On-Site Cable Waste Management During the Construction of Energy Networks

A THESIS DISSERTATION

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by

Isabela Zurita Proano S265255

Supervised by

Leon olde Scholtenhuis, Koen Siers, Mechiel van Manen

University of Twente and Siers Groep, Netherlands

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UNIVERSITY OF TWENTE. siers

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Summary

The Netherlands is undergoing an energy transition while striving to be sustainable. This shift in energy sources and overall energy production requires a rapid reconstruction of energy infrastructure. New forms of electrification will replace fossil fuel gas with electricity and transform for connections to renewable sources. Due to environmental goals for 2050, these changes need to be implemented in twenty years, a work that previously would have taken forty years (Circular Manager, 2024).

The accelerated change places stress on the environment, particularly because the cables used for electricity generation are made of scarce materials like copper and aluminum. Despite this, efficient waste management in the construction of electricity projects has not been thoroughly investigated. This report aims to analyze how cable surplus is managed during the construction of energy networks considering the amount of new infrastructure that will be implemented in the future with electricity transported through cables.

The investigation employs an ideal framework based on Ajayi et al. (2017) on Critical Management Practices Influencing On-site Waste Minimization in Construction Projects. The framework provides twelve measures that represent an ideal successful waste generation based on the four components of contract management, waste segregation, material reuse, and logistics management. The goal of this framework is to describe what is the best way to perform waste management on-site. The analysis will study the framework in comparison with the projects for constructing energy networks conducted between Alliander and Siers from the energy network construction sector. The application into the construction of energy networks so it is possible to minimize waste and reduce environmental impact from the industry.

This qualitative research used triangulation to increase the validity of findings, meaning that data was collected from multiple sources. The study gathered 3 observations on-site construction areas, 11 interviews with professionals from different backgrounds in the supply chain, 19 national policies, and 33 company documents.

The data was categorized, clustering it into groups based on the different measures from the framework. Grouping the methods was done by identifying patterns and conducting a thematic analysis, from which data was categorized into the measures from the framework. This approach helped conclude the current situation regarding waste management of cables in the construction of energy networks. Further conclusions on the success of waste management were drawn by comparing the situation described in the literature. The results indicated that seven out of twelve measures were properly applied by Alliander and Siers.

Contract management is not practiced as ideally presented in the framework. ***The waste target set for sub-trades [M 1]*** is not utilized. There are special conditions for the disposal and treatment of materials, but these lack specifications on how to apply them. The targets could be clearer and include incentivization and penalties for the workers, but they do not. ***Recycling targets set for every project [M 2]*** are not directly set by the client to the contractor. Governmental documents are used by each company, but there are no goals for recycling materials on a project basis. The projects between Alliander and Siers, ***sub-contractors are***

responsible for waste disposal [M 3]. Workers are responsible for collecting and disposing of waste and then transporting it for processing and recycling by a designated company.

Waste segregation is implemented similarly to the ideal situation, with ***dedicated space for storing waste [M 4] and specific waste skips for different materials [M 5].*** Workers on-site properly divide materials, with cables disposed of in specific skips and processed by the metal recycling company.

Material reuse is not practiced in the projects due to the potential risk of damaging the quality of the energy network. While there is no ***reuse of off-cut materials [M 8] and the maximization of reuse of materials on-site [M 9]*** is not entirely practical, workers have been ***detecting construction activities that can admit reusable materials [M 6] and use reclaimed materials [M 7].*** There is interest in implementing scrap cables in other projects, developing new ways to connect cables, and exploring other activities where materials reuse is possible. Additionally, various types of reclaimed materials are used throughout the energy network projects, such as sustainable cables used in the construction and recovering unused materials after project completion.

Material logistic management is achieved using ***safe material storage facilities [M 10] and central areas for storage [M 12].*** The available storage facilities are metal containers that protect cables from theft and damage. Although storage areas may not be centrally located on the construction site due to issues with public and private area storing, Siers finds the appropriate locations to leave the storage containers. The areas are also important for the ***adequate delivery and movement of materials [M 11]***. Material movement efficiency can be improved by planning materials per activity and implementing just-in-time delivery.

