

A case study of plastic pipe recycling within Civil Engineering

*Master's Thesis in the master's programme Design and Construction Project
Management*

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EXAMENSARBETE ACEX30

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Gothenburg, Sweden 2020

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Abstract

The basis of this master's thesis is to investigate how recycling of pipe scraps is currently being handled at NCC and also how the whole system for pipe scraps is currently set up. The aim of the study is to compare this system with the models of circular economy in order to investigate if they are compatible, and to analyse what further measures need to be taken so that the recycling of pipe scraps can be improved and further adhere to the principals of circular economy.

In order to acquire information about how NCC is handling pipe scraps today, several interviews have been conducted. Workshops at two different construction sites have been carried out. Attending the workshops were craftsmen, supervisors and subcontractors. To gain further information about how the whole pipe scrap system is set up, interviews have been conducted with pipe manufacturers, and a waste management company. On a separate note, the author of this paper is working at NCC which could increase the risk for blind spots and biased analysis.

The results of the workshops and interviews indicate that the current system for handling plastic pipes is not adhering to the principals of circular economy. The reason for this is:

- 1) Manufacturers cannot produce plastic pipes made from recycled pipe scraps in large enough scale due to material demands.
- 2) There are currently no profitable collection systems that can maintain the material value of plastic pipe scraps.
- 3) Rules and regulation fail to create incentives for recycling and circular business models.
- 4) It is not possible to deploy a green procurement strategy.

NCC and the actors who are involved in the recycling process for plastic pipes could further adopt the principal of circular economy by adhering to activities such as: research on sustainable business models for collecting pipe scraps, research in material technology for plastic pipes, endorsement of collaboration between companies involved in the recycling chain and implementation of new rules and regulations.

Sammanfattning

Målet för detta examensarbete är att undersöka hur återvinning av plaströr för närvarande hanteras på NCC men också att undersöka hur hela systemet för plaströrs återvinning just nu är inrättat. Syftet med studien är också att jämföra detta system med modellerna för cirkulär ekonomi för att se om de är kompatibla men också att analysera vilka ytterligare åtgärder som måste vidtas för att systemet ska följa principerna för cirkulär ekonomi.

För att få information om hur NCC hanterar plaströrs spill genomfördes flera intervjuer, men också två workshops på två olika byggplatser hantverkare, arbetsledare och underleverantörer deltog på workshoppen. För att få ytterligare information om hur hela systemet för plaströrs återvinning är uppbyggt har intervjuer genomförts med rörtillverkare, ett avfallshanteringsföretag och en beställare inom byggsektorn.

Resultaten från workshops och intervjuer påvisar att det nuvarande systemet för hantering av plaströr inte följer principerna för cirkulär ekonomi. Anledningen till detta är att tillverkarna inte kan producera plaströr gjort av återvunnen plast i tillräckligt stor skala på grund av materialkrav, samt att för närvarande finns det inga lönsamma samlingssystem som kan bibehålla värdet på plaströrsspill.

Nuvarande regler och förordningar misslyckas även med att skapa incitament för ökat nyttjande av återvinning och cirkulära affärsmodeller och slutligen är det inte möjligt att implementera grön en upphandlingsstrategi.

NCC och aktörer som är involverade i återvinningsprocessen för plaströr kan underlätta implementationen av cirkulära modeller genom att introducera åtgärder såsom: Undersökning av utformningen för lönsamma affärsmodeller som underlättar insamlingen av rörspill, Forskning i materialteknologi för plaströr, fördjupat samarbete mellan företag som är delaktiga i återvinning av rörspill och implementering av nya lagar och regler.

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1 Introduction

1.1 Background

The research project REPIPE is originally an innovation project that has been funded by the research programme RE: source. RE: source is driven in cooperation by Vinnova, the Swedish Energy Authority and Formas (RE:SOURCE, 2018). The original aim of the project is to investigate the possibility of recycling plastic pipes and profiles in the construction industry by creating new models for collecting, sorting and recycling the pipes (RE:SOURCE, 2018).

The plastic industry has a demand for used plastics with high quality. However, it is a problem to find large amounts of plastics with the right quality. Thus, came the idea of using waste plastics from the construction industry since large amounts are generated in the construction process (RE:SOURCE, 2018). The first step in REPIPE was consequently to do a pilot study investigating the idea mentioned above, while the second step called REPIPE-demo was to do a demonstration project where contractors and other actors in the industry are participating. The REPIPE-demo aims to demonstrate and develop resource- and cost-effective methods for collecting, sorting and recycling plastic pipes. In addition, the REPIPE-projects aims to gain knowledge about incitement and working procedures that could increase the amount of pipes being recycled. NCC is one of the companies participating in the Demonstration project (RE:SOURCE, 2018). This master's thesis is connected to the REPIPE project because it aims to investigate the possibilities for NCC to participate in a demonstration project. The master's thesis will investigate how recycling of plastic pipes can be improved for the whole construction industry which also can be connected to the REPIPE project. The study of the master's thesis in relation to the other research projects can be found in Figure 1.

This report is written with the support of NCC. NCC is a contractor company, mainly operating in Scandinavia with over 17000 employees in Norway, Denmark, Finland and Sweden. NCC is one of the largest contractors in Sweden. NCC has ambitious sustainability goals and are aiming to reduce their CO₂ emissions by 50 % and to recycle 70 % of the waste generated at their construction sites by 2020. (NCC, 2019). This can be tied to one of the 16 Swedish environmental quality objectives which is "a good built environment", as follows.

"cities, towns and other built-up areas must provide a good, healthy living environment and contribute to a good regional and global environment. Natural and cultural assets must be protected and developed. Buildings and amenities must be located and designed in accordance with sound environmental principles and in such a way as to promote sustainable management of land, water and other resources." (Swedish Environmental Protection Agency , 2019)

One way for contractors such as NCC to reduce their CO₂ emissions is to increase their recycling (Islama, o.a., 2019) Taking part in REPIPE is one way for NCC to acquire knowledge on how to reduce their CO₂ emissions by recycling pipes. Thus, it becomes a steppingstone in fulfilling the company's sustainability goals, as well as to contribute to the overall Swedish environmental objectives.

1.2 Research questions

Main research question:

- Can *the current material system* of plastic pipes be compatible with the model(s) of circular economy?

Sub-questions:

- How are the circular economy models described in the literature?
- How is NCC currently handling the recycling process for plastic pipes?
- How could NCC/the industry adopt a circular business model for its uses of plastic pipes?

1.3 Aim and Scope

This study has 3 aims,

1. Recycling of plastic pipes in this report refers to the collection, transport, processing and remanufacturing of plastic pipes scrap. The first aim of this thesis is how the current material system for plastic pipes is set up and how that system can be altered to better fit the models of circular economy. Consequently, a part of this aim is to broadly define what circular economy is.
2. The second aim of the study is to be a pilot study for the demonstration project that NCC is planning to carry out. The demonstration projects aim to investigate the possibility of collecting plastic pipes at one or several of NCC's construction sites for recycling instead of incineration
3. To contribute to a better use of material and to reduce waste within the construction sector

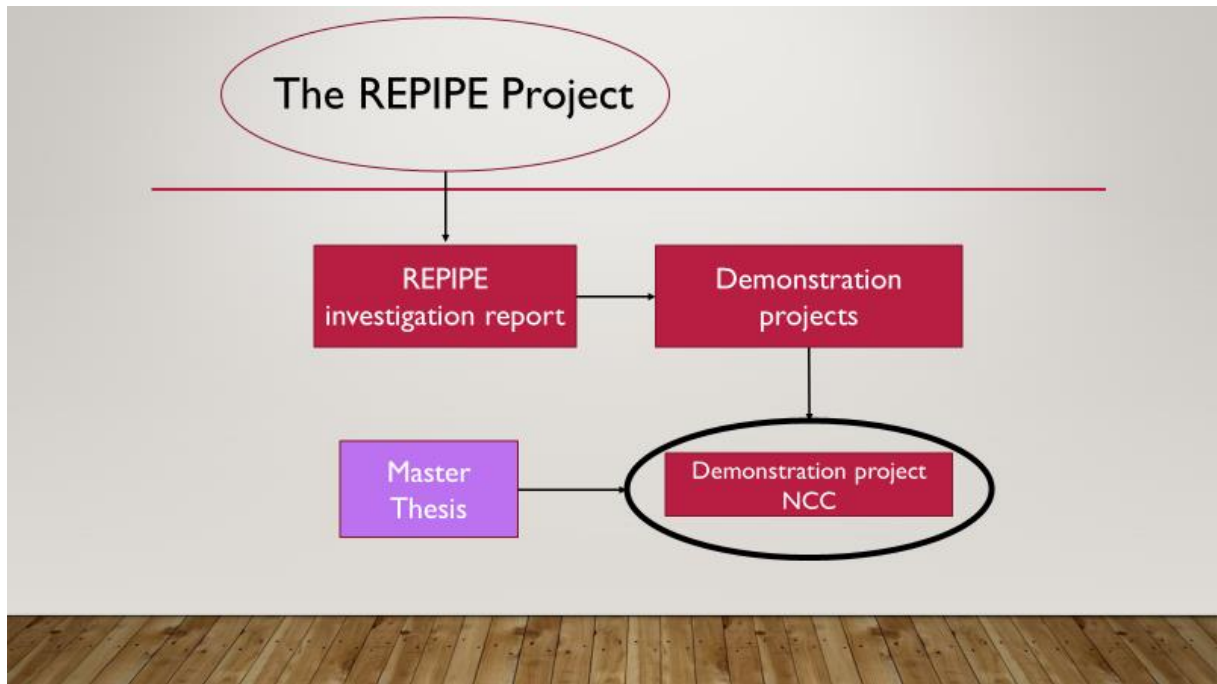


Figure 1 The master thesis Study's investigation in relation to other research projects

2 Research Method

Different types of information are needed to conduct the paper. Information regarding how the plastic pipes are handled on the construction site has been acquired for the study. Information on how different actors within the material system is working with recycling of plastic pipes is also information that has been acquired for the study.

The research method included the following:

1. Two workshops at different NCC projects
2. Interviews with actors within the recycling chain
3. A literature study on circular economy and circular business model

The information gathering process started with planning, forming and conduct of the workshops at the construction sites. After the two workshops had been carried out, the interviews with the different actors concerned were conducted. After all the information from the workshops and interviews had been summarized, the information extracted was then analysed. When the information gathering process was done, the report was lastly written. Below the method for each step in the study is described.

The author of this master's thesis is working part time at NCC. This affects the process of collecting information and the analysis made on the information recovered. For instance, makes it possible to collect information from NCC through informal channels. In addition, since the author is a part of the organization, finding certain information regarding recycling and handling of plastic pipe scrap could be a lot easier.

2.1 Case study

A case study can be defined as an in-depth analysis of a subject, inquiry, method, organization, system or individual. Emphasis lies on that the researcher has taken information from a certain case, processed the information and analysed it. Proper understanding and explanation of the full case and what it entails is a vital step for the researcher in order to make the case study comparable (Juričić & Strmčnik, 2010).

The case study for this master thesis is the pilot study of the research project REPIPE. The research project REPIPE aims to investigate how efficient models for collecting and recycling plastic pipes could be developed. The report generated by the REPIPE project has served as a case study for this master thesis. Three different research reports regarding plastic waste from the construction industry are presented in the REPIPE-demo report. Two the research reports conclude that in Sweden 3,3 kilotons of plastic pipe waste and 1,6 kilotons of plastic profiles waste is generated each year from the construction industry. Furthermore, there is a study of where geographically in Sweden the waste is generated. This analysis is based upon how many residences that are planned to be built and where they should be built in Sweden. The case study is done in order to obtain information about potential blind spots and perspectives that needs to be analysed to gain a complete picture of the issues regarding recycling of plastic pipes. The case study enables analysis and understanding of different perspectives and knowledge about how the current system for recycling plastic pipes is set up. Furthermore, the case study provides information about the stakeholders of the REPIPE

project and their motivation for taking part in the research project. This is also a basis for the system analysis done on the material system of plastic pipes as it provides information regarding potential issues for different stakeholders within the material system. The REPIPE-demo report thus becomes an important source of information for implementing circular economy within the material system.

2.2 REPIPE

In Sweden every year about 100,000 tons of plastic pipes are produced, although 5000 tons of installation scrap is produced as a result of the installation of the pipes. The installation scrap generated is incinerated and thus its energy is recovered instead of being material recovered. If the plastic pipes instead would be recycled about 50 million SEK could be saved each year. Recycling the pipes could also reduce climate impact by reducing emissions by 10 000 tonnes of CO₂ equivalents per year (RE:SOURCE, 2018).

REPIPE is an innovation project that is focused on recycling plastic pipes and profiles mainly from the construction industry. This section will contain further information of the project report generated by RE:source. The aim of the REPIPE-demo project is to find and develop new cost- and resource- effective systems for gathering and recycling pipes from installations in the construction industry (RE:SOURCE, 2018).

The REPIPE report provides an analysis of the current situation regarding the waste that comes from the construction industry, where it is generated geographically, and how it is allocated in the industry. Estimations on the waste from plastic pipes and profiles generated in the industry has been made on previous statistics from research and from interviews with people from the industry (RE:SOURCE, 2018). The analysis shows that the main waste from plastic pipes is generated in southern Sweden, more specifically in the three largest cities, Stockholm, Gothenburg and Malmö (RE:SOURCE, 2018).

Companies that are today working with recycling of material are receiving approximately 75 tons of pipe scraps from construction sites and waste management companies in Sweden each year. After the pipe scraps have been refined, they are sold to pipes producers in Sweden (RE:SOURCE, 2018). Although the companies that are collecting scraps says that only a small portion of the scrap, they get are sent to material recycling. It usually only happens when they get a bigger portion of cleaner fractions of pipe scraps, and then they are often sent to material recycling companies abroad. This means that only a small part of all the pipe scraps that are generated is being recycled as materials each year in Sweden (RE:SOURCE, 2018).

Finally, several interviews have been carried out for the REPIPE report order to investigate how pipe scrap is gathered today and how it could be done more effectively (RE:SOURCE, 2018). One suggestion from the report is to first sort and collect pipe scraps at the construction site. The advantage would be that the pipe scraps would be collected at once and put in the same place, this would be easier for those who are collecting the pipes (RE:SOURCE, 2018).

