EOW FROM A DANISH PERSPECTIVE

A case study in washed soil and upcycled plaster

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ABSTRACT

This thesis investigates the implementation of the End-of-Waste (EoW) framework within the context of the circular economy, focusing on its application to waste-derived building materials in Denmark. The study examines two specific cases: Genjord, a company specialising in soil washing, and Norrecco, a company that receives and treats multiple types of waste here amongst plasterboard. Through literature review, stakeholder interactions, and the application of Actor-Network Theory (ANT) and Staging Negotiation Spaces (SNS), the research identifies key challenges and opportunities associated with the EoW framework.

The findings highlight significant implementation barriers, including the fragmentation of application processes across municipalities and environmental legislations that complicate the reclassification of waste materials. The analysis underscores the necessity for clear, standardised guidelines to document the variability and technical quality of waste-derived products, ensuring they meet both environmental and market demands.

The study also emphasises the importance of continuous stakeholder engagement and collaboration to address conflicts and align interests within the actor network.

In conclusion, while the EoW framework has the potential to significantly advance the circular economy by reclassifying waste as valuable resources, its success requires addressing current implementation gaps, fostering a transparent regulatory environment, and enhancing stakeholder collaboration. This research contributes to understanding the practical application of the EoW framework and offers recommendations for improving its effectiveness in promoting sustainable waste management and resource efficiency.

FOREWORD

This project is a master thesis written by Astrid Yde Larsen in the masters Sustainable Design at Aalborg University, Denmark. The author is co-owner of the company Genjord, where the interest in the topic stems from.

The thesis seeks to explore the possibilities of End-of-Waste in the relation to the two chosen cases, in addition to highlighting issues faced by such case companies. Case studies like this is important, since there is a lack of research on practical cases with an End-of-Waste Perspective

I would like to thank Norrecco, and especially Jette Johansen for participating and sharing her knowledge. It has been invaluable. Additionally, a thank you is appropriate for Erik Yde and Julie Jensen, who also shared their knowledge in the field.

1 CONTENTS

1. INTRODUCTION

As our society strives for a sustainable future, we face an urgent need to optimise resource use. The industrial revolution and subsequent technological advancements have spurred economic growth, but often at the expense of extensive resource depletion and environmental degradation. The finite nature of many resources and the pollution affecting others highlight the critical challenges of sustainability.

The circular economy presents a viable solution by rethinking production, consumption, and waste management. Unlike the traditional linear economy, which follows a 'take-make-dispose' model, the circular economy aims to minimise waste and pollution by keeping products and materials in use and regenerating natural systems. This approach reduces reliance on finite resources, lowers greenhouse gas emissions, and promotes sustainable economic growth. By closing the loop, the circular economy conserves resources and creates resilient systems capable of adapting to and mitigating climate change impacts.

However, transitioning to a circular economy involves significant challenges, as existing systems are not designed for circular practices. Legislative frameworks such as the EU's End-of-Waste (EoW) framework are crucial for creating opportunities for waste-derived products and facilitating their trade across borders.

This thesis examines the EoW framework from a Danish perspective, focusing on case studies of Genjord and Norrecco. It explores how this framework can influence and create opportunities for waste-derived building materials and products. Additionally, it analyses the conflicts and interests within the relevant actor network and provides an overview of the demands for the examined products concerning a potential material-specific EoW guideline.

The primary research questions guiding this study are:

- What challenges do waste-derived building materials face within the actor network, and how does the End-of-Waste framework impact these challenges?

- What characterises the issues faced by Genjord and Norrecco with their waste-derived building materials?

- Does the End-of-Waste (EoW) framework address these issues, and how does it work in practice?

- How does the EoW framework influence the arena for waste-derived building materials?

To address these questions, this research employs a design engineering approach, using frameworks such as Actor-Network Theory (ANT) and Staging Negotiation Spaces (SNS). These methodologies facilitate the exploration of stakeholder interactions, conflicts, and the development of sustainable innovations.

2. RESEARCH AND ANALYSIS APPROACH

This project explores the EoW framework from the perspective of two Danish product cases - Soil washing at Genjord and recycled plaster at Norrecco.

The problem statements of the project is:

"What challenges do waste-derived building materials face within the actor-network, and how does the End-of-Waste framework impact these challenges?"

Accompanying Research Questions:

- What challenges do waste-derived building materials face within the actor network, and how does the End-of-Waste framework impact these challenges?

- What characterises the issues faced by Genjord and Norrecco with their waste-derived building materials?

- Does the End-of-Waste (EoW) framework address these issues, and how does it work in practice?

- How does the EoW framework influence the arena for waste-derived building materials?

These research questions have led to an exploration of which existing criteria and standards could be included in potential product specific guidelines for the two products. The questions are explored through the literature review as well as the chosen analytical and methodological framework.

The cases have been explored through interactions with actors in both of the companies. There has been 1 planned interaction with Erik Yde from Genjord, and 2 planned interactions with Norrecco - one with Jette Bjerre Hansen (head of development) and one with both Jette and Julie Jensen (senior project manager). In addition to this there has been ongoing correspondence between myself and the two companies. Lastly, it is important to mention that I am part owner at Genjord, and have responsibilities in the companies. This means that I have an insight into the company, but also that it should be considered when reading this paper.

The EoW framework and the field surrounding it is explored through the literature review as well as an expert interview with Kathrine Hauge smith who works as an environmental specialist at WSP and has co-written the article "End of Waste som metode"(Hauge Smith, Køster, & Christensen, 2020) for Teknologisk Insittut. This interview was planned to give an insight to the Danish perspective on End of Waste as a method.

The literature review was performed by conducting an online search through AAUs online university library Primo. The search was initially focused on End of waste and its implications and application in EU member countries as well as benefits and downfalls to the framework. Since the literature in this area is sparse, the search was expanded to also include the relation circular economy.

This is a design engineering project, meaning it takes a basis in design methods as both the research method and analytical approach. The frameworks of staging negotiation spaces (SNS) and arena development, as well as the overall perspective of actor-network theory (ANT) has been chosen as the methodological frameworks. By setting the stage for interactions and framing the arena with diverse actors, this method emphasises continuous stakeholder engagement, and the negotiation of interests. It allows for the examination and shaping of sociotechnical networks, ensuring that both human and non-human elements will be considered in developing a sustainable and impactful innovations . (Pedersen et al., 2020; Andreasen, 2015)

The project is exploratory in nature, and so these frameworks have been employed as methods to map out the actor network and its conflicts, interests, and dynamics as well as using them as analytical tools

throughout this paper, but also during the project work with the relevant actors. In appendix A there is an overview of the project process.

2.1 Actor-Network Theory (ANT)

Actor-network theory (ANT) provides a valuable framework for understanding the interactions between human and non-human actors within networks. Aka (2019) and Hernes (2010) highlight the role of ANT in exploring the relationships between actors and how they influence each other. ANT aids in understanding how arenas are composed of various interconnected actors and elements, each playing a role in shaping the outcomes of the development process. This theory emphasises that both human actors (e.g., stakeholders) and non-human actors (e.g., technologies, artefacts) are integral to the network, and their interactions drive the development process. By applying ANT, it is possible to analyse the complex interplay of these actors and devise strategies to manage their interactions effectively. ANT is implemented as the overall theoretical framework for the project, as well as inspiration for the ANT mapping in the analysis.

2.2 Action-Oriented Participatory Approach and SNS

An action-oriented participatory approach to design work has an emphasis on the active involvement of stakeholders in development processes. According to Pedersen, Dorland, and Clausen (2020), this approach is central to Staging Negotiation Spaces (SNS), as it is the outset for facilitating collaboration among diverse stakeholders. Integration of multiple stakeholders ensures that multiple perspectives are considered in addressing complex societal issues. By involving stakeholders directly, this approach helps in understanding and managing their needs and expectations, which is crucial for successful project outcomes. This participatory approach is not only about gathering inputs but also about fostering a sense of ownership and commitment among stakeholders, which can significantly enhance the effectiveness of the development process.

