tested.

Some of the respondents mentioned mechanical or by hand made tests, identification or separation measures. Quick tests like pH or thermometer, are used to get more precise information in the reception. Testing pH gives indication if the solution is acid or base. Temperature measurement is needed to know what equipment can be used for unloading and storage. Different features of materials help identification, like if plastic stretches but does not rattle, it is LDPE. One simple technique mentioned is done by dropping a water drop to liquid, if water stays on surface, liquid is oil.

A quick test can be made with handheld x-ray device to determine metals in metal reception. Metals can be separated with material machine. On sorting conveyor from smaller metal parts other materials are handpicked to get copper and brass out. Magnet finds ferrous metals like iron from mixed materials. Metals can be sorted from soil by placing magnet to material machine’s shovel.

Some automated detection is already in use. In Riihimäki there is radiation detector at gate, as no radioactive material is accepted for reception. Metal recycling site located in Ikaalinen, will also have radiation detector at gate. Until now handheld radiation detector has been used to check metal loads. Waste bunker has gas detectors, which alert if there is danger of explosion. This could happen if there is something mixed in the waste load that is not mentioned and content starts to react in an unexpected way.

In plastic refinery infrared recognition is used to sort plastic waste. Near-infrared technology is used for sorting and separating the different plastics and to prevent non-plastic materials from going further along in the recycling process. The main types of plastics recycled are LDPE, HDPE and PP.

2. Value

All the respondents mentioned pricing, when considering what value does material identification have. The better the material is identified, the easier it is to set price. Consistency is base for pricing, but especially regarding recycling materials to meet the quality criteria is prerequisite for operation. The more reactive, more detrimental elements and size of material parts waste contains, more difficult it is to handle the waste and treatment price is higher. Like an Interviewee says, to optimise production and pricing have the biggest value. For example, caloric value and composition of waste determine how the waste can be treated. Value is the most obvious insight in pricing. Amount of waste is significant, but more important is the composition of waste and amount of different substances. One Interviewee brings up also the customer point of view where more precise reporting is possible and follow up on how the customer can meet the targets in recycling if identification is more accurate. Reporting can be required by environmental system or authorities.

Safety can be considered as one of the value bringing aspects. It is important to identify materials to ensure safe handling and choosing correct processes. Company's safety regulations determine use of protective gear. Process safety can be enhanced through identification, there should be no risk to machines or humans. Reception of only permitted materials enables to follow the environmental permits. Material identification is important when choosing ways of transporting waste safely. It is also important to know the materials, when deciding on correct packaging.

In production material identification has value in operation management, to optimise operations, in emission control, sorting and use of recyclables and in quality of recycling material. One of the Interviewees finds most value for material identification in production. The whole process works faster when there are no interruptions caused by unexpected materials. Pricing can be done more accurately for identified materials. Identification of materials increases process safety, there are no risks to machinery or humans as materials are directed to correct treatment. To be able to work according to environmental licenses, it is essential that the received materials are permissible for treatment.

For production it is good to know the caloric value of the waste materials. If the caloric value is high, it is possible to feed less materials for treatment. If the caloric value is low, waste does not combust that well. In case the material is not what expected, production planning needs to be changed, which might lead to increase in warehousing costs.

3. Future methods

Respondents see many possibilities for material identification with new technologies in the future. One Interviewee interprets that within ten years every waste bin will have some kind of connection or tracking device. This device will give possibilities to other methods too, than degree of fullness or location of the bin. If the collection equipment has LoRa (Long Range, low-power wide-area network technology) or some other connection device with sim-card, it could be possible to use it to send also other information. This other information could be data from for example pH-measurement, computer vision, infrared sensor, weight sensor or other sensors. An interviewee thinks that different on-line methods are the biggest trend in development to identify raw materials and different streams and to control detrimental elements. As an Interviewee sees that development of efficient recycling methods requires more versatile, accurate and faster methods in analysing and identification combined with different sorting processes and quality control of products.