A disadvantage brought up during interviews is that there is often a lack of space in the material storage area on construction sites and consequently it could be hard to find room for another container. Another possible disadvantage with this idea is that on many construction sites there will not be enough pipe scraps generated to fill an entire container. Thus, the amount of scrap generated at the site would not be profitable for having a container permanently at the site. Some have suggested that it is possible to use waste sacks or smaller waste containers, although some have suggested that the pipes would be too long for smaller containers (RE:SOURCE, 2018).

2.3 Workshops

In order to gather information about the construction site's handling of plastic pipes two workshops have been conducted. The workshops took place at two NCC projects that are handling large amounts of plastic pipes. The first workshop took place in Trollhättan 2019-10-02 and entailed earthworks and replacement of old plastic pipes. The second workshop took place in Ljungskile 2019-10-03, the project entailed earthworks and replacement of plastic pipes. The workshops took about 2 hours each, and approximately 15 persons at each project attended each workshop. Those attending the workshops were craftsmen, supervisors and subcontractors to NCC who were working at the projects. The craftsmen at both workshops was at the time actively working with the replacement of plastic pipes. The workshops were conducted with the help and support of one environmental specialist at NCC and one project manager from Chalmers Teknologkonsulter that are both involved in the REPIPE project.

The role for the author of this paper were design the workshops and to guide the participants through it. The workshops were carried out in order to gather information about how NCC is currently handling pipe scraps on the construction sites and to gain further information about how the current system could change regarding recycling. The most prominent question discussed during the workshop was how NCC could enable an effective collection of plastic pipes scraps and how the company should motivate a change in the current working systems. The workshop was divided into four different exercises where the staff on the construction site interacted with each other in order to discuss problems regarding recycling of plastic pipes at the construction site. In Appendix 8-9 the workshop exercises are presented, as well as notes from the different group discussions at the workshop. The general assumptions and questions discussed are also included in the Appendix.

2.4 Interviews

In order to gain understanding on how plastic pipes are currently being handled at the construction site interviews has been made with Site managers, supervisors and craftsmen that are working on NCC. Since the author of this master's thesis was working part time at NCC, the process of contacting employees at NCC working on the construction site was smooth. Working at NCC also enabled the author to extract the information in a less formal way, since it was possible to also interact via discussion and not only by formal interviews.

Interviews are a good way to gain further knowledge on a research topic by accessing people's views, perceptions, experiences and actions (Zhang & Wildemurth, 2017). In this report, the interviews have been mostly unstructured (view appendix 1-7). This means that the interviews carried out in this paper have not contained any predetermined questions or answers. The questions posed in the interviews have been fairly open ended. This was done in order to gain a fuller picture of the problem and a wider range of knowledge. One of the advantages of unstructured interviews is that it enables extraction of in-depth knowledge of a phenomenon without a context (Zhang & Wildemurth, 2017). The questions for the interviews were made in such a way so that a discussion could occur. Structured interviews could potentially have hindered maximum extraction of information of the topic research in this report. Therefore, the author deemed that the most appropriate way to extract information was through unstructured interviews.

Since the author of the paper was at the time was working at NCC, the interviews that were done with NCC employees were less formal, and thus the questions posed in those interviews were also more informal.

The interviewees selected had different roles in order to obtain nuanced information and a broad spectrum of knowledge for the study. The knowledge obtained is focused on how the plastic scrap waste is handled at the construction sites and how improvement can be made in collection the scraps. Picking interviewees with different roles enables a broader picture of the problems studied and mitigates the chances to miss important facts and perspectives. These interviews made it possible to map current issues regarding recycling of plastic pipes connected to the construction site. Figure 2 illustrates the numbers of interviews and who the interviewees are.

Interviews with a waste management company and two different manufacturers of plastic pipes have been made in order to gather information about issues connected to other stakeholders who are involved in the recycling process. In total, interviews with representatives from two different manufacturing companies, one waste management company and four different representatives from NCC were conducted. The interviews and interviewees were chosen on the basis that a full picture of the problem was needed as well as knowledge and perspective from all actors connected to the issues analysed. These interviews enabled mapping of actors connected to the current material system of plastic pipes and to identify potential bottle necks and issues that could arise within the system. The length of the interviews varied from 20-40 minutes. The full interviews can be found in appendix 1-7.

Interviewee	Supervisor NCC	Craftsmen NCC	Project Manager NCC	Waste Management Company	Manufacturer 1	Manufacturer 2
Number of interviews	1	2	1	1	1	1

Figure 2: number of interviewers and types of interviewees

2.5 Literature study

A literature study about circular economy and circular business models has been conducted. Information to the literature study was gathered from research papers. The research papers were typically found by using google scholar, using key words such as circular economy, circular business models, recycling of plastics. This was done in order to analyse vital data from the literature and to be able to compare the models of circular economy to that of the current general material system of plastics pipes. The literature study describes typical traits of circular economy and circular business models, its strengths and weaknesses, but also typical activities that can be implemented to further transit from the current economic system into a more sustainable circular system.

The literature study also contains information about plastic as a material system. What characterises it, how it is set up and how recycling and reuse is currently functioning within the plastic system. This is done in order to get a general overview of how the system works, but also to compare it with the literature on the circular economy and the current material system of plastic pipe.

2.6 Trustworthiness and Limitations

This master's thesis has some limitations in order to narrow the information extracted and to make the study more comprehensible. The study will only investigate plastic pipes in earthworks and civil engineering projects at NCC. The study will not investigate recycling technologies and technical bases on material technology for increasing recycling. Furthermore, plastic pipes from housing installations have not been considered in this master's thesis.

The results of the study are trustworthy in the sense that the main information extraction has been made from interviews and workshops. The interviewees have been picked by the author of this master's thesis because of their relevant competencies and their knowledge about issues connected to handling plastic pipes and pipe scraps. When doing qualitative research, reliability is one of the main factors to consider in order to ensure the quality of the information gathered and the results derived from it. Reliability can be defined as "The extent to which results are consistent over time and accurate". Consequently, trustworthiness is an important part in ensuring reliability in research and therefore also ensuring the quality of the research. Without trustworthiness it is hard to achieve reliability. (Golafshani, 2003)

The workshops were done with participants that on a daily basis on the construction site handled plastic pipes and thus they are deemed as competent and knowledgeable in issues regarding plastic pipes. The results from this study could therefore be deemed as trustworthy since the main information extraction has been made from people with knowledge and competence about the main issues analysed.

The author of this master's thesis is working at NCC during the time of the conduct of the report. This fact is important, as it affects trustworthiness in the results as well as how the results are interpreted. Being part of NCC while conducting research with the company at the same time gives opportunity for participant observation.

The information obtained in research by the author could be more nuanced since the author has access to more informal information channels that otherwise would be closed. The author also has access to a more in-depth view of the corporate culture at NCC which could increase the understanding of the context of the information obtained and also provide further understanding of the researching problems (Mack, Woodsong, M.Macqueen, Guest, & Namey, 2011). However, being a participant observer also entails some disadvantages. Being a participating observer, it might become difficult to stay completely unbiased. The author must be mindful when collecting data and doing the analysis so that the research stays objective. One of the risks is that the author unknowingly is subjective in his analysis. (Mack, Woodsong, M.Macqueen, Guest, & Namey, 2011)

2.7 Ethical and sustainability considerations/contribution

This master's thesis focus is recycling of plastics pipes and connecting the recycling process to models of circular economy. The master's thesis has its main focus towards recycling and circular economy which is closely connected to sustainability. Thus, the research done in this master's thesis is contributing to sustainable development. Recycling and the reuse of materials is one of the measures that greatly can reduce carbon emissions from heavy industries and are therefore important activities to consider for sustainable development (Material Economics, 2018).

Plastics are one of the materials greatly used in society which contribute to carbon emissions. Material recirculation of plastic is therefore an important measure that could be taken in order mitigate climate change. Plastics are also one of the materials that have a large potential to become circular since the recycling rate of plastics today is fairly low. (Material Economics, 2018). It is evident that finding more pathways towards circular economy and material recirculation is increasingly important to mitigate climate change.

The focus and research of this master's thesis is in alignment with the relevant measures for mitigating environmental impact from the plastic material system. As one of the main goals is to investigate the current material system for plastics, hopefully the results uncovered can help promote sustainable development in the plastic material system.

One of the main reasons NCC is a part of the REPIPE project is to be able improve their own sustainable development. Research projects is one way for NCC to lower their own environmental impacts, thus it becomes an important part in reaching their own sustainability goals.

4 Literature review

4.1 Linear Economy, Circular Economy and the Circular Business Models

This section will review the three main topics of the literature study which are Linear economy, Circular economy and Circular business models

4.1.1 Linear and Circular Economy

Our current economic system can be viewed from two different perspectives: linear or circular. The linear economy is based on the idea of turning raw natural resources into products and goods through a value adding process. (Stahel, 2016). The linear model adheres to principals such as extracting natural resources, manufacturing and disposing of the waste (Sheposh, 2017).

The principal of linear economy can be referred to as the take-make and dispose principal where companies takes the resources they need, makes products of these resources to be sold and then disposing of every biproducts from manufacturing that the company does not need (Sariatli, 2017). The consequence of the linear economy is a system that neglects recycling, reuse and the management of waste. This system has made manufacturers oblivious of the responsibilities they have towards the external costs on the ecosystems made by their operations. (Sariatli, 2017).

A circular economy is concentrated towards measures that are reducing and eliminating waste. Circular economy has the potential to minimize waste through the recycling of goods and the closing of loops in the industrial ecosystem. The model of circular economy could change the way companies treat material and resources. Careful management of resources through reuse, repair and remanufacture would be a common feature in the business model of companies that adheres to circular economy (Stahel, 2016). Typical activities in the circular economy are described in figure 2.

The strength of the circular economy as a system is that incorporation of the system would yield higher incitements for research and development in material science towards products that are more durable with higher quality and has a longer life cycle (Sariatli, 2017) . Profitability for manufacturing of goods could increase as waste is eliminated from the material chain which would lower dependency of resources and reduce material costs. Companies adhering to circular economy could also gain a competitive advantage as they become more cunning at handling recycling. (Sariatli, 2017). Studies shows that a shift to circular economy could reduce a country's greenhouse gas emission by up to 70 % and potentially increase its workforce by up to four procent. (Stahel, 2016). Furthermore, a circular economy could reduce the consumption of new material by 32 % within 15 years. (Esposito, Tse, & Soufani, 2018)

Although the system comes with its weaknesses. Investments done in a circular economy has not been enough to encourage trust in the system. Laws and regulation connected to circular economy and its application has not yet been implemented. Furthermore, The idea of circular economy has not yet been widely accepted in public and private agencies therefore it could take time before the models gain favour in the eyes of the public (Sariatli, 2017).

However, it is also important to take note of that the models for circular economy won't always lead to sustainable outcomes, changing to a circular economy comes with its issues (Friege & De man, 2016). For example, it could cost tremendous amounts of energy to maintain material and waste in a closed loop through recycling. Furthermore, development in human technology will always facilitate the production of new goods and products. With this development comes new materials and substances that could be potentially harmful for the environment. Feeding the ecosphere with new pollutants will require new measures to take care of these. Consequently, there is a need to consider multiple strategies in order to mitigate the environmental impact caused by the current economic system and the transition to a more sustainable economic system. (Friege & De man, 2016)

Stakeholders who are involved in a transition to a circular economy are companies such as manufacturers, designers, waste management companies, construction companies and investors. Policy makers such as government, local and regional authorities are also involved in the transition to a circular economy. Consumers and users are a big group of stakeholders that can affect the transition to a circular economy. (Houston, Casazza, Briguglio, & Spiteri, 2019)

Some of the barriers for transformation to a circular economy connected to stakeholders are having tendering based on the lowest price instead of green procurements, rewarding linear products rather than circular ones. Reaching high enough demands for recycling and reprocessing goods so that there can exist a "green market" is a challenge. Not understanding the costs of not transcending to a circular economy and a lack of understanding of the concept of circularity and its benefits are also barriers to consider. Lastly resistance to change in business culture are also challenges for the stakeholders as they have to change the way they way resources (Houston, Casazza, Briguglio, & Spiteri, 2019). Below is a figure that shows a comparison between the linear and circular model.

Factors	Linear Economy	Circular Economy
Actors	Consumers, Investors, resource companies, authorities, governments	Manufacturers, waste management companies, construction companies, investors
Traits/actions	Take, make, use, dispose, pollute	Recycle, make, reuse, remake, remanufacture
System boundaries	Short term, from purchase to sale	Long term, multiple Life cycles
Who profits from it	Short term investors, Companies who profit from short-term . Conservative businesses, Businesses where products have a more "linear" design	Long term investors, markets where reuse and remanufacture is integrated in the business. Markets where products have a "circular" design
Responsibilities	Responsibility ends when the product have been discarded or turned into waste	Responsibility is ever shifting from different actors

Figure 3: Comparison of linear and circular economy, made by the author using information from different research papers

4.1.2 Circular business models

The circular business models are based on recirculation of material and a value stable system that mitigates value loss of materials in the system. Other traits are the development of business models, materials and products that reduces waste by maintaining the maximum value in the material system. The circular business model adheres to processes such as reduce, reuse and recycling. For instance, recycling of materials, reuse of products and reduction of natural resources abstracted from the natural ecosystem (Sheposh, 2017)

Circular business models can be divided into two groups: reuse and recycling. Reuse promotes activities that can extend the life cycle of products. Such activities are reparation, upgrades and retrofits. Recycling on the other hand focuses more on turning waste into new material and goods (Stahel, 2016). But there also those that foster both recycling, reuse and elimination of waste by designing products that facilitates recycling or reuse (Siew, 2019).

There are several circular business models (Haupt, Vadenbo, & Hellweg, 2017) that focuses on increasing the lifespan of products similar to the reuse model. What these

models have in common is that they all focus on activities such as upgrading, refilling, repairing and increasing durability of products (Esposito, Tse, & Soufani, 2018). Circular supply chain is a business model that focuses on substituting linear products with material that can be recycled or reused. The circular supply chain model focuses on taking materials from products that are being manufactured in large scales and replacing it with more renewable sources of material (Esposito, Tse, & Soufani, 2018).