Introduced by Pedersen (2020) SNS expands the role of designers from creative experts to facilitators who *stage and manage negotiation space*s. SNS is built on the principles of participatory design in which importance is put on the direct involvement of those affected by new technologies in their design and development. (Pedersen, Dorland, & Clausen, 2020).

Negotiation spaces are environments created with the intent of collaborative dialogue and negotiation. SNS employs a theatrical metaphor *staging*. In this metaphor the designer is seen as an inviting *stage director* who sets the scene for negotiations, interpreting a given problem statement or design brief as a script, assembling stakeholders as cast members, and guiding the actions that take place on stage. It is especially important to integrate a diverse cast of stakeholders (Jepesen and Eskerod, 2009). Additionally, it is emphasised that the stage director should design and employ objects in the negotiation spaces. This process involves both *backstage* and *frontstage* activities. Frontstage activities are the visible interactions that occur during design events such as workshops, while backstage activities include the preparations, negotiations, and political work that shape these events' setup and outcomes (Bødker, Dindler, & Iversen, 2017). (Pedersen, 2020)

The participatory approach has been employed in the project by using the SNS framework and inviting stakeholders to participatory interactions that have been planned out according to the SNS framework.

SNS has also been employed as an analytical tool. The analysis has started in the ANT perspective by mapping out the actor-network, and from this planning interactions and negotiation spaces. The staging perspective

of SNS also provides the opportunity to analyse the negotiation spaces and use this analysis to reframe the project. *Framing* in Staging Negotiation Spaces (SNS) involves defining the context and perspectives for discussions, guiding stakeholder interactions. (Pedersen, 2020). *Reframing* adjusts this context in response to new insights or conflicts, enabling continuous alignment and mutual understanding among diverse actors during collaborative innovation processes (Pedersen, 2020). In this project I do not explore the reframings of the project process in depth.

Throughout the negotiation spaces in this project, intermediary objects have been introduced. These were designed to afford exploration of the field based on the actors perspective, and through the negotiation spaces they have been moulded and in that way they have produced analytical points and important information. This will be explored more in depth throughout the analysis.

2.3 Arena Development

Sociotechnical change involves the intersection of society and technology, with changes occurring in both social and technical elements. In this project we are looking into a network that faces sociotechnical change both from a technological and legislative standpoint. Jørgensen and Sørensen (2002) and Hernes (2010) highlight the importance of managing these changes within arenas. Arena development aims to facilitate and manage sociotechnical changes by creating and analysing environments where stakeholders can collaborate and innovate. (Pedersen, Dorland & Clausen, 2020). Understanding the broader societal context is important for effective arena development and to address problems and conflicts within the arenas and actor-networks. Andreasen (2015) highlights the importance of societal systems, describing them as *"large-scale systems that encompass various societal needs, technological advancements, and industrial capabilities''*. This view of sociotechnical systems is employed in the arena mapping and interest and conflict analysis of this project, where Matters of Concern (MOCs) are explored.

Arenas are the spaces where stakeholder interactions and innovations occur and arena development is the creation and management of environment where diverse stakeholders interact and influence project development (Pedersen, Dorland & Clausen, 2020). In the context of arena development and staging negotiation spaces, human and non-human actors interact and influence each other within networks. Hernes (2010) discusses how material objects and technologies (non-human actors) play a crucial role in shaping interactions and outcomes within these networks. These actors are important because their interactions drive the development processes. Actor worlds, a concept highlighted by Jørgensen and Sørensen (2002), operate within these arenas, interacting and shaping the outcomes through their dynamic relationships. Understanding these interactions is essential for managing the negotiation spaces effectively and ensuring that the development processes are inclusive and comprehensive. These concepts are employed in the arena mapping as well as the solution work, as an overall theoretical framework.

3. LITERATURE REVIEW: END OF WASTE AND CIRCULAR ECONOMY IN DENMARK

This literature review aims to give an overview over End of Waste (EoW), its relation to sustainability in the form of circular economy, and its benefits and downfalls. In addition to this it will give a surface level description of the most relevant Danish laws in regard to building waste and waste-derived products. This scope was chosen to give a thorough introduction to the field, and to create a basis for the analysis and case work.

3.1 THE END OF WASTE FRAMEWORK ITS RELATION TO THE CIRCULAR ECONOMY

The EU's "End of Waste" (EoW) framework, established through Directive 2008/98/EC on waste (European Parliament and Council of the European Union, 2008) offers a way to determine when waste materials can be classified as non-waste materials or products again. This is possible if the materials have been processed to meet certain safety- and technical standards, and have a market demand. The purpose of this is to promote a circular economy, reduce waste volumes, and minimise environmental impacts of waste management. The intention of the EoW framework is to create a standardised process for assessing materials previously considered as waste can become recycled or reused as a raw material or product again. By establishing this type of criteria, the EoW framework can aid in removing unnecessary barriers to recycling and promote more sustainable waste management. With this framework, the EU is also trying to create a more transparent and predictable environment for businesses and industries that want to recycle materials, as it provides them with clear guidance on when their waste is no longer subject to waste legislation but rather can be considered a resource again. This helps create incentives for businesses to invest in recycling facilities and develop circular business models.(Johansson, 2023; Zorpas, 2016).

Initially, the plan for the EoW framework was to establish EU-wide standards for various materials that would be uniform across member countries. However, this proved to be challenging because of the complexities inherent in waste management and the diversity of waste regulations among countries. Moreover, differing national priorities influenced the development of standards; some countries favoured more lenient standards due to material scarcity concerns, while others advocated for stricter standards to safeguard the environment. (Johansson & Forsgren, 2020)

As a result of these complexities, it became each member country’s responsibility to make its own material specific standards for the materials that have not already been treated by the EU. Subsequently, in countries like Denmark and Sweden, the task of handling applications for EoW was given to smaller institutional bodies such as the Danish municipalities. However, this has not proved effective. Johansson & Forsgren (2020) deemed it suboptimal to apply for End of Waste in all 98 Danish municipalities. Additionally they argue that the framework does not take into consideration the space between waste and non-waste products, and this should be researched further. (Johansson & Forsgren, 2020; Johansson, 2023)

The circular economy (CE) perspective fits well with the EOW framework, since this concept emphasises the need to close material loops and maintain the value of resources within the economic system for as long as possible. The CE model seeks to decouple economic growth from resource consumption by extending the lifecycle of products, optimising resource use, and minimising waste generation through strategies like reuse, recycling, and remanufacturing (Dahlbo et al., 2015; Pietzsch et al., 2017). This approach is exemplified in various sectors, such as the construction industry(Santais et al., 2018). As an example, using recycled

aggregates and supplementary cementitious materials in concrete production decreases carbon dioxide emissions and conserves natural resources (Bostancı et al., 2018; Santos et al., 2024)

The EoW framework provides the benefit of pushing the circular economy agenda, and thereby increasing sustainability in regards to resource use. It does however pose some challenges. As mentioned, setting EU-level criteria is challenging because they give the opportunity to overrule national environmental protection laws, creating a concern that making that level of standardisation might not be safe. Furthermore, it can be difficult to navigate the individual EU-member states' concerns.

The EoW framework can also be criticised for being too deterministic, as it only looks at a material as waste or non-waste. Johansson & Forsgren (2020) argues that this is over simplified and that the greyzone in between waste and non-waste should be further studied and encompassed in the waste directives and frameworks.

3.2 EoW CRITERIA (EWC)

The main objective of the EoW criteria is to ensure that waste materials, once they have been processed, can be reclassified as non-waste products. This reclassification is contingent on meeting specific criteria that ensure the material is safe for human health and the environment, has a market demand, and complies with technical standards. According to the Waste Framework Directive (WFD) 2008/98/EC, these criteria must ensure that the material:

- Is commonly used for specific purposes.
- Has a market or demand.
- Meets technical requirements and existing legislation.
- Will not lead to adverse environmental or human health impacts.

