THE ROLE OF INNOVATION ECOSYSTEM FOR THE CIRCULAR PLASTICS ECONOMY

Master thesis

Msc. Environmental Management and Sustainability Science

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Synopsis:

The current critical situation of the plastic waste industry is undeniable. The increasing importance of the circular economy is raising the awareness of managing those plastics in a sustainable way. Innovation ecosystems seem to be a solution to incorporate circular economy in the plastic waste industry. However, the role of innovation ecosystems is debatable. There are different authors defining innovation ecosystems, which will be critically examined. The aim of this thesis is evaluating the role of innovation ecosystems in the circular plastics economy, through choosing some relevant best practices in the field and comparing them with the theoretical background of innovation ecosystems.

Problem formulation: *Which are the roles of innovation ecosystems for the circular plastics economy?*

Results: Collaboration is the is the basis of innovation ecosystem. They work as source of collaborative ideas between different actors, where they exchange knowledge and benefit mutually. This collaboration and cooperation is essential to implement circularity in the plastic waste industry.

Contents

Preface

This master thesis has been written by Maddalen Ayala during the Spring Semester of 2018. Student at 4th semester at the master's program *Environmental Management and Sustainability Science*.

This thesis is a proposal of a collaboration in the *Genanvendelse af plast – en styrket dansk industri* project (*Improving the recycling of plastic - a strengthened danish industry*). A collaboration between *Plastindustrien*, *Aage Vestergaard Larsen* and *Aalborg University*, where they are willing to improve the recycling of plastic in Denmark.

First of all I would like to thank Edward Vingwe for proposing this master thesis and supervising it, together with Søren Løkke. I would like to thank both of them for their ideas, suggestions and inputs during the process of the thesis, giving helpful and inspitational guidance as well as constructive criticism throughout the thesis.

I would also like to thank the for interviewees Christina Busk (*Plastindustrien*), Hanne Juel (*Region Midtjylland*), Susanne Backer (*Aarhus Universitetshospital*) and Mats Linder (*Ellen MacArthur Foundation*) for taking time to be interviewed, and their useful inputs, essential for the development of this thesis.

Finally, I will also mention Ivar Lyhne, as the Semester Coordinator, providing his help and guidance.

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1 | Introduction

The idea of this thesis emerges from a proposal of a collaboration in a project *Genanvendelse af plast – en styrket dansk industri* (*Improving the recycling of plastic - a strengthened danish industry*). This project is a cooperation between *Plastindustrien*, *Aage Vestergaard Larsen* (AVL) and *Aalborg University* (AAU). The goal of the *Genanvendelse af plast – en styrket dansk industri* project is to provide tools to danish companies willing to increase the recycling of plastics in Denmark. The purpose is doing efforts in building new knowledge, developing a strategy to increase the recycling of plastics, establishing a knowledge platform in recycling plastics, implementing courses and establishing networks for companies interested in recycling plastic waste (Plastindustrien, 2018). Enjance collaboration is a key point to succeed achieving the goals in the project.

Plastics are extensively used in our everyday life. They are versatile, durable and inexpensive materials with numerous utilities (Thompson et al., 2009). The main problem of plastics in their low recyclability rate, and consequently their accumulation in the natural environment, causing irreparable environmental damages (Geyer et al., 2017).

One solution for that problem is incorporating the principles of circular economy into the plastic waste industry. The main principle in the circular economy is keeping material in use instead of disposing them, which would minimize plastic accumulation in the environment. Collaboration between different actors is also one of the essential drivers to achieve the circular economy goals (Ellen MacArthur Foundation, 2015). Collaborative practices between different organizations are increasing in the last decades. Organizations are more aware of the benefits of collaboration (Chesbrough, 2003a). Following with the principle of collaboration, the concept *Innovation Ecosystem* emerged, based on the cooperation between different organizations willing to achieve the same goals. The proper use of this concept of collaboration will potentially benefit the *Genanvendelse af plast – en styrket dansk industri* project.

Nevertheless, the role of *innovation ecosystem* has barely been analyzed as a solution for the critical situation in the plastic waste industry. Taking into consideration the current situation in this industry and with the aim of providing an insight of the importance of collaboration to the *Genanvendelse af plast – en styrket dansk industri* project, the role of innovation ecosystem is going to be examined.

With that in mind, this thesis aims to analyze the role of innovation ecosystem to incorporate circular economy practices in the plastic waste industry. In order to provide an answer to that, it is important knowing what innovation ecosystems are and how they are established and managed. In order to have incomes from practical examples, danish and international case studies of organizations working within the field of the plastic industry are going to be analyzed. Once theoretical background and the case studies are analyzed, the research aims to provide recommendations to integrate circular plastics economy in Norther Jutland, and ideally also applicable to other organizations in different countries willing to have collaborative practices.

The report follows the coming structure: It begins with the problem analysis (Chapter 2), which includes an review of the current plastic waste industry and its environmental impacts, circular economy and innovation ecosystem as potential solutions of that problem. Following with the problem formulation (Chapter 3), where the proposed research questions are framed. After that, the methodological framework is presented, explaining the use of the literature review, data collection, and methods of analysis. The analysis is presented in Chapter 6, which leads to the discussion and conclusion in Chapters 7 and 8.

2 | Problem analysis

This chapter frames the problem area of the thesis. Starting with an overview of the plastic waste industry, including some numeric data about the waste management; followed by some environmental impacts of plastic in the environment, as a consequence of the current plastic waste management. After that, circular economy is introduced as a solution for the plastic waste industry, ending with an introduction to innovation ecosystems.

2.1 The plastic waste industry

Plastics are an important and widespread material in the everyday life. They are essential in the current economy and have multiple uses that help to ease a number of challenges that our society is facing (European Commission, 2018). Plastics are versatile, lightweight, durable and relatively inexpensive materials products (Thompson et al., 2009). Plastics are widely used, and the amount of plastic manufactures is increasing exponentially. The global plastic production has increased from 322 Mt in 2015 to 335 Mt (million metric tonnes) in 2016 (PlasticsEurope, 2017).

Nevertheless, the fact of having this economical and widely extended material, has also raised the amount of plastic waste. The numbers speak for themselves: Since 2015, 6300 Mt of plastic waste have been generated (Geyer et al., 2017). In Europe, 27.1 million tonnes of plastic waste were collected just in 2016 (PlasticsEurope, 2017). The key issue in plastic waste is the increasing production and consumption of single-use plastic items. Plastic packaging is the largest plastic market (Geyer et al., 2017). 42% of plastics are used for packaging globally, 39.9% in the case of Europe (PlasticsEurope, 2017). The high amount of single-use plastic leads to a massive amount of plastic debris, polluting significantly the environment (European Commission, 2011).

The following image shows the global production, use and fate of plastics in million metric tons, from 1950 to 2015 (Figure 2.1). As the figure shows, 8300 Mt of plastic were estimated to be produced. From those, 4900 Mt were discarded, 700 Mt incinerated, and just 600 Mt recycled.

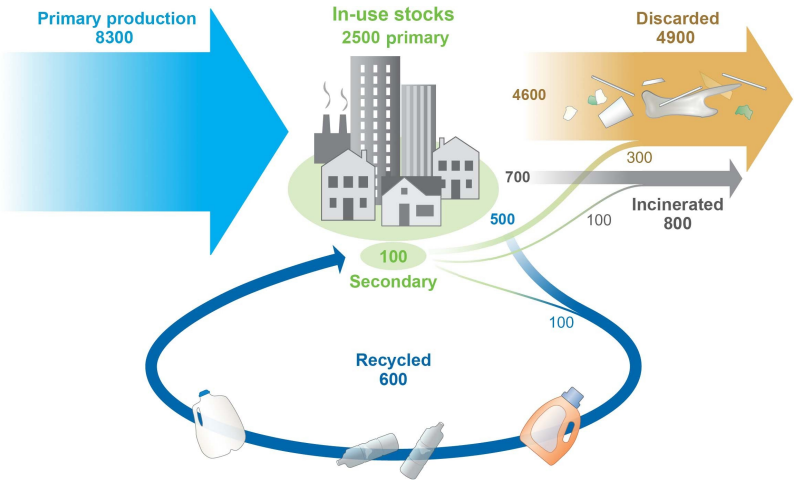


Figure 2.1: Global production, use, and fate of plastics. (Geyer et al., 2017)

According to the study made by Geyer et al. (2017), globally, 79% of that plastic waste is landfield, 12% incinerated, and just 9% recycled. In the case of the EU, the recycling rate is bigger (31.1%), but incineration and accumulation in landfills still remain high (41.6% and 27.3% respectively) (PlasticsEurope, 2017).

The following graph gives an overview of the global plastic waste generation, divided into different categories in the plastic waste management (Figure 2.2). The graph shows a significant increase since the beginning of plastic manufacture in the 1950s. It is also noticeable the appearance of recycling and incineration after the 2000s. The most significant estimation in the graph is the exponential increase in the primary waste generation by 2050. The graph also shows a future trend of an increased amount of incinerated and recycled plastic waste. In spite of that, the amount of discarded plastic waste is estimated to be significantly high. 12.000Mt of plastic are estimated to accumulate in landfills by 2050 (Geyer et al., 2017).

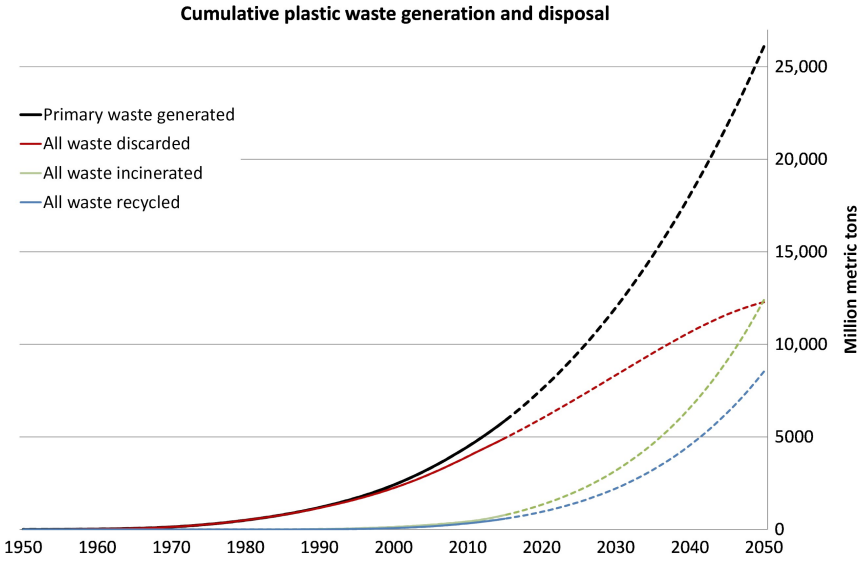


Figure 2.2: Cumulative plastic waste generation and disposal (in Mt) (Geyer et al., 2017)

Depending on the type of plastic, recycling could save up to 88% of energy (in the case of PS, No. 6) and 76% of (PET, No. 1) (see type of plastics in Figure 2.3). Carbon emissions also decrease. In the case of PS 1.3 tons of CO_2/ton plastic is prevented, and in the case of PET polymer 1.7 tons CO_2/ton plastic. Not only that, but also recycling polymers is cheaper than virgin materials, depending on the polymer type (Huchinson, 2008).

Nevertheless, the recycling rate of plastics is considerably low compared to other sort of materials. This reclyclability varies depending on the type of plastic. To understand the recyclability of plastic products, it is important getting familiar with the plastics in the market. Plastics are classified in 7 categories. The following Figure 2.3 summarizes the type of plastics:

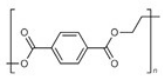
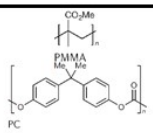
SPI n.	Full name	Chemical structure	Uses	Currently recyclable	Density (g cm^{-3})	Recovery Rate (%)	Image
01 PET	**Polyethylene terephthalate**		Disposable bottles for drinks, medicines and many other consumer products	Yes	1.38–1.40	19.5	
02 PE-HD	**High-density polyethylene**		More durable containers, such as those for detergent, bleach, shampoo or motor oil	Yes	0.93–0.97	10	
03 PVC	**Polyvinyl chloride**		Piping, cables, garden furniture, fencing and carpet backing	No	1.10–1.45	0	
04 PE-LD	**Low-density polyethylene**		Plastic bags, wrapping films, trays and computer components	Mostly no	0.91–0.94	5	
05 PP	**Polypropylene**		Bottle caps, reusable food containers and car parts	Sometimes	0.90–0.92	1	
06 PS	**Polystyrene**		Plastic utensils, packaging peanuts and styrofoam (EPS)	Sometimes	1.04–1.11; 0.016–0.64	1	
07 O	**Other**: for example, polycarbonate and polymethyl methacrylate		Multilayer barrier films, toothbrushes, some food containers, CDs and DVDs	No	Varies	Varies	

Figure 2.3: Type of plastics divided in 7 categories. Based on Rahimi and García (2017)

In summary, just a few plastics are recyclable (PET, HDPE), some type of plastics have a very low (PP, PS) or even unresistant rate of recovery. Nevertheless, it is worth mentioning that PET and HDPE are the most common type of plastics. Not only that, but also are the plastics used for single-use packaging, that as mentioned before, almost 50% of plastic waste come from that kind of plastic. On the other hand, it is remarkable that LDPE, which form plastic bags, are mostly not recyclable. Hence, the importance of minimizing their consumption.

The current situation in the plastic waste industry also has significant economical consequences. According to the report of Ellen MacArthur Foundation (2016), 95% of plastic packaging material value are lost in the economy, which is between 80 and 120 billion $ loss annually. The cost of production, due to greenhouse gas emissions, is estimated to be 40 billion $.

2.2 Environmental impacts of plastics

It is undeniable that plastics pollute the environment. The extended use of plastic, together with their durability and the conventional plastic waste management, carries a large amount of plastic litter accumulated in the environment (Thompson et al., 2009).