Using AI and intelligent sensors in bins, that could describe the content precisely, is seen as possibility. This more precise content information could assist in planning the optimal treatment. One respondent mentioned AR (augmented reality) goggles or helmet like device, that could give different kind of information about materials. This AR would be helpful working in the field. Many of the respondents bring up AI and benefits it could have in material identification, already in customers process, equipment, unloading, warehousing and in recovery or treatment process. There are new possibilities with digital technologies, that should be researched further to get more value out of processes. It is important to choose the most valuable fractions, where possible, to get more out of development of identification. For example, in pricing knowing the water or chlorine content is valid. To optimise production some information is critical and identification valuable.

Some of the respondents had ideas on how to make the daily work easier with automated material identification. Camera detection could be used to show, not only what type of waste, but also content of waste, like caloric value. In tank emptying, measurement of liquid waste could be done already during suction, to have quick results of content. This measurement in tank emptying would give indication, if there are unexpected substances that could mess the whole content of tank or even break machinery. One thing mentioned was possibility to test and verify waste content right away in the reception if needed. This quick testing would make waste handling process easier, faster and safer. There was also an idea of AI analysing waste stream constantly in the waste bunker. For easier identification of different contents, waste containers could have automatically changing colour codes based on content. Tank containing liquid waste could be with sensor, not only to show degree of fullness but also different phases and water content in the tank.

Now waste compactor can have sensors to notify about degree of fullness or need for maintenance. In metal recycling there is under construction cable crusher that produces metal granulates. Separation of different metals is based on gravity and colour. There is in the market available a handheld metal analyser that uses laser. With that it is possible to identify stainless steel, acid-proof steel and aluminium. This handheld laser measurement device is a bit quicker than the x-ray one used in metal recycling, and does not require radiation security organisation, but it is not as good in identifying brass and red brass.

7.2 Analysis according to Porter’s value chain

When looking at the responses from value chain point of view and comparing with Porter’s value chain, there are benefits and value to be found in different activities with material identification.

In Primary activity Inbound Logistic, more precise material identification at earlier stage could add value at RWS. Customer would pay correct price for known materials and amounts. Also logistics can be optimised with correct pickup times and packaging materials. In logistics it is possible to optimise routing and means of transportation and this will also reduce negative environmental impacts and improve profitability when not driving short loaded.

For Operations material identification has the most benefit, as it allows more accurate planning of processes. Value is achieved with process optimisation, improved safety and emission control. More precise material identification helps in material handling and warehousing, as known materials and amounts would be in correct place. It would also make it easier to decide where the waste will be treated and deliver straight to correct location.

In Outbound Logistics selling the produced district heating, electricity and recycled materials like metals and plastic granulates. As value can be seen better quality of products through raw material purity.

For Marketing and Sales is material identification essential in pricing. Here customer can also benefit from sorting or if possible, to find new ways to use the materials even in customer’s own processes. With the whole service sale packages, both RWS and customer can benefit.

In Service can customer service focus on serving the customer, taking orders, confirming schedules, and advising the customer on recycling and waste services, when waste content is identified more automatically. When processes and products are clearly defined, value can be found as order processing can be automated with RPA. For customer, ordering is easier and quicker when customer has more precise information of their waste. It can be even easier if information is transferred digitally or with mobile applications. Customer service can be supported by Chatbot solution.

In Support Activities values cannot be seen as directly, but Company Infrastructure can work more ideally as planning is easier with stable and known material flow. Human Resources can have right people in correct places as functions are more stable. Technology Development can make correct investments based on the information gathered from customers.

7.3 Analysis

The case company is operating in the field of circular economy, making sustainability possible and developing processes and technologies for getting the most value out of materials. There are still possibilities to get even more value with digital development.

When analysing the results of the study, it is worth noticing, how much weight in identification is still put on pre-information from customer and especially on visual examination. RWS is taking new ERP (enterprise resource planning) system in use in near future. That and programmes around it might bring some benefits and help to execute some process steps. Digital possibilities in identification should be researched further and considered when planning new investments and maybe these digital identification methods would be possible to connect with new ERP. Digitalisation is one way of helping Fortum to achieve its vision “For a cleaner world”.