Additionally there are a number of material specific guidelines developed on an EU level. These encompass waste paper, glass cullet, and certain types of iron, steel and copper scrap (Elena et al., 2011; Villanueva & Eder, 2011; Muchová, Eder & Villanueva, 2011; Muchová & Eder, 2010;Muchova, Eder, & Villanueva, 2011;Muchová & Eder, 2010)

As per EoW Criteria for Waste-Derived Aggregates: “Waste-derived aggregates are being considered as possible candidates for development of End-of-Waste (EoW) criteria at European Union (EU)” (Hjelmar et al., 2013, p. 1). Hjelmar et al. (2013) explores a framework for developing EoW criteria for waste-derived aggregates. The premise is that if EoW status is given to the aforementioned products, it will become a (construction) product, and in thai way regulated by the Construction products Regulation (CPR), meaning in most EU Member States there will be no applicable environmental protection regulation. Therefore it is crucial to establish a clear path for a waste product to become a product that takes the protection of the environment, human health, safety standards and product quality into account.

Hjelmar et al.(2013) discusses the need for robust control and monitoring systems to ensure continued compliance to the EoW criteria. These criteria being evaluating the chemical and leaching behaviour of these aggregates, performing life cycle assessments to determine the environmental benefits relative to using natural aggregates.Hjelmar highlights case studies of successful implementations of the EoW criteria for varying types of waste-derived aggregates, though he concludes this is an essential step to enhance resource efficiency and achieving sustainable waste management, several challenges are apparent:”The example calculation shown in this paper clearly indicates that if the EoW criteria do not include specified conditions for the use of waste-derived aggregates with EoW status for specific purposes, then leaching

limit values aimed at the protection of soil, groundwater and surface water will have to so stringent that very few, if any, waste aggregates can meet them."

The EoW criteria for waste paper align with industry standards and ensure the material is safe and suitable for recycling into new paper products. Requirements include:

- Grading according to the European standard EN-643.
- Limiting non-paper components to 1.5% of air-dried weight.
- Ensuring the waste paper is free from hazardous properties and contamination.
- Documenting compliance through a statement of conformity

(Villanueva & Eder, 2011)

The criteria for glass cullet emphasise high quality and suitability for manufacturing new glass products. Requirements include:

- Ensuring the glass is free from hazardous contaminants.
- Meeting specific technical standards.
- Documenting compliance through a quality management system and regular monitoring.

(Elena et al., 2011)

3.3 Danish Waste Regulations and How They Relate to the End of Waste Framework?

As mentioned there is a concern for the environment that needs to be taken into account when talking about waste. In relation to the cases that will be presented in this project there are a number of regulations that are important to introduce.

Miljøbeskyttelsesloven (Environmental Protection Act) (Bekendtgørelse af lov om miljøbeskyttelse, 2024) encompasses the protection of the danish environment and natural landscape from various forms of pollution and degradation, with the aim of promoting a sustainable development by ensuring that environmental concerns are represented in the economic & social evolutions of Denmark. This is done through a legal framework that designates responsibilities to the various authorities such as the Danish Environmental Protection Agency (MST), the municipalities, etc.

Affaldsbekendtgørelsen (Waste Management Regulations) (Bekendtgørelse om affald, 2024) establishes the legal framework for handling, classification, and disposal of waste in Denmark. It provides comprehensive definitions for various waste types, criteria for classifying waste, and the responsibilities of municipalities in waste planning and handling. Special regulations for handling hazardous waste and penalties for non-compliance are also included.

Affaldshåndteringsbekendtgørelsen (Waste Handling Regulations)(Vejledning om håndtering af bygge- og anlægsaffald, 2019) provides detailed guidelines for the practical handling and disposal of waste, focusing on operational procedures for waste collection, transportation, and disposal. It emphasises recycling and reuse,

including end-of-waste criteria to determine when waste ceases to be waste, thus promoting resource efficiency and safe environmental practices.(source)

Restproduktbekendtgørelsen (Residual Utilization Regulations)(Bekendtgørelse om anvendelse af restprodukter, jord og sorteret bygge og anlægsaffald, 2016) focuses on the use of residues, soil, and sorted construction and demolition waste, providing guidelines for their safe application in construction and other projects. It establishes requirements for testing and controlling residues before use and lists specific activities where residues and soil can be used without additional permits, ensuring compliance and monitoring mechanisms.

These regulations collectively form a comprehensive framework for handling waste-derived products. In the literature search, no literature was found on how they correlate to the EoW framework. However it can be deduced that they aim to address a common concern of handling waste-derived products in a safe way while pushing for use of residual materials. The implications of these on the field will be discussed through the analysis of this project.

3.4 How Does the End of Waste Framework Affect Waste-Derived Building Materials in Denmark?

A core component of the EoW framework is that it gives an assessment of waste streams to determine their potential for safe and effective reuse involving physical, chemical, and biological tests to identify and mitigate any hazardous properties. For example, research by Bandarra et. al (2022) on incineration bottom ash (IBA) from municipal solid waste demonstrated that with proper treatment, IBA could achieve non-hazardous classification, enabling its use in construction applications such as roadbeds and concrete products. This was examined through an evaluation of the material in comparison with already existing EWCs. Since the transformation of the product aligns with EoW principles, by preventing landfilling and conserving natural resources like sand and gravel (Bandarra et al., 2022). This is an example of how you can achieve EoW, and gives an indication of the testing that products in Denmark will have to go through.

Although there are no specific studies on how EoW has been implemented in Denmark, there are studies on how urban settings can effectively transition to a circular economy. Since circular economy is a key driver for frameworks like EoW, this should also be explored. The book "Achieving the Circular Economy: Exploring the Role of Local Governments, Business, and Civic Society in an Urban Context," edited by Jenny Palm and Nancy Bocken, provides a comprehensive examination of how urban settings can effectively transition to a circular economy (Palm & Bocken, 2021). In this it is emphasised that in such transitions it is important to consider stakeholder inclusion, as well as considering different governance modes where local authorities can facilitate the circular economy (Palm & Bocken, 2021). In the text this is explored through a case study in Gothenburg Sweden focused on sharing economics facilitated by the city, and in the implementation achieves a reduction of waste and extending the life of products through shared usage and repair initiatives (Palm & Bocken, 2021).This can be used as an estimation of how implementing something like EoW could require action from governing bodies such as municipalities, cities and so on.

Other studies agree that effective governance involves clear regulatory guidelines, robust policies, and economic incentives that encourage the adoption of sustainable practices. Additionally it is found in the literature search that technological innovations, such as AI, robotics, and blockchain, play a significant role in

optimising waste management and facilitating circular practices (Davidescu et al., 2020; Huntzinger & Eatmon, 2009). Although interesting, this does not bring us closer to understanding the effects of EoW.

Case studies have demonstrated the practical application of CE principles, showcasing how modular designs, energy-efficient retrofits, and recycling of construction materials contribute to more resilient and sustainable building practices (Santos et al., 2024; Zimmermann et al., 2020) Since we have established that EoW is supported by CE concepts, it can be deduced that there is a possibility that it can create sustainability benefits in the construction industry. The construction sector benefits from EoW criteria by incorporating recycled construction and demolition waste into new projects, thus closing the material loop and reducing reliance on virgin resources (Smith et al., 2020; Ruiz et al., 2020). This not only promotes sustainability but also supports economic efficiency by lowering the costs associated with waste disposal and raw material extraction (Smith et al., 2020).

Additionally the study by Dahlbo et al. (2015) examines the Finnish waste management system's transition to sustainability, with a focus on circular economy and the EoW concept. In this study, the environmental performance of a common Finnish C&DW management system was assessed with MFA, LCAand ELCC methodologies and by applying the BAT approach to bring up different aspects of the performance (Dahlbo et al. 2015). The study also outlines the legislative and operational changes in Finland's waste management, focusing on the EoW criteria. The study's key findings highlight that the legislative frameworks play an important role in promoting recycling and resource recovery. The authors underscore the importance of clear EoW criteria to facilitate recycling markets and enhance material recovery.The study concludes that achieving a sustainable circular economy requires continuous adaptation of policies and practices, engagement of stakeholders across the value chain, and investment in innovative recycling technologies (Dahlbo et. al, 2015). While this study deems the framework important, it does not touch on the implications of it.