The environmental pollution due to plastics begin with the extraction of raw materials. Vast majority of monomers to produce plastic polymers, such as ethylene and propylene, come from fossil hydrocarbons (Geyer et al., 2017). The raw hydrocarbon material for most synthetic plastics is derived from petroleum, coal or natural gas, and the extraction of monomers to produce plastics accounts approximately 8% of global oil production (Geyer et al., 2017).

Those monomers derived from fossil hydrocarbons are not biodegradable. The mentioned durability, together with the high rate of landfield plastics, results in accumulation in the natural environment. Between 4 to 12 Mt of plastics are estimated to be accumulated in oceans since the plastic production started in the 1950s (Geyer et al., 2017).

Oceans are the most damaged ecosystems due to plastic pollution. Between 60 to 80% of debris in oceans is estimated to be plastic. Plastic particles that are filtered from plastic waste accumulation, and those plastics end in the ocean. Through degradation by sunlight, biodegradation, chemical and mechanical degradation, plastics fragments disperse globally. According to some studies, there is more plastic in the ocean than plankton, that plastic is eaten by marine life, and that plastic ingestion harms marine species (Andrady, 2011).

Even if incineration is considered a more sustainable waste management technique than landfill accumulation, the air pollution of incineration is also an impact to be considered. Incineration of plastic waste is a major source of air pollution, toxic gases like dioxins, furans, mercury and polychlorinated biphenyls. Those toxic substances also threat vegetation, animal and human health (Verma et al., 2016).

2.3 Circular economy as a solution for the plastic waste industry

The current economic system is linear. Natural resources are extracted, those resources are produced to create new products distributed for consumption, and those products are disposed as waste in their end of life. Linear Economy brings a lost value of materials and product, depletion of scarce resources, volatile resource prices, unstable supply of raw materials, waste generation, security and stability of raw materials supply, environmental degradation and climate change (European Commission, 2015).

This linear model can clearly be seen in the case of the plastic waste industry. As mentioned in the previous sections (Sections 2.1 and 2.2), the plastic waste industry has considerable impacts, due to the high amount of plastic waste in landfills and incinerated. All those environmental impacts that generate this industry need to be mitigated. However, there is room for improvement. The concept of circular economy is emerging these last years and seems to be a potential solution to reduce the amount of plastic waste and manage that waste in a more sustainable way.

Circular economy (CE) is an economic system where products and services are traded in closed loops. Stahel (2016) defines it as a solution to the current linear economy, which turns goods in their end on life into resources, closing the loops and minimizing waste. The implementation of a circular economy would reform the economic logic, due to the replacement of production with sufficiency, prolong the value of materials, resources and products, minimize waste generation, and increase competitiveness of businesses and innovation, among others. In other worlds, circular economy would bring economic, social and environmental gains (European Commission, 2015). Ellen MacArthur Foundation (2015), describes CE as *A continuous positive development cycle that preserves and enhances natural capital, optimizes resource yields, and minimizes system risks by managing finite stocks and renewable flows.* CE is about preserving and enhancing capital, optimizing resource yields, and fostering system effectiveness.

This concept of circularity would generate a major change in the economic system, and it would also imply a positive revolution in the social and environmental pillars, by creating closed-loop value chains and moving towards zero waste industries. It represents a definitive paradigm shift in how industrial processes are related to the current economy (Ali, 2016).

The following picture (Figure 2.4) shows the biological loops (in the left) and the technical loops (in the right). The image shows the closed system where the waste goes directly back to the same manufacture chain. This thesis focuses in the external loops of the circular economy, due to the current recycling structure of the plastic waste industry.

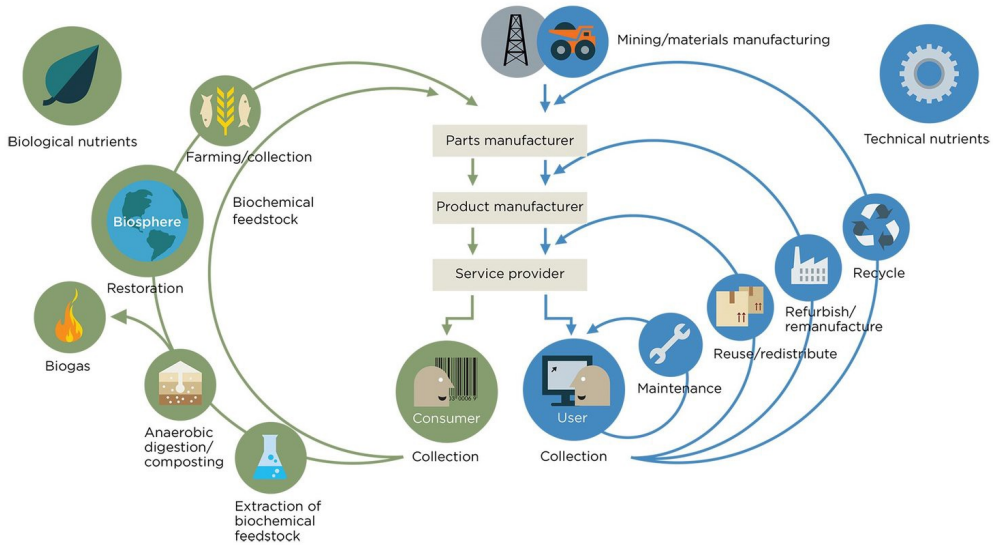


Figure 2.4: Loops and principles in the circular economy (Ellen MacArthur Foundation, 2015)

CE thinking should be systemic and holistic. It is essential focusing on system flows, stakeholders and their interactions. Collaboration is a key aspect in the circular economy. Collaboration between different stakeholders propose a new framework for the understanding of value creation between the player in the circular economy. That collaboration between accountable stakeholders also facilitates the shift from individual technologies towards the creation of a new system.

Collaboration generally has mutual benefits to the stakeholders, catalyzing their efforts and reducing their costs (Veleva and Bodkin, 2018).

Circular economy is gaining importance this last decade and new actions are arising. Aware of the importance of the circular economy, the European Commission launched the *EU action plan for the circular economy*. The European Commission states the Circular Economy as a priority the main objective of building a sustainable future, where protecting the environment and boosting competitiveness are closely associated (European Commission, 2015). In that action plan for the circular economy, plastics was one of the priorities, as the plastic industry is essential for the European economy. Therefore, the EU launched some strategies to manage the plastic industry in an innovative and sustainable way. In 2018, the European Commission adopted a *European strategy for plastics in a circular economy* (European Commission, 2018).

2.4 Innovation ecosystems as a potential solution for the circular plastic economy

Innovation ecosystems are said to be a potential solution to incorporate circular economy practices in the plastic waste industry. Innovation ecosystem could be understood as a collaboration between a set of actors to achieve an innovation (Dedehayir et al., 2016). Nonetheless, the role that innovation ecosystems play in the plastics waste industry has barely been explored.

To integrate new practices, it is necessary to innovate. Innovation could be defined as the process of invention, development and implementation of a new idea (Garud et al., 2013). Open innovation could be a theory to follow when it comes to incorporate circular economy in the plastic waste industry, defined as: *Companies sharing ideas and seek ways to develop pathways together, in a business strategies with open boundaries* (Chesbrough, 2003b).

With the aim of managing plastic waste with a more sustainable approach, *Plastindustrien*, together with *AVL* and *Aalborg University*, launched a project called *Genanvendelse af plastik – en styrket dansk industri* (*Improving the plastic Recycling - A Strong Danish Industry*).

3 | Problem formulation

The plastic waste industry is highly polluting, as mentioned in Section 2.2. The awareness of this problem is increasing and solutions to mitigate the impacts are emerging. There are existing strategies to implement circularity in the plastics economy. To develop that circularity, the integration of innovative systems are needed. Aware of that situation, this mater thesis aims to analyze the role of innovation ecosystems for the circular plastics economy. The theory regarding innovation and innovation ecosystems is compared with some exemplary case-studies. In this case, exemplary is defined as context depending role models in the circular plastics economy, representing the state of the art.

This are the proposed research question and the sub-questions to answer the main research question:

Which are the roles of innovation ecosystems for the circular plastics economy?
Sub-questions
1. *What are innovation and innovation ecosystems? How are they established and managed?*
2. *Which are exemplary national and international case studies currently working on the field of circular economy in the plastics industry? What characterizes them?*
3. *Knowing the exemplary case-studies and the role of innovation ecosystems, which would be the key-leanings that could be integrated in Northern Jutland's circular plastics economy?*

4 | Methodological framework

This chapter aims to define the methodology of the thesis. The methodological framework provides scheme to solve the research question:

What are innovation and innovation ecosystems? How are they established and managed?

The chapter starts with a literature review, followed by the data collection, which includes semi-structured interviews. Methods of analysis are also introduced in this chapter, finishing with some information confidentiality, in case of having to deal with that issue.

4.1 Literature review

From the literature review, *Research sub-question 1* will be answered:

1. What is innovation and innovation ecosystems? How are they established and managed?

A deep literature review is the initial research method, in order to analyze the following subject matters:

- Background of the plastics industry and the circular economy.
- Theories of innovation, applicable to the research scope.
- Conceptual framework of innovation ecosystems.
- Case-studies.

Not only the concept of innovation ecosystems needs to be analyzed, but also other theories about innovation to be applied in the research questions. Starting with the choice of theories that could be part of the focus, and following with a deep examination of those theories. First of all, the concept of innovation is introduced, in order to have a basic understanding of the term innovation. The theory regarding innovation follows with a description of different innovation systems, and innovation processes. After that, the concepts of open innovation and collaborative innovation are explained. And the theories about innovation conclude with innovation ecosystems.

The fact of *innovation ecosystems* being an ambiguous and debatable, implies a literature review to examine the concept. The complexity of the terminology demands a comparison between several authors and different reviews.

The literature review about the concept aims to narrow down the theories, coming up with concrete aspects, which are later used to outline the interview guide (specified in the next section 4.2.2). That specification of the concept will also guide the analysis, comparing the result of interviews with the theoretical background about innovation.

Literature review is also used when it comes to the choice of the case studies. Either by articles in the field of plastics or circular economy, or by desk-research, some potential case-studies will arise. The specifications about the choice of case-studies are dined in the coming section 4.2.1.

4.2 Data collection

The purpose of the initial data collection is to gather the most relevant case-studies currently working on the circular plastics economy, addressing the *Research sub-question 2*:

2. Which are exemplary national and international case studies currently working on the field of circular economy in the plastics industry? What characterizes them?

The data collection is mainly made by a literature review to find case-studies of existing organizations in the plastic industry currently implementing circular economy in their business models. Following some criteria, detailed in the next Subsection 4.2.1, the most relevant case-studies for the research are chosen. After choosing them, interviews are conducted with a contact person of the organization. Those interviews are semi-structured, and they are specified in Subsection 4.2.2.

4.2.1 Criteria

The starting point to identify case studies is gathering information about every organization working in the field of circular economy regarding plastics. Collected institutions are summarized in an *Excel* table with an overview and some important parameters and characteristics, such as a short description of the company, the country of the headquarter, the website, and whether or not the company collaborates. The most important followed criteria is choosing organizations with a strong collaborative approach.

The initial literature review remarked the figure of *Plastics Europe*, a leading organization representing the plastic industry in Europe. In the research of case-studies, *Plastics Europe* is contacted and they proposed some relevant organizations to analyze.

A part from the national and international case-studies, it was considered important having an insight of one of the organizations involved, in order to get an insight of the project. Therefore, *Plastindustrien* is interviewed.

4.2.2 Semi-structured interviews

The goal of the interviews is to obtain information about the case-studies, mainly about collaboration and information to compare those inputs with the theory about innovation. The result of the interviews and the analysis gives a resolution to the *Research sub-question 3*:

3. Knowing the exemplary case-studies and the role of innovation ecosystems, which would be the key-leanings that could be integrated in Northern Jutland's circular plastics economy?

Interviews are the most common method of data collection for qualitative research. There are three types of interviews: Structured, semi-structures and unstructured. In structured interviews, predetermined questions are asked and there is usually no variation in the questionnaire.

Unstructured interviews follow the opposite principle, they generally lack of an interview guide. Those interviews usually start with an opening question for the interviewee to discuss, and according to the answers, the interviewer manages following questions. The last interview type is semi-structured interviews. Here, key questions are asked to define areas that want be developed during the interview. The interviewee develops the answer broadly, remarking the key points they find the most important. The interviewer follows the interview guide, with possible modifications during the interview (Gill et al., 2008).

In structured interviews, responses are limited and sometimes some information is absent because of not being asked during the interview, and some detailed might be lacking. On the other hand, in unstructured interviews, as the questions are not predetermined, some key points to be explored might be missing. Semi-structured interviews, on the contrary, enables the interviewee to develop an answer in an open way, giving them space to explain the areas remarkable for them, depending on the interviewees preferences (Gill et al., 2008). Taking all that into consideration, semi-structures interviews were chosen to analyze the case studies.

Semi-structured interviews have the risk not gathering all the necessary information and having information gaps. Therefore, it is essential to develop an interview guide (Gill et al., 2008). As mentioned, the interview guide is not strictly followed. However, every question in the interview guide is attempted to be covered. The following subsection frames the most significant points of the interview guide, and the complete guide can be seen in Appendix A.

The interview guide

Interview guides vary slightly depending on the case-study. Nonetheless, all of them follow the same pattern. Having the same main areas to be explored, makes the answers comparable and eases the analysis.

The interview guide is written based on the most significant aspects of innovation gathered during the literature review. The main asked areas during the interview are the following:

- **Self-introduction** of the interviewee and the **introduction to the project**, including the background of the project they are working on. This introductory questions will give a insight of the organization's strategies and their reasons of to develop the project.
- The **processes in the project and implementation of innovation**. The aim with these questions is to understand the creation phase of the innovation, and the implementation of innovation and challenges and opportunities related to that phase.
- Transition to **collaboration** and **stakeholder involvement**. Here, questions about partners involvement and their connections are asked.
- **Opportunities and challenges**. The interviewees are asked about the opportunities and challenges they found in general, and more specifically in the innovation or collaboration processes of their projects.
- **Key lessons** after a period of time implementing the project, and recommendations for organizations willing to implement that kind of innovation.