Other studies suggest that a circular business model can be built upon business activities that are generating circular business opportunities. Such activities could be to use more renewable energy and materials. Another circular business model is shared action which aims to increase the utilization of products by having systems that facilitates sharing of goods and products. Optimizations emphasizes the development of performance and efficiency of products and the removal of waste in the manufacturing process. Finally, *Looped actions* aims at closing the loops in which material and components are confined in. (Lewandowski, 2016).

4.1.3 Enablers for circular economy

The circular economy is a system that could provide several advantages concerning management of waste and recycling of resources. The system could provide profitable business models that are less harmful for the environment. Although a transition to the circular economy also entails problems that needs to be dealt with (Sariatli, 2017).

It is questionable if information and knowledge of circular economy has been obtained within public agencies and governments. Consequently, there are still measures that can be taken in order to integrate circular business models in the current economic system. (Sariatli, 2017) For a circular economy to be realized there are several steps that are deemed necessary in order to incorporate it in the current economic system (Stahel, 2016).

To enable circular economy, it is important to develop materials that are recyclable, has lower toxicity and better fits the circular business models. Material development can be increased by embedding recycling and circularity in the design process. This would facilitate the process of eliminating waste altogether from the material life cycle (Esposito, Tse, & Soufani, 2018).

The elimination of waste in the product life cycle can be achieved by adhering to circular principals in the design process. Designing products that are better adapted to reusability and circulation, meaning designing products that can be recycled or reused. One way to favour design that facilitates recycling is to have procurements strategies that takes waste into consideration. A waste efficient procurement strategy would entail that designers made analysis of the potential waste that could occur in the life-cycle of the product (Esposito, Tse, & Soufani, 2018). Designing for recycling could enable access to products that are cheaper and better fits the system of circular economy (Sariatli, 2017).

Further research and development is needed to further persuade public opinion and governments of the feasibility of circular economy. Although it is important to use

communication and information methods to be able to enlighten manufacturers of their responsibility towards the environmental impacts that is caused by the manufacturing of their products. For example, media could be used to spread information of the environmental impacts from manufacturing (Stahel, 2016). In order to develop business opportunities related to circular economy it is of importance to develop expertise related to circular economy that can be used in legal, operational, mechanical or cross sector challenges (Sariatli, 2017).

There is a need to introduce policies that promotes activities favouring circular economy and punishes those activities that are adhering to the linear economy, For example, consumption of goods that are non-renewable (Stahel, 2016). There are two main policy strategies that can be made in order to accelerate the use of circular business models, which is to fix current market and regulatory failures that hinders circular business activities instead of promoting them. The second strategy is stimulation of the market by changing public procurement policies, create company collaborations and provide technical or financial support towards circular business models (Lewandowski, 2016). In addition, Green procurement can act as way to encourage environmental responsibility when it is used in in public procurement (Varnäs, Balfors, & Faith-Ell, 2007).

In order to incorporate the ides of circular economy into to the current industries and markets it is of importance that reuse, and recycling of waste is continuously increased. An increase in reuse and recycling will then facilitate the idea of circular economy as being profitable and less harmless for the environment. (Sariatli, 2017). Although in order to increase recycling and reuse it is of importance that companies reevaluate the way they think about resources and materials. For instance, companies need to rethink how products and services are offered, more emphasis need to be put on recovering secondary material, and design of products need to consider end of life-recycling and for reuse. Strategies in resource sourcing and design needs to be implemented to achieve this (Esposito, Tse, & Soufani, 2018).

RR (recycling rates) is also a useful tool for enabling a circular economy. Recycling rates could be used to measure the performance of the economy in terms of circularity. Basically, recycling rates are the total amount of a certain type of waste that is recycled in a material system (Haupt, Vadenbo, & Hellweg, 2017). However, it is important to differ between waste that is recycled in an open loop and a closed loop. Open loop recycling gives opportunity for the waste to be recycled into a wide spectrum of different materials and gives a higher recycled yield. Although this also encompasses downgrading in the quality of the material as it is adapted to a new product rather than staying in the loop for the original application. The closed loop recycling does not give the same high yield of recycled waste but as the material is maintained in a closed loop it gives opportunity through better recycling methods to preserve the quality of the materials. But a closed loop requires that the materials recycled are used in the same applications, hence the lowered recycling yield (Haupt, Vadenbo, & Hellweg, 2017).

Clients in the construction industry have a prominent role to play in the transition towards a circular economy as well. For example clients can help to further adopt

circularity in the construction industry by setting high standards for innovations and collaboration in construction projects (Adams, Osmani, Thorpe, & Hobbs, 2017). Other actors within the construction industry such as designers, manufacturers, contractors request clearer visions, guidelines and demands for sustainability. However, clients usually don't see this as a big problem. In order to enable clients to make the step towards a more circular economy and more sustainable construction projects, support from all the actors within the construction industry is needed (Adams, Osmani, Thorpe, & Hobbs, 2017). Support in the form of implementation of new business modes and technical innovations is needed in order to enable clients to make the transition to a circular economy (Adams, Osmani, Thorpe, & Hobbs, 2017).

CLOSING LOOPS

Using resources for the longest time possible could cut some nations' emissions by up to 70%. Increase their workforces by 4% and greatly lessen waste.

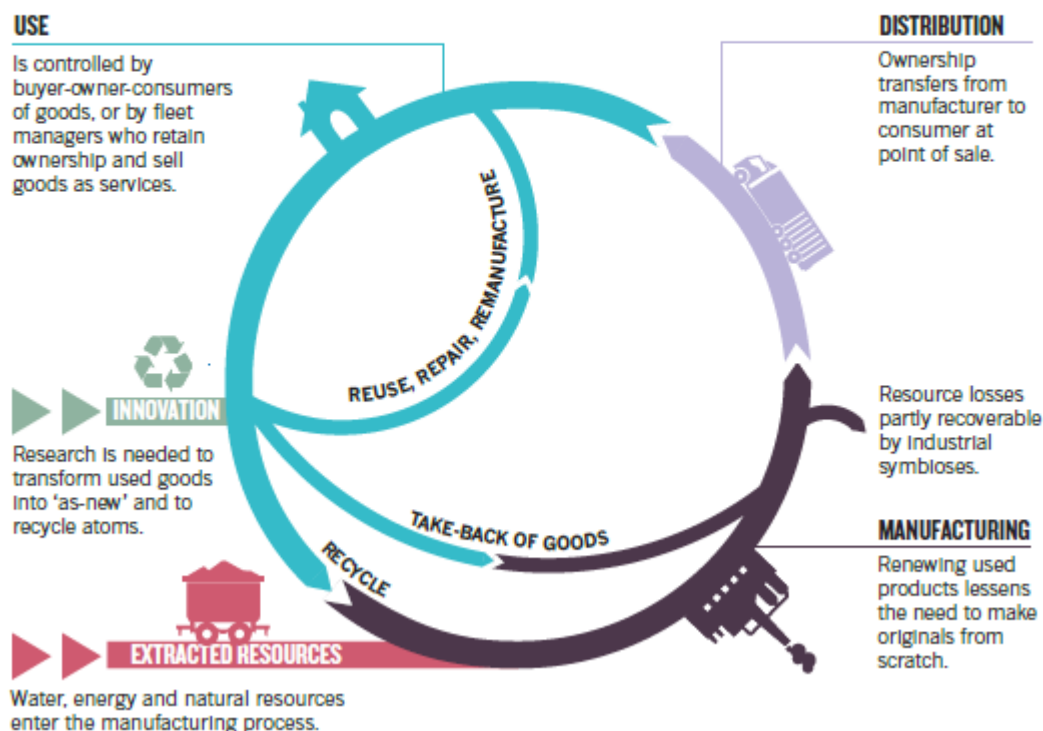


Figure 4 Natural resource entering the manufacturing process (Stahel, 2016)

4.2 Plastic as a material system: Flaws and Opportunities

The report "a value stable Swedish material system" (*Ett värde beständigt svenskt material system*) from material economics addresses some of the problems regarding

recycling plastics in Sweden (Material Economics, 2018). One of the main problems being that plastics is losing some of its original value when it is being used in the material chain. There are a lot of different phases in the material system where plastic can lose its value. For example, the construction industry are missing collection and recycling system that can maintain the value of plastics. (Material Economics, 2018). Recycling system for PVC plastics could give a high yield of recycled plastics in the construction industry, considering that such recycling systems has given good results in Denmark and Germany. PS-plastics could also be recycled if such systems were implemented in the construction industry (Material Economics, 2018).

Another problem is that of small flows. The flows plastics plastic waste are often smaller than those flows that characterize primary plastic production this means that economies of scale that could reduce costs are not realized (Material Economics, 2018). Current standard demolishing processes in construction are today excluding a recycling process. There are none or very little plastic that are being recycled from the construction industry when building are being demolished (Material Economics, 2018).

Furthermore the Recycling companies don't see that the demands for recycled plastics is high enough at the same time as the demand that exists are not met by the plastic that is recycled by the industry (Material Economics, 2018). The market for recycled plastics has reached a catch 22-phase where the companies that are producing products from recycled plastics says that they can't procure enough recycled plastics that has the right quality. At the same time as the companies that provides the recycled plastic emphasises that the demand for recycled plastics is too low or the incentive to pay more for higher quality plastic is too low. Meaning there is today a hidden demand for recycled plastics that is not fulfilled (Material Economics, 2018).

Regulations have for a long period of time steered the waste process towards incineration of the plastics rather than recycling. Energy recycling through incineration have been an effective way of handling plastics. From sanitary perspective and economically it has been effective to incinerate the waste since energy produced from burning the plastics have been used as a energy source for district heating (Material Economics, 2018). The rules and regulations on the market have not yet been fully adapted towards the use of recycled plastics. This becomes evident when looking at how the market is designed. There are for example limitation on trade with secondary plastics. Today the secondary plastics has high demands of traceability and they are sometimes classified as dangerous material, this in combination makes it hard to have a broad use of the plastics in the industry. These laws and regulations have often been implemented for the management of waste in the industry, but often becomes obstacles when the goal is to produce new materials from the waste (Material Economics, 2018).

The reason for that the material system in Sweden is not adapted to recycling is that the market fails to create incentive for recycling and actors within the market has a more "linear" view then "circular". The companies that are producing materials for society often have none or little incentives to create products that are adapted for recycling or/and could maintain its material value throughout its life-cycle (Material Economics, 2018). Negative effects on the environment are not considered, such as CO₂ emissions

and future material quality decline. These need to be priced in order for the circular economy to be made more accessible (Material Economics, 2018). These are some examples of the current flaws the market has regarding incentive structures. There are several different aspects to work with in order to increase recycling for products. Material value loss is occurring in several places along the material chain but the current laws and legislations could also be improved in order to mitigate value loss in the material chain (Material Economics, 2018).

5 Empirical Material

In the following section data will be presented from the interviews and workshops. All the information will then be analysed and processed in chapter 5 discussion. The information presented from the workshops and interviews has been shortened and summarized in order to present the most relevant information. Explanation of the whole workshop can be found in appendix 8-9 and the interviews can be found in appendix 1-7.

The result section is divided into 3 subjects that were most prominent during the interviews and workshops. The subjects are the following:

1. Waste generation, Collection models and profitability
2. Rules, regulations and procurement strategies
3. Material specification for pipes

The information that concluded to these subjects was derived from

1. Workshops at NCC's construction site
2. Interviews with craftsmen, site managers and project managers at NCC
3. Interviews with two different employees at a waste management company
4. Interviews with two different manufactures of plastic pipes

5.1 Waste generation, Collecting models and profitability

In the current section results connected to waste generation, collecting models and profitability are presented.

5.1.1 Waste generation and origin of plastic pipe scrap

At both workshops the staff on the construction sites agreed that scrap from plastic pipes is generated at four different stages in the material chain, these stages can be seen in figure number 5. Firstly, the pipes could already be damaged when delivered to the construction site. In those cases that would often render them useless and they cannot be used for installation and will thus be thrown into the combustible container. The second source of pipe scraps is when the pipes are being stored in the material area, scrap is generated here because the material is worn down by the weather, for example the sun could cause the pipes becoming bent or the cold at winter could make the pipes frail, in either case they cannot be installed and are thus considered pipe scraps.

The third source of scrap is when the pipes are being installed. In order to make the pipes fit for wells, and branches the pipes are cut in different lengths, some of the pipe being cut will have very small lengths, under 1 meter. These pipes are considered too small to use for installation and are thus considered pipe scraps. Finally, there is scrap generated from the left-over material from the installation, these pipes are usually saved as backup material for the current project or the next one, but due to regulations and structures in the construction industry they usually end up being thrown away into the combustible container.

According to the staff working on the construction site who was interviewed, pipe scraps are mostly generated when pipes are being cut in order for them to fit in the

section they are going to be placed into. Although only very small amounts of waste are generated, because a large portion of the pipes that have been cut are saved as back-up material on the construction site. The pipe pieces that do end up being thrown away are usually very small (under 20-30 cm), these smaller pipe scraps are thrown in the combustible container.

The consequence of how the pipes were handled on the construction site is that a waste container containing only scrap from plastic pipes would be hard to fill and therefore it is more profitable to throw the scraps into the combustible container. Waste from pipes can be generated at the delivery of the pipes due to the pipes being damaged when they are delivered. Storage of the pipes is another source of waste since the pipes can become damaged depending on how they are stored and under which conditions they are stored. Disconnecting and digging up old pipes that are no longer in service was a source of waste considered in the interviews. However, these were deemed as minor sources of waste at the construction site and the main source of waste according the interviewees are still when the pipes are being installed. The waste sources and where they are generated are illustrated in figure 5 and 6.

The leftover material from the installation process usually ends up in a “scrap heap” at the project’s storage area, as back up material should the need arise to use them again. As the projects moves forward the scrap heaps grows as more installation are done. Finally, when the project is over the scrap heap is usually sent as back up material to the next project. The scrap heap grows, and it continues to the next project until finally when the site managers thinks that the scrap heap is abundant and decides that all of the reserve pipes should be thrown into the combustible container. Sometimes the pipes that have not been used are sent back to the supplier enabling the contractor to get some of the money paid back. Although in that case the contractor themselves are responsible for delivering the pipes to the supplier. The pipes discussed at the workshop were foremost made of PE-plastics and PVC-plastics. The suppliers of the pipes were usually one or two big pipe manufacturers or a material supplying company that buys the pipe from manufactures and then sells them to the contractors.