The report "End-of-Waste as a Method for Recycling Construction and Demolition Waste" by Smith, Køster, and Christensen (2020) from the Teknologisk Institut explores the potential of the End-of-Waste (EoW) concept to enhance the circular economy in the construction sector. The primary aim is to provide a framework that helps transition construction and demolition waste into valuable raw materials. The report "End-of-Waste as a Method for Recycling Construction and Demolition Waste" by Smith, Køster, and Christensen (2020) from the Teknologisk Institut explores the potential of the End-of-Waste (EoW) concept to enhance the circular economy in the construction sector. The primary aim is to provide a framework that helps transition construction and demolition waste into valuable raw materials. They find that the EoW framework is crucial for overcoming barriers to market development and fostering trust in the quality of recycled materials. They outline a set of criteria that should be considered when applying for EoW in Denmark for products that do not have material specific EWC. These are:

The substance or object has undergone a recovery operation, including recycling.

The substance or object is commonly used for specific purposes.

There is a market or demand for such a substance or object.

The substance or object meets the technical requirements for the specific purposes and complies with applicable legislation and standards regarding products.

The use of the substance or object does not have overall negative impacts on the environment or human health.

Definition of waste types that may be used as input material for the recovery operation (i.e., what type of waste it is).

Permitted treatment processes and techniques.

Quality criteria (limit values) for materials that, as a result of the recovery operation, have ceased to be waste. They must comply with the applicable product standards. If necessary, there should be limit values for contaminants.

Requirements for handling systems that can demonstrate compliance with the criteria for the end of the waste phase. Quality control, self-monitoring, and, where relevant, accreditation may be part of the handling system.

A requirement for a declaration of conformity.

3.5 CONCLUSION

The integration of End-of-Waste criteria within the circular economy framework is crucial for achieving resource efficiency, minimising waste, and promoting sustainable development. By reclassifying waste as valuable resources, the EoW criteria support environmental protection and drive economic growth. The regulatory framework in Denmark, encompassing the Waste Management regulations, Waste Handling Regulations, Residual Utilisation regulations, and Restproduktbekendtgørelsen and the Environmental Protection Act, provides a robust foundation for implementing EoW principles. These regulations ensure that waste materials can be safely and effectively reused, thus supporting the transition to a circular economy. The case analysis of upcycled soil and plaster will further illustrate the practical applications and benefits of the EoW framework in real-world scenarios.

4 CASE DESCRIPTIONS

4.1 GENJORD AND SOIL WASHING

Genjord is a soil washing company, started in 2022, and so it is a fairly new company. Genjord is founded by Erik Yde who also runs the Company Vils Entreprenørforretning and has over 30 years of experience within civil engineering as well as experience with running a gravel pit. This led him to an interest in the technology of soil washing.

Genjord currently has a collaboration with Norrecco, where they wash soil that Norecco receives, which Norecco then sells. Norecco also helps out with batch testing of the soil.

4.1.1 What is their product and how is it circular?

Genjords machinery is mobile, meaning that their main product is the service of soil washing. This produces a clay fraction that is landfilled or further treated as well as a range of fractions depending on the input to the process. For the purpose of this project I have chosen to focus on Genbrug Stabil 0-32 which is stabel gravel in the corn size 0-32mm.

In the figure 1 and 2 below, a general overview of two possible value chains of Genjord products is shown. The input as well as the use cases of the products differ, so these are examples. Figure 1 showcases how virgin gravel is used in construction projects. At some point this will be excavated in relation to demolition

and new construction. The products can then go to Genjord, where they will be treated and then can be reused in new projects.

Another option is showcased in figure 2, where you excavate soil in relation to a construction project, but here the soil hasn't been laid out as part of previous construction. The soil can then be recycled at Genjord, and the resulting product can then be reused in new construction work. A third option is that Genjord is hired for a large project and washes the soil in situ. The soil can then be directly reused on the site or it can be sold. These figures are excerpts from miro representing an interaction with Eric the 02-05-2024, Appendix B1. The same day he drew a more general image which can be seen in figure 3.

What is important to notice in this, is that the sites from which the soil comes from changes, and so the input for soil washing changes, which affects the types of output. The classification of the input in regards to soil classes is decided before Genjord receives it, and the quality after the upcycling process is tested by Genjord.