Further analysis of the efficiency in waste management suggested innovation and legal documentation to enhance waste minimization on-site construction of energy networks. Although the management of reuse and recycling is crucial for reducing landfill waste and minimizing environmental impact, the investigation discovered that waste reduction should be focused on reducing waste. With less additional waste on-site, there are fewer requirements for workers, a rescued need for space, lower transportation costs and emissions, and less waste is generated.

Nevertheless, based on the analysis of current waste management practices, it can be concluded that the current situation can be further developed for more efficient cable waste management, in the construction of energy networks.

For contract Management, the measures such as legal documents to reduce waste are not applied. Contracts should include specific targets and incentives related to waste reduction and recycling to encourage collaboration in waste minimization. Reusing materials is not implemented as effectively as in the ideal situation. Further experimentation and development on integrating reused cut-off materials into the network and refurbishing cables can be investigated. Finally, Material Logistics Management improvements can be made in the delivery and movement of materials on-site. Efficient logistics can reduce surplus waste and improve the overall efficiency of the construction process.

Samenvatting

Nederland ondergaat een energietransitie terwijl het streeft naar duurzaamheid. Deze verschuiving in energiebronnen en de totale energieproductie vereist een snelle reconstructie van de energie-infrastructuur. Nieuwe vormen van elektrificatie zullen fossiele brandstof gas vervangen door elektriciteit en verbindingen transformeren naar hernieuwbare bronnen. Vanwege milieudoelen voor 2050 moeten deze veranderingen binnen twintig jaar worden geïmplementeerd, een werk dat eerder veertig jaar zou hebben geduurd (Circulair Manager, 2024).

De versnelde verandering legt druk op het milieu, vooral omdat de kabels die voor elektriciteitsopwekking worden gebruikt, zijn gemaakt van schaarse materialen zoals koper en aluminium. Desondanks is efficiënt afvalbeheer bij de bouw van elektriciteitsprojecten nog niet grondig onderzocht. Dit rapport heeft tot doel te analyseren hoe kabel overschotten worden beheerd tijdens de constructie van energienetwerken, rekening houdend met de hoeveelheid nieuwe infrastructuur die in de toekomst zal worden geïmplementeerd met elektriciteit die via kabels wordt getransporteerd.

Het onderzoek maakt gebruik van een ideaal kader gebaseerd op Ajayi et al. (2017) over Kritische Managementpraktijken die Invloed hebben op Afval Minimalisatie op de Bouwplaats in Bouwprojecten. Het kader biedt twaalf maatregelen die een ideale succesvolle afval minimalisatie vertegenwoordigen op basis van vier componenten: contractbeheer, afvalscheiding, hergebruik van materialen en logistiek beheer. Het doel van dit kader is om de beste manier te beschrijven om afvalbeheer op de bouwplaats uit te voeren. De analyse zal het kader bestuderen in vergelijking met de projecten voor de bouw van energienetwerken uitgevoerd tussen Alliander en Siers uit de sector van de bouw van energienetwerken. De toepassing in de bouw van energienetwerken moet het mogelijk maken om afval te minimaliseren en de milieu-impact van de industrie te verminderen.

Dit kwalitatieve onderzoek gebruikte triangulatie om de validiteit van de bevindingen te vergroten, wat betekent dat gegevens werden verzameld uit meerdere bronnen. De studie verzamelde gegevens uit 3 observaties op bouwplaatsen, 11 interviews met professionals uit verschillende achtergronden in de toeleveringsketen, 19 nationale beleidsdocumenten en 33 bedrijfsdocumenten.

De gegevens werden gecategoriseerd door ze in groepen te clusteren op basis van de verschillende maatregelen uit het kader. Het groeperen van de methoden werd gedaan door patronen te identificeren en thematische analyse uit te voeren, waarbij de gegevens werden gecategoriseerd in de maatregelen uit het kader. Deze benadering hielp conclusies te trekken over de huidige situatie met betrekking tot afvalbeheer van kabels in de bouw van energienetwerken. Verdere conclusies over het succes van het afvalbeheer werden getrokken door de situatie te vergelijken met de literatuur. De resultaten gaven aan dat zeven van de twaalf maatregelen correct werden toegepast door Alliander en Siers.