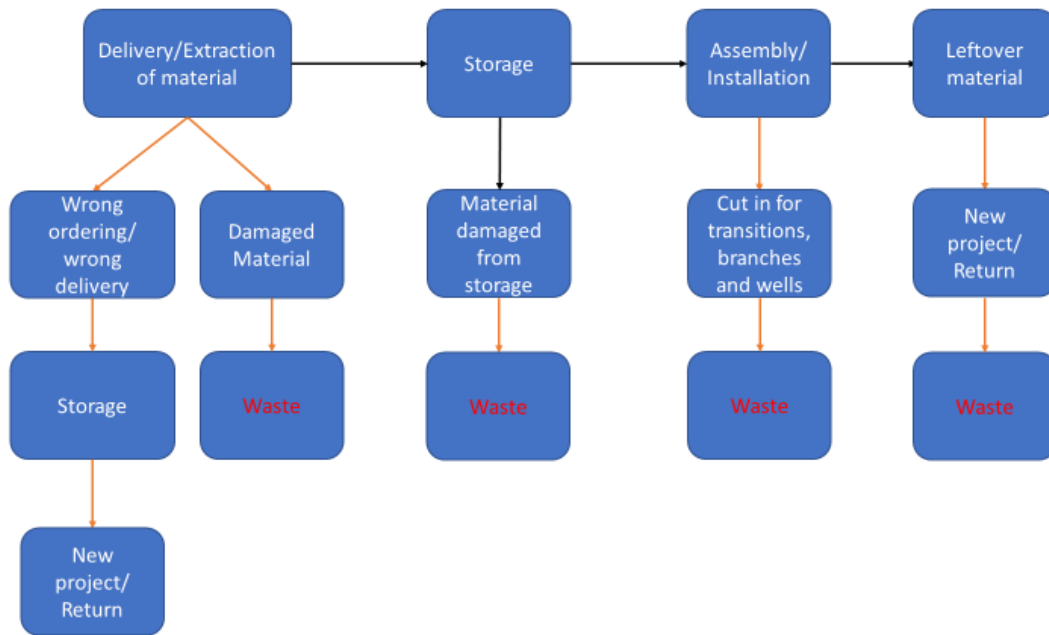


Figure 5 Flowchart for pipes on the construction site: Scenario 1 Generation of pipe scraps on the construction site. Constructed by information from interviews

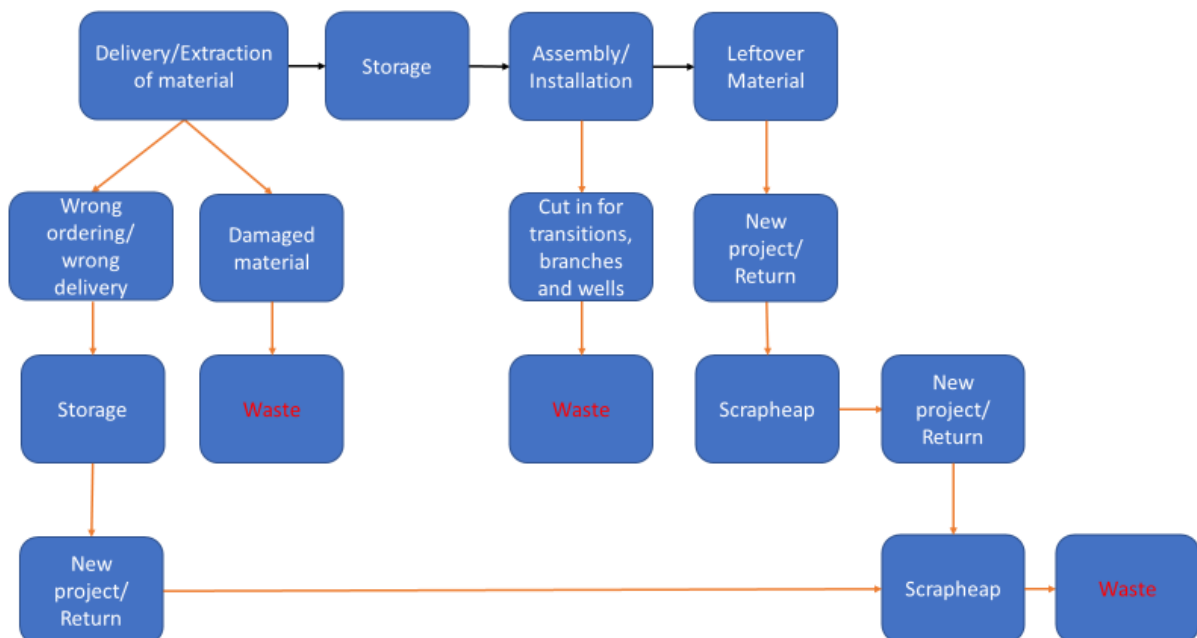


Figure 6 Flowchart for pipes on the construction site: Scenario 2 Generation of pipe scraps on the construction site with scrap heaps. Constructed by information from interviews

5.1.2 Obstacles and solutions for collecting plastic scrap

The first exercise at the workshop identified where the waste was generated. In the second and third exercise at the workshop, several obstacles for collection of pipes were identified, and several solutions and ideas on how to increase collection of pipe scraps at the construction site. Typical obstacles that brought up were that there was usually a shortage of space on the construction site and that having another container for waste could be hard considering that space is already in such a hard demand at the construction site. However, several solutions to this obstacle was also brought up during the workshops. One such solutions could be to use the wood containers that the pipes are being delivered in and use them as a collection vessel for the pipe scraps in order to save space. Other methods for saving space could be to use old pallets collars to store pipe scraps in,

Another obstacle that was identified was the amount of pipe scraps that were generated at the different projects. On some projects there were larger amounts of pipe scraps generated, enough to fill an entire container, but on other projects the amounts were considerable smaller. This means that different projects might need different solutions regarding how the scrap should be collected since they all generate different amounts of scrap. A solution identified for smaller project, with smaller amounts of pipe scraps was to have one-time collections at the construction site. The waste management company would then only come and collect the pipe scrap when enough of it has been collected. Waiting to collect the pipe scraps when higher amounts have been collected could be more profitable and thus an alternative to having a container. Although an alternative storage method would be needed for the pipe scraps at the smaller project if a container is not used.

In the fourth and last exercise at the workshop the participants discussed how a change in the current working procedures should be motivated in order to increase collection of pipe scraps at the construction site. One idea was to have clear goals for each project regarding how much scrap that is collected and recycled compared to the total amount that is generated. For example, setting the goal that the project should collect and sell 80 % of its pipe scraps each month. Other ideas were to make the whole project more aware of the recycling process and how their parts in recycling chain created value for projects and more knowledge about the impact from recycling on the environment.

The interviewees from NCC did not think that motivating craftsmen to start sorting pipes scrap on the construction site would be a problem, as long as the craftsmen have a clear directive of how the sorting process should work. The most pressing issues connected to collecting pipe scraps for recycling at the construction site identified by the interviewees were that of space and profitability. Space at the storage area is usually an issue for most projects, space is almost always in shortage at the storage area, thus the idea of having another container for sorting plastic waste is possibly not that appealing for most site managers.

5.1.3 Profitability in collection pipe scraps

Profitability was brought up as an important factor during the workshops. The staff at the construction sites emphasized that in order for the collection of pipe scraps to be motivated there has to exist a system that is profitable for the project. Here the solutions regarding storage of the pipe scraps and collection from the construction site by the waste companies were important factors to consider according to the staff at the construction site. The cost for having containers to store the pipes scraps was one factor discussed that could affect the profitability.

Another factor discussed was how the current system for handling pipe scraps was set up. If there are no demands in the industry for recycled pipes there is little profitability in collection pipe scraps and selling it to the waste collections companies. Premium for new pipes in new projects makes it harder to use old pipes and they are thus more likely to be thrown into the combustible container. The reason for this is that the contract often stipulates in new projects that new materials bought for the project shall include a profit margin. Using old pipes would neglect this profit margin.

Profitability of collecting the pipes scrap and then sending it to the waste management companies is a problem that was brought up during the interviews. The reason that a profitable solution is hard to find is that the scrap generated at the site is not enough to fill an entire waste container according to the interviewees. Each container sent for waste collection at the construction site costs rent each month, and for it to be profitable to have those containers they have to be filled with enough waste, and they have to be filled quickly enough. This is not the case with the pipe scraps generated at the construction's sites.

According to the representatives from the waste management company, the biggest obstacle to collecting more plastic and plastic pipes from the construction site is that of profitability. When pipe scraps are transported, they take up big volumes. In order for the waste management company to have a profitable operation for collecting pipe scraps from construction sites they need a solid logistics system. This means that the container that they transport from the construction sites needs to be filled to maximum, otherwise it would lower profitability. Unfortunately, the pipe scrap takes up big volumes of space in the same time as they are fairly light. This lowers the profitability for the waste management company since they have to maximize the weight for each transport in order to make it profitable to collect the waste.

Another issue that is affecting the profitability is that of different types of plastics. If the waste management companies collect plastic pipes of different types for instance PP or PVC, they need to sort the plastic out in order to further refine it or sell it. This lowers profitability of collecting the pipe scraps since the collector then need to spend resources on sorting the material. So, it is ideal that the material is already sorted when the waste management company comes and collect it.

In order to address these issues, the waste management company is constantly trying to develop their business and making their organization more efficient in terms of transportation and logistics. One of their most important tools for development is trying

new idea with their customers and trying to learn from the different project they are involved in about how they can develop their organizations.

5.2 Rules, regulations and procurement strategies

In this section, information about how the current rules and regulations are affecting sustainable development of pipe scraps handling is presented. The information in this section is mainly derived from interviews with the waste management company and manufacturers

5.2.1 Rules and regulations within construction and the plastic industry

In order for the waste management company to influence clients and contractors to use more renewable materials in the construction process, the waste management company emphasize that they can work with material/waste specifications. If the company wants to resell the waste that they have collected there are sometimes some material standards that they need to fulfil. In order for the contractors and clients to understand how the waste is losing its value it is important that the waste management company is open and transparent with the contractors. The waste management company has to communicate the material standards to the contractors. This could ensure that the waste is handled in such a way, so it does not lose value in the recycling process.

Furthermore, they emphasize the responsibility and risks when it comes to increasing the recycling of plastic and plastic pipes in the construction industries. The risks have to be allocated and spread out to all the different actors in the industry through regulations if recycling is to be increased. Therefore, it is important that every actor has an open communication about what is needed for them in order to increase the recycling. It is crucial for the plastic to maintain its value throughout the material chain that all the actors in the industry are working together towards the same goal.

The manufacturers that were interviewed stated that in order to increase the recycling of plastics there needs to exist financial incentives to do so, since the market is driven by profitability. If plastic recycling should be made more profitable it is beneficial to introduce the market to financial incentives that would steer the market towards recycling the plastic and the pipes rather than burning them up. Such financial incentives could be laws and regulations/taxes, for example taxes on burning plastics would help maintain the value of the plastics throughout the material chain according to one of the manufacturers. The manufacturers also emphasize that when new ways of working are introduced into such a large system it is important that the cost for such a system change is evenly distributed among the actors within the system, in this case the plastic pipe industry.

5.2.2 Procurement strategies

According to the waste management company, one possible way of putting pressure on clients and contractors to use more recycled material would be to promote recycled materials in the contract of the construction projects as this would probably increase the

demand for recycled materials and recycled products. Although there is still the problem of the client needing to fulfil some material requirements for the products, they are using that could make a larger use of recycled material difficult.

However, the manufacturers emphasized that using recycled material/products in the procurement process could be problematic since the manufacturers and contractors still have to adhere to the material specifications. For example, if more secondary plastics were to be incorporated into the pipes and this made the life span shorter, for example 50 years instead of 100 years. Then this measure could be counterproductive from a sustainable perspective since the pipes then gets a shorter life cycle.

5.3 Material specification/demands for plastic pipes

In this section, information connected to material specification on pipes are presented. This information is derived from the interviews with the manufacturers.

According to the manufacturers, the biggest issue for increasing products/pipes with recycled plastics is the material demands placed on the products that they are selling. In this case the customers (often the contractors) do not check if the product they are buying are made of recycled material. What the contractors are looking for is if the materials they is using meets the material specifications and demands. The current material standards demand high quality, solidity and life span of the pipes, but demands for circularity are not included in the standards. The contractor is responsible for that the material that they use has the right quality, thus this is what is most important for them to check.

Most plastic pipes used in the construction process have high material demands. For instance, water pipes have quite high material demands since they need to last for 100-150 years and thus, they need to have high durability. This makes pipes made from recycled plastics unsuitable to be used in most pipe applications since with the current technology they do not meet the current material standards. An application where the recycled pipes can be used are in stormwater pipes, because these pipes usually don't require higher specifications. But this is only one segment of the market and it is thus harder to sell recycled pipes are a larger scale because the demand for them are not that high.

The manufacturers say that they are constantly trying to improve their products so that they can have more renewable materials in them. For example, they are participating in different research project to improve the basis for using more plastic pipes with recycled materials.