- **Future expectations** regarding the project they are implementing.

The template interview guide can be found in Appendix A.

Transcription

Notes are taken during the interviews, and those help to get a general idea and most remarkable point of the interview. It has been considered important to transcribe the interviews, in order to get every detail from them, analyze them more extensively, and make a qualitative data analysis. The software *Temi* was used to facilitate the transcription of the interviews.

4.3 Methods of analysis

As previously mentioend, this thesis aims to compare the theoretical background of innovation with current practices. Therefore, the obtained information through the interviews is compared, contrasted and analyzed with the theoretical background of innovation. The software *Nvivo* is used for the qualitative data analysis.

4.3.1 Coding

The software *Nvivo* is used to code the transcribed interviews. Different themes are established when coding in *Nvivo*, and those themes are called nodes. Those codes are set based on the themes of innovation, gathered during the literature review (defined in the previous section *The interview guide* and Appendix A). The answers of the interviewee are grouped in the following codes:

1. Self-introduction and introduction to the project
2. Processes in the project and implementation of innovation
3. Transition to collaboration and stakeholder involvement
4. Opportunities and challenges
5. Key lessons
6. Future expectations

Each code gathers the answers of the interviewees regarding those specific topics. The answers are analyzed, and the most remarkable concepts are highlighted. Once the most significant ideas, thoughts and aspects from the interviews are identified, they are compared with the theoretical background of innovation. That comparison would enable bringing different perspectives of innovation, obtaining experts knowledge of in the field, and that way, answering the research question:

Which are the roles of innovation ecosystems for the circular plastics economy?

The following Figure 4.1 is a screenshot of the software and shows the chosen codes for the data analysis.

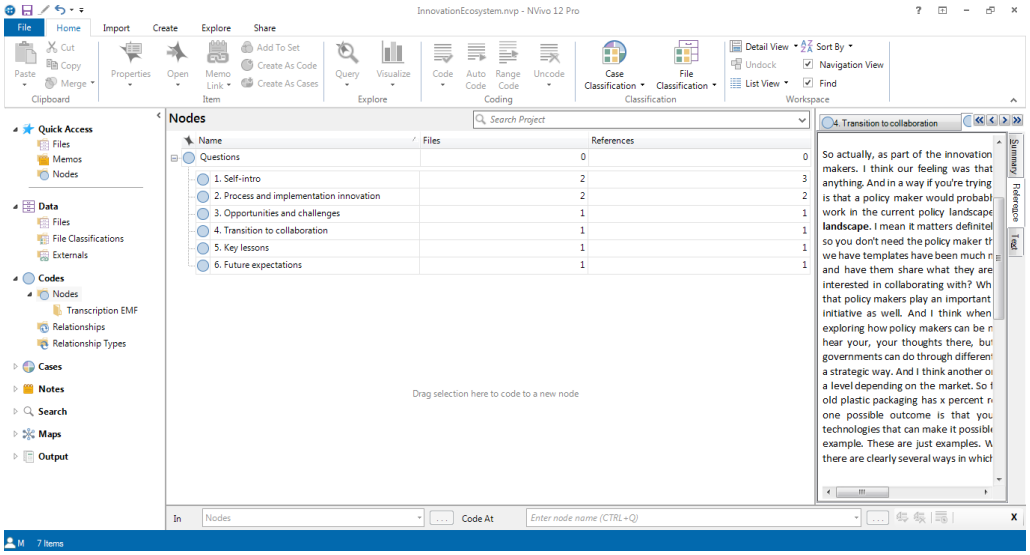


Figure 4.1: Screenshot of the software Nvivo's interface

4.4 Confidentiality

It might be possible that some organizations share confidential information that could not be published. There are various procedures to follow in case of having any confidential information to be used in the thesis.

In case of having a confidential project, the Project Library is capable of handling confidential material. In that case, the project would be uploaded as confidential and it would be available only for the most relevant member of the University's administrative staff, including supervisors, the student responsible of the thesis, and the research registration system behind the Research Database of Aalborg University (VBN) and the Project Library.

However, there is the option of managing confidential information without making it entirely confidential. On the one hand, there is the option of giving the data, without sharing the name of the institution. On the other hand, it is also possible to give the name of the organization, avoiding giving those confidential details.

Having this into consideration, the procedure to follow would be writing the given information avoiding the parts are meant to be confidential, and after using that information, sending it to the organization to verify that the used information can be published. In case of not getting the confirmation of the organization before uploading the thesis, the Project Library has the option of modifying the status of the project from confidential to non-confidential, and vice versa.

5 | Theoretical framework

This chapter frames the theory used in the thesis. Innovation is the key terminology. Nonetheless, the concept is broad and there are some theories emerging from innovation. This chapter introduces innovation in general terms, innovation systems, innovation processes. Open innovation and collaborative innovation are also described, and chapter concludes with a theoretical background of innovation ecosystems.

5.1 Innovation

As mentioned in the Problem Analysis (Chapter 2), the current situation in the plastic waste industry is critical, and there is a need to incorporate circular economy practices in the current system. Such a change demands a new action plan. Innovation is the key when it comes to incorporate renewed strategies in existing models.

Innovation is a broad topic, which can be defined based on different parameters. Garud et al. (2013) remark the organic growth of firms, innovation as catalyst for regional development, and the comparative advantage of regions that actively implement innovation. Garud emphasizes the 3 steps in the process of implementation: Invention, development, implementation (Garud et al., 2013) (Garud et al., 2015) (specified in Subsection 5.1.2). The OECD (Organisation for Economic Co-operation and Development) defines it as the process of creation of new ideas and inventions that generate goods and services, creating value for customers OECD (1996).

The *Oslo Manual*, from the OECD (1996), defines four types of innovation. **Product innovation** would be a new or significantly improved good or product. This includes improvements in technical specifications, components and materials, functional characteristics, etc. **Process innovation** understood as a new or significant improvement in production or delivery methods, including techniques, equipment or software. **Marketing innovation** is understood as a new marketing method, which involve significant changes in product design or packaging, promotion or pricing. And the last type is **organizational innovation**, which is a new organizational method in business practices, external relations or workplace organization.

Innovation could be also understood from a collaborative perspective. Here is when *Collaborative innovation* comes into play. Collaborative innovation (specified in Section 5.3) focuses on the importance of the synergies, co-operation and alliances between different stakeholders in the innovation.

Open innovation is also a relevant theory when it comes to innovation. Open innovation is the knowledge and material exchange between different organizations with the same innovative approach Chesbrough (2003a). This concept is more broadly explained in Section 5.2.

Innovation could seen from a systemic approach perspective. In the system thinking in perceiving innovation, the agents or elements would be firms, universities, research institutes, governments, incubators, science parks, etc. As interactions or relations, user-producer, trade, research collaboration, investment, support schemes, or facilitation. And regarding processes, learning, knowledge creation and diffusion (Galanakis, 2006). The following Figure 5.1 is a simple representation of the systemic thinking in innovation, where elements are represented in green, relations are the grey lines linking elements, and processes would be the actions creating those relations between elements.

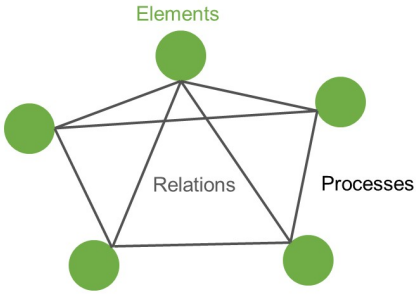


Figure 5.1: Graphical representation of system thinking

5.1.1 Innovation systems approaches

The following subsection describes the different innovation systems. Starting from the geographical level, following with sectoral systems, technological systems, and concluding with spatial innovation systems.

Innovation could be defined at geographical level. Here, there are the concept of Global Innovation Systems, National Innovation Systems and Regional Innovation Systems. The concept of **National Innovation Systems** (NIS) appeared for the first time in 1882 by Freeman in a working paper for the OECD (Organisation for Economic Co-operation and Development). Freeman (1987) defines NIS as *the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies.* The paper of the OECD highlights the importance of interactions and linkages among the stakeholders in a country involved in innovation processes, specially then it comes to technological development. According to this theory, the innovation performance of a country rely mainly on how actors involved interact to each other, using a collective system of knowledge and technologies (OECD, 1997). Ludvall (1985), expert in NIS, underlines the analytical approach of NIS, starting from the analysis of the role of knowledge and learning in connection with the innovation process. The concept of **Regional Innovation Systems** (RIS) arrived in 1997 by Cooke, and it basically also remarks the interation between actors to enforce innovation, but in a regional level (Cooke et al., 1998).

The concept of **Technological Innovation Systems** (TS) goes beyond national borders. First mentioned by Carlsson and Stankiewicz (1991), describes the function of technological systems with the participation of various economic agents. This concept is more industry and technology based. They define technological system as knowledge and competence flows in a network of agents interacting in a specific institutional infrastructure (Carlsson and Stankiewicz, 1991).

Some years later, the concept of **Sectoral Innovation Systems** arose with Malerba (1997). The Sectoral Innovation System focuses on certain sectors of the economy as its system boundary, regardless the geographical location or the technology of the innovation. The Sectoral Innovation Systems framework gives an integrated, multidimensional and dynamic overview to analyze the

innovation, actively considering involved stakeholders (Malerba, 1997).

The last concept is the **Spatial Innovation System**, Oinas and Malecki (2002). This combines national and regional perspectives with the technological system. When the definitions of NIS, RIS and TS came up, those concepts where presented independently. However, Oinas and Malecki (2002) state that technological development is spatially limited. Technology is driven by social relation involved in production and consumption of those technologies. That interplay was the origin of Spatial Innovation System.

The following Figure 5.2 shows the innovation system dimensions and the relationships between the systems. In the Global System of Innovation we find multinational firms, international laws, regional laws, regional trade agreements, intellectual property rights and international. National Innovations Systems are composed by infrastructure, institutions, education and training systems, financial system, R&D system, and governance system. The boundaries of NIS are determined by the clusters, regional administration, institutions, etc. Regional systems provide external economies, which also depends on the level of openness of the global and national system. Sectoral systems extend across regions and nations, and are bound by specific industries. And to conclude, technological systems are applied across different sectors and nations (Frenz and Oughton, 2005).

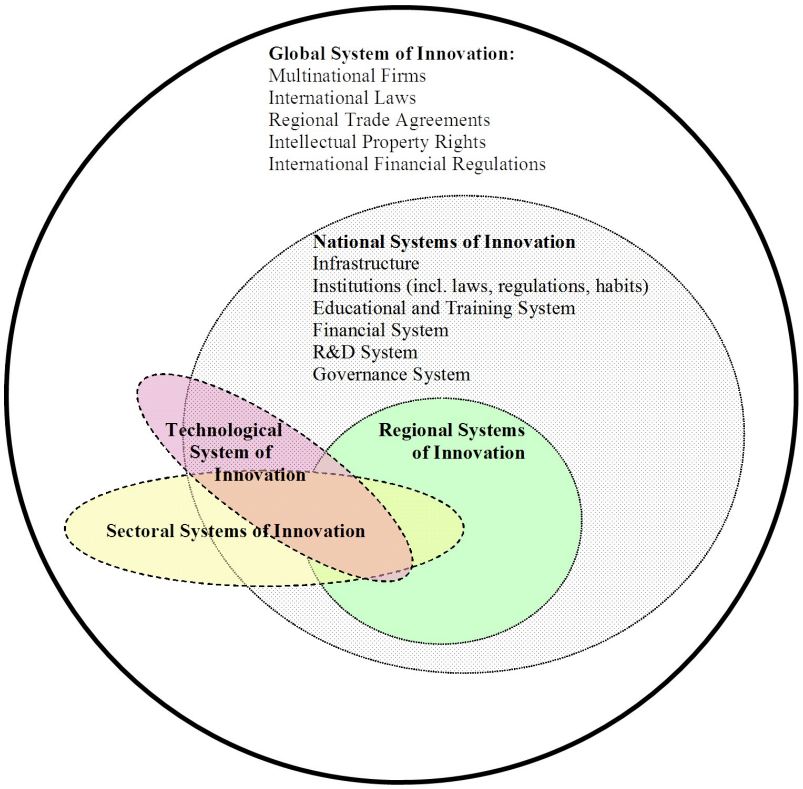


Figure 5.2: Relationship between global, national, regional, sectorial and technological systems of innovation. (Frenz and Oughton, 2005)

5.1.2 Innovation processes

When it comes to implement an innovation, it is important to recognize and get familiar with the process. Ignoring the stages in an innovation could entail in a failure of the innovation, bring significant economic loss.

The process of innovation can be understood in various ways. On the one hand, Garud et al. (2013) divides the innovation process in 3 activities: Invention, development and implementation. On the other hand, Moore (1993) explains the 4 phases for innovation ecosystem progress: Birth, expansion, leadership and self-renewal or death.

Garud (Garud et al., 2013) (Garud et al., 2015) describes the process of innovation. It basically consist of 3 stages: **Invention**, **development**, and **implementation** of new ideas. Innovation process could be defined as sequences of events to emerge, develop and implement new ideas across firms, multi-party networks, and communities (Garud et al., 2013). In their research, they characterize innovation processes as **co-evolutionary**, due to the multiple levels of analysis they involve; **relational**, connecting diverse material elements and actors; **inter-temporal**, occurring temporal sequences in numerous ways; and **cultural**, an aspect that need to be taken into consideration to contextualize settings.

As mentioned, the process of innovation can be classified in three phases: Invention, development, and implementation. Garud et al. (2013) propose certain mechanisms to approach those three phases, and give some guidelines for the different levels in which those innovation processes unfold: Firms, multi-party network, and communities.