1. Current methods
Pre-information from customer is according to this research the most important way to have information about the materials. That is why the role of sales and customer service is extremely important, that the customer knows what is expected and how to give correct information. Here is also possibility to find new ways with technological development. There could be sensors already in customer’s processes to monitor the components or sensors in waste containers to give information not only about content levels but also about composition of waste. Precise knowledge of the content helps to organise and optimise logistics, and in process planning.

Visual examination is a common way to identify materials. In the field at customer site or in reception, a look at the waste can already give confirmation about the material. This lays a lot of weight on the expertise of personnel and can possess a risk for treatment process and safety. Disadvantage of visual examination is that it is not possible to identify all the materials or the actual content of the waste, like concentration of substances in liquids. Ultimate target is that the visual examination is not needed as the identification is reliable in earlier process steps.

Laboratory testing is not possible at every stage of the process. Tests can be taken at customer end, before pickup and then after reception, either to know if the waste composition is what expected, for invoicing or production’s interest. Sensors providing data from waste at customer end, would also help customer to notice, if their process is running as supposed to. If the shipment from customer is not what expected and therefore laboratory analysis is required, the load needs to be kept in stock. Laboratory analysis takes time and process needs to be re-planned while shipment waits in warehouse. If size of shipment waiting in warehouse is large, it can impact the environmental licenses, as only limited amounts of hazardous waste can be stored.

Quick tests like handheld x-ray device in metal recycling could be an option to reinforce the pre-information and visual examination. X-ray device analyses the sample of metal within seconds. There is a handheld gas meter in laboratory, that detects for example ammonium and hydrogen sulphide, but this is not used at reception. Laboratory has quick test for example for peroxides and Chrome6. It is recommended to check, if the handheld gas meter or quick test used in laboratory could be taken into use also in hazardous waste reception. Already used quick tests like pH, thermometer, x-ray and magnet are all useful in material identification, but could to some extend be replaced by sensors in the future.

2. Value

Material identification done at the earliest possible point, can add value in every step of the supply chain. Identification will result in correct pricing, unbroken process, enhanced safety and sustainable solutions. Value can appear in different forms for customer and case company. Customer will benefit in accurate reporting and invoicing and more precise information about customer's own processes. Controlled waste management can decrease costs when using correct type of collection bins and collection periods. Customer achieves savings in prices, when paying only for identified materials without unknown substances. When the content can be identified, it is simpler to set price. For mixed unidentified waste content price is higher as safe handling, storing and treatment requires more work.

In some cases, like in metal recycling, customer can receive refund for waste. Metal prices follow the world market prices. There is a huge difference in metal price depending on the metal and if material is pure or mixed. Mixed metals do not have that many markets, but by sorting they can be refined for sale. To be able to set the price, currently at least visual examination of the waste material is required. Customer can be asked to send a picture of the materials, if a site visit is not possible. Not only for the price setting, but to be able to advise on delivery and packaging, it is important to identify the materials.

Material identification is essential for production. To be able to define correct treatment for waste, content needs to be known. The biggest value can be achieved if materials are identified in early process steps to enable proper production planning. If waste content is not what expected, it could be that load needs to be temporarily stored in warehouse instead of direct treatment. This will increase storage value. If treatment is not possible as planned, for example because of safety reasons, waste has to be treated in smaller batches, this will affect on treatment schedule and the whole production planning and delay other treatments. Customer can benefit on increased information generated at customer end. When analysing and identifying waste content, customer might get more information on how their production is running. Varying or changing waste content or amount can be detected and process can be checked and adjusted accordingly.