Contractbeheer wordt niet uitgevoerd zoals ideaal gepresenteerd in het kader. Afvaldoelen voor onderaannemers [M 1] worden niet gebruikt. Er zijn speciale voorwaarden

voor de verwijdering en behandeling van materialen, maar deze missen specificatie over hoe ze moeten worden toegepast. De doelen zouden duidelijker kunnen zijn en prikkels en straffen voor de werknemers kunnen bevatten, maar dat doen ze niet. Recyclingdoelen die voor elk project zijn gesteld [M 2] worden niet rechtstreeks door de opdrachtgever aan de aannemer gesteld. Overheidsdocumenten worden door elk bedrijf gebruikt, maar er zijn geen doelen voor recycling van materialen op projectbasis. In de projecten tussen Alliander en Siers zijn onderaannemers verantwoordelijk voor afvalverwijdering [M 3]. Werknemers zijn verantwoordelijk voor het verzamelen en verwijderen van afval, dat vervolgens wordt verwerkt en gerecycled door een aangewezen bedrijf.

Afvalscheiding wordt op een vergelijkbare manier geïmplementeerd als in de ideale situatie, met speciale ruimtes voor het opslaan van afval [M 4] en specifieke afvalcontainers voor verschillende materialen [M 5]. Werknemers op de bouwplaats scheiden materialen correct, waarbij kabels in specifieke containers worden weggegooid en verwerkt door het metaalrecyclingbedrijf.

Hergebruik van materialen wordt niet toegepast in de projecten vanwege het potentiële risico van kwaliteitsverlies van het energienetwerk. Hoewel er geen hergebruik is van restmaterialen [M 8] en de maximalisatie van hergebruik van materialen op de bouwplaats [M 9] niet volledig praktisch is, hebben werknemers bouwactiviteiten gedetecteerd die herbruikbare materialen kunnen toestaan [M 6] en gebruiken ze teruggewonnen materialen [M 7]. Er is interesse in het implementeren van schrootkabels in andere projecten, het ontwikkelen van nieuwe manieren om kabels aan te sluiten en het verkennen van andere activiteiten waar hergebruik van materialen mogelijk is. Daarnaast worden verschillende soorten teruggewonnen materialen gebruikt in de energienetwerkprojecten, zoals duurzame kabels die worden gebruikt in de bouw en het terugwinnen van ongebruikte materialen na voltooiing van het project.

Materiaal logistiek beheer wordt bereikt door veilige opslagfaciliteiten voor materialen te gebruiken [M 10] en centrale opslagruimtes [M 12]. De beschikbare opslagfaciliteiten zijn metalen containers die kabels beschermen tegen diefstal en schade. Hoewel opslagruimtes mogelijk niet centraal gelegen zijn op de bouwplaats vanwege problemen met openbare en privé-opslagruimtes, vindt Siers de juiste locaties om de opslagcontainers te plaatsen. De ruimtes zijn ook belangrijk voor de adequate levering en verplaatsing van materialen [M 11], waarbij de efficiëntie van de materiaalbeweging kan worden verbeterd door materialen per activiteit te plannen en just-in-time levering te implementeren.

Verdere analyse van de efficiëntie in afvalbeheer suggereerde innovatie en juridische documentatie om afvalminimalisatie op de bouwplaats van energienetwerken te verbeteren. Hoewel het beheer van hergebruik en recycling cruciaal is voor het verminderen van stortafval en het minimaliseren van de milieu-impact, ontdekte het onderzoek dat afvalreductie de focus zou moeten zijn. Met minder extra afval op de bouwplaats zijn er minder vereisten voor werknemers, minder behoefte aan ruimte, lagere transportkosten en uitstoot, en wordt er minder afval gegenereerd.

Desalniettemin kan, op basis van de analyse van de huidige afvalbeheerpraktijken, worden geconcludeerd dat de huidige situatie verder kan worden ontwikkeld voor efficiënter kabelafvalbeheer in de bouw van energienetwerken.