In the **invention** phase, where new ideas are born, recombination of ideas and artifacts across different domains is the key mechanism. In this phase, the technology push plays an important role, and also having a deep knowledge and practice on demand and supply. Those mentioned mechanisms could be settled in three levels: Firms, multi-party network, and communities (Garud et al., 2013). Firms are sources of new ideas. To overcome the challenges that they have to face from time to time and to generate new ideas, they have to be creative. For multi-level networks, knowledge networks play an essential role, sharing and transferring ideas withing the network (Garud et al., 2013). Barrett et al. (2011) also remark the importance of sharing data when it comes to enhance collaboration among the community of firms. Regarding the key factor in the invention phase in communities, agreeing common actions withing the community is crucial, in order to have a common idea, goal, and perspective between members in the community (Garud et al., 2013).

It takes time and effort to put an idea into practice in the **development** phase. The ideas have to escalate into assets, resources and capabilities, in order to manufacture and sustain the innovation (Garud et al., 2015). This process involves different actors and artifacts and could result being complicated. Therefore, transformation in the identity of actors, material artifacts and institutional resources is the key mechanism in the development phase. Firms offer ideas and resources. Having those key elements, internal venturing is the action to follow (Garud et al., 2013). In the case of multi-party networks, the development of the idea for commercial application is

distributed among the firms in the network. Counting with a leadership platform facilitates the proper management of the network. And in the case of development within communities, having a industry infrastructure supporting the public and private sector helps to develop the innovation (Garud et al., 2013).

Implementation is the last stage in the innovation process following with Garud et al. (2013)'s theory. Institutions come into play to make an innovation viable and to implement it. Institutions regulate the logistics of production and use of the innovation. Having the institutional support, firms are responsible of adopting the innovation into their business strategies (Garud et al., 2013). Implementation across a multi-party network involves different actors cooperating and competing. Diffusion is the mechanism to escalate the innovation at the network level. This is related to open and collaborative innovation (see Sections 5.2 and 5.3). In communities, stabilization between actors involved in the ecosystem plays an essential role (Garud et al., 2013).

Moore (1993) explains the 4 stages in the innovation progress. Starting with the **birth** of the innovation, including the common understanding of the product or service that is meant to be innovated, and collaboration between involved stakeholders. The second stage is the **expansion** to new territories of application. The expansion requires stimulation of market demand and a strong relation between actors and the leader. Related to that, the third stage comes into play: The importance of the **leadership**. This third stage is marked by the consolidation and establishment, where stability and vision of future development is needed. The role of the leader is vital in order to have a stable innovation and institutionalizing a solid network of cooperators. The last stage would be **self-renewal or dead**. This phase refers to a mature innovation system, which demands a significant change in order to remain alive. In this last stage leaders have the role of mitigating the threats to the innovation, and restructuring their current system (Moore, 1993).

5.2 Open Innovation

The concept of open innovation (OI) came out by Chesbrough (2003a). In the 20th century, internal research and design was a beneficial strategy for leading companies. This internal innovation is also known as closed innovation, which enforces the importance of an internal approach to innovate. The principle in closed innovation is that *Successful innovation requires control*, where self-reliance is key. Companies generate, develop, and commercialize their own ideas (Chesbrough, 2003b).

Nonetheless, collaboration with outside partners is getting more popular in the last years, and influential firms are incorporating innovation in their business strategies. That is how the concept of open innovation came up. Open innovation supporters claim the potential of a determined innovation when collaborating, sharing knowledge, R&D with external actors.

5.2.1 Closed and open innovation

It is undeniable the considerable differences between the principles of closed and open innovation. In the closed model, is key having experts and strong knowledge in the field. While in the open innovation, that knowledge is also found in experts outside the company (Almirall and

Casadesus-Masanell, 2010). The difference in R&D is also noticeable. It is more profitable, in a short term, doing internal R&D, discover, development and shipping. Internal R&D is needed in open innovation, but it also recognizes the value creation of external R&D. Intellectual property is also something that is very protected in closed innovation, in order competitors not to profit from those ideas. Whereas, in open innovation, sharing intellectual property is a business strategy to advance in their business model (Chesbrough, 2003b).

Another characteristic is the competitiveness in closed innovation towards other companies, when it comes to be the first discovering, commercializing an innovation, and creating the best ideas in the industry. On the other hand, in the open innovation system, there is no need to originate the research in order to obtain profit from it. Originating a better business model is prioritized to being the first to get into the market. And it is also key not to only making the best use of internal ideas, but also external ideas (Almirall and Casadesus-Masanell, 2010).

The following image (Figure 5.3) is a graphical comparison between the closed and open innovation systems. As it can be seen the picture the left, the boundaries in the closed innovation model are closed. Research projects are developed internally, and come out in the market, where they would compete with other companies. The picture in the right, open innovation, shows the opposite concept. The boundaries of the company are open. That means that a company commercializes not only it own innovations, but also other firm's innovations. This model develops pathways to outside the company's current businesses, exploring ways to export internal ideas to the market (Chesbrough, 2003a).

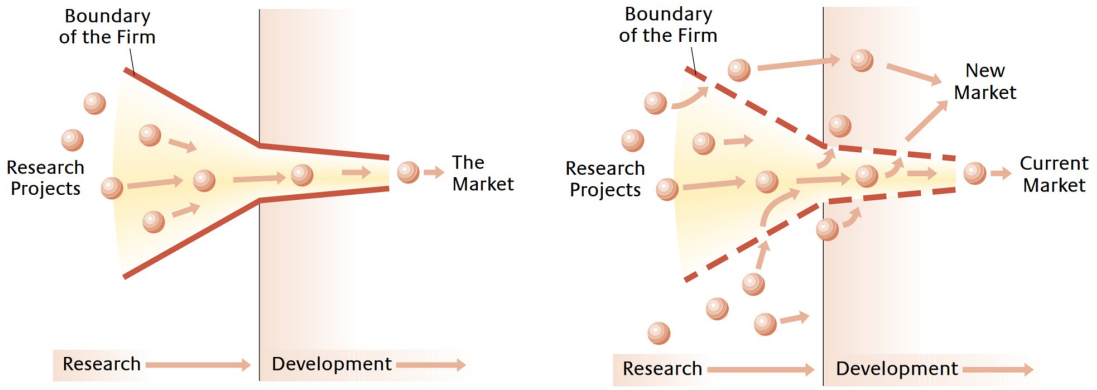


Figure 5.3: The closed innovation model (left) and the open innovation model (right) (Chesbrough, 2003a)

5.2.2 Transition to open innovation. Barriers, drivers and opportunities

The open innovation approach requires a different knowledge landscape, and a different source and use of ideas (Chesbrough, 2003a). A large number of leading firms, like *Procter & Gamble*, *Unilever*, *Glaxo Smithkline*, *Philips*, or *IBM*, among others, have modified their business strategies and implemented a more open innovation approach in their business models. Furthermore, this open innovation has noticeably benefited those companies (Golightly, 2012). Start-ups and young companies are avoiding innovating in a closed strategy, and since their found, most of them take a change on open innovation. Nevertheless, the transition from closed to open innovation is a complicated process, specially for settled and profitable companies that have been

successful for years using the closed innovation approach (Chesbrough, 2003a).

As mentioned, the transition from closed to open innovation is a complicated process and there are some challenges and barriers that have to be taken into account. The first barrier that could be found is the internal culture change. That internal culture could be modified by involving expertise in open innovation, creating a department which focuses on open innovation, and/or getting involved in collaborative projects. The next challenge that could be found is the performance managing in open innovation. Finding the balance between open innovation maintaining closed strategies seems to be complicated. A proper culture change eases the this performance barrier, and also, the experience in open innovation projects might reach the best configuration in that sense. Another issue that large companies found while engaging open innovation, was interacting with other big companies and creating networks with smaller businesses (Golightly, 2012).

Drivers are necessary to turn barriers into opportunities. Golightly (2012) describes the open innovation journey, the drivers to overcome the barriers when innovating. Even if those steps can vary depending on the case, the following 8 steps seem to repeat in most of the cases.

1. Establish internal resources to leverage open innovation.
2. Create value and culture change
3. Identify external expertise but retain control
4. Develop relationships & new ways of working
5. Build ecosystem & internal skills
6. Create accurate & relevant open innovation metrics
7. Move to decentralize many open innovation
8. Increase integration with the ecosystem

(Golightly, 2012)

There are several opportunities attached to open innovation. Bakar (2015) and West and Bogers (2017) mention some in their studies. OI consist of knowledge flow exchange, and that is one of the most notable opportunities that firms have when innovating. Both, inbound and outbound knowledge flows. This knowledge flow is an opportunity to grow internally (West and Bogers, 2017). This knowledge exchange is linked with emphasis in services. Innovation in services give opportunities for value creation, by customizing and personalizing, which could face challenges in value capture (West and Bogers, 2017).

Chesbrough (2003a) highlights the the opportunity of OI specially for big firms and multinationals. Nevertheless, West and Bogers (2017) remarks the opportunities for other type of organizations, such as medium- and small-scale firms. The opportunities for start-up also seem promising and gaining importance. They represent a powerful tool of open innovation processes, selling

new ideas to the market and transforming enterprises in a sustainable way (Spender et al., 2017). Not only that, but OI models can be also applied to public organizations, such as government agencies, and non-profit organization (Chesbrough and Bogers, 2014).

As collaboration is the key in open innovation, West and Bogers (2017) highlights the valuable opportunity for network collaborations. There are various network typologies of collaborations, such as alliances, communities, consortia, ecosystems, and platforms. The network requires coordination and negotiation between the organizations, creating and capturing value jointly. Collaboration is the key concept in open innovation. Collaborative innovation is also been a widely used term in innovation. In the following Section 5.3, the collaborative innovation theory is explained.

5.3 Collaborative innovation

Collaborative innovation refers to the process of innovating, where multiple actors, inside and outside the organization, interact jointly with the same purpose. In general, collaborative innovation creates symbiotic connections between organization, where every company inside the collaboration benefits Khosrow-Pour (2013). As it can be seem in the definition of collaborative innovation, the concept is closely related to open innovation.

5.3.1 Collaborative innovation models

Moving towards a collaborative innovation requires an internal change. Innovation models could be understood from the collaborative perspective, where Barrett et al. (2011) proposes 4 collaborative models. Chesbrough (2003a) refers to models of innovation, but focusing on the activities of innovation and the role of involved organizations. Starting with the collaborative models by Barrett et al. (2011), innovation models are divided in the following cathegories (see Figure 5.3).

- In the first model, called **Ad hoc**, there is a focal firm and the collaborations are just transactions. In this kind of models there is usually an absence of policies to engage partners. In other words, there is no platform supporting the collaboration. The control is just on the focal form, and there are no interaction among 3rd parties (Barrett et al., 2011).
- The second model, **hub-and-spoke** is a closed platform, where there is an central platform for collaboration controlled by the focal firm. This framework facilitates the interaction and between firms in the community with the focal firm, but there is no interaction among third parties (Barrett et al., 2011).
- The third model is a **network model**. The principles are the same as in the second model: There is a focal firm leading, with a platform from the focal firm supporting the innovation. The difference with the previous model is that the focal firm enables interactions between actors in the network(Barrett et al., 2011).
- The forth model is an **open platform model**. In this model, all the involved firms interact with each other within an ecosystem. The control is distributed, the platform is shared among participants in the network, and interactions among thirds parties are common (Barrett et al., 2011).

These model are directly related to the level of openness. In the first model, even if there are some collaborations, the The first model is a closed innovation compared to the next models. The open platform model is the one with the biggest level of openness. The following Figure 5.4 summarizes the collaborative innovation models.

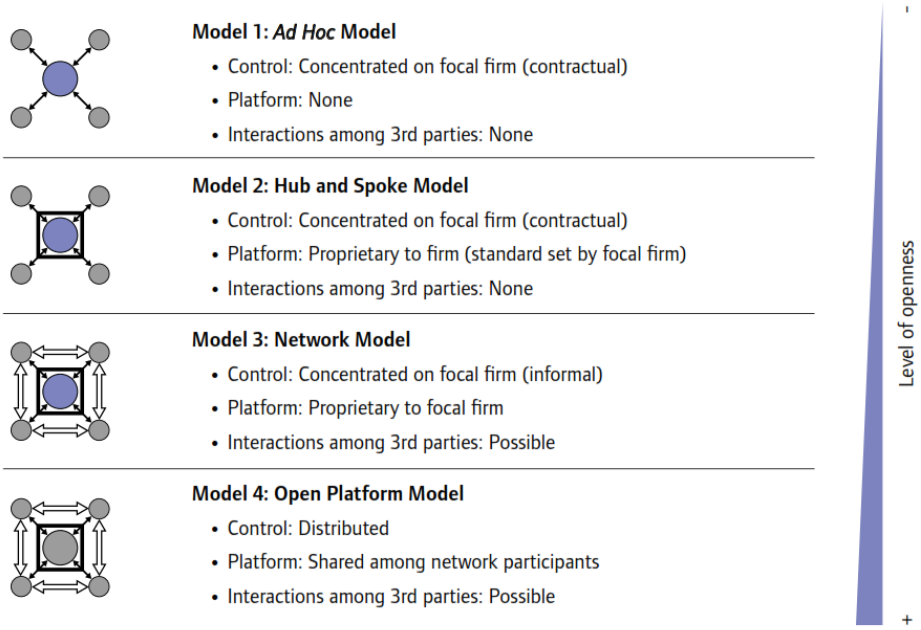


Figure 5.4: Models for collaborative innovation (Barrett et al., 2011)

Chesbrough (2003a) also refers to Innovation Models, but classifying stakeholders in a different way, regarding their role. Firm's activities could be divided in funding innovation, generating innovation, and commercializing innovation.

In **funding** innovation activities, there are 2 type of organizations. On the one hand, innovation investors. They are responsible of proceeding ideas from researchers to markets, and also supply valuable advice. This organizations are R&D budget, angel investors, venture capital, private equity investor, among others. On the other hand, the type of organizations are innovations benefactors, which include foundations or research agencies. These organizations provide new resources of research, and support financially the research in early stages (Chesbrough, 2003a).