Safety has been pointed as one of the most important topics at RWS, as also hazardous substances are being handled at site. Goal is that everyone can go home healthy after day's work. No doubt that working according to precise information increases safety throughout the whole chain. Starting from customers processes moving on to logistics, reception and treatment at RWS. If there are not enough collection bins at customer end or bins or packages are incorrect, safety issues can occur. For example, there might be leakages or unexpected reactions already at customer site, during transport, at reception or in production. Leakages may contaminate environment or be harmful or even dangerous to humans. Unexpected reactions can cause smoke, fire, chemical reactions causing harmful gases or even explosions. All of these can cause serious physical damage to people, vehicles and equipment.

3. Future

Digitalisation offers a lot of opportunities in the future. Using sensor technology and analysing tools will create possibilities to develop the process more efficient, safe and sustainable. This all will bring value in sense of getting the most out of materials, exceeding customer expectations and being agile in forefront of development.

Good way to start development work with customer would be performing Waste Flow Mapping with case company's experienced sales. Process steps which needs more focus can be identified with WFM and at the same time possibility to use new techniques can be detected. Many of the techniques do already exist and are available, only the price of using them might prevent implementation. Especially when considering waste management, as main thinking often is, just to get rid of the waste with at low cost as possible. That is why it should be further examined which waste streams are valuable enough for new techniques and clearly define the point where the identification should be done. Important part of the examination is to define information flow and how that should be managed.

In metal recycling some new techniques, which will make process easier, more accurate and safer, are taken into use shortly. Radiation detector at gate will ensure that possible radiative materials in loads are found easily and quickly before reception. Some manual work and visual examination can be eliminated with new cable crusher. With the cable crusher waste cables can be separated to different metals and plastic. End products are pure metal granulates. Separation process is faster and more precise and increases the material value.

8 DISCUSSION

As a response to the main question, what value does material identification give, responses confirm, that material identification is essential to production planning and safe handling of waste. Most value can be seen in more precise identification, to assure continuous flow of materials in the process. Responses to sub question about how material identification is currently done at case company, were pre-information from customer, visual examination and laboratory analysis of the received waste. Some of the future techniques are already available, it just needs to be defined for which waste streams these should be tested and taken in to use.

When comparing results of this study with previous study at the case company, similarities can be noticed. Previous study focused on finding sensor technology for measuring the degree of fullness in waste bins. Current study showed that need to also identify the content is important. Similarity would be for example in value for RWS in dynamic pricing, optimising profitability of waste treatment through better control over incoming streams and reduce logistics costs through more optimised planning and collection. For customer, value would come for example from process optimisation to reduce waste, on-demand collection of waste reducing costs, improved quality monitoring and reporting and reduction of overfilled and overflown containers causing safety and environmental hazards.

For researcher, this study deepened the understanding of the field of waste management. It was eye opening to realise how much of the identification is still done by visual examination and regarding own experience in customer service the significance of pre-information from customer became clearer. The work done at RWS is meaningful in regards of treating waste in environmentally sound manner and being a vital part of the circular economy. Further studies are required and investments in automated material identification recommended.

8.1 Methods for identification in the future

There are some companies that offer future technologies for material identification. Here presented a few methods that could be helpful in the future.

ZenRobotics Ltd
ZenRobotics Ltd produces AI-based sorting robots that bring efficiency, accuracy and profitability to recycling. According to ZenRobotics, robotic waste sorting system lower costs, reduce manual labour, increase recycling efficiency and increase the purity of recycled materials. ZenRobotics Recycler sorts valuable raw materials from waste with the

help of robots and advanced machine learning technology. Robotic waste sorting does not require complex waste pre-processing. For optimising performance and throughput, it is recommended to remove fine and clearly oversized objects by screening and distributing the material evenly on the sorting belt to optimise throughput. ZenRobotics is a Finnish company and their first robot is in use at Remeo Finland. Remeo is a waste management company, who wants to increase the efficiency of waste processing with this robotic waste sorting station. (ZenRobotics, 2020)

Enevo
Company started in Finland 2010. Enevos sensors can be added to any type of waste containers, from large, fully underground containers to street litter bins. The sensor can determine fill levels even when the surface is unevenly shaped. The sensors use ultrasonic sonar to monitor the waste levels, this way emptying can be optimised. (Enevo, 2020)