Organizational map and bottlenecks for recycling

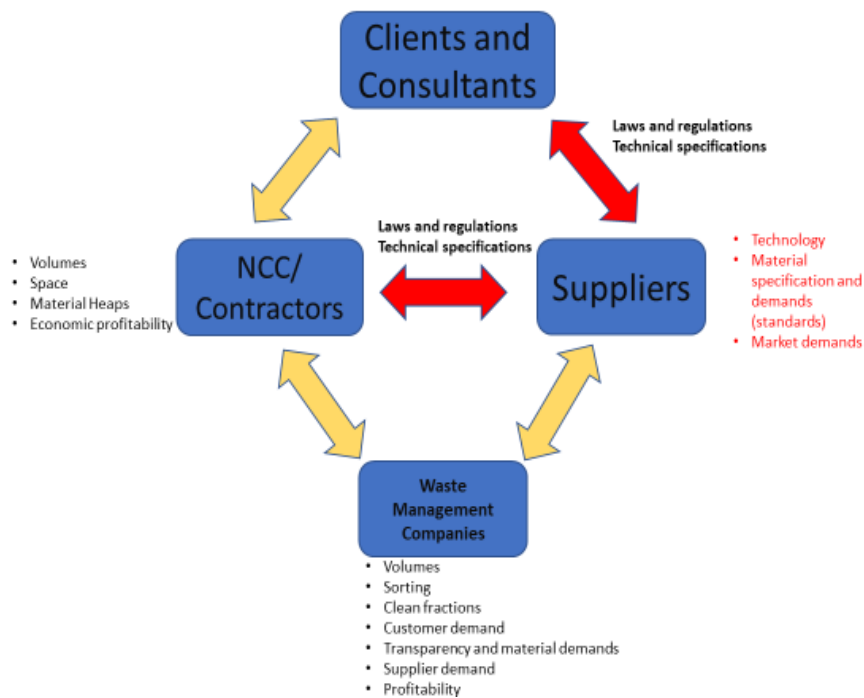


Figure 7 Organizational map of actors and issues connected to increasing recycling of plastic pipes in the construction industry

6 Discussion

In the following section the discussion of the master's thesis is presented. The discussion section is divided into the issues that were found upon analysis of the result and the literature study. The issues were the following:

1. The current collection and gathering models are not capable of maintaining the value of the pipe scraps and are not profitable
2. Current rules and regulations are hindering sustainable handling of the pipe scraps and the development of sustainable business models that can maintain the plastic value.
3. The manufacturers cannot produce large amounts of recycled pipes, due to material specification which lowers demands for recycled plastics pipe scraps
4. Green procurement strategies are not possible to deploy due to material demands placed on the plastic pipes

6.1 The current collection and gathering models are not capable of maintaining the value of the pipe scraps and are not profitable

A problem that is brought up in this master's thesis is the fact that the plastic loses its value throughout the material chain. One potential explanation provided from the workshop was that new plastic pipes were usually in the contract with a profit premium. This made it harder for the craftsmen and supervisor to reuse the old pipes and pipe scraps, thus the incentive to discard the pipes increases and in that process the value of the recycled pipes probably decreases.

The information gathered in this master's thesis confirms that the construction industry is lacking collection systems that can maintain the value of plastics throughout the material chain. This is problematic in other ways since then there exists a hidden demand for recycled plastics that today is not met according to material economics. Furthermore, the report from materials economics states that current legislation fails to create incentives for recycling and that rules and regulations within the market are not yet adapted towards recycling (Material Economics, 2018). This is also seen at the construction site since the supervisors and craftsmen say that it is cheaper for them to throw all of the pipes in the combustible container rather than sorting them out for recycling.

Profitability was one of the main points made at the workshop towards why recycling and gathering of plastic scrap was currently not incorporated at the construction site. This further reinforces the argument made in materials economics that rules and regulations have steered the system not towards recycling but rather toward a more linear economy. Consequently, in order to increase the collection and gathering of pipes at the construction site the economic incentives have to increase or in some regards change.

So, the main problems for a more effective collection and gathering of pipe scraps at the construction site is that there are currently no systems that allows for a profitable collection of the pipe scraps, current laws and regulation are probably hindering such a system to be implemented. This leads to plastic losing its value in the material chain. If there is not any value in the plastic scraps the craftsmen and supervisors will treat the scraps as waste and throw it in the combustible container. This is largely due to that it is cheaper for the project to dispose all of the pipe scraps there, consequently it is cheaper to burn all the plastic scrap from the project.

One of the biggest issues for the waste management companies concerning recycling of plastic scrap was also profitability, this is of no surprise since the contractors according to the interviews and workshops are experiencing similar problems. In order for the waste management company to be profitable they need to transport large volumes of pipe scraps with each transport which is hard to do since the contractor themselves says that it is not profitable for them to collect pipe scraps and store them somewhere on the construction sites. This is a bottleneck for the waste management company since they need to have a steady supply of pipe scraps in order to develop a profitable system for recycling.

Furthermore, the waste management company experienced sorting of the plastic as an issue that could affect their profitability. If the waste management company collected pipe scraps that had different types of plastics for example PVC, PP and PE it would cost them money to sort these plastics out for recycling hence it would also affect their profitability. As discussed before there is a need to somehow change the system in order to make it more profitable for both the contractor and waste management company to collect and sort the pipe scraps. It becomes obvious that the contractor, installers and waste management companies are dependent on each other in order to make recycling work in a better way.

Communication and transparency between companies was brought up as important in order to increase recycling. This is described in the literature as an important measure to take. In order to increase recycling, it is important to use strategies to enlighten manufacturers and other actors of their responsibility towards recycling (Stahel, 2016).

6.2 Current rules and regulations are not supporting sustainable handling of the pipe scraps and development of sustainable business models that can maintain the value of the plastics.

From the workshops there were a couple of things that became apparent. It is possible that most pipe scrap generated at NCC's construction sites are thrown into the combustible container to be incinerated for energy recycling. Secondly, that they had trouble managing space for additional waste containers and that it was hard to generate enough volumes of scrap in order to make the collection and sorting of the pipe scraps profitable.

These findings conform to the information stated in the report “a value-stable Swedish material system”. Small flows of plastics are presented as one of the reasons recycling is hindered. Another obstacle are rules and regulations which has steered the market towards recycling of plastic waste through energy incineration (Material Economics, 2018). This was confirmed at the workshops as the construction sites employees confirmed that most of the pipe scraps is thrown in the combustible container.

From the interviews it become evident that most demolition waste of plastic pipes was thrown into the combustible container. Materials economics also emphasises that the current demolitions process in construction is not taking the recycling into consideration. Since the interviewees said that they directly throw the demolished pipes into the combustible container, this information conforms to what is described in the material economics report. There is therefore a need to look at laws and legislation regarding how recycling can be an integrated part of the demolition process. But in regard to demolition projects, it is also important to develop new collection models for pipe scrap in order to mitigate value loss of plastic pipe scrap and increase recycling.

Furthermore, the interviewees expressed that it was hard to recycle pipe scraps because a lot of material was saved in heaps as material banks. Although finally the material bank material was discarded as the plastic pipes thrown into the combustible container because they were deemed unfit for use. This is proof that current system and legislation is lowering the value of the plastic scrap and steering handling of the material towards incineration rather than sorting and recycling.

The literature study concerning circular economy also touches on this subject as it is stated that as regulations have steered the market towards incineration rather than recycling for some time (Material Economics, 2018). In order for a transition to take place certain policies and regulations can be changed. For instance, policies could be made favouring activities adhering to circular economy and punishing those that are not. This could be taxation on burning of plastics, which was a suggestion given in the workshops. Such a tax would promote the value of plastic as well as punishing activities that lowers the value of plastic such as incineration. This could change the way plastics pipe scraps are handled on the construction site and how resources are viewed. Incentives towards actually collecting the pipes and sorting them would increase as it would become more expensive to throw them in the container for incineration.

Such changes could promote circular business activities and remove the regulatory failures that hinders circular business activities as stated by material economics (Material Economics, 2018). Collaboration between waste management companies would be easier to pursue since there is greater incentive for both actors to avoid burning the plastic and instead focus on reuse and recycling. Hopefully this could enable them to together further develop circular business models that would facilitate the recycling of plastic pipes.

The representatives from the waste management company spoke of the importance of allocating the risks that comes with a system change to all the actors in the system so that all risks are not allocated to only one actor. Material economics also touches on this

briefly as the catch-22 of the industry is described. Basically, some of the actors in the industry are caught in bottlenecks where a lot of resources are needed to fix those bottlenecks concerning recycling (Material Economics, 2018). The question then becomes who should shoulder these costs, and how the risks should be allocated in order for the costs to be distributed evenly among the actors who are involved in the recycling process

6.3 The manufacturers cannot produce large amounts of recycled pipes, due to material specification which lowers demands for recycled plastics pipe scraps

According to the manufacturers, the issues they had with increasing recycling of plastic pipes within the construction industry was that of managing the demands placed on the plastic pipes. For example, the entire production chain of plastic pipes in Sweden has aligned itself with the current EU legislation. The requirements in the legislation states that only virgin material should be used in plastic pipes in order to maintain the quality of the products produced. These technical demands make it harder to use more pipes made from renewable plastic, since these pipes usually can't achieve those demands and standards regarding quality that is placed on plastic pipes except small segments of application that does not require such high quality.

This is problematic from several perspectives. Firstly, it creates a bottleneck for the whole system. If the manufacturers can't sell higher amounts of plastic pipes made from recycled plastics, then the incentive from them to buy recycled plastic from waste management companies is lowered and in turn the incentive for waste management companies to collect pipe scraps is lowered. Consequently, the value for the secondary plastic is lowered in the whole chain. For instance, it becomes less profitable for the contractors to collect and sort the pipes scrap if there does not exist any buyers who are willing to pay for the pipe scraps.

There are few incentives for the manufacturer to produce large quantities of recycled plastic pipes since the demands for them are not adequate for larger volumes of production. Materials economics touches on this subject as it is mentioned that the market for plastics is not adapted to recycling due to that it fails to create incentives for recycling which is clearly the case here (Material Economics, 2018).

The manufacturers also spoke of the profitability of the plastic system, that there have to be financial incentives to increase recycling and that risks as well as costs has to be distributed evenly in a system change from a linear to a more circular business. These are important factors to consider for the actors within the industry if a system change should take place. The literature on circular economy supports this way of thinking as it is stated that new business models and opportunities that better fit a circular economy need to be developed in order to enable a wider system change towards a circular economy (Sariatli, 2017).

6.4 Green procurement strategies are not possible to deploy due to material demands placed on the plastic pipes

The interviewees from the waste management company thought that a good way to increase the use of recycled material and mitigate its value loss in the material chain was to promote recycled material in the procurement process. This seems to be a viable way to address the recycling problem since the literature study also supports these measures. Changing the current procurement policies is seen as one way to accelerate the use of circular business models and increase recycling within the sector. In this case the change would be towards procurement policies that are taking waste of the products used into consideration.

This would hopefully enable contractors to use more recycled materials and perhaps the manufacturers could do that as well. Although there is the problem of having the right quality of the plastic pipes so that they have enough durability and a long period of use. The issue being that plastic pipes made from recycled material have lower material quality.

However, the manufacturers emphasised that the material specifications would hinder the basis for using more green procurement in order to increase recycling of the plastic pipes. There are specific standards and technical demands that must be upheld on the plastic pipes, and if the clients are adhering to these demands and standards then there are not any incentives for them to allocate a profit premium on pipes made of recycled material. In fact, if a pipe made from recycled is used instead it could be counterproductive from a sustainable perspective since it has less durability and thus a shorter life cycle. The manufacturers agreed upon that awarding recycling material for the plastic pipes in the procurement process would be problematic considering the material demands placed on the pipes.

With the information at hand here, there is evidence that in the current system, plastics pipe scraps are losing its value because new pipes are being premiered in the procurements process, and because it is cheaper to burn the plastics scrap rather than recycling it. Both concerns could be derived from the fact that laws and legislation are not currently supporting a circular model where plastic scraps are easily recycled as stated in the report from materials economics.

Consequently, there must be a change in the current system in order to mitigate value loss in the material chain and to facilitate recycling rather than incineration. Current laws and legislation can be improved in order to better fit a circular material system. Additionally, companies need to change the way they look at resources, thinking more of waste as a resource rather than something to be disposed of as stated in the report from material economics.

6.3 General discussion/the system perspective

When comparing the literature on circular economy with the results from this master's thesis report it becomes obvious that current system for handling of plastic pipes scrap is not adhering to the circular economy or the circular business models. The reason for this will be discussed in this section.

According the results acquired from this master's thesis, most of the plastic pipes scrap at the construction sites are thrown into the combustibles container. As the waste management companies then collect these pipe scraps for incineration, the current system is adhering to linear economy. As described in the literature, the plastic pipes are made from natural resources and then disposed of (RE:SOURCE, 2018). Most of the waste in this case is not taken care of or being reused in any other way. The life cycle ends instead of having a closed loop as advocated in the circular economy and the circular business models (Stahel, 2016) . Furthermore, in the current system the waste from the plastic pipes are not reduced in a sustainable matter and the maximum value of it is not obtained throughout the system.

The collection models for the pipe scraps need to be improved in order for them to be more adapted towards recycling. Contractors like NCC need to re-evaluate how they think about resources as stated in the literature study (Esposito, Tse, & Soufani, 2018). This is done in order to mitigate value loss of the pipe scraps on the construction site and find models for collecting and gathering the pipe scraps. This is especially important for those working on the construction site that are directly handling the plastic pipes.

In order for NCC to develop sustainability within the company and become more credible as an actor within society, it is important for the company to reach their own sustainability goals. Therefore, it is important for the company to take such measures presented here to achieve more sustainability in their construction projects.

Manufacturers are also to some extent adhering to the linear economy. Most of their pipes are made from raw resources and materials, although they are working with increasing the amount of pipes made from recycled material, their core business is still focused on the take, make and dispose principals. In order to fully incorporate a circular business model, plastic pipes need to be manufactured from renewable material on a large scale which is not the case today.

As discussed earlier, this is where the main bottlenecks exist, although to no fault of the manufacturers. Legislation and material specification makes it more difficult to produce recycled pipes in larger scale. This hinders the whole system in adhering to the circular business principals since there is little demand for recycled pipes today, which in turn yields little incentive to gather and collect pipe scraps. As mentioned before, this prevents the material loops from being closed and waste cannot be seen as a resource to be used but rather something to be disposed of.

Current legislation and rules are two of the main factors why the system still adheres to the linear economy rather than creating incentives for recycling and circular business models. As one of the main criteria for circular business models is that the business model used creates incentives for recycling and reuse. Thus, it is clear that the current systems rules and legislation do not abide by these principals since many interviewees are experiencing a lack of incentive towards recycling in the system. This is made clear from the example with the incineration of plastics, right now there are no taxes on burning plastic scraps. Incineration is an easy way to get rid of the plastics scrap, but it also hinders incentives for recycling and reuse. However, the European government has set goals for the future to implement a more circular economy throughout the European union. This includes sustainable management of plastic waste through a higher use of recycling (European Commission, 2019).

Finally, the current system for plastic pipes are not adhering to traits of circular economy because it is currently not possible to deploy a “green procurement” strategy, where the client can promote recycled materials in the plastic pipes used in their projects. Having procurement policies that are minimizing waste is important when trying to adopt to circular economy, alas such policies are missing in the current system. Once again one could argue that this is out of the client’s control since they have rules and regulations concerning material quality which they have to comply with.