The next activity is **generating** innovation, where we can find four organizational categories. Innovation explorers perform the discovery research function. They could be considered spin-offs of laboratories, and usually do not innovate for commercial goals. Contrarily, innovation merchants innovate for financial purpose. Other type of organizations in innovation generators are innovation architects. They provide a valuable service, and create value for their customers. The last category is innovation missionaries, which consist of people and organizations that do not chase financial profits. They create and advance technologies to serve a cause, and mission is their motivation (Chesbrough, 2003a).

The last innovation activity is **commercializing**, which are the responsible organizations of

bringing innovations to the market. Innovation marketers understand necessities of the market and commercialize ideas profitably. The last type of organization is innovation one-stop centers, who take the best ideas and offerings and deliver those products and services to their customers at competitive prices (Chesbrough, 2003a).

5.4 Innovation ecosystems

Innovation ecosystems (IE) is a topic emerging from innovation. The principles applied in innovation ecosystems are the similar to the ones in innovation. The term *ecosystem* is the one emerging in this new concept. Nevertheless, the adoption of this term is debatable according to a number of authors. In this section, the concept Innovation Ecosystem will be defined, followed by a critique made by some authors regarding the terminology.

IE could be defined as the collaboration between a diverse set of actors towards innovation. In other words, it is an heterogeneous group of organizations, co-evolving capabilities to co-create value (Dedehayir et al., 2016). Witte et al. (2016) defines it as *the large and diverse array of participants and resources that contribute and are necessary for ongoing innovation in a modern economy.* Those ecosystems include researchers, investors, entrepreneurs, policy makers, business developers, etc. Those actors interact and exchange knowledge flows (Witte et al., 2016). Firms in this context of collaboration, recognize the holistic value in products and services for future customers, and create and capture value by actors. This collaboration involves producers, suppliers, distributors, financial institutions, research institutions, clusters, value networks, etc. The existence of an innovation ecosystem would provide platform to the organization to exchange products and services to the users of those products and services (Dedehayir et al., 2016). The importance of public and private investment and inter-organizational network are also emphasized by Witte et al. (2016).

Innovation ecosystems could be understood as an metaphor or analogy between IE and biological ecosystems. The dynamics in the economic models, the relationships between stakeholders, and the material resources exchange in innovation ecosystems, could be compared with the complex relationships among the living organisms, habitats, and residents of an area. In the case of IE, the functional goal is to enable innovation and technology development, while in the case of biological ecosystems the functional goal is maintaining an equilibrium between the living and non-living resources in the habitat (Jackson, 2015).

5.4.1 Innovation ecosystem emergence

Dedehayir et al. (2016) highlights 4 roles in the innovation ecosystem emergence: Leadership roles, direct value creation roles, value creation support roles, and entrepreneurial ecosystem roles.

The **leader** is the central actor and the responsible of delivering holistic value. The main activity of the leader is governing the ecosystem, initiating, maintaining and developing functionality, developing actions such as coordination of internal and external actors, design of the the role of the actor, and controlling resource flows within the network. Creating the network is a vital

role of the leader. Gathering partners together, attracting companies with different resources. The leader is also responsible of managing the platform, providing a technical basis, such as the design and build of the platform, creating an open platform with an exchange of knowledge and data between the partners, and controlling the platform. Managing value is also a role to take into consideration, building offerings and supplying components, and stimulating value appropriation for producers and end-users (Dedehayir et al., 2016).

In the **direct value creation**, Dedehayir et al. (2016) explains the 4 roles: Supplier, assembler, complementor, and user. The supplier delivers technologies, materials and services to other actors in the ecosystem. The assembler provides products and services. The complementor is responsible of achieving compatibility with the platform, utilizing the design of the ecosystem for other offereings, and creating customer specifications. And the user contributes to value creatin, though defining a need, developing ideas, purchasing the offering, and integrating product and services (Dedehayir et al., 2016).

In **value creation support**, there are the role of the expert, supporting value creators, and champion, supporting ecosystem construction. The expert generates knowledge, provides advice and encourages technological transfer and commercialization. The champion build interconnections between actors, interacts between partners, and provides access to markets (Dedehayir et al., 2016).

Last but not least, Dedehayir et al. (2016) defines the roles of **entrepreneurial ecosystem**. The entrepreneur sets up a focused network of actors, and coordinates the collaboration between research and collaboration partners. The sponsor supports new venture creation by financing low-income markets, providing resources to entrepreneurs, and linking entrepreneurs to other ecosystem actors. The last role is the regulator, which is responsible of supporting entrepreneurial activities and supporting ecosystem emergence, though economical and political reform. This innovation ecosystem emergence could also be applied to any innovation system creation.

5.4.2 Types of innovation ecosystem

Oh et al. (2016) classifies innovation ecosystems in different types.

- **Corporate/open IE**: The involvement of different stakeholders in the innovation process (suppliers, users, partners, etc). It could be considered as interactions with external actors from the ecosystem.
- **Regional and national IE**: It is basically the same concept as RIS and NIS, mentioned in 5.2.
- **Digital IE**: Represents online platforms involved in innovation. Is the digital network formed by customers, users, and developers.
- **City-based and district IE**: These are innovations developed by municipalities and small companies. They generally focus on small and new companies.

- **High-tech small and medium-sized enterprises centered ecosystems**: Those systems work in small countries, where manufacture is generally made by small and medium-sized companies.
- **Incubators and accelerators managers**: Create hyper-local innovation ecosystems.
- **University based ecosystems**: Most universities focus on the entrepreneurial part of innovation.

5.5 Conclusions of the theories

During the theoretical framework, some concepts are repeated or are very similar and named by different authors. Some definitions and concepts merge. The following table (Table 5.1) groups the theories explain during this Chapter 5. They are grouped in 5 main themes. Each theme includes the key concepts involved in those themes, the authors that mentioned them, and the sections in the theoretical framework where those concepts appear.

Table 5.1: Summary of the theoretical framework

Main themes	Key concepts	Authors	Sections
Principles	Knowledge flows External RD Share intellectual property No competitiveness Collaboration Co-evolve Co-create Holistic value Private-public investment	Chesbrough Garud et al. Barrett et al. Almirall and Casadesus-Masanell Khosrow-Pour Dedehayir et al. Witte et al. Jackson	5.2 5.3 5.4
Type of innovation	Global IS / NIS / RIS / City-based IS TS / Digital IE Sectoral IS Spatial IS Others (Small/medium sized enterprises, incubators accelerator managers, university based ecosystems)	Freeman Cooke et al. Carlsson and Stankiewicz Malerba Oinas and Malecki Oh et al.	5.1.1 5.4.2
Innovation processes	- Invention/IE emergence/birth, and role of founders - Development, and the role of generators - Implementation/expansion, and the role of commercializing	Garud et al. Moore Dedehayir et al. Chesbrough	5.1.2 5.3 5.4
Transition to collaboration	Start-ups Internal culture change OI department Knowledge flow exchange Value creation Opportunity for big firms Sell new ideas Transform enterprises	Chesbrough Golightly Bakar West and Bogers	5.2.2
Role of the leader	Leadership OI models	Moore Barrett et al.	5.1.2 5.3

As it can be seen in the definitions about IE, it describes some of the principles in innovation systems, open innovation, and collaborative innovation. Starting with the concept, the definitions of IE mentioned by Dedehayir et al. (2016), Witte et al. (2016) and Oh et al. (2016) follow the same principles cited by Chesbrough (2003b), Almirall and Casadesus-Masanell (2010), Garud et al. (2013), Khosrow-Pour (2013) and Barrett et al. (2011) in open and collaborative innovation. They all enforce the knowledge and exchange between stakeholders in the network, lack of competitiveness, the benefits of collaboration between different stakeholders in the network, co-creation, holistic value, and the importance of the cooperation between public and private sector. The key principles of collaboration, that involve the definitions of open innovation, collaborative innovation and innovation ecosystem, are grouped in the theme *Principles* in the table above (table 5.1), together with the key concepts of collaboration, and the author that mentioned those concepts.

Another similarity is the classification of innovation ecosystem types by Oh et al. (2016) with innovation systems (Subsection 5.2). Oh et al. (2016) refers to Regional and national innovation ecosystems, following the concept of NIS (Freeman, 1987) and RIS (Cooke et al., 1998). City based innovation ecosystem (Oh et al., 2016) is also included in this categorization of type of innovations, together with Global Innovation Systems. They all represent the same idea, but applied in different scales. Following with the type of innovation, Technological Innovation Systems (Carlsson and Stankiewicz, 1991) (merged with the Digital IE (Oh et al., 2016)), Sectoral Innovation System (Malerba, 1997), and Spatial Innovation System (Oinas and Malecki, 2002), from the Subsection 5.1.1 *Innovation system approaches* are also included in the theme of *Type on innovation* in the Table 5.1. There is another type classified as *others*, which include the remaining types of innovation ecosystem (see Subsection 5.4.2) by Oh et al. (2016): Small/medium sized enterprises, incubators accelerator managers and university based ecosystems.

The next proposed theme is *Innovation processes*. These are grouped in three processes. Invention phase (Garud et al., 2013), innovation ecosystem emergence (Dedehayir et al., 2016), and birth of the ecosystem and the role of founder (Moore, 1993). Following with the development phase (Garud et al., 2013), together with the role of generators (Chesbrough, 2003a). The last group merges the implementation phase (Garud et al., 2013), expansion of the ecosystem (Moore, 1993) and the role of commercializing (Chesbrough, 2003a).

Looking at the theory by Barrett et al. (2011) describing models for collaborative innovation, we can see that the innovative model that could be applied in the theory of innovation ecosystem is the *Open platform model*. In this collaborative model, every involved firm interact with each other and the control is distributed among the firms in the network.

In the transition to collaboration, the concepts of Chesbrough and Bogers (2014), Golightly (2012), Bakar (2015), and West and Bogers (2017) in Subsection 5.2.2 *Transition to open innovation. Barriers, drivers and opportunities.*

The last theme in table of summary of theories is the *role of the leader*. Is is considered essential when it comes to settle collaboration. Moore (1993) and Barrett et al. (2011) mention the importance of the leader. In the case of Moore as as one of the 4 innovation progress stages, and as a focal figure in open innovation models (Barrett et al., 2011).

6 | Analysis

The analysis begins with a description of the chosen institutions and the interest of interviewing them. After that, the interviews are analyzed. Every interview is divided in 5 main categories: *Processes in the project and implementation of innovation*, *transition to collaboration and stakeholder involvement*, *opportunities and challenges*, *key lessons*, and *future expectations*. The result of the interview is compared with the theory about innovation and innovation ecosystem. To conclude, some recommendation for the implementation of innovation ecosystem Northern Jutland are suggested.

6.1 The case studies

After a deep research and comparison between different organizations working on the field of circular plastics economy, the following organizations were chosen: *Plastindustrien*, *Region Midtjylland*, *Aarhus University Hospital*, and *The Ellen MacArthur Foundation*.

Plastindustrien

Plastindustrien was chosen as the internal case study. *Plastindustrien*, together with *Aage Vestergaard Larsen* (AVL) and *Aalborg university* (AAU), is responsible of the project *Genanvendelse af plast – en styrket dansk industri* (*Improving the recycling of plastic - a strengthened Danish industry*). It is considered important having an insight of one of the companies involved in the project. *Plastindustrien* is the chosen one to get that insight, as a trade association of plastics. The aim of this interview is to get familiar with the creation phase of the project, their expectations, and the standpoint of the organization towards collaboration.

Plastindustrien is the trade association for plastic companies in Denmark, working to ensure danish plastic companies a framework for optimization and success (www.plast.dk). The interviewee of this organization is Christina Busk. She is working within environmental politics in the area of plastics in Denmark. She is responsible of bringing the association's policy on a number of current environmental debates that are particularly relevant to the Plastics industry's members. Busk is working within circular economy and recycling of plastic, plastic littering and chemicals. She is the one in charge of environmental politics in *Plastindustrien*. Her role on the *Genanvendelse af plast – en styrket dansk industri* project is not completely defined yet, but it would be setting up the coming network, contacting all the relevant businesses, and managing the network afterwards.

Region Midtjylland

Region Midtjylland (RM) is the administrative unit of Central Denmark, responsible of healthcare, nature, environment, business and tourism (www.rm.dk). At the Circular Economy Team at Central Denmark Region they accelerate circular economy by helping companies and business to get a scope and scale. Their aim is making changes on a system level, through mobilizing

and cross-cutting initiatives and activities at a regional, national and international level. All this makes RM a key interview target for the research.

The interviewed person at RM is Hanne Juel, the leader of the Circular Economy Team at Innovation and Research in Central Denmark Region. She is focused on innovation and research, transforming circular economy into praxis.

The Circular Economy Team is the key player in Circular Economy in Central Denmark. They bring innovation into their strategies. The team is involved in different project regarding circular economy. They developed a business in a circular way, called *Rethink business*. They educate partners, in order them to minimize their waste. The Circular Economy team also runs a symbiosis program, they are involved in the public procurement program from the EU, and have strategies to go up in the supply chain, among other projects where they are involved.

The most significant project for this research, where RM is involved, is a project about circular plastics economy in Aarhus Universitetshospital (AUH). They are leading a project about the plastics in hospitals in how to become plastic waste into a resource. Aarhus University Hospital works with recycling of plastic waste as part of Central Denmark Region's overall focus on circular economy. This project is considered important for the research, and in the chosen national case study to analyze.

This interview is slightly different to the others. The aim of the interview is obtaining the perspective of the public sector in the area of innovation and circular economy in different fields, not focusing just on one single and remarkable project where RM is working.