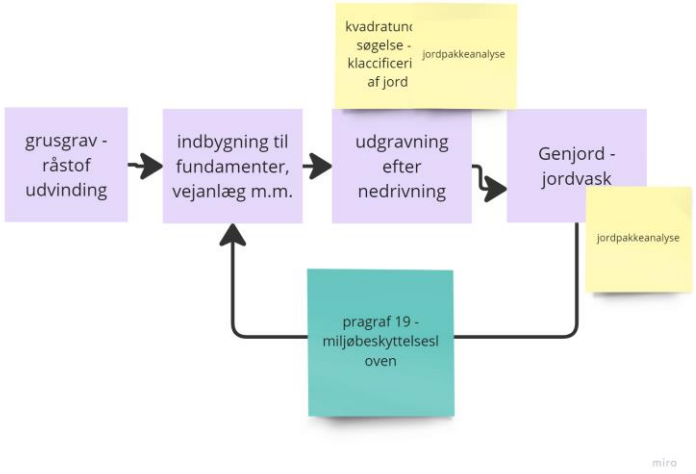

Figure 1value chain for soil - from interaction

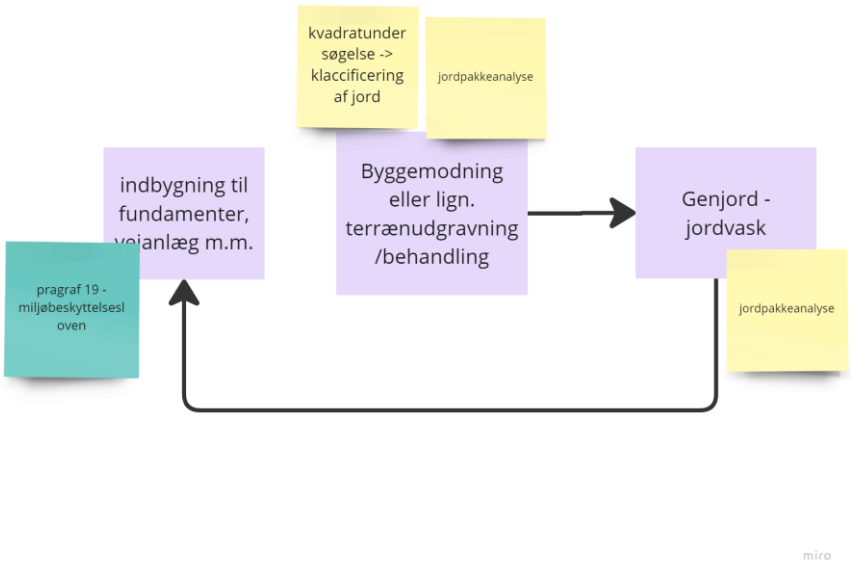

Figure 2 value cahin for soil - from interaction

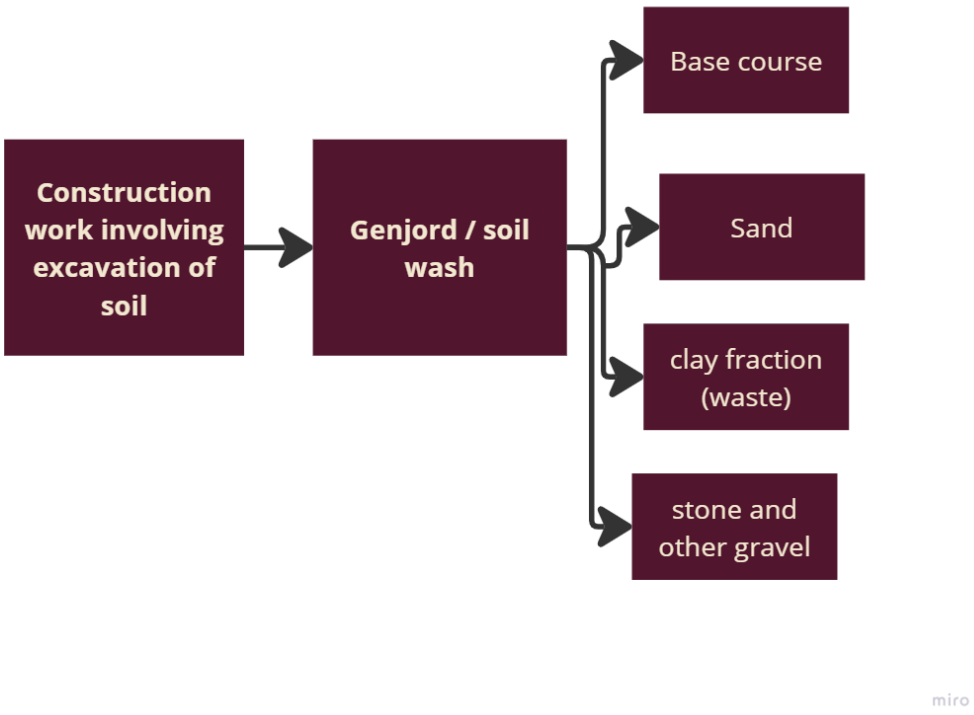

Figure 3 value chain for soil - from interaction

4.2 NORRECCO AND PLASTER

4.2.1 Who are Norrecco and what do they do?

Norrecco is a company that receives waste from the construction industry, including renovations, demolitions and building projects as well as other related waste types. Their goal is to recycle as much of the waste as possible. At their core, they value contributing to reducing use of natural raw materials through upcycling construction waste to waste-derived resources.(Norrecco.dk). The Main contact at Norecco for this project has been Jette Johansen.

4.2.2 What is their product and how is it circular?

Norrecco handles many different types of waste, but for the purpose of this project, I have chosen to focus on their treatment of Plasterboards.

Norecco receives unpolluted and sorted plasterboard for recycling. They then sort out any paper or cardboard and crush it into gypsum powder, which is sold to Danish plasterboard producers. The recycled gypsum powder replaces a part of the natural gypsum used for plasterboards. Today a standard plasterboard contains 25% recycled Gypsum powder. A general overview of the lifecycle of gypsum can be seen in the figure 4 below.

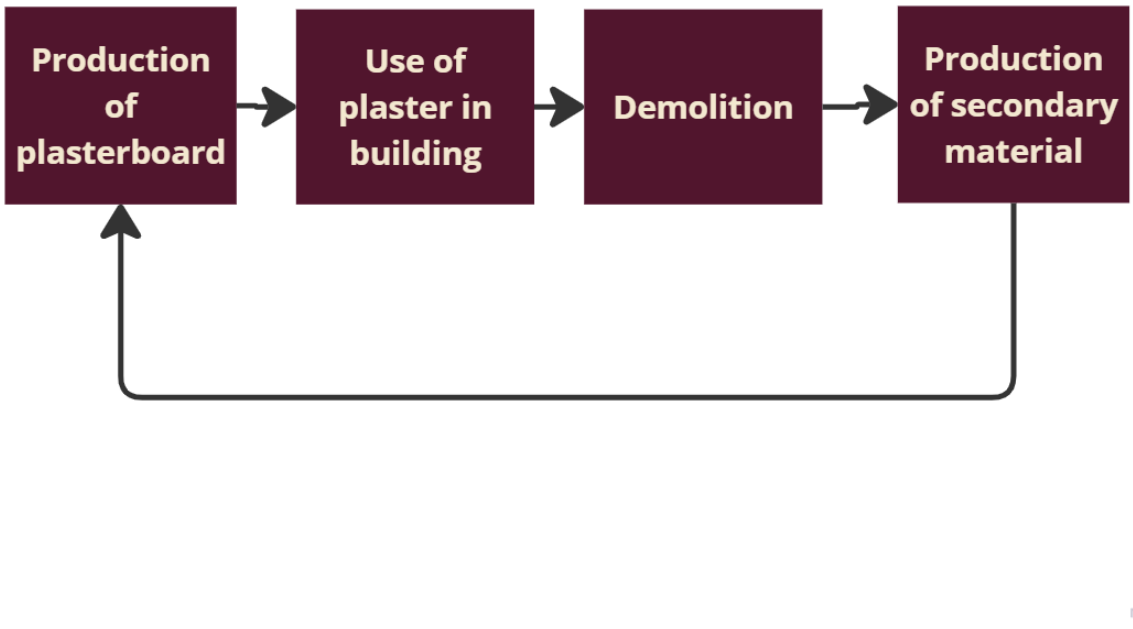

Figure 4 value cahin for plaster to gypsum powderv - from interaction

5 ACTOR NETWORK MAPPING

In the following section the surrounding actor network of the two cases will be presented. This has been visualised as a mapping showing the human and non-human actors and their relation. By mapping these relations, one can uncover the underlying structure, influence patterns, and collaborative potential within complex systems. The actor network also serves as the blueprint for the following arena mapping.

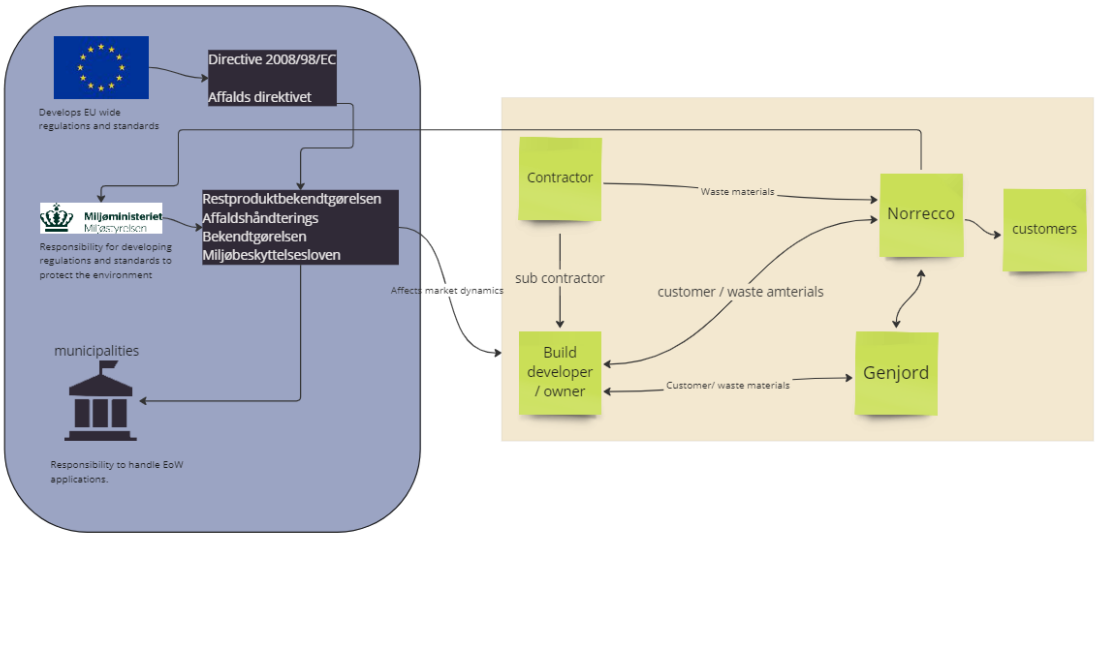

Figure 5 Actor network

In the actor mapping (figure 5), there are two groups of actors. On the left side we have the legislative bodies that have decision power in regards to waste regulations. The EU develops the waste directive and is also in charge of initiatives like the EoW framework. This has an effect on all of the EU member states national regulations. In Denmark it is MST that has the responsibility of developing regulations and standards to protect the environment. As mentioned in the literature review important regulations encompass: Residual utilisation regulation, The waste handling regulations, the Waste management regulation, and the Environmental protection act.(Bekendtgørelse om anvendelse af restprodukter, jord og sorteret bygge og anlægsaffald, 2016; Vejledning om håndtering af bygge- og anlægsaffald, 2019; Bekendtgørelse om affald, 2024; Bekendtgørelse af lov om miljøbeskyttelse, 2024). According to the Danish waste regulation laws, it is the Danish municipalities that have the responsibility to handle applications in relation to waste, and so it is also their responsibility to handle EoW applications.