On the other hand, from the interviews it is clear that the companies that are involved in the plastic pipe business are actively working towards enabling a more circular system for the pipe scraps. Both the waste management company and the manufacturers were involved in a research project aiming to increase their recycling of pipe scraps in regard to both technical and logistic systems. In order to enable a basis for a circular economy these are vital steps to take according to the literature (Sariatli, 2017). Continuous increase in recycling and reuse will facilitate the idea of circular economy as being profitable (Sariatli, 2017). These measures are being exercised by the companies involved in the plastic pipe business as they try find new ways to increase their recycling of plastic and pipe scraps.

The REPIPE project is another enabler for the plastic pipe system towards more recycling as it can create collaborations between companies and provide technical as well as financial support in increased recycling of pipe scraps. A change in the mindset of how the companies are regarding their resources is a vital change towards circular economy. Judging from the interviews the companies involved are trying to reassess their view of resources in order to be better equipped for future challenges concerning sustainability and circular growth.

Although actors within the plastic pipe system are working towards increasing recycling, in some regards there are still measures that need to be taken in order to further increase recycling and make the system compatible with the models of circular economy. The biggest bottleneck that is hindering the system from adopting circular business models is the manufacturing demands on plastic pipes and the fact that pipes made from recycled material do not meet these demands. To address this issue further research into technical development of plastic pipes is needed to ensure that pipes made

from recycled plastic can achieve the same material quality as regular pipes made from raw resources.

This would enable recycled plastic pipes to be used in a wider set of applications and thus be manufactured at larger scales. Consequently, demands for secondary plastic and pipe scraps would increase, further enabling circular business models and the basis for profitable gathering and collection models for pipe scraps that contractors and waste management's companies can take advantage of. Strategies for green procurement would be easier to implement since the client would in that case be able to fulfil the material requirements at the same time as they are promoting recycled material in the contract. Summarily, more resources in plastic pipe development will be needed to further increase recycling and to facilitate recycling for plastic pipes, but right now the technology does not exist.

Other areas that could be improved in order to facilitate the recycling process is the collection systems for pipe scraps. Further development and research about how the collection of the pipe scraps should be handled is needed to find the most effective way to handle the pipes regarding profitability and material value for both contractors and the waste management companies. There are several possible ways to collect the pipe scraps and demonstration project are needed to analyse different possibilities and to gather knowledge about what systems work best and are most effective. Luckily NCC have ambitions to carry out such projects in collaboration with a waste management company.

Communication between actors involved in the recycling process is important as has been stated in both interviews and in the literature to enable a more circular system (Stahel, 2016). Although measures have been taken to increase this communication through for example the REPIPE project, there are probably more opportunities to develop this concept further. Increased collaboration and communication between waste management companies and contractors could yield better logistics models for handling pipe scraps. The case could be the same for manufacturers and waste management companies, increased collaboration could be beneficial in terms of environmental development. These measures are necessary in order to adopt circular business models and to adhere to principals of circular economy.

Rules and regulations have been pointed out as a powerful tool for change towards sustainability and is therefore important to incorporate in a change towards circular economy in a system. In this case, as has been discussed before, the most plausible solution would be to tax incineration of plastic waste. According to the Swedish government, such a law will be implemented in Sweden 2020 (Government offices of sweden, 2019) . Such a tax would help the industry to find more profitable solutions regarding the recycling of plastic pipes. Although there are hopefully other rules and regulations that also could help.

stakeholders who are connected to issues regarding recycling of plastic pipes and circular economy are also a part of the problem. Viewing from a more general perspective, it is important that every stakeholder takes responsibility in order to transition into a more circular economy as has been described in the literature (Houston, Casazza, Briguglio, & Spiteri, 2019). Challenges for the stakeholders described in the literature are that there does not exist a green market and demands for recycled products (Houston, Casazza, Briguglio, & Spiteri, 2019). Similar problems and challenges can be found in this master's thesis described in figure 7. Stakeholders in the recycling process such as contractors and waste management companies are having trouble finding profitability in collecting/recycling plastics. The results of the master's thesis point towards that the reason for this is that there is a lack of profitability in recycling the plastic scraps because of the low demand. Consequently, the literature supports the findings of the thesis concerning the problems and challenges that stakeholders within the recycling system for plastic pipes are facing.

When comparing the literature on the circular business models with the findings of master's thesis there are some barriers to develop the circular business models. The literature states that in order to enable circular business models it is important to develop materials that are recyclable (Esposito, Tse, & Soufani, 2018). This is clearly not the case for the plastic pipes. The pipes are recyclable to some extent since they can be used in a narrow set of applications. But for them to be fully recyclable they need to be able to be used in all kinds of applications, which is not the case today, thus the development of circular business models is hindered.

Furthermore, the literature states that in order to enable circular business models it is important to produce policies and regulations that favour circular business models and punishes those that are adhering to linear economy (Stahel, 2016). One such policy could be to implement green procurement (Varnäs, Balfors, & Faith-Ell, 2007). However as has been discussed in great length in this master's thesis this is not possible due to the material specification placed on the plastic pipes. This means that the current technology through which recycled pipes are made today is in itself a barrier to developing circular business models. In order for this barrier to be overcome, better material technology for making pipes out of recycled plastic scraps has to be developed.

To make better use of and enable circular business models and increase sustainability, it is important that clients within the construction industry have a clear vision and strategy for developing sustainable projects (Adams, Osmani, Thorpe, & Hobbs, 2017). This is also emphasized in this master's thesis, many of the interviewees want clients to take more responsibility towards using more recycled pipes and to develop more sustainable projects or methods.

It is important that actors such as contractors, designers and manufacturers support the clients by developing new business models, technologies and by exchanging information about the positive effects of circular business models (Adams, Osmani, Thorpe, & Hobbs, 2017). This was touched upon in the interviews as the waste management company and employees at NCC emphasized that their responsibility was together to develop smart methods and business models for gathering plastic pipe scrap

at the construction sites. Consequently, the contractors and waste management companies can contribute to the implementation of circular business models by having a close collaboration.

Finally, it is also worth considering if a closed loop system is the best option for recycling of plastic pipes. In the literature it is described that a closed loop system yields lower flexibility concerning the application that the recycled materials can be used for (Haupt, Vadenbo, & Hellweg, 2017). Therefore, it is worth considering if the plastic that is recycled from plastic pipes could be used as raw material for other plastic applications. Consequently, a suggestion for further research concerning recycling of plastic pipes would be to investigate if it is possible to use the plastic recycled from the pipes in other plastic applications. If this is possible, would potentially facilitate the recycling process as the recycled material could be used in a wider range of applications.

In summary, it is clear that the current material system for plastic pipes is not adhering to the principals of circular economy. The main reasons for this are:

1. The manufacturers cannot produce large amounts of recycled pipes, due to material specification which lowers demands for recycled plastics pipe scraps
2. The current collection and gathering models are not capable of maintaining the value of the Pipe scraps and are not profitable
3. Current rules and regulations are hindering sustainable handling of the pipe scraps and development of sustainable business models that can maintain the plastic value.
4. Green procurement strategies are not possible to deploy due to material demands placed on the plastic pipes.

Changes that needs to occur within the material system to increase recycling and develop a more sustainable system adhering to circular economy are:

1. More research and resources in material technology that further could spur improvement of material quality in plastic pipes made from recycled plastics
2. Further collaboration and communication between actors in the material system to spread risk, more evenly allocate costs and to be able to further identify obstacles and opportunities concerning recycling of Pipe scraps
3. Implement rules and regulations which punish activities that are interfering with sustainable development in the material system. In this case this would be taxes on burning plastic waste.

Lastly addressed is what NCC specifically as a company can do in order to increase their recycling of pipe scraps. Evident from the workshops and interviews is that there are still problems regarding the collections and gathering system for pipe scraps. More research is needed in order to make these systems more efficient, such measures is supported by the empirical evidence of this master's thesis as well as the literature study. Demonstration projects could be such a measure as collection provide research and analytic data about how the collecting system of pipe scraps should be set up in order to be profitable and effective. The demonstration projects provide learning and development opportunity for both NCC and the waste management company that is involved.

Changing the way NCC views the pipe scraps is another way for them to further address increase of pipe scraps recycling. Viewing the pipe scraps as a resource rather than waste could increase the incentive to recycle them rather than throwing them in the combustible container. Further collaboration with the waste management companies will also be needed to further increase knowledge about how waste should be handled, in particular the pipe scraps.

6 Conclusion

The following research questions were used in this master's thesis:

Main research question:

- Can the current material system of plastic pipes be compatible with the model(s) of circular economy?

Sub-questions:

- How are the circular economy models described in the literature?
- How is NCC currently handling the recycling process for plastic pipes?
- How could NCC/the industry adopt a circular business model for its uses of plastic pipes?

The current material system for plastic pipes scrap is not adhering to the principals of circular economy or circular business models due to the fact that there are not any profitable systems that can maintain the value of the plastic scrap, Manufacturers can't produce high volumes of recycled plastic pipes to due material demands and standards. Furthermore, rules and regulations within this system are failing to create incentives for recycling and circular business models. Lastly is not possible to deploy a green procurement strategy to increase recycling of plastic pipes due to the material demands.

The industry could further adopt the principals of circular economy inti in to the plastic pipe system by adhering to activities such as collaboration between companies, further research in material technology in order to be able to use recycled pipes in more applications. Implementation of rules and regulations which punish activities that hinder sustainable development and incentives to develop circular business models.

Currently NCC are handling pipe scraps at the construction site by transporting them to the waste management company for incineration or gathering them in material heaps and then transporting them to the waste management company.

The literature on circular economy models adheres to activities such as reuse, recycling, repair and waste management. Implementation of laws and regulations which creates incentives for recycling are also important activities. The circular business models are described as models that generate business opportunities connected to the circular economy principals.

NCC could further adopt the circular economy principals by cooperating more with the waste management companies and researching material waste systems by doing demonstration projects on how to collect pipe scraps. Furthermore, it is important that they change their view of waste on the construction site, viewing pipe scraps as a resource that can be recycled rather than waste.

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8 Appendix

Appendix 1 Interview X

Appendix 2 Interview Y

Appendix 3 Interview Z

Appendix 4 Interview A

Appendix 5 Interview B

Appendix 6 Interview C

Appendix 7 Interview D

Appendix 8 Workshop exercises

Appendix 9 Summary of Workshop Exercises

Appendix 1 Interview X Supervisor at NCC (BM) 2019-09-03

- Where is pipe-waste generated on the construction site?

Most commonly, pipe-waste is generated when cutting pipes to fit wells, pipe-branches and transitions. But also when we make estimations of how much material (pipes) we need for a certain area, we purposely overestimates, We can then get an abundance of pipes and those we don't use are either sent to a new project or usually back to Ahlsell (main material supplier for NCC) for a reduced cost. (about 30 % lower than the original price).

- Is Pipe-waste generated during the delivery, when the pipes are unloaded from the trucks?

No that rarely happens, It has happened but only in rare cases from what I've seen. It can happen if the pipes have been damaged or have construction flaws. But also, if the unloading process are done improperly or more reckless there is a small risk, but as I said beforehand there is usually no real risk in unloading the pipes.

- When you are doing jobs where you are supposed to change old pipes in the ground to new ones, how do you go about that?

First we have to find the pipes. After that we usually have a machine that does the excavating, after then with the help of the craftsmen we get the pipes out of the excavating pit with the excavation machine. We put the pipes on the ground until we have enough of them to be carried away with the machine. The machine grasps the pipes with its claw and carries it away to the combustible's container, where the pipes are cut with the claw so that they fit inside the container.

Appendix 2 Interview Y Craftsman at NCC (MA) 2019-09-15

- When you're constructing new piping systems on the construction site, where is most waste generated?

Waste is always generated when we cut the pipes, for wells, transitions and branches, to make sure that the installation is according to the blueprint, you have to cut pipes. For example, you may have gotten a delivery of plastic pipes that are 3 meters long. If you need to lay a 5-meter section, you have to use 2 pipes, but you have to cut one of them down into a smaller piece in order to make it fit. The same goes for changes in dimensions of a pipe for, for example going from 160 to 200, then you also must cut the pipes

Another way waste can be generated is when the pipes are left uncovered for long periods of time on the material storage area. In that case the sun could cause sun kinks in the pipes thus rendering the pipes useless as they are to bent to be able to fit into the pipes network.

- What does the work process of replacing old pipes with new ones look like?

After we have found the pipes, the machinist usually excavates the area around the old pipes. After that the old pipes are removed from the excavating pit and put on the main ground level. When the machinist has gathered a sufficient amount of pipes, they will be cut by the machine claw and then moved to the combustibles container.

- Would it be possible to implement material recycling where the waste pipes are cut down into smaller pieces and then thrown into a material recycle container for plastic? Would it be a problem to remove the rubber gaskets from the pipes in the same process?

No I don't see any problems with that, I can't imagine see that any of the craftsmen would be reluctant to do that, especially not if the directives from the supervisors and site managers are clear and we know what we are supposed to do. It probably won't take that long to remove the rubber gaskets from the pipes anyway. I don't think that it will take extra energy from the work we usually do. So in terms of motivating the craftsmen to adopt a new working procedure, it should be fine as long as the site managers and supervisors are clear on what we are going to do and how we should do it. It's possible that someone will forget to remove the rubber gaskets in the beginning, before the new work process has become a routine for them. But after a while the routine will stick.

Appendix 3 Interview Z Craftsmen at NCC (TM and MA) 2019-09-15

- Where is most of the waste generated when you are laying new plastic pipes in projects?

Generally, waste is generated when the pipes are cut in order for them to fit in the sections they are going to be placed in, but also to make them fit for the wells, branches and transitions that are part of the piping network. Although the waste generated from laying and cutting pipes at a normal construction project are usually quite small. The reason for this is that a large amount of the pipes that are being cut are usually saved as extra material that can be used either for finish pipe sections that require certain lengths or for other purposes (what purposes?). The parts of the pipes that are thrown into combustibles container are usually only very small parts (under 20 cm) that can't be used for anything else. This leads to very small amounts of waste from pipes on each project, not nearly enough to fill a whole container.