Aarhus Universitetshospital

Aarhus Universitetshospital (AUH) is leading a project in circular plastics economy in their hospital, called *Materialestrømsprojektet*, which could translate in *CE in Healthcare*. It is a cooperation between RM and AUH, started 3 years ago. In the project they investigate how to increase recycling resources and packaging, based on the large amounts of plastic packaging of hospitals. They work with a value chain approach and they mapped plastic types in 9 different departments at AUH. They facilitate a dialogue across the value chain, between the producers and suppliers that they have identified. Their purpose is to find solutions that can help to increase recycling of resources and the quality of recycling plastic packaging.

The interviewee for this case study is Susanne Backer, the project leader of *Materialestrømsprojektet* in the technical department of Aahrus University Hospital.

The project is a remarkable example, because it is happening now and is a national case-study. The practical aspect of this project, is that the material flows that go in and out of the hospital are known, and, therefore, easier to manage. This project is also a collaboration between public and private sector.

Ellen MacArthur Foundation

The Ellen MacArthur Foundation (EMF) is a non-profit organization and a worldwide reference in circular economy. They are mostly funded by philanthropic organizations and businesses to collaborate in their initiatives. Their mission is to accelerate the transition to circular economy. They are running various programs to enable different kind of organization to develop new opportunities and fulfill their circular economy ambitions faster. They also published a number of papers, reports and videos, in order to raise awareness in this topic (Ellen MacArthur Foundation, 2015). Since 2015 EMF is leading a project regarding circular economy in plastics, called *The New Plastics Economy* (NPE). The aim of the project is to minimize plastic waste by creating an effective after-use plastics economy. The outcome of this project would capture more material value, increase resource productivity, and reduce the amount of plastic waste in the environment (Ellen MacArthur Foundation, 2016).

The interviewed expert is Mats Linder, project manager at EMF. He has been working in different organizations involved in sustainability, and currently he is the founder and circular economy expert and leader at *MLSH consulting AB* in Stockholm. He is committed to sustainability and supporter the circular economy as a tool, in order to make the world more sustainable.

Having information about this NPE project would enable having an insight of a big scale program in the circular plastics economy, where innovation plays an essential role and which collaborates actively with a number of significant stakeholders in different innovation phases.

6.2 Interviews

In this section the gathered empirical data will be analyzed, using the main research method in this thesis; interviews. The aim is to get an insight of the national and international case studies, recognizing their characteristics and comparing them with the theory about innovation and innovation ecosystems. This section will give an answer to the second research sub-question:

2. Which are exemplary national and international case studies currently working on the field of circular economy in the plastics industry? What characterizes them?

The analysis of the interview is going to be developed based on the 5 main topics of the interview, specified in Subsection 4.2.2 and 4.3.1: *Processes in the project and implementation of innovation*, *transition to collaboration and stakeholder involvement*, *opportunities and challenges*, *key lessons*, and *future expectations*. The answers from the interview are going to be contrasted with the theories from theoretical framework. The highlighted terms are the concepts that are contrasted with the theory and summarized in the tables.

6.2.1 Processes in the project and implementation of innovation

The following Table 6.1 summarizes the outcomes of the interviews, contrasted with the theoretical background. Each section of the table is specified bellow.

Table 6.1: Summary of processes in the project and implementation of innovation

Org.	Interview	Theory	Authors
Plast.	Map plastic		
	Know the best business	Invention phase	Garud et al.
RM	Involve people	Principles OI, NIS/RIS, Spatial IS	Chesbrough, Freeman, Oinas and Malecki
	Implement new ideas	Dev. phase/ Transition to OI	Garud et al., Chesbrough, Golightly
	Get a value	Create value/ IE	Golightly, West and Bogers
	Scalable model	Expansion and dev. phase	Moore and Garud et al.
AUH	Mapping exercise	Innovation processes	Garud et al.
	Identify waste and type of plastic	Innovation processes	Garud et al.
	Logistic plan for recyclable plastics	Innovation processes	Garud et al.
	Identity suppliers	Innovation processes/ birth IE	Garud et al., Moore
	Choice type of product to innovate	Innovation processes	OECD
	Be organized		
	Reach out international environments	Expansion and dev.phase	Moore, Garud et al.
EMF	Do an effort in a particular industry	New ideas/ System thinking	OECD, Galanakis
	Catalyze innovations	Inn. as catalyst for regional dev.	Garud et al.
	Transition to circular economy	Transition to OI	Golightly
	Target innovation	Product innovation	OECD
	Set criteria for challenges	Role of investor	Chesbrough
	Accelerated program	Incubator & accelerator managers	Oh et al.
	Design a system	System thinking/ role of investors	Galanakis, Chesbrough
	Regulatory incentives	Implementation phase-Institutions	Garud et al.

Plastindustrien

First, the insight of *Plastindustrien* is going to be considered regarding the processes they followed in the creation of the project, in order to get familiar with the *Genanvendelse af plast – en styrket dansk industri* project. They highlight the importance of **mapping plastics in Denmark**, the **amount** of plastic, and knowing where the **business cases** are, with the aim of **recycling** them, instead of incinerating. In the invention phase of innovation processes (Garud et al., 2013) emphasizes that having a deep knowledge of the business, demand and supply is essential. The project is currently on the invention phase. Therefore, following the key points of this phase, enables proper future development and implementation phases. AUH also did a mapping process in the stating point of their project, specified bellow.

Region Midtjylland

When it comes to RM's vision about the processes and implementation of innovation, Hanne Juel remarks various key points. She highlights repeatedly the importance of **involving people** and bringing them together. Involving people is the base of open and collaborative innovation (Chesbrough, 2003b) (Barrett et al., 2011). NIS and RIS also remark the importance of interactions and linkages among stakeholders (Freeman, 1987), and according to the Spatial Innovation Systems theory, the technology is driven by social relations.

Another process RM follows is **implementing new ideas** and making a movement around the

idea. This is reflected in the development phase of the innovation processes, where ideas are escalated to make them viable and be able to implement them later in the implementation phase of innovation (Garud et al., 2013). In the transition to open innovation, Chesbrough (2003b) and Golightly (2012) emphasize selling ideas to the market. Juel also highlights that everyone in the value chain could **get a value**. Value creation and culture change is one of the steps in the open innovation journey. Golightly (2012) and West and Bogers (2017) say that innovation gives opportunities for value creation.

Another important aspect for her is creating a **escalable model**. This idea can be reflected on the theory in the expansion stage of innovation progress (Moore, 1993). Having an idea that escalates is also mentioned in the development and implementation part of innovation processes by Garud et al. (2013).

Aarhus Universitetshospital

When AUH was asked about the processes they followed in the implementation of the project, Baker mentions various points. They started with a **mapping exercise** to get an idea of what kind of plastic they would work with. **Identifying plastic waste and type of plastic** was the next step. They already have a **logistic plan** for one of the recyclable plastics, LDPE. Another essential process is **identifying suppliers and the value chain**. In their case, they identified 162 suppliers and the top 5 suppliers. Once the previous stages were fulfilled, they chose the **type of product to innovate**. The chosen product was a bottle of plastic containing medical irrigation fluid, a very common product in every hospital. In all this process of creation and implementation, she highlights the importance of being **organized**. This processes that AUH followed to implement the innovation processes by Garud et al. (2013), innovation, development and implementation phases.

Last but not least, AUH's goal is to reach out to the **international environments**. Here, the theories of Moore (1993) and Garud et al. (2013) are reflected, when it comes to expansion and implementation phases of the innovation. Garud et al. (2013) remark the escalation when implementing the innovation.

Ellen MacArthur Foundation

As mentioned in the description of EMF, their mission is to accelerate the transition to a circular economy. With the project NPE, they aim to do a concerted **effort in one particular industry**, the plastic industry, in this case. For such a transformation of the industry in a systemic way, they recognize the essential role of innovation. This statement could be compared with the definition of innovation as *the process of creation of new ideas* (OECD, 1996) and the system thinking (Galanakis, 2006). Part of their innovation program is to stimulate or **catalyze** the crucial innovations to remodel the old system, the linear economy, and move to a function system based on the circular economy. Garud et al. (2013) remark the innovation as catalyst for regional development; and the **transition to a CE** can also be compared to the transition in the OI. Mats Linder also mentions targeting innovation where they can catalytic.

On the other hand, they also realized about the importance of **targeting innovations**, by establishing some priorities. The target segment was plastic packaging, reducing packaging and looking for alternative materials. This improvement can be contrasted with the theory about product innovation, due to renewing or significantly improving a product (OECD, 1997). Together with a funding organization (role of founder by Chesbrough) they created a set of **criteria** to overcome the challenges that they find.

Another process that EMF followed was putting some partnesr in an accelerated program where they are given support to accelerate and develop their business on their innovation. Oh et al. (2016) mention the figure of incubator and accelerated managers to enhace the innovation ecosystem. It is also necessary **designing a system** that works for them. Aware of the limitations of the conventional recycling methods, like mechanical recycling, and hence, the need of chemical methods to keep plastics in the close loop. Therefore, it is necessary investment in support in order to scale and become visible. Once again, remarking the role of investors (Chesbrough, 2003b). **Regulatory incentives** and also needed in order to implement innovations (Garud et al., 2013). Institutions are necessary to regulate the logistics of production and use of the innovation.

6.2.2 Collaboration and stakeholder involvement

The following table (Table 6.2) is the summary of the analysis of collaboration and stakeholder involvement of the interviewed organization, explained under the table.

Table 6.2: Summary of collaboration and stakeholder involvement

Org.	Interview	Theory	Authors
Plast.	Find solutions together	Principles of collaboration	Chesbrough, Almirall, etc.
	Have different perspectives	Principles of collaboration	
	Work among the supply chain	Principles of collaboration	
	Central role	CI models	Barrett
RM	Meaningful proposals for actors		
	Actors with the same interest		
	External knowledge	Open innovation, NIS/RIS, invention phase	Chesbrough, Freeman, Garud
	Start-ups and small/local companies	Transition to OI	Chesbrough
	Collaboration with big companies	Transition to OI	Chesbrough
	Focal public role of RM	CI models/RIS	Barrett. Cooke
AUH	Identify suppliers	Principles of collaboration	
	Round table processes	Principles of collaboration	Chesbrough, Dedeyadir, etc
	Dialogues with stakeholders	Principles of collaboration	
EMF	Confidential material challenge	Closed innovation	Chesbrough
	Open platform for the design	Open platform model	Barrett
	Open collaboration	Principles of open innovation	Chesbrough, etc.
	Benefit from people	Share knowledge	
	Involve paying members	Innovation investors. Role of stakeholders	Chesbrough

Plastindustrien

Plastindustrien was asked about the reasons of wanting to implement collaboration in their business strategy, and the answer was: *Because we think we **find solutions together***. When working together with expertise from different organizations, new solutions arise, and there are higher chances of seeing the problem from **different perspectives**. For example, they are currently working with a forum about circular economy within plastic packaging. They have also been

working together among the **supply chain**, to be aware of the designer, recyclers, and distributors act and think. The aim of that would be taking solutions from different angles. This shows the awareness in collaboration of *Plastindustrien*.

Plastindustrien would have a focal role in the collaborative innovation model (Barrett et al., 2011). Towards their partner, they would support the network by informing them about the project, using their knowledge, facilitating the development of the project, and making some political changes in the implementation phase.

Region Midtjylland

Hanne Juel mentions different concepts when it comes to collaboration and stakeholder involvement. When involving stakeholders, it is essential doing something **meaningful** for the actors, in order to catch their attention. Choosing actors with the **same interest** as them is also important, as a way engaging them. Hanne Juel also mentions the importance of looking for external **knowledge** in the topics where they have less specialized. This quest of external knowledge is mentioned by some authors in the theory regarding innovation and innovation ecosystems. In NIS or RIS some collective systems of knowledge are created (Freeman, 1987). This knowledge exchange is also one of the main principles in open innovation (Chesbrough, 2003b). Garud et al. (2013) mentions role knowledge networks in the invention phase of innovation process. In their case, they look for external knowledge for innovation, as they are weaker in that field.

Following with cooperation, Hanne also remarks the important role of **Start-ups, small and local companies**, and at the same time collaborating and having the support of **big companies**. Both concepts mentioned in the transition to open innovation and open innovation journey (Chesbrough, 2003b).

Finally, analyzing the role of RM according to the collaborative innovation models (Barrett et al., 2011), RM is the **focal organization**. The same as *Plastindustrien* in the *Genanvendelse af plast – en styrket dansk industri* project. It is also worth mentioning that they are a public figure. Taking that into account and that they operate at a regional level, RM would be classified in the category of Regional Innovation System (Cooke et al., 1998).

Aarhus Universitetshospital

As mentioned in the process of innovation, AUH **identified suppliers** and the value chain in the initial phases of innovation. Once they were identified, they were gathered in a meeting in Denmark. They also invited the three global suppliers of irrigation fluids in individual basis in **round table processes**. During the interview, Backer highlights the importance of having **dialogues with stakeholders**. This active stakeholder involvement is a clear example of collaboration, where actors exchange knowledge flows, co-evolve, co-create, etc. (Chesbrough, 2003b) (Dedehayir et al., 2016).

Ellen MacArthur Foundation

In the case of the NPE project, there were some phases during the project that were more collaborative than others. **The material challenge**, for instance, was not particularly collaborative,

since the submissions were **confidential**. This could be considered a closed innovation process, were ideas are not shared among the network (Chesbrough, 2003b). The design challenge, however, was more collaborative. They ran an **open platform**, OpenIDEO, where they could benefit from involved people and get different perspectives. This open platform is the same concept of Barrett et al. (2011) in the 4th model of collaborative innovation, *Open Platform Model*. Furthermore, this concept of **open collaboration** reflects the principles of open innovation. The importance of people and benefiting from was is also mentioned by Hanne Juel in the interview with *RM*. As a consequence of the open platform they obtained some low-quality submissions from some amateurs. Even if they possibly have good ideas, they might not be well informed in terms of understanding of the system in which they would operate. This fact of not gathering the right experts also arose in the interview with AUH. So in that sense, Linder emphasizes the limitations of an open platform for collaboration. And he admitted that *the best ideas weren't very collaborative*.