On the right side are all of the actors who interact with the two case products. Firstly there are the two case companies, Genjord and Norrecco. Their relation is that they have a collaboration. Genjords machinery is mobile and so it is designed to move from project to project. At the moment they are at Norreccos waste revival site and handle soil that Norrecco receives, and Norrecco then aids in the sampling and testing of the soil. Genjord can also move to building projects and treat soil in situ or make arrangements to receive soil

from contractors and treat that. Their main clients are contractors, but as shown with their Norecco collaboration this can differ. Noreccos receives waste materials from contractors and treats them. Their clients vary based on the material, but in relation to plaster, their clients are plaster manufacturers.

The legislations set by MST affects the dynamics of the market for waste products, because it decides how the materials are moved, treated, and used in the market, as well as putting demands on the environmental exposure limits. The Environmental Protection Act paragraph 19 states that polluted soil or other products, that can possibly pollute the groundwater or soil and underground, cannot be built in or layed up without a permit. These permits are not general but are tailored to the individual cases, which implies that any construction or demolition activity requiring the handling of waste materials would need to be evaluated and potentially permitted under this jurisdiction.

The Residual utilisation regulation can be seen as an extension of the Environmental Protection Acts. operationalizing the requirements set in paragraph 19. It sets the specific requirements and procedures for managing residual products from construction and demolition that can be reused in construction projects. It details the necessity for notifications, information provisions, and potential conditions or restrictions imposed by the municipality to ensure environmental protection. This regulation divides waste derived products and materials into categories (1,2 and 3) based on how harmful they are considered to be, which in term is part of deciding how and when these products may be used, as well as making exemptions for certain materials such as concrete.

In this way these laws decide how waste-derived building materials and products may move between the actors in the network. In the cases where you have to get a paragraph 19 permit, the material is viewed as waste.

According to Erik Yde from Genjord, the customers are not interested in paying for a product that needs a paragraph 19 permit, either because they don't want that as part of their project, or because they view the material as a waste that they should be paid to receive. There can be multiple reasons for this; the customer has an interest in getting the material at a low price or for free or the customer does not want to run the risk of putting a waste product into their project.

Another major reason for the unenthusiastic reception of the washed earth according to Erik Yde is: "The potential customers we refer to, and that could be a utility company or municipality or entrepreneurs, they falter a bit, as they have a hard time placing our product. There is an economic gain to be had as well as a sustainability gain, which they would like to capitalise on, in regard to DGNB certification their developments or CO2 calculations. There are many who take a wait and see approach, if something won't happen, as it just isn't recognized yet" (Appendix B1) Where Erik Yde laments the lack of clarity from a governing entity in regards to his product, further being unlined by other quotes such as: "The road directorate have no problem with it, if the customers also found out it was unproblematic, then they probably also would apply for paragraph 19 for their land"(Apendix B1)

In Genjords case, when they clean soil, they will have different sizes of gravel from the process. This can for example be stable gravel in the size 0mm to 32mm. Due to the way the Genjord washing process works - what comes in must come out. The pollutants from the soil are gathered in a clay

fraction, meaning the chemical pollutants have been removed. But the soil they receive comes from environments where it has been mixed with other materials, such as asphalt. Because the machinery removes physical pollutants based on size and density, the asphalt will remain in the cleaned soil. Although the chemical values from the soil tests will not necessarily warrant a paragraph 19 permit, the fact that there is asphalt in it will, due to the restproduktbekendtgørelse. Stable gravel is often used in construction of roads or in other cases, where you would actually add asphalt to clean stable gravel. In these cases, the stable gravel from Genjord would not create any problems, as they are entering a use case where new asphalt is already being used or old asphalt would anyways be added. This example showcases that the paragraph 19 and restproduktbekendtgørelsen creates problems where there should not be any, just because they change the way a customer values the material. This point was emphasised in dialog with Erik Yde regarding the use of washed soil with slight asphalt contamination:

Erik Yde stated: “It’s completely okay, normal even, because a new layer of asphalt will be layered on top and there will be no seeping, so it is seen as unproblematic. That is the case in many places already today”

Astird Yde state: “Why is it you must take extra considerations when it is regarding a residual product left from your washing process, but not when using the soil in the area”

Erik Yde stated: “Well, it’s the law, that's how it is. That's why it is waste”

Astrid Yde stated: “But is there no technical reason for it?

Erik Yde stated: “No.”(Appendix B1).

Normally lightly polluted soil would be utilised in noise barriers or other types of utilisation projects, where the projects are paid to receive it. This creates an initiative to overuse the utilisation option. There have been some issues with utilisation projects using more soil than needed. (*Afgørelsesportal* (No date))

From the dynamic between these regulators and actors related to Genjords product, it can be argued that there is a disconnect between intent and effect of the laws. Although there are solid arguments for the soil classifications, the residual utilisation regulation categories and the, in the residual utilisation regulation determined, exposure values, as well as a need to protect the environment from harmful pollutants, there is a clear need to address certain issues that are created for waste-derived soil materials. This could possibly be handled both through the EoW framework or through remediating the regulations.

To make sure that the materials from Genjords processes are not polluted, they do regular batch testing. For the purpose of this paper I will not go into a full evaluation of this, but it is important to mention that they have gained some important knowledge through this. An important point to make is that what comes into the process must come out, either in the form of a waste fraction that can be further treated, repurposed og landfilled or in the final material as mentioned with the asphalt fractions. This does not mean that the material is harmful or that it does not have a use, it just means that there is one more factor to consider in regards to a framework like EoW.Not only should the

market and use for the material be defined, but the input also needs to be considered when giving an EoW this type of material. One could argue that this is where the “grey”-zone for materials, as mentioned by Johansson & Forsgren (2020), comes into play - that in order to increase sustainability and implement circular concepts, we need to discover and describe use scenarios for materials that are in between waste and non-waste and apply this knowledge to frameworks such as EoW.

In regards to gypsum powder from Norrecco the dynamics are less complex. The image below shows an interaction with Jette Johansen from Norrecco, where we have discussed the need for EoW in relation to the life cycle of plaster. The yellow note shows Noreccos interest in EoW for plaster powder, and the blue note is the interest from a client perspective.