The longer part of the pipes that have been cut are saved at the material area as a reserve for laying new pipe section at the project as mentioned. Although as more pipes are being laid in the ground this reserve will continually grow as the project moves forwards and more pipes are being cut. Some pipes can be used for filling out sections at the pipe network but usually the reserve will grow bigger since more waste is generated from new pipes than is re-used from the reserve pile.

After the project has been completed these reserve piles are usually sent of to another project in hopes that the pipes will be of use at the next project. The problem with this is that the client usually demands that all pipes that are being laid in a new project shall be new directly from the supplier. This puts limitation on how much of the saved reserve pile that can be used in the next project, but it will also be easier to use the new pipe parts since you that they will fit and has the right dimensions and lengths.

However, this means that the reserve pile will grow with each project it is transferred to. This continues until the supervisors/site managers think that it takes up too much space in the material area or has no further use and decides to throw all/part of the pile in the combustible container.

Since the waste generated at each individual project is that small and it is not enough to fill an entire container it is probably not profitable either. It might be profitable at larger projects where the main work of the project is to lay pipes and dig up non-serviceable pipes, because then you might generate enough waste to fill a container. Otherwise for projects that are smaller or not only entailed to lay pipes, another solution is needed to gather the waste.

-If you would start to use a container to recycle all the plastics instead of burning the, but at the same time give the craftsmen directive to remove all the rubber gaskets before putting the pipes in the container, would that be a problem?

No that wouldn't be a problem, Removing the rubber gasket would go fast with a knife, that wouldn't mean much extra work. Therefore, it shouldn't be that hard to motivate the craftsmen to do it as long as the supervisors and site managers have given us a clear picture of where we should put the pipes.

Appendix 4 Interview A Project manager at NCC (CC) 2019-09-15

-If we would introduce a container for material recycling for plastics at the site, would it be problem to use that container and throw all the plastics tubes and pipes in that container?

To motivate the craftsmen to use such a container would not be a problem. As long as we have been straightforward why want them to recycle the pipes and we have given them clear instruction on how that would work. In that case it would not be a problem to introduce this new work process.

The difficulties with such a new working process could be to motivate it economically, since we generate quite small amounts of waste on a normal construction project it would be hard to fill an entire container with waste from plastic pipes. Even if we could sell the waste that someone picks up from the site, the container stills cost money to rent. It could be profitable on larger project that handle larger amounts of pipes, but it is a question of investigating how much the container rent would cost in comparison of how much income is generated by selling the plastic waste.

Another thing to consider is how much space this container would take, on some projects the material storage area is very small, and you are fighting for every inch of space that you can get there. In those cases, it is hard to motivate putting another container there without knowing if that would generate profit or potentially increase your costs on the project. However, each project has its own conditions thus the space problem might be a minor issue on certain projects.

Appendix 5 Interview B Waste Management Company 2019-10-31

- What are the biggest obstacles for increasing the collection of plastic and plastic pipes in the construction industry?

Profitability, right now it is difficult to gain profitability in collected pipe scraps from the projects, it is a matter of transportation of the pipes and the volumes of pipes that are being transported. When transporting pipes, there are often small volumes of pipe scraps that you transport, because the pipes take up a lot of space. This means that the weight per transport becomes very light and when the weight is low on each transport it costs more per transport and therefore each transport becomes more expensive and less profitable. But it also depends on what fractions we get from the construction site and how mixed the different fractions are. For us to get large volumes of mixed pipes can be a loss affair because we must first sort out the pipes before selling them away to the suppliers. This entails extra costs for us and thus lowers the incentives for us to collect pipes from the construction sites.

The profitability is dependent on what kind of plastic you get, some plastics are fully recyclable in Sweden and other are not, other plastics must be recycled in other countries hence gathering plastics that can't be recycled in Sweden is more difficult and expensive.

- Which do you think are the potential solutions to achieve an increased collection of plastic and plastic pipes in the construction industry?

Our solutions are based on the flow of the material, plastic scraps is always interesting to collect and sell. Although collecting mostly air is not as interesting (That is, filling large transports with a lot of pipes scrap that are light and taking a lot of volume in the transport). We constantly try to look at different solutions regarding the logistics for recycling, we also try to test new ideas with the help of entrepreneurs and other customers. When we make new collecting attempts with customers, we look at what can we recycle, And how can we sort it. We try to find different transport routes for the materials. You usually want to avoid expensive transportation of materials, because that is where the losses occur when collecting the material, so we work a lot with looking at different collecting sites and construction sites in order to puzzle together the most profitable routes when collect waste.

For us, solutions can be reached through learning from the different projects, testing with the customer and learning what works is important for us. But innovations also depends a lot on what the customer wants, some are not willing to pay more to be able to recycle the waste that they generate and would prefer to just get rid of their waste as cheaply as possible in those cases the basis for developing functional recycling system are not as big.

- Which solutions can your company provide in order to increase the collection of plastic pipes in the construction industry?

We try to test new solutions with the customers, we often want to test new solutions in different controlled environments, In order to gather knowledge about how they work

and what works. But above all we assist with technical and logistics solutions. For profitability, however, it is important to not get too much unsorted material, in order for our company to become profitable because such large quantities of unsorted materials might be profitable to sort and recycle.

-Is there anything your company can do in order to put pressure on clients and contractors to use more renewable materials in the construction process?

Yes of course we try to work with requirements specific to the materials. There are different quality requirements for materials that we as a waste management company must fulfill. Our company must be better at communicating these requirements to our customers. The waste management companies might also get better at communicating what kind of material they can receive, and that if they collect/receive material that is unsorted and divided into different fractions it will get much more expensive to collect the material. Open communication between us and the customer is also important. For example, when we are doing pilot projects regarding recycle, you see the requirements and problems from both sides and can communicate about them. Then it becomes easier to make a framework agreement with the customers.

- Would it be possible to work with one-time pick offs on project where little waste is gathered in order to make it more profitable to sell the waste once it has been collected, do you think that model could work?

Yes absolutely here we just have to work together and find a solution that works for both companies, NCC must be transparent with how much material they have and where they are located, but such a solution would be relevant.

-What do you think that clients and governments agencies has to do in order to increase recycling of plastics and plastic pipes in the construction industries?

It would be better if the client could promote recycled materials in the contract, this would ease the recycling process and the demand on recycled material would probably increase. This would put pressure on suppliers to increase products with recycled materials. But one bottleneck is that the client will not reduce the quality requirements because the materials used in the construction projects must fulfill certain standards and regulations. Thus, pipes made from recycled materials must also reach the proper quality that the clients demand.

There are also problems with everyone in the value chain helping to maintain the value of recycled products. For it to work, all parties in the value chain must help to maintain value of the plastic. But the cost allocation of this could be different for different actors in the chain and thus it is important that everyone is helping each other in order for it to work properly, and it is therefore important that everyone is together on what needs to be done in order for it to work.

It may be good to start with the procurement, this is where the driving forces are to change the industry, recycled products are rarely cheaper than new products and therefore change must start with the client.

Working on climate calculations: What does it cost to emit someone to drive from Kiruna to Germany and recycle the material in Germany, instead of burning it in Kiruna?

Many more regulations and certifications are also in progress regarding recycled materials.

For example, the swan certification has requirements for recycled materials to be used in the new construction projects

-Does the structure of the industry has to change in order to make increased recycling a possibility?

It would be an idea to work with softer parameter, for example: Procurement; We want x percent of the building to be built from recycled material, and then hopefully the construction company will receive X percent deduction for the recycled material that the project has been built. Even the manufacturers must act even more and make more products with recycled material to put pressure on customers.

-How do you view the market for secondary plastic? Is it possible to sell the gathered plastics from sites to manufactures of plastic pipes?

The demand for recycling a material sometimes depends on how much pure fractions can be obtained from the material, for example how dirty the plastic that is recycled is a hot issue.

Previously, most of the plastic that was difficult to recycle was sent to Asia, especially to China, "It was pure junk that was sent" but now they have placed higher requirements on quality of the plastic they receive, and thus they don't take plastic with poor quality anymore and therefore it has to be handled locally in Sweden.. As mentioned before, there is a demand for secondary plastic today, but it has to be clean enough in order to be refined further. The problem lies in the fact that it is more difficult to recycle plastics with several substances in them, take the example with plastic films. It is much more profitable to recycle transparent plastic films, compared to coloured plastic films because the coloured plastic films have to undergo a purification process. Better demand for secondary clean plastic makes the prices for secondary plastic better, but there is a bottleneck there since it is sometimes hard to get clean plastic with the right quality now thus it becomes more expensive to refine the material and use it again rather than burning it

Appendix 6 Interview C Manufacturer (OS) 2019-11-09

-How do you work in order to increase the amount of recycled materials in your products?

We are constantly striving to improve our products by working with innovative solutions and new products that can better meet the demands of clients and customers. We are constantly having conversations with different customers in order to have an open communication about what we can offer and what the customers wants. Most importantly, we want a Win-Win situation where both the customers, the manufacturer and the environment win on the product we are manufacturing.

As a profit-driven company and a manufacturer, we must be able to find financial incentives for our product as we develop our business. If we can make new pipes of recycled plastic and thus reduce our production cost and work more sustainably. In that case there is a driving force for us to develop that concept

-Which are the biggest issues regarding increasing your production of pipes made of recycled plastics?

We work with different surveys of the market in order to see what applications and products we can sell at the market. But the most important thing for us is that the products we sell for fill the material specifications that are placed on the products. For example, there are certain types of pipe that are sold that must be certified. Certified pipes requires that the pipes are made of new raw material and not recycled pipes. So within those segments of products and applications that require certification of the pipes, there is no potential to work with recycled material.

However there are pipes that do not require certifications and thus within those products there is a bigger potential to work with recycled materials. For example stormwater pipes usually don't need certification and are thus such a product. Another problem is that it can be troublesome to find recycled plastics of sufficient quality. secondary plastics that we receive for manufacturing has to undergo certain quality checks in order for use to them. The reason being that the secondary plastic has to have a certain durability and quality for us to use it in the manufacturing process of new pipes.

-Is the demands a big issue? Is there a shortage of demands on products made of recycled plastic on the market?

In general, the customers (in this case the contractors) do not check whether the pipes are made of recycled material or not. The contractors are mostly concerned with if the products they are using meet the material specification and requirements placed on them. The contractor is responsible for the products and materials they use in their projects; thus, they need to ensure that the products they buy for the projects meets these specifications So the most important thing for us as a manufacturer is that our products fulfils these requirements.

Therefore, the demand for recycled pipes is not presently a problem for us , as long as we can supply the right material requirements specification for the pipes, we have a large market for selling pipes.

-Is there any solutions to the issues of increasing products with recycled materials?

The most important incentive in a market driven by profitability is that you can make a profit with the business you conduct. In this case, there is a need to introduce financial incentives in the markets towards to recycling plastics and plastic pipes rather than tossing them in the combustible container and burning them up. For such an incentive to exist, it must be more expensive to burn the plastic / plastic tubes through energy recycling rather than material recycling the plastics. Such regulations that changes how the current system is working can be achieved by, for example, introducing taxes on burning plastics. This way, you increase the cost of burning the plastic, the plastic gets a higher value and it therefore become more profitable to recycle it or to put it in a recycling container rather than burning it

It is also important when introducing new ways of working in such a large system that the cost is evenly distributed among all the actors so that all costs are not allocated to one or a few actors within the system. The costs have in such a system change most be allocated evenly between all the different actors. The industry has to help each other and communicate about what is needed for this system change as best they can.

-Why is recycled material not awarded today in the procurement process? Is there a structure that needs to be changed in order for recycled material to be used more ?

If the client are going to award recycled material in the procurement phase, it is important that the quality of the products is not compromised since it is very important that the pipes used in building project are durable and last for a longer period of time. For example, if more secondary plastics were to be incorporated into the pipes and this made the life span shorter, for example 50 years instead of 100 years, this measure could be counterproductive from a sustainable perspective as the pipes then becomes less durable with a shorter life cycle.

However, it is possible to award recycled materials on part of the building project where the quality of the pipes is not as important. For example on stormwater pipes. What clients, on the other hand, are poor at and which they should be better at is to follow up on materials and specifications. Often, they do not follow up on the requirements they place on the procurement, it is important for them to do this if it is to act as an incentive to make tougher requirements in the procurement on, for example, recycled material.

Today, there are already certain requirements / ecolabelling on the pipes, for example the swan labelling, but these ecolabelling places no requirements on the proportion of recycled material in the pipes.

Appendix 7 Interview D Manufacturer (MS) 2019-11-11

-How are you working towards increasing the amount of recycled plastics in your production?

Presently, only land drainage pipe are made of Recycled plastic, the reason for this is that the entire production chain in Sweden has aligned itself with the current EU legislation. The requirement in this legislation is that only virgin material should be used in plastic pipes in order to maintain the quality of the products produced except for land drainage pipes. In Sweden and the Nordic region, we have also complied with a tougher legislation called the Nordic poly mark. This is because we have a harsher climate (especially cooler) which requires that we have a little stricter regulations and requirements for the pipes we use.

These Standards are made in such a way that all risks to which the products can be exposed during their life cycle are taken into consideration, it is everything from cold to mechanical stresses that they are exposed to during their life cycle.

Yes, we are constantly working to develop our business. We are a part of the Nordic plastic pipe group and are involved in a recycling projects where containers have been placed in different locations where installers and contractors installing pipes can put their waste from the installation in order to make it easier to recycle them. In addition, we are constantly working to develop new products and new materials in order to increase the proportion of recycled materials in our products and to meet the market's needs. We are also working on various innovation projects to develop new products.

-Which are the biggest issues regarding increasing your production of pipes made of recycled plastics?

We have no own operations to that can wash the pipes, consequently we have to find secondary plastic that is already washed and granulated in order to use it in our production. The secondary material that we use must reach some quality. However, we do not buy that much secondary material at the moment, so to find secondary plastics is not a major problem for us?

The most pressing issue today regarding increased use of recycled plastic for new pipes is that the technology today for incorporating secondary plastic cant satisfy the quality demands. Since a lot of plastic pipes most reach a certain quality according to laws and regulations, pipes made of recycled plastic may have a fairly narrow use and thus there is not a large market for the use of recycled pipes..

However, right now there is a greater will from the industry to use innovation in order to increase recycling and it is noticeable that several more actors within the industry are working towards increasing their recycling. So in that sense the issue is becoming more and more relevant.

-Is the demands a big issue? Is there a shortage of demands on products made of recycled plastic on the market?