When it comes to the involvement of different stakeholders, more than 40 organizations in the value chain were involved. Some of them are **paying member** of the initiative. Those paying members are related to the figure of innovation investors, as one of the roles of stakeholders by (Chesbrough, 2003a). Investors also provide value in time. As a result of the stakeholder involvement, they had 15 individuals from some of the largest consumer good companies in the world, including recyclers, academia, and NGOs. He said that *That sort of gave a collectively rounded view which innovations were promising had high potential*. Related to collaboration, Linder also mentions the fact of benefiting from other people adding new ideas and different perspectives to the innovation. This knowledge flow exchange is one of the principles in open innovation (Chesbrough, 2003b).

When they were asked about the involvement of policy makers, he said that they had the feeling that the innovation phase is an early stage to involve them, and he does not necessarily see their role in this case. *A policy maker would probably be able to say something about how that innovation might work in the current policy landscape* This statement is contradicting with the statement made by RM and AUH about the need of institutions in the implementation phase of innovations.

6.2.3 Challenges and opportunities

Following with the same structure as in the subsections above, first the table of summary is presented (Table 6.3) and then the explanation of challenges and opportunities of each organization.

Table 6.3: Summary of challenges and opportunities

Org.	Interview	Theory	Authors
Plast.	Plastics with low recyclability rate Having a better technology Mixed plastics	Technological IS	Carlson
RM	Make it scalable Strategic dialogue Consider meaningful things for actors Difficulty of not failing	Expansion, dev. & implementation phase Transition to OI Transition to OI	Moore and Garud Golightly West
AUH	High percentage of unknown plastic Getting close to the core business Not have enough institutional support Be a small organization Easy getting interest of stakeholders	Institutionalization Importance of small organization Innovation journey	Garud Chesbrough Golightly and West
EMF	Prioritize areas Proper investment Difficulty of breaking the "status quo" Help new player	Development phase Funding role – Investors Implementation phase Principles collaboration	Garud Chesbrough Garud Chesbrough, etc

Plastindustrien

Plastindustrien sees two main challenges: Dealing with plastics with low recyclability rate and mixed plastics. Even if **plastics with low recyclability rate** would be a challenge, their idea is not focusing on the difficult aspects in the beginning. They would start with the things they are able to solve, and then develop the project from there. This statement is related to the explanation made by AUH when it comes to have an logistic track for certain type of plastics, LDPE in their case. She also mentions that **having a better technology**, the economy will be better. This is related to the Technological Innovation System by Carlsson and Stankiewicz (1991). And the believes there will be possibilities soon. **Mixed plastics** is also a challenge they have to deal with. Therefore, their idea is to collect plastics separately, because there is a business for that. They will not focus on household plastics, because they are mixed, and it is complicated and costly managing them.

Region Midtjylland

When it comes to the challenges, the first challenge to face is how to make it **scalable**. To build models in a scalable way, **regulations** are needed. Scalability is important when it comes to the expansion phases in ecosystem progress (Moore, 1993), and development and implementation phases in innovation process (Garud et al., 2013). Having a **strategic dialogue** is also key, in order to address goals. Even is the considers important doing something meaningful for everyone, another challenge for her is considering what it **meaningful** for the actors. That means that the knowledge exchange has to benefit every interested parts. The knowledge flow and strategic dialogue are a crucial steps in the transition to open innovation (Golightly, 2012) (West and Bogers, 2017). She also says that it is difficult developing something and not failing.

Aarhus Universitetshospital

Backer mentions the problem of having a high percentage of **unknown plastic**, 40% in their case, and not having it marked. So the difficulty of the product is one challenge. Another mentioned

challenge is the trouble of getting sufficiently **close to the core businesses** of the companies, that is complicated in most of the cases. **Not having enough institutional support** is also a challenge they have to deal with, *medical device manufacturers are exempted from the EU waste directive and the EU packaging directive.* Having institutional support to regulate the logistics and use of the innovation is an important part for the implementation of innovations (Garud et al., 2013). Another challenge is being a **small organization**. *Being just one single hospital in a very small country, we don't have enough market force in order to push them.* They make efforts in influencing bigger organization in order to have a positive impact in the market. That statement relates to the importance of stat-ups and small organizations in the transition to open innovation (Chesbrough, 2003b).

As an opportunity, she mentions how easy it was to gaining **interest** of stakeholders. This is reflected in the transition to open innovation, more specifically to the 4th point of the innovation journey (Golightly, 2012) about development of relationships and new ways of working. And in general to the concept of collaboration.

Ellen MacArthur Foundation

Linder mentions erasing innovation in areas that could not be **prioritized** otherwise. For instance, innovation in an industrial scale is done, so the idea would be focusing in other kind of department. R&D department is usually a proper starting point. This prioritization is linked with the development part of the innovation. This could be related to the development phase by Garud et al. (2013) in the sense of following an strategy. **Investing** money well is also essential. That enables taking less risk, and focusing more on incremental innovations by putting some incentives. Here is when the role of founders come into play (Chesbrough, 2003a).

He also highlights that the solution space is narrow and the difficulty of *breaking the status quo.* This could be reflected on the theory of implementation phase of the innovation and the transition to open innovation (Garud et al., 2013). When he was asked about opportunities and challenges he also mentioned **helping new players** to overcome barriers. This is one of the principles of collaboration.

6.2.4 Key lessons

As the project of *Plastindustrien* is not developed yet, they were not asked about their key lessons. Getting an insight in the key lessons of other organizations with experience in projects that are already running is essential, in order not to make the same mistakes other organizations made. The following Table 6.4 frames those key learning, developed later.

Table 6.4: Summary of key lessons

Org.	Interview	Theory	Authors
RM	Take time to test ideas with people with different opinions	Collaboration, Knowledge flow	Chesbrough, Almirall
	Choose people to cooperate	Collaboration	Chesbrough, Almirall
	A good project leader	Leadership	Moore, Dedehayir et al.
	Collect knowledge	Collaboration, Knowledge flow	Chesbrough, Almirall
	Be ambitious		
	Be concreate		
AUH	Not having the right experts		
	Bring people with new ideas	Principles of OI	Chesbrough, Almirall
	Being close to the strategic part of the business	Transition to OI	Golightly
	Doing information work		
	Organize more procurements		
	Standardized guidelines		
	Have a long-term strategy		
EMF	Spend time thinking about the new system	Invention and development	Garud et al.
	Observe the challenges	Invention and development	Garud et al.
	Need a good designer		
	Identify new investors	Funding	Chesbrough
	Embrace a solution space		
	Accelerator program	Type of IE (Accelerator managers)	Oh et al.

Region Midtjylland

A key lesson, according to Hanne Juel, are the following. Have an idea and test in people with **different opinions**, take time to involve stakeholder and enhance the collaboration in the network. This is also the basis of collaborative and open innovation (Garud et al., 2013) (Almirall and Casadesus-Masanell, 2010), etc. Related to the previous point, she also mentions the importance of working with **people** that are meant to be willing to **cooperate**. *Having a movement strategy is the way to* ***communicate*** *to others.*

Another essential aspect for her is having a good project **leader** and take care of her/him. This is also a key point for Moore (1993) as one of the states in the innovation progress. Is is also a central figure in innovation ecosystem emergence (Dedehayir et al., 2016).

Collecting **knowledge** and finding the essence of each stakeholder is another key lesson, mentioned several times during the interview and by several authors in open and collaborative innovation. She also mentions the importance of being **ambitious**. **Be concrete** in order to get abstract, and not the other way, in the process of convincing other actors. However, she sees the difficulty of this last key lesson.

Aarhus Universitetshospital

As the main key lesson, AUH highlights is having much deeper dialogues on the issues that were closest to the business interests of the companies they wanted to involve. Something that learned during the process of collaboration was that they did **not have the right contacts** in the beginning. She also emphasizes the importance of bring people with new ideas, a concept that has been remarked also by the rest of the interviewees. This collaboration and knowledge exchange, as mentioned before, are the most significant principles of open innovation (Chesbrough, 2003b) (Almirall and Casadesus-Masanell, 2010), etc.

Being close to the strategic part of the business is another emphasized key learning. Getting familiar with the strategies of businesses will facilitate the modification of their business strategies to implement a more open innovation approach in their business models (Golightly, 2012). She also explains the importance of doing a proper information work. Another suggestion is having standardized guidelines or criteria for procurement as a key to succeed. And last but not least, having a long-term strategy. On the one hand, to be able to fulfill the established criteria, and on the other hand, to see the results of the innovation.

Ellen MacArthur Foundation

Spend time **thinking about the new system** is a mentioned advice, so that **challenges** can be observed. He said that there was no conceptual innovation that took them by surprise. He also remarks the need of having **good designer** to execute. This could be applied to the theory about the invention and development phase in the processes of innovation (Garud et al., 2015).

Identifying new **investors** for the NPE project is also something EMF needs. Here is when the role investors in funding innovation activities take place (Chesbrough, 2003a). Linder also highlights **embracing the solution space**, for both the attention spam and the agenda of the key stakeholders in the value chain. Another key lesson that EMF proposes in creating **accelerator programs** with the partner organizations. Incubators and accelerators managers are one of the types of innovation ecosystems (Oh et al., 2016).

6.2.5 Future expectations

The last analyzed area is the the future expectations of the interviewees regarding their projects. The next table (Table 6.5) outlines those future expectations, which are detailed in the following paragraphs.

Table 6.5: Summary of future expectations

Org.	Interview	Theory	Authors
Plast.	Find good business cases	OI better BM	Chesbrough
	Raise knowledge	OI principles	Almirall
	Educate people		
RM	Multilateral cooperation with producers	System thinking, Innovation ecosystem	Dedehayir et al., Galanakis
	Contact small/local companies	Opportunity for star-up	Spender et al.
	Collaborate with big companies	Opportunity for big firms	West and Bogers
AUH	Scale geographically	Expansion and development phase	Moore, Garud et al.
	Use other kind of materials	Expansion and development phase	Moore, Garud et al.
	New ways of analyzing	Expansion and development phase	Moore, Garud et al.
EMF	Mobilize larger scales of investment	Role of investor	Chesbrough
	Create a strong narrative		
	Deliver a goal to scale up	Expansion and development phase, Global IS	Moore and Garud

Plastindustrien

It is important getting the insight of *Plastindustrien* about their future expectations, so that we know that they would expect from the project. Her expectations about the result of the project is to find good business cases, where companies see an opportunity in recycling plastics. They expect **raising the knowledge** about how to recycle, what to use, what material they are going

to recycle. They would also like to **educate people** in how to recycle, depending on where they are in the supply chain. To spread knowledge and to get something done as part of these collaborations. One of the priorities of open innovation is to originate a business model (Almirall and Casadesus-Masanell, 2010). Helping partner and educating people is a way of helping them to create a better business model. The fact of wanting to improve their business model is also one of the key points in open innovation (Chesbrough, 2003a).

Region Midtjylland

When Hanne Juel was asked about the expectations of what should change in the plastics in order to make a change in the current plastics industry, she expects more **multilateral cooperation with producers** in some specific projects where they are involved. This is reflected on the system thinking, where producers are one of the actors that they interact with (Galanakis, 2006). Dedehayir et al. (2016) also talks about multilateral cooperation with suppliers when defining innovation ecosystems. Even if they already cooperate with different kind of companies at different levels, they expect to enforce that collaboration and increasing the network. It is also important getting in contact with small/local companies and **start-ups** in the transition to open innovation (Chesbrough, 2003b). Spender et al. (2017) also mentions the opportunities for start-ups. But RM are also working making pressure and collaborating with big companies. For instance, they are making pressure to the UNDP and have a strong collaboration with EMF. The opportunity for big firms is mentioned by West and Bogers (2017).

Aarhus Universitetshospital

The main future expectation of the *Materialestrømsprojektet* project is to upscale, both geographically and to innovating in other kind of materials. They are working on **escalate geographically** and expanding. This escalation could be found in the expansion stage of Moore (1993) and development phase of Garud et al. (2013). And as mentioned, they would also like to implement circularity in **other kind of materials**, in metals, for instance. As a future expectation, she also mentions finding and **building new generic models for cooperation**.

Ellen MacArthur Foundation

In the case of EMF, they expect to mobilize **larger scales of investment**. They are looking for investment to fund the innovation. They also expect creating **stronger narratives** and having a slightly different approach. They would also like to deliver their goal to really **scale**, the same as in the case of AUH, and related to the expansion stage of Moore (1993) and development phase of Garud et al. (2013). The difference is that their ambition is doing it in a **global** scale. So in this case we would have a *Global Innovation System*.

6.3 Conclusion of the case-studies

After analyzing the interviews and comparing them with the theory about innovation and innovation ecosystem, this last section aims to provide some key-learning, some advice and recommendations to be potentially applied in the project *Genanvendelse af plast – en styrket dansk industri*. This section would provide an answer to the third research sub-question:

3. Knowing the exemplary case-studies and the role of innovation ecosystems, which would be the key-leanings that could be integrated in Northern Jutland's circular plastics economy?

Starting with the **processes in the project and implementation of innovation**, there are different remarkable concepts from each interview. As a general matter, it is important getting familiar with the field that wants to be innovated. First, identifying the product that want to be innovated. Followed by doing a mapping exercises, involving stakeholders that want to cooperate and have ideas, to exchange knowledge. Being organized during the process is important. Creating a scalable model is also key to succeed. Regulatory incentives also have to be taken into account. And as a consequence of the collaborating, getting a value.

Regarding **collaboration and stakeholder involvement**, everyone agrees with the importance of collaboration in order to innovate and progress in a proper way. Taking the outputs of the interviews into account, the first step to follow to enhance collaboration would be identifying suppliers. Once they are identified, it is recommended gathering them to exchange perspectives. When looking for external collaboration, it is also important doing something meaningful to catch their attention. Collaborating with multilateral organizations is also a remarkable point. Public-private collaborations, as well as collaboration between small and big companies. Communicating among the network is also important, and having a central and leading figure too.