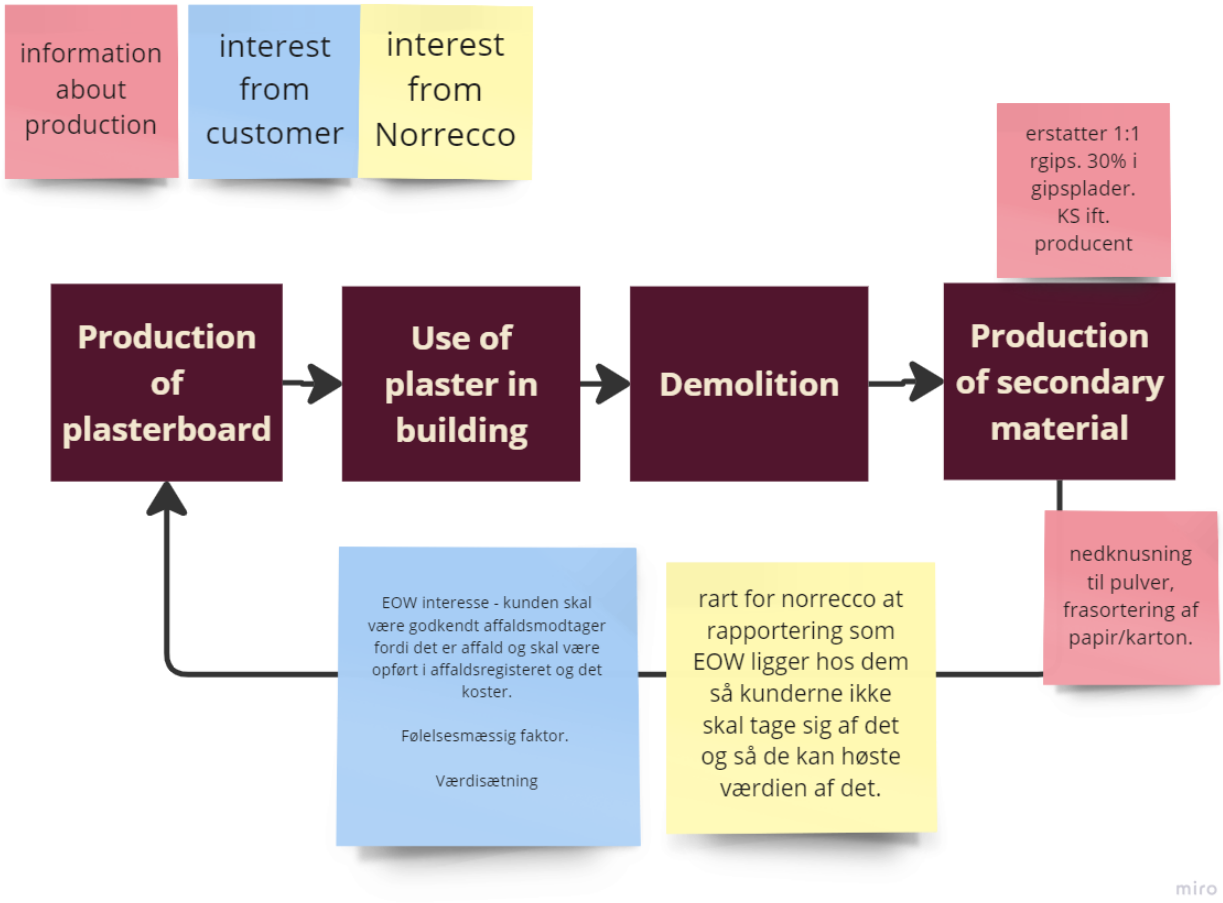

Figure 6 comments from Jette on the calue cahin and itnerest

Currently, waste-derived plaster is sellable and is not hindered by the same laws as soil is. However, in order to receive the plaster powder for production, the customer needs to be approved to receive waste. This has an effect on the value the customer attributes to the product, since this defines the product as waste.

In a quote from Julie Jensen, another reason for wanting the EoW assignment is that it would act as a proof of quality of the product, as they assume there would be very stringent guidelines their product must live up to: “You get a clear documentation of your products capabilities. In reality we would like there to be put demands to the products we create.”(Appendix B2)

Julie Jensen stated:"I have also written that this would help secure a uniform treatment of the product in the process, where it internally would help us reach great quality on our products."(Appendix B2)

Jette emphasised that it would be beneficial for Norrecco to carry the waste-reporting burden rather than their customer.

Jette Johansen stated:"Our interest is to get this end of waste reporting to lie on our shoulders, as we are the ones who know the process, we are the ones that must take samples, we are the ones that are responsible for getting it lab documented." (Appendix B2)

If the product had an EoW certification, it would be valued as a non-waste product and therefore have a chance to become an acknowledged quality product.

6 ARENA MAPPING - ANALYSIS OF INTERESTS AND CONFLICTS

Figure 7 Arena itnerest mapping

Mapped in the figure 7 above, is the arena for end of waste. It is composed of a series of actorworlds based on shared Matters of Concern (MOC). These actorworlds will now be presented, wherafter conflicting dynamics will be discussed.

MOC: Increase circularity through legislation and protecting the environment

The EU and The Danish government (Represented by miljøstyrelsen and its regulations), are concerned about pushing an agenda for a circular economy in order to reach shared sustainability goals. These actors also share the concern of protecting the environment from pollution.

MOC: Run a healthy business that sell products that promote a sustainable future

Genjord and Norrecco, share the concern of running healthy businesses that promote a sustainable future through their product offerings (Norrecco.dk, 06-06-2024). It is inherent in all private companies, that they need to make a profit in order to survive, and in order to grow and develop, and this is what's meant by running a healthy business.

MOC: source materials that have technical quality and are not environmentally harmful, at the right price point.

It can be assumed that contractors and other customers have an interest in running projects that have a healthy economy and live up to current laws and standards as well as buying quality products at fitting price points. Therefore their concern in relation to this arena would be to buy materials that are proven to have the needed technical quality and are environmentally safe. As mentioned in the actor network mapping, the customers also have expectations to prices, and this is contingent on the perceived value.

6.1 DYNAMICS OF THE ARENA:

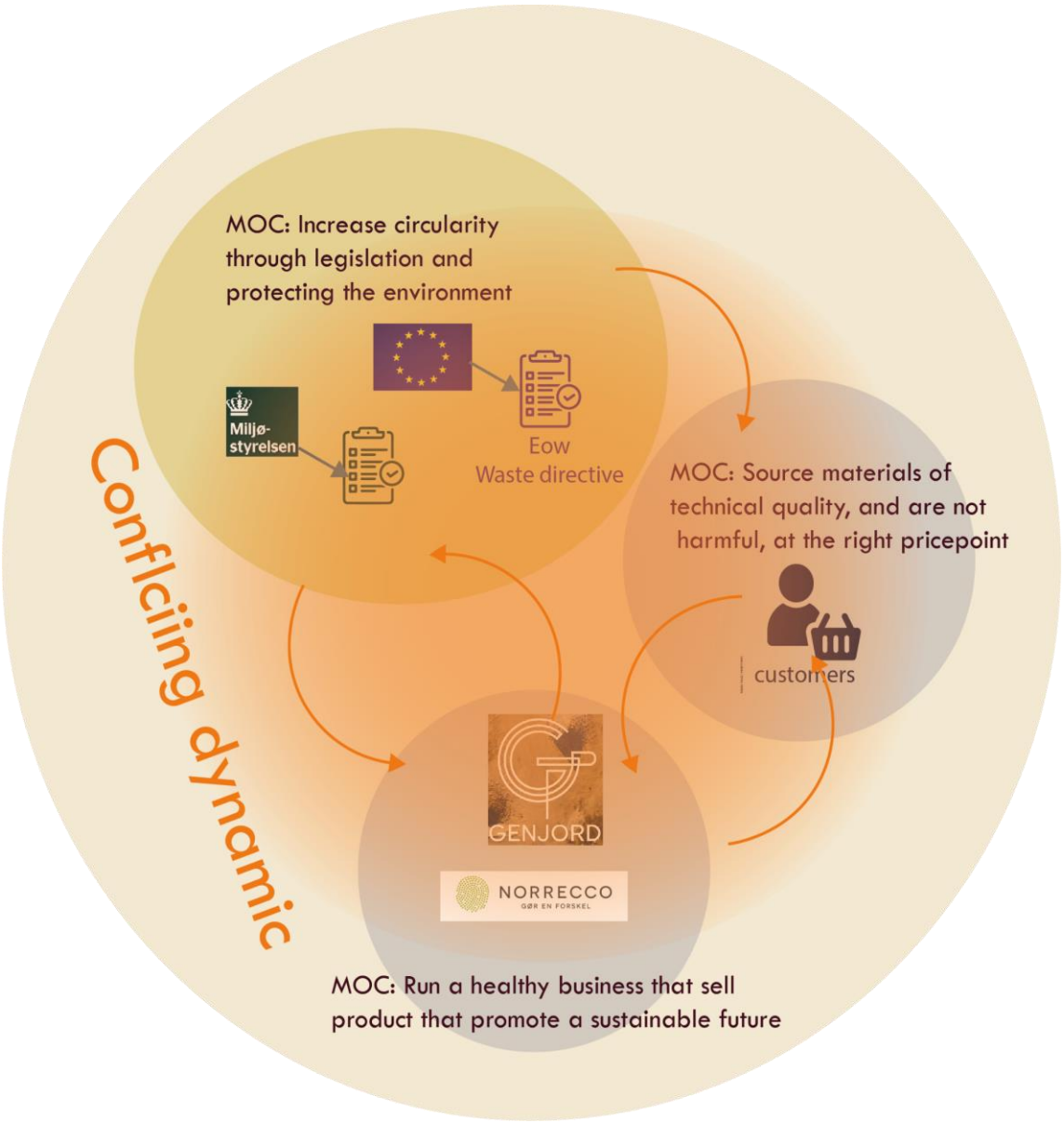

Figure 8 Arena conflict mapping

Through the actor-network mapping and interactions with the companies, some main conflicts and interests can be derived. The conflicts are showcased in figure 8 in some way.