Voor het contractbeheer worden de maatregelen zoals juridische documenten om afval te verminderen niet toegepast. Contracten zouden specifieke doelen en prikkels met betrekking tot afvalreductie en recycling moeten bevatten om samenwerking in afvalminimalisatie aan te moedigen. Hergebruik van materialen wordt niet zo effectief geïmplementeerd als in de ideale situatie. Verdere experimenten en ontwikkeling met betrekking tot het integreren van hergebruikte restmaterialen in het netwerk en het renoveren van kabels kunnen worden onderzocht. Tot slot kunnen er verbeteringen worden aangebracht in het logistiek beheer van materialen, de levering en verplaatsing van materialen op de bouwplaats. Efficiënte logistiek kan overtollig afval verminderen en de algehele efficiëntie van het bouwproces verbeteren.

Introduction

The construction industry is 40% of the world's consumption and approximately 50% of the greenhouse gas emissions in the European Union (EU). Materials commonly disposed of in landfills, such as concrete, steel, copper, and aluminum have a long-term negative impact on the environment (Dutta & Dagwar, 2024). Landfills produce harmful pollutants through the mixture of waste that affects the ecosystem. According to Papadaki et al. (2022), 80 to 70% of materials from construction end up as waste in landfills. The global climate crisis demands the reduction of greenhouse gas emissions.

According to the International Renewable Energy Agency, renewable technologies should account for 70% of the energy demand to reduce carbon emissions (IRENA, 2022). The abrupt change towards renewable energy implementation requires altering the existing infrastructures and connections between energy networks. The shift to using renewable energy can harm the environment through waste generation which increases land, water, and air pollution. The energy transition can be understood from the term “direct electrification”, the process of substituting electricity from direct fossil fuels into renewable energy (Alliander, 2023). The goal of direct electrification between 2024 and 2035 is to complete 80 to 90% of the energy transition in the Netherlands (Alliander, 2023). The pressure comes from ambitious goals of reducing greenhouse gas emissions by 55% by 2030 (Ministry of Economic Affairs and Climate Policy, 2019) and the Netherlands to operate 100% in renewable energies in 2050 (Integrated National and Climate Plan of the Netherlands, 2019).

Now that the energy transition and energy demand are growing, there is pressure on the energy networks and the infra consultant businesses to build fast and efficiently while also incorporating environmentally friendly and resource-efficient construction. In this industry, the main components for constructing underground energy networks are pipelines and cables. Siers is responsible for the construction of the operators of the energy network.

Siers specializes in underground infrastructure in the Netherlands, working in the gas, water, electricity, telecommunication, and heating sectors. In collaboration with their clients, the energy network owners, Siers construct the underground infrastructure. Alliander, one of the network owners in the Netherlands, is responsible for the operation and transportation of energy. These companies work together such that Alliander tenders projects to Siers, and provides the necessary materials for their execution.

Although these companies collaborate on the same projects, their waste management practices are not entirely understood by each other. Therefore, the current collaboration between Siers and Alliander in effective waste management will be analyzed to identify potential areas for improvement. This could have a significant impact on reducing waste and carbon emissions in the industry, given their responsibility for constructing and operating energy networks.

Waste generated in the construction of infrastructure in the energy sector can be produced from excess material on-site. The cause of the surplus material can result from over-ordering or the extraction of existing cables underground. The materials are disposed of despite having the potential to be reused and repurposed to extend their useful life. These strategies to prolong the serviceable life can also help reduce waste and hence achieve successful waste management. The European Commission (2020) explains that material efficiency integrated with successful waste management can reduce greenhouse gas emissions by 80%.

The problem is that cable waste management is not sufficiently efficient when constructing energy networks. Therefore, comparing an ideal waste management framework from the literature to assess the waste management practices of Siers and Alliander construction projects can help identify potential improvements. The analysis can achieve waste minimization and align with reducing the greenhouse emissions and environmental impacts that energy infrastructure projects have on the environment.