There is currently no demand for recycled products of what we can see from the contractors and other construction companies who install pipes.

One of the issues regarding recycled pipes is that of drinking water pipes that cannot be produced from recycled material at this moment. The reason for this is that the drinking water pipes must have a life cycle of up to 100-150 years and therefore the materials used must be so durable that they can withstand the stresses during life cycle. This means that these pipes must be made of virgin material in order to secure the material quality of the pipes.

In addition, we have a slow replacement of these pipes in Sweden and the municipalities are lagging in this work. It is therefore of the utmost importance that pipes of this type that are laid in the ground have a long durability and therefore we cannot use recycled materials in these pipes, as we would in this case compromise the quality of the pipes.

-Is there any technical obstacles today to increase the rate of production of pipes made of recycled material?

Right now, the technology for making pipes from recycled materials that meet the requirements you have for pipes that must be durable for a longer time period does not exist. For example, drinking water pipes as previously mentioned. Here it is necessary to develop new products that better meet the material specifications that are included in different standards in order to be able to increase the production of pipes that have more recycled material in them.

Why is recycled material not awarded today in the procurement process? Is there a structure that needs to be changed in order for recycled material to be used more ?

Presently, we do not have the logistics or capacity for a large-scale production of pipes made from recycled plastics. Therefore, it becomes problematic for us to produce larger numbers of recycled pipes of the client or contractor would require us to do, or if they had included such a requirement in the contract of a construction project. So if we are going to produce pipes made from recycled materials on a larger scale to a customer, is it first necessary that we can increase our capacity.

In addition, it is difficult for us to deviate from the material requirements that the pipes should have because we have laws and regulations to take into consideration.

-What's your reaction on that a lot of the plastics are today being burned instead of being recycled?

Spontaneously, the pipe industry should be much better at recycling than other industries are. We have systems that have been used longer, so if you look at such rules / laws to increase recycling, I do not think they will affect us as much as other industries that handle plastics.

Appendix 8 Workshop Exercises

Exercise 1:

Purpose:

To get to know where pipe scraps is generated at the construction site and to get to know how the scrap is currently handled

Execution: A material flow-chart for plastic pipes and profiles on the construction site was written on a whiteboard. The staff on the construction site could then give opinions on how the chart should be written also enabling discussion about material flow in the process.

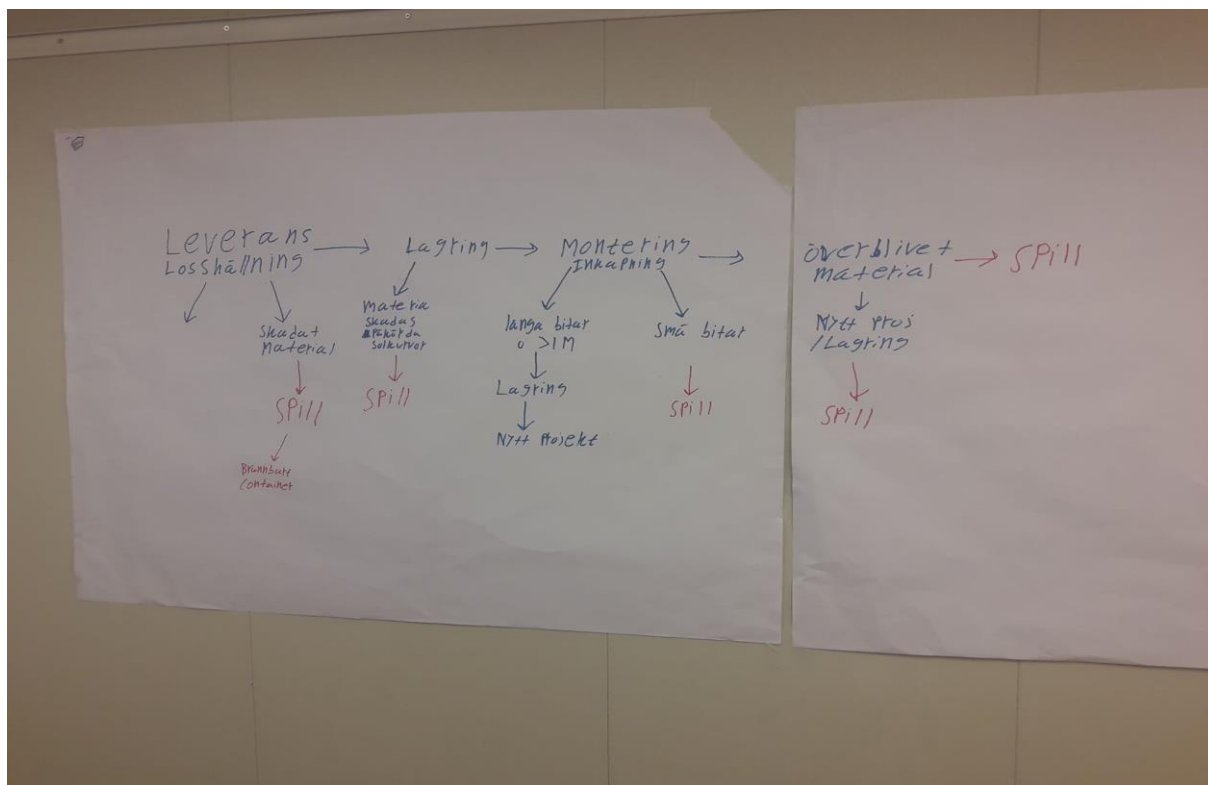


Figure 8: Flowchart from Workshop at Trollhättan

Execution:

The staff at the construction site was divided into three groups, each group discussed the following questions and problems

- Which are the main obstacles for increasing the amount of pipes collected for recycling at the construction site?
- Which are the main solutions for increasing the amount of pipes collected for recycling at the construction site?
- Discuss how your different roles at the site can contribute to an increased collection of pipes for recycling? What are the requirements, which tools are needed? What does the team need?

Exercise 4:

Purpose:

To get to know what motivates change at the construction site, in case change is needed in order to recycle more pipes, how do we motivate that change.

Execution:

The staff at the construction site was divided into three groups, each group discussed the following questions and problems

- In case we need to introduce new working procedures, what do you think is the best way to motivate such changes?
- Is it going to be hard to motivate such changes? How can we support each other if that is the case
- Are there any working procedures that could be extra hard to motivate?
- What do you think you need personally to be motivated to work with further increasing the recycling at the construction site?

Appendix 9 Summary Workshop Exercises

Summary Exercise 1

- At both workshops there arose a discussion about how the material flow worked in practise and how that flow should look like. Both exercises yielded similar results, presented in figure xx and figure xx. In total four different sources of waste were identified in the material flowchart, these were: Waste from delivery of the pipes, waste from storing of the pipes, waste from installing the pipes and waste from leftover materials. These four main waste sources can also be seen in figure xx.
- Waste generated at delivery occurs when the pipes that are delivered to the site are already damaged. The pipes could be bent or have manufacturing defects making them unfit for use at the construction site
- Waste from storing the pipes is generated due to the pipes being worn out by the weather. A common phenomenon is that the plastic in the pipes are damaged from the sun, becoming too frail to use for installation. Thus, failure in covering the pipes properly when storing them at the construction site can cause them to become damaged, generating pipes that can't be used.
- Waste from installing the pipes occurs when the craftsmen are cutting the pipes in order to make them fit for wells, branches and transitions. The waste generated here are pieces of the pipes that are too short to use anywhere else, usually pipes that are under 1 meter are not usable and are thus considered as waste.
- Lastly waste can also be generated from the left-over material when the project is done. These pipes cannot usually be used in the next project since the client often has demands of new pipes being used and not pipes from other projects. This means that the left-over pipes will be sent to storage, or thrown into the combustible container, another reason for the pipes being thrown away is that they have already been paid for with a premium. In order to increase profit for the project new pipes are bought with the same premium instead of using old pipes. The business model in itself is thus opposing further recycling of pipes.

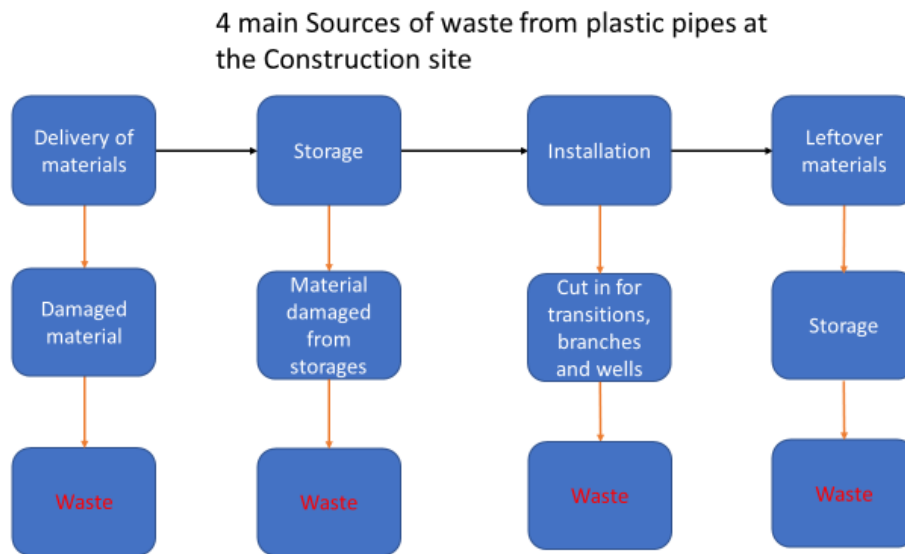


Figure 10: Waste generated from pipes at the construction site

Summary Exercise 2

The following became apparent after discussion at the groups in exercise 2

- The hedges that the pipes are delivered in can be used as collection vessels for pipe scraps. This could be beneficial as it would save space at the construction site using hedges instead of waste containers. However, these hedges need to be adjusted in order for them to be better adjusted to carrying the pipes.
- It is important that the craftsmen never walk “empty-handed” at the construction site. That they always bring some waste with them to the waste container at the site, however it is here important to work with the disposition of the site.
- The formation of that which has been built is also important and affects the amount of waste generated, for instance at the Trollhättan project they had a lot of “round forms” of pipes that should be built. This causes more waste to be generated when installing the pipes.
- How the waste should be handled is very different from project to project, bigger project might generate more waste compared to smaller projects. The amount of pipes laid down during the project is also an important factor, for instance if a project needs to lay 3 km of sewer pipes the amount of waste will be increased and the project will have the capacity to collect all of that waste. It is important to also find economic incentives when recycling so that the project does not lose money by collecting and recycling the pipes.

- An alternative to collecting the waste since there are uncertainties regarding the amount of waste generated at different project is to have process where the waste collection company comes out and does a one-time pick off. In this case a waste container would not be needed thus saving money for the project, although a alternative storage method would be needed for the pipes at the construction site. One such method could be to use pallet collars to store the waste in, that had been tested once in a project by the craftsmen as a alternative and they thought it worked out well. Another alternative would be that the staff from the construction site at the end of a working day would take all the waste generated that day from pipes and delivered it to a nearby recycling station as a part of the daily routine.
- It is important that the construction site is properly managed considering space and routines for keeping the storage area organized in order to avoid the area getting to messy. It would not be a big deal to have a special container for throwing pipe waste, it would not mean any bigger changes in the way the craftsmen already work

Summary Exercise 3

- According to some craftsmen one of the biggest obstacles for collecting more waste is their feelings towards responsibility. It is not hard to place all of the waste from pipes in a recycling container that has been placed at the construction site. It would neither be a problem to remove all the rubber gaskets from the pipes before throwing them into the recycling container to avoid contamination. There is a slight possibility that some of the craftsmen could forget these steps in the beginning if the working process would change, but as soon as a routine has been established it should not be a problem. But many also thinks that in general there is no real incentive problems to collecting an recycling more pipes, if there is a container for pipe waste or another practical solution the craftsmen use it.
- It is important that the site managers and supervisors are giving clear guidelines about how the collecting of waste is going to be implemented at the construction site and what is required from the craftsmen in terms of new routines and work procedures. For example, the craftsmen need to know how which pipes should be put together? Should old pipes that have been dug up of the ground be put with the general pipe waste from the installation. In general, there is a need of increased knowledge of how to handle these questions. But it is also important to introduce these working routines to co-workers that are new at the construction site, giving them an opportunity to also be part of these routines.
- A challenge is the space in the storage area that the different project have, it is hard to motivate to have an extra container at the construction site if there is a shortage of space. Limited area on the project could be one of the biggest challenges for attaining better collection and recycling at the construction site.

- It is also important that the containers that would be used for recycling pipe waste have proper signs on them, so there is no confusion as to where the pipes should be put. It could also be a good idea to give general information about how the pipes should be handled on the sign. For instance, that the rubber gasket has to be removed before the pipes are put into the container.
- On the workshop in Trollhättan it became apparent that they have access to a general storehouse for pipes that can be used to store waste from pipes, several other project in the same region also had access to this storehouse. The storehouse could be used better with proper organization, but right now there are few people who use it and who knows what kind of material that is stored there. If a system was implemented where everyone knew what material was stored in the storehouse, the waste material could still be of use in project instead of being worn out in the storehouse.

Summary Exercise 4

- One way of motivating changes in the projects regarding recycling is to show how much profit that is gained from recycling the pipe scraps. In this case it is important that the supervisors and site managers are transparent about the profits and mediates these numbers to everyone at the projects. It could also be motivating if some of the profit from the recycled pipe scraps would go back to the project to be used for some positive encourage, free breakfast or such a thing.
- To have an increased understanding of the material chain and what is happening the pipe scraps in the recycling process is also motivating for the staff at the project. An increased knowledge about the recycle process and why NCC is working towards increasing recycling is more motivating than if someone says that we have to increase recycling without giving an explanation.
- Clear goals for the project could also help to increase motivation for recycling. For example, the project could have a goal of recycling a certain amount of their plastic waste each month, say 80 %. When that goal is reached it is also important to highlight it and bring to attention for the staff that the goal has been fulfilled. It could also be interesting here to compare the amount of pipe scraps recycled with other projects, making it a little bit competitive.
- It is important to remind each other why we are recycling and support each other in order for the motivation to last longer. But also to have “room for errors” when we are working with new procedures and routines since it can take some time for them to be adopted by the whole working staff.