In addition to the matter of concern, they share with the other legislative bodies, the EU has an interest in creating European trade markets, and with this also an interest in creating markets for trading waste and waste products. This is part of the purpose of the EoW framework - they want to strengthen economic initiatives for the circular economy and make it possible to have a standardised system across borders.

The Danish Environmental Agency has an interest in protecting the environment from being polluted with harmful substances (Bekendtgørelse af lov om miljøbeskyttelse, 2024) as well as sharing the previously mentioned MOC with the other legislative bodies. This is showcased through the regulations they have made. These frameworks also seek to drive the use of waste derived materials as showcased in the residual utilisation regulations paragraph 1:

"**§ 1.** Bekendtgørelsen fastsætter regler om anvendelse af restprodukter, jord og sorteret bygge- og anlægsaffald til bygge- og anlægsarbejder og om anvendelse af sorteret, uforurenet bygge- og anlægsaffald med henblik på at nedbringe mængden af affald, der skal deponeres eller forbrændes, og på at reducere råstofforbruget."(Bekendtgørelse om anvendelse af restprodukter, jord og sorteret bygge og anlægsaffald, 2016)

As argued earlier, both Genjord and Norecco are producing waste-derived materials and have an interest in making it easier to put these to use. It was showcased how the waste regulations impacts the value setting of the materials by the customers - thereby creating issues for both Genjord and Norecco in marketing their products. In this way the dynamic that is staged by the Danish waste regulations (also affected by the MOC of the clients) creates a conflict with the MOC of both the legislative bodies, the legislations themselves, as well as the MOC of the companies producing waste derived products. Norecco and Genjord have an interest in solving this conflict, and so should the legislative bodies.

EOW is put in the world to solve this issue in some regard, however at the moment we don't have any set guidelines as to how to apply, and as mentioned in the literature review the EoW framework has to some degree failed or has not been utilised due to the fragmentation of the application system into the municipalities .(Johansson & Forsgren, 2020)

The companies want to apply for EOW, but it is unclear to them how to achieve it. In the next section I will explore how such guidelines can be formed.

7 SYNTHESIS OF EXISTING DEMANDS TO MATERIAL SPECIFIC GUIDELINES

As established in the literature review, the EoW framework is closely related to CE concepts. Through the case descriptions, actor mapping and arena analysis it became evident that in order for Norreccos gypsum powder to increase in value and Genjords stable gravel to gain value and market traction, they need to have EoW on their products or the relevant legislations should be edited. The problem with this is that currently there is a need for a more specific guideline on how to achieve this.

As stated in the literature review a guideline for EoW should ensure safe use of the products as well as living up to the 4 main demands of the EoW framework. Following MOCs of the legislative bodies and CE concepts, this should include data that shows that it is environmentally sustainable. Additionally, CE emphasises that it should be sustainable from a climate perspective.

In an interview with Kathrine Hauge , when asked about wether climate demands should also be integrated in the EoW perspective she says that:

"Well when some goes from being waste to a resource then it of course has to comply with technical demands. But there are also other factors like how energy demanding it is. Then it could be a factor"

Suggesting that the climate impact part should be taken care of by following. From my own study knowledge I know that this could be calculated with for example the EPD standard or LCA ISO 14040. In addition to this there will be materials specific demands on technical and environmental demands that should be considered.

In the following two sections, 7.1 and 7.2, I will outline the existing frameworks that can inspire guideline design for Gypsum powder and stable gravel. This is only meant to be an exploration of possible demands that can be incorporated.

7.1 GYPSUM POWDER GUIDELINE SYNTHESIS

To explore the existing frameworks, standards, and requirements that could be developed into a guideline, an interaction was planned with Norrecco. During this session, participants were given a sheet of paper divided into two categories: Measuring quality of environment and measuring quality of technical ability. They were instructed to brainstorm and document their ideas regarding technical quality and environmental quality. The results of this exercise are detailed in Appendix C, and the full transcription of the session is available in Appendix B2.

This i have transformed into the following table and added the climate impact from EPDs in the table below.

Environmental factor	● Bekendtgørelse nr. 559 af 04/07/2002 om særlige pligter for fremstillere, leverandører og importører mv. af stoffer og materialer efter lov om arbejdsmiljø. ● Bekendtgørelse nr. 507 af 17/05/2011 om grænseværdier for stoffer og materialer, med senere ændringer.
Technical factor	● Bekendtgørelse nr. 559 af 04/07/2002 om særlige pligter for fremstillere, leverandører og importører mv. af stoffer og materialer efter lov om arbejdsmiljø.
Climate factor	● EPD or LCA based on ISO14040 and any relevant CPCRs

In addition to this i would like to refer to also describe the points mentioned by Smith, Køster, and Christensen (2020), shown again below in a report:

The substance or object has undergone a recovery operation, including recycling.

The substance or object is commonly used for specific purposes.

There is a market or demand for such a substance or object.

The substance or object meets the technical requirements for the specific purposes and complies with applicable legislation and standards regarding products.

The use of the substance or object does not have overall negative impacts on the environment or human health.

Definition of waste types that may be used as input material for the recovery operation (i.e., what type of waste it is).

Permitted treatment processes and techniques.

Quality criteria (limit values) for materials that, as a result of the recovery operation, have ceased to be waste. They must comply with the applicable product standards. If necessary, there should be limit values for contaminants.

Requirements for handling systems that can demonstrate compliance with the criteria for the end of the waste phase. Quality control, self-monitoring, and, where relevant, accreditation may be part of the handling system.

A requirement for a declaration of conformity.

7.2 BASE COURSE GUIDELINE SYNTHESIS.

At the session at Norecco we also went through the same process for the base course, however it has not been explored with Genjord due to time constraints. The result can be seen in the table below:

Environmental factor	● Udvaskningstest (leaching test I/500t ● Jordpakken (the soil package
Technical factor	● I/500t sigtekurver (gradation curve)
Climate factor	● EPD or LCA following ISO 14040 and relevant CPCRs

Again it would also be beneficial to address the points from Smith, Køster, and Christensen (2020) in a report. Additionally, there are a few factors that should be considered when dealing with soil washing. From the already established knowledge there are a few things that are evident. First of all, soil washing has a variable input. Secondly the output in relation to the input will also vary since it is contingent to the input. These variance should be described by having an appropriate sample size.

8 CONCLUSION

This project has explored the application of the End-of-Waste (EoW) framework within the context of the circular economy, with specific focus on the cases of Genjord and Norrecco in Denmark. Through a comprehensive analysis involving literature review, stakeholder interactions, and methodological frameworks such as Actor-Network Theory (ANT) and Staging Negotiation Spaces (SNS), several key insights have emerged.

Firstly, the EoW framework faces implementation challenges at both the EU and national levels. The fragmentation of application processes across numerous municipalities in Denmark has led to inconsistencies and a lack of clarity, hindering the use of the framework. This lack of clarity is evident in the cases of Genjord and Norrecco, who want to apply for EoW, but are unsure of the material specific demands.

Secondly, the analysis highlights the importance of clear, standardised guidelines on the use and application of the EoW framework. The experiences of Genjord with soil washing and Norrecco with recycled plaster demonstrate the need for robust criteria that ensure environmental and human health protection while also

being practical and feasible for companies to meet. The development of such guidelines would not only facilitate the EoW application process but also enhance market trust in recycled materials.

Furthermore, the actor-network and arena mapping revealed the dynamic interplay between various stakeholders, including regulatory bodies, companies, and consumers. These interactions underscore the necessity for continuous engagement and mutual learning to address conflicts and align interests. The participatory approach advocated by SNS has proven beneficial in fostering collaboration and co-creating solutions that are both innovative and sustainable.

In conclusion, while the EoW framework holds significant potential for advancing the circular economy, its success is contingent on addressing the current implementation gaps and fostering a more cohesive and transparent regulatory environment. Future efforts should focus on refining the guidelines for EoW applications, enhancing stakeholder collaboration. By doing so, we can better harness the value of waste-derived materials, reduce reliance on virgin resources, and move towards a more sustainable and resilient economy.

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APPENDIX LIST

Appendix A: Overview of process
Appendix B1-B3: Interview
Appendix: objects from inteactions