This document will initially provide the theoretical background on the energy industry and describe the current problem encountered. It will then present the framework chosen for assessing the current waste management practices on-site in the construction of energy networks. The method of investigation and data collection will be presented to support the discussion on the findings of current waste management. Finally, the document will discuss the results and offer further suggestions for research.

Figure 1 - Electricity grid operators 2023
Siers Projects Road Map, slide 7

1. Energy Network in the Netherlands

The grid in the Netherlands consists of main energy plants generating high-voltage electricity (110kV-380kV), operated by TenneT. Through transformers located throughout the country, high-voltage electricity is converted to medium-voltage and distributed nationwide. Medium and high-voltage cables carry direct current (DC). From the sub-converter stations, energy is transformed and regulated to low voltage with alternating current (AC), which is the electricity entering households.

The Netherlands' electricity network is publicly funded and managed by seven independent companies responsible for operating and transporting energy (de Rio Merino et al., 2009). These companies are: 1. Enexis, 2. Liander (Alliander), 3. Stedin, 4. Westland Infra, 5. Rendo, 6. Coteq, and 7. TenneT TSO. The responsibility for energy distribution is based on geographic territory, as illustrated in the accompanying figure, 2.1.1.

Alliander (Liander) manages 96,000 km of the energy, transporting 40TWh through 5.9 million connections. Although these companies are responsible for the network operation, construction is carried out with the collaboration of infrastructure contractors such as Siers. Alliander works with contractors through a tendering process that starts after identifying a need and sourcing a strategy. The process begins with determining specifications such as design and engineering, followed by negotiation and contracting with InfraConsults, and concludes with the purchase of materials. Alliander owns all cables, which are supplied by other companies, while contractors handle construction using their workers or subcontractors.

Contracts vary based on the actions expected from InfraConsult. Some projects include engineering by the InfraConsult, while others have predefined designs and procedures for the contractors to follow step by step. The project type and size determine whether Siers uses its personnel or subcontracts the work on-site. However, Siers' mechanics are always involved in grid connections while subcontractors handle excavation. All these stakeholders collaborate in the construction of the energy networks.

The need for collaboration and accelerated processes began with the Dutch government's decision to stop using and pumping gas. This decision required replacing gas with electricity, leading to significant growth and development of the current electricity infrastructure, including renewable energy. By 2025, the demand is expected to be around 100,000 km of cables, 670 high-voltage stations, and 5,000 mid-voltage stations with respective low-voltage connections. This all sums up the need for 11,00 football fields of space (Alliander, 2023).

The transition generates environmental impacts during construction, where waste from materials ordered is not used in the building process and disposed of (Al-Hajj & Hamani, 2011). Waste minimization, prevention, and management should be carefully followed during the energy shift. Implementing the waste hierarchy (Appendix A) is key to successful waste management through reduce-reuse-recycle strategies (Zhang et al., 2022).

The best way to reduce environmental impact is by avoiding waste production from the beginning (Wand et al., 2014). Unnecessary waste in energy network construction often comes from surplus cables on-site, which are usually disposed of or returned to the material owners. Reuse and recycling once waste is generated reduces demand for new resources, transportation, and energy production (Al-Hajj & Iskandarani, 2015). The goal is to use all existing materials rather than sending them to landfills and need for purchasing new materials.

2. Problem statement

Unnecessary waste in the construction of energy networks primarily arises from the surplus cables. In energy network construction projects, the management of cable waste has not been thoroughly analyzed. Issues of over-supply and the extraction of cables during construction contribute to generating excess and unused waste on-site.

2.1 Theoretical Model for Effective Waste Management

Previous studies on construction waste management have focused on enhancing efficiency. Examples include waste management mapping by Shen et al., 2024, schematic diagrams for managing waste from different perspectives by Rani et al., 2022, and waste hierarchy investigations by Pier & Martinho (2019). While these are valuable for the construction industry, none have specifically addressed waste management on energy network construction sites.