In the case of **opportunities and challenges**, the organizations see different challenges. The challenges mentioned by *Plastindustrien* are more related to the challenges regarding plastics recycling. AUH also mentions the fact of having a high percentage of unknown plastic. Other kind remarkable challenges regarding collaboration are doing something meaningful and having an strategic dialogues with stakeholders to catch their interest and enhance collaboration with them. Scaling up is also a challenge that some organizations found.

About **key lessons** there are some important points. It is recommended spending time thinking about the new system, doing information work and observing possible challenges that might be found in the future. About collaboration, bringing people with good ideas is key. And related to that, chooseing the right people to collaborate with. Another important point is having a good project leader is also important, as well as being ambitious.

7 | Discussion

This chapter aims to discuss some concepts emerging from the research and the results. Starting with a review about the usefulness of the thesis, following with barriers and sources of error, which include terminological barriers, methodological barriers, possible issues about the application in practice, and barriers related to the limited amount of time for the research. The methodological barriers include a discussion about the choice of the case studies, the limitations regarding interviews, and a review to the coding method. The discussion chapter concludes with some suggestions for further research.

7.1 Usefulness of the thesis

The integration of innovation ecosystems as a solution for the plastic waste has barely been analyzed before. Innovation ecosystems strength the collaborative efforts of diverse actors, providing a holistic value, which may benefit the plastic industry. The result of this master thesis will potentially help the project *Genanvendelse af plast – en styrket dansk industri* (*Plastic-recycling – A strong danish industry*).

Collaboration is meant to be an essential part of the *Genanvendelse af plast – en styrket dansk industri* project. Having national and international examples of collaborative innovation enables obtaining a more specific insight of the business, useful for the coming project.

The result of this thesis and the outputs from the interviews could not only be useful for the *Genanvendelse af plast – en styrket dansk industri* project, but also for other organizations wanting to implement innovative solutions with collaboration as a key strategy. Either a public-private collaboration, or between private organizations.

Nonetheless, during the research there are different barriers that have to be taken into consideration.

7.2 Barriers and sources of error

Even if the result of this thesis might be relevant, it is important being aware of the limitations of the research and have a critical point of view over some aspect. This section aims to analyze possible barriers and sources of error found during the research process. Starting with a critical analysis of the terminology *innovation ecosystem*, following with the limitation of the methodology, which includes the choice of the case study, the interviews and coding, possible problem in the application of the results in practice, and concluding with the time limitation.

7.2.1 Terminology

The term *innovation ecosystem* was ambiguous since the beginning of the research. There were some critical reviews about the concept. Starting from the use of the term *ecosystem* to refer to an

innovation system. In this context, it is used as a metaphor to compare the interactions between species in natural ecosystems, with the interactions between stakeholders in innovation ecosystems. Under my point of view, it is not the most appropriate term to use. The term *ecosystem*, emerging from the natural system, has certain connotations further than the interactions and connections between different beings in a system. It may lead to confusion, because of its origin from the natural environment, it is usually associated with the ecologists and eco-friendliness.

A part from the proper or inappropriate use of the concept *ecosystem*, there is another questionable aspect about the terminology. After analyzing the theory of innovation ecosystems, the similarity with open and collaborative innovations were noticeable. Therefore, presenting the term innovation ecosystem could bring confusion to the understanding of some organization, when they already innovate within an open system.

7.2.2 Methodology

There are some methodological gaps that decrease the accuracy of the research. Starting from the choice of the method, and following with the main method of analysis: interviews, and concluding the tihe coding of those interviews.

Choice of case studies

There are several organizations working in the field of circular economy within plastics. However, the approach of most of them is closing the loop of plastics by using plastic waste to create new products, and not focusing much in the collaborative approach of the innovation. For that reason, most of the found case-studies were discarded. After defining some criteria to chose the case studies, there were just a few that were relevant for this research.

Furthermore, arranging interviews of meaningful case studies was complicated in some cases. More interviews with interesting case studies were planned, but some of them were not achieved, either because the project was no longer existing or because of not obtaining an answer from the interviewee.

Interviews

The first critique regarding the interview as a method is its reliability. After all, the researcher has to rely on the interviewee's word. They knew forehand that the aim of the interview was getting an insight in their collaborative practices. Therefore, they could conceal information regarding collaboration in case their practices not being very collaborative. This possible information concealment is more likely to happen in the cases of EMF, RM and AUH. Nevertheless, in the case of *Plastindustrien*, giving us all the info is beneficial for them, so it is less likely that they hide information.

Another critical consideration is that the interviewees will probably try to merchandise themselves saying they have the best practices and incorporate circularity in their business models. Therefore, it is recommended having a critical point of view towards some of the information they facilitate.

Another possible problem is the language barrier. Even if the English level of the interviewees was high, most of them are not English native speakers. For that reason they might not express themselves as in their own language.

Coding

As mentioned in the analysis (Chapter 4), the interviews were developed following the 5 main topics in the analysis (*process and implementation*, *collaboration and stakeholder involvement*, *opportunities and challenges*, *key lessons* and *future expectation*), and the first introductory question about self-introduction and a summary of their respective projects. The interview guide was developed following those 6 main themes.

Nevertheless, semi-structured interviews usually do not follow the interview guide strictly. As mentioned in the methodology (Section 4.2.2), interviewee's develop their answers in answer broadly, and some answers where not grouped in the 5 main topics. For that reason, in some cases was complicated classifying the answers into those main themes.

7.2.3 Application in practice

An important aspect to have into consideration is that the analyzed case studies worked under their specific circumstances. The analyzed case studies are successful in their location, under their budget, in their surrounding environment and in within an specific time frame. Hence, the applicability of the results are time and place dependent. To deal with that issue, the given recommendation in this thesis are general and potentially suitable for different circumstances and places, and specially for Norther Jutland. Moreover, not only analyzing an international case study (EMF) but also two national examples (RM and AUH), makes the researcher specifically suitable for this case in Norther Jutland.

7.2.4 Limited time

The thesis is meant to be developed within 4 months, so this time limitation also narrowed the scope of the study. Having more time for the thesis would enable doing a more accurate research. Analyzing more case studies, for instance, would be beneficial for the outcome of the research. The following section suggests some aspects to be developed in case of having more time.

7.3 Suggestions for further research

The first suggestion for further research is getting an insight of the other two involved organizations in the *Genanvendelse af plast – en styrket dansk industri* project, *AVL* and *AAU*. That would validate the necessity and usefulness of the thesis.

The key suggestion for further research is analyzing more case studies, in order to get a more precise analysis and being able to give more interesting and complete output of the role of innovation ecosystems for the circular plastics economy. Time limitation and the difficulty of obtaining some interviews, mentioned in the previous Section 7.2, limited the amount of gathered interviews. Therefore, it is suggested analyzing more case studies. Not only that, but having more

analyzed case studies would make the results more comparable and would enable giving more inputs to apply circular economy in Northern Jutland.

Another suggestion for further research is analyzing more in depth the solutions for plastics, not focusing just on innovation ecosystems. The specific case of plastics is complicated because of the low recyclability of the product. Even if the interviewed organizations are working on projects in the circular plastics economy, and the collaboration is key to achieve their goals, it would also be interesting having a deeper understanding of their solutions for plastics and the technicalities of this product. However, it is important reminding that the scope of this thesis was the role of innovation ecosystem.

The last suggestion for further research is to analyze other areas. It would be interesting having an insight of other organizations also incorporating innovation ecosystems, but in other fields further than plastics. After all, collaboration is the analyzed topic and the plastic industry is the good where the innovation is applied.

8 | Conclusion

This study provides recommendations to incorporate circular economy practices in the plastic industry using collaborative innovative solutions. Those recommendations are based on interviews with case studies currently working in the field of circular plastics economy, which are contrasted with the theory about innovation and innovation ecosystem. This chapter aims to summarize the results from the analysis (Chapter 6) and the discussion (Chapter 7), answering the research questions in the problem formulation (Chapter 3).

To give an answer to the main research question, first the sub-questions are going to be discussed. *What are innovation and innovation ecosystems? How are they established and managed?* Innovation could be understood as the creation of new ideas, following a process to implement that new idea into the market. The concept innovation ecosystem basically refers to the collaborative aspect in an innovation process. Innovation ecosystems emphasize the importance of collaboration between a heterogeneous group of stakeholders, which includes collaboration between the public and private sector, and the inclusion of big, medium and small-size companies. This interaction is said to benefit every actor in the network (or *ecosystem*), and increases the value of the innovation. Nevertheless, the concept of innovation ecosystem follows the same principles as open innovation and collaborative innovation. Therefore, using the terminology innovation *ecosystem* is arguable.

To see the role of innovation ecosystem in practice, some case studies were analyzed. *Which are exemplary national and international case studies currently working on the field of circular economy in the plastics industry? What characterizes them?* These are the analyzed cases:

Region Midtjylland is a national example of circular economy and collaborative innovation. The analysis of this case is not focusing just on one project they are developing, but more in general terms. It is a public institution leading collaboration with different kind of organizations and working in projects regarding circular economy. The case of *Aarhus University Hospital* is another national example of a successful project in the circular plastics economy. They are leading the project *Materialestrømsprojektet* in their hospital (AUH) recycling a certain type of medical plastic bottles, while collaborating with suppliers. *The Ellen MacArthur Foundation*, a worldwide reference in the circular economy, launched the project *The New Plastics Economy*, where the aim is to keep plastics in the economy instead of disposing them in the environment, following a systematic and collaborative approach. To get an idea of the scope of the project and the validity of the research, *Plast industrien* was interviewed, a founder of the *Genanvendelse af plast – en styrket dansk industri* project.

The most significant outcome from the interviews is the importance of collaboration. Every interviewee agreed on that aspect, in one way or another. However, each organization has different perspectives and processes to cooperate. The following lines aim to describe the general standards that could be applied in Norther Jutland, answering the 3rd research sub-question *Knowing*

the exemplary case-studies and the role of innovation ecosystems, which would be the key-leanings that could be integrated in Northern Jutland's circular plastics economy?

The starting point is getting a deep knowledge on the business and the innovation that is going to be developed, spending time thinking about the new system, such as observing the needs, or thinking about the specific material or product to innovate. It is important being ambitious and concrete at the same time, while being aware of the limitations. *Plastindustrien* is already planning to do a mapping exercise to know where the plastics and where to start innovating.

Regarding collaboration, every interviewee agrees with the potential of collaboration as knowledge exchange, source of ideas, have perspectives from different expertise and finding solutions together. The proper way to involve stakeholders is doing something meaningful for them and having strategic dialogues to increase their interest in collaborating, which could be a challenge. Involving them actively is also recommended, organizing meetings with them and having regular dialogues. Following with stakeholder involvement, having a leading figure is also important. Using an open platform to exchange ideas and facilitate a direct dialogue among the network.

When it comes to which stakeholders to involve, involving investors or paying members is essential to have economical support. Identifying suppliers is also recommended. Working together with start-ups, small, and local companies is also beneficial, as well as with big companies, to have the support of big institutions. Something learned is the importance of involving the right people. Another suggestion, is that not every stakeholder has to be involved in every step of the innovation process. And having institutional support for the implementation phase of the innovation. It is also worth mentioning that most of the interviewees mentioned that, in general, it was easy involving stakeholders.

The organizations have similar prospects about their projects. They expect cooperating with more stakeholder, either small or big companies, or investors. Also scaling up in different aspects. Could be geographically, expanding to other sectors, innovating other products, or reaching international environments. Therefore, following with escalation, it is also recommended creating an scalable model, even if that could be a complicated.

Even if the given recommendations are general and potentially applicable to Northern Jutland, it is important considering that the analyzed case studies succeeded in their conditions and circumstances, as mentioned in the section 7.2.3 of the discussion. Nevertheless, as explained before, the given directions are general, and potentially applicable to any organization willing to increase collaboration.

To conclude, and answering the main research question *What is the role of innovation ecosystem for the circular plastics economy?*, we could say that innovation ecosystem work as a source of collaborative ideas. The collaboration between different actors is essential in the circular plastics economy. As an emerging and critical topic, knowledge exchange between different actors and public-private collaborations, increases the value of innovative solutions in the plastic industry.

As a summary, we can say conclude the following. Integrating circular economy, the value of the

product does not end after being sold. There is a feedback loop, where the used product is not becoming waste. The way to get the feedback loop is having interactions with other stakeholders, like recycling stations or having dialogues with consumers. To enable that, organizations need to transform their business as usual and handle an experimentation process to improve certain quality, where they innovate and try new processes and interactions. This experimentation process, together with sharing and knowledge flow, would enable organizational learning.

Following with that organizational learning, companies are aware of the benefits of collaborations. Different actors are engaged across organizations, but to do that, they have to see the benefits of the collaboration. The key of networking is benefiting from each other. Without mutual benefits, organization would refuse collaborating. It is important remarking that in the experience of case studies, most of the actors were inclined to collaborate. As a result of this, the value increases along the value chain. Therefore, the companies in the danish plastic waste industry that will be willing to implement the solutions to increase recycling, as part of the *Genanvendelse af plastik – en styrket dansk industri* project, will increase their value in the mentioned aspects.

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A | Appendix

A.1 Interview guide

Main concepts	Question for interviewee
Self-intro and **Intro to the project**	- Which is your role in the organization? - Could you briefly introduce the project? - Which is the purpose of the project?
Process in the project and **Implementation of innovation**	- Which are the main processes you are following in the project? - Which are the main phases followed in the creation of the project? - Which is the process that you follow to implement innovative solutions in the project?
Transition to collaboration: **Stakeholder involvement**	- How do you involve different actors? - Which is their level of involvement? - To what extend do you involve your partners? - Which is your role towards your partners? - Which is the connection between those actors?
Opportunities and **challenges**	- Which are the challenges you found when you were trying to collaborate? - Which are the main opportunities and challenges that you found during project in general?
Key lessons	- After this time developing the project, which are the key lessons that you learned? - What would you recommend to other organizations starting an innovation process in the circular plastics economy?
Prospects	- Which are your future expectations?