Lehtovuori
CitySolar waste bins have solar energy powered compressor unit. CitySolar is compatible with FinbinCare app. FinbinCare uses mobile technology to inform about emptying need. (Lehtovuori, 2020)

Cyborg grasshoppers
Besides mechanical scent detection, electronic nose and sensor or dog, it is also possible to train insects to detect scents like explosive materials. Cyborg grasshoppers have been engineered to sniff out explosives. New Scientist paper writes about research made at Washington University in Missouri by Barani Raman and his colleagues. Scientist tapped into the olfactory senses of the American grasshopper, to create biological bomb sniffers. Olfactory receptor neurons detect chemical odours in the air. These neurons send electrical signals to a part of the insect brain known as the antennal lobe. Each grasshopper antenna has approximately 50000 of these neurons. By implanting electrodes into the antennal lobes of grasshoppers, the researchers found that different groups of neurons were activated upon exposure to the explosives. When the electrical signals were analysed, it was possible to tell the explosive vapours apart from non-explosives, as well as from each other. Grasshoppers carried tiny, lightweight sensor backpacks, which were able to record and wirelessly transmit the electrical activity of their antennal lobes almost immediately to computer. (Lu, 2020)

8.2 Trustworthiness of the study

Reliability means that the study is objective in the sense that other researchers should reach the same conclusions in the same setting. Research is trustworthy when appropriate methods for the research aim and questions are used. Research is precise in its execution and uses suitable methods for data gathering, analysis and drawing of conclusions. (Karlsson, 2016, p. 31)

Half of the recipients responded to the research. The ones who answered, responded quite quickly. Responses are well aligned, researcher did not see need to get more answers. Comparing the results with previous study responses, they are similar, which enforces the reliability of the results. If more answers would have been received, maybe more examples especially for future techniques could have come up. Questions were only semi-structured to give respondents possibility to answer in that extent they feel like and from their own point of view.

Main findings of the research are presented in this thesis and analysis is made based on the research and theory. Results are founded on respondents' views. If the survey would be conducted the same way, with same specimen of respondents, the results would be similar. But if respondents would be selected from other parts of the organisation, variation in responses could occur. This survey is only valid in this case company. Research results cannot be generalized. Researcher works for case company and this can give deeper knowledge and understanding of current situation and processes. Research concentrates on finding answers for the research questions and research was conducted in a good manner. Results of the study gave answers to all research questions, which makes the study reliable.

8.3 Suggestions for future research

This being such an interesting and versatile subject, there are issues that could be further researched. As a suggestion for future research would be to choose only one waste stream and find solutions for identification. It could be good to benchmark competitor or some other actor in the same field for deeper knowledge about current methods used. To be able to calculate the value more precisely, price information from robots and sensors could be useful. Originally it was planned to have benchmarking also part of this study. Due to current rapidly evolved state of emergency in spring 2020, already agreed visit and interview to a company was postponed. When the visit will be carried out, a separate report of observations will be written.

9 CONCLUSIONS

New technologies are changing the world in fast pace. Waste management is no exception there. To make a real difference in sustainable development, waste management should not be overlooked. Circular economy returns materials to cycle by reuse and recycling. Also circular economy will benefit from enhanced material identification, as material efficiency is increased and processes run sustainably. Energy recovery is a good option for content that cannot be recycled anymore. Safety is an important value also in waste management. A lot of good can be done to the environment, economy and material efficiency without forgetting safety in every step of the process. Case company is in the forefront of development and saving natural resources for a cleaner world. By taking into use the new possibilities technologies offer also for material identification in waste management, company is more likely to maintain the position as leading environmental company in the Nordics and be able to reach out also to other regions. Research with theoretical background and interviews showed, that there is a need to find more automated ways to identify waste components and that would also bring value to company. Value can come from more accurate pricing, enhanced safety and in better production planning and more efficient and sustainable ways to work.

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