Figure 2- Underlying measures for reducing waste through site management practices. (Ajayi et al., 2017) Figure 2, pg 337

However, Ajayi et al. (2017) have developed a framework for effective on-site waste management in the construction industry. Although this framework has not been directly applied to energy network construction, the principles and measures can potentially be adapted and implemented in such projects.

Ajayi et al. (2017) focus on identifying measures for efficient waste management rather than providing diagrams for waste management execution. The report investigates waste management across various sectors of the construction industry, utilizing field studies and literature reviews to highlight effective strategies. Through statistics and exploratory factor analysis, they pinpoint essential techniques for minimizing waste on construction sites. Figure 2 illustrates the four components of effective site waste management encountered by Ajayi et al. (2017).

Ajayi et al. (2017) developed a framework (Appendix B) for the construction sector in general, but can also be helpful to assess the effectiveness of waste management practices at underground infrastructure projects such as in the energy network construction.

For this study, it is important to note that several measures from the original framework by Ajayi et al. (2017) were omitted. Out of 21 measures, 9 were excluded because they were not relevant or due to time constraints. For instance, all the design-related measures were disregarded because the analysis specifically focused on on-site cable waste. The investigation centered on physical waste, so measures such as ensuring fewer design changes during construction and following project drawing/design were not measured but superficially discussed by interviewees on the component of material logistic management. However, the measure of over-ordering (M 5 in Appendix B), was included in the discussion on adequate materials delivery and movement.

Additionally, three measures, such as preventing waste mixture with soil and setting up temporary bins for each building zone, were also excluded. These exceptions stem from the nature of network construction, where factors like distinct construction zones do not apply.

The updated framework, which applies to the research objective and analysis of waste management, is presented in Table 1, furthermore, the table aims to find and present the practices that will determine the extent to which cable waste management is efficient on-site during the construction of the energy networks.

Table 1- Components with the respect measures for successful on-site waste management.

COM-1	***Contract Management***	Measures that require contracts and regulations within the project goals and workers to incentivize waste minimization with the construction of a project.
M - 1	*Waste target set for sub-trades*	Waste targets for on-site workers such as incentives or sanctions. Sub-trades can achieve waste reduction during their work with waste management plans and objectives (Marinelli et al., 2014).
M - 2	*Recycling target to be set for every project*	Ensure stakeholders collaborate effectively to optimize waste reduction in network construction projects, including setting recycling as a shared goal across the supply chain (Trkman et al., 2007). Properly managing interactions throughout the supply chain ensures all workers have aligned performance and optimization targets for the project. An integrated supply chain is necessary to prioritize recycling in waste management activities.
M - 3	*Making sub-contractors responsible for waste disposal*	Subcontractors with the responsibility of disposing of waste can contribute to waste reduction (Ajayi et al., 2017). The responsibility of waste disposal includes collection, transportation, and procession of the waste materials. Checklists and detailed records on material flow and mindful use of materials can help with the responsibility (Jingkuang & Yousong, 2011).

Table 1- Components with the respect measures for successful on-site waste management.

COM-2	***Waste Segregation***	Refers to different ways of dividing waste on-site after it is produced. Waste segregation is described as the most efficient way to reduce waste and facilitate reuse and recycling, once it is generated through proper separation (Ajayi et al., 2017). When non-recyclable and recyclable materials are appropriately sorted and provided to the waste processor, the efficiency and likelihood of effective recycling increase (Wang et al., 2014).
M - 4	*Dedicated space for sorting waste*	A designated space should be provided on-site to support easing sorting of waste. The place should help workers properly separate materials.
M - 5	*Provision of waste skips for specific materials*	Separating waste streams is essential for achieving reuse and recycling. According to Al-Hajj& Hamani (2011), segregation is effective when waste skips are clearly labeled for different materials. On-site waste skips significantly enhance recycling efficiency (Marinelli et al.,2014).

Table 1- Components with the respect measures for successful on-site waste management.

COM-3	***Material Reuse***	Reusing materials by incorporating waste mitigation strategies to reduce the need for transportation and recycling. The aim is to avoid using additional energy and resources, thereby prolonging the serviceable life of materials. Reuse is considered the second step in the waste hierarchy (European Union, 2008). This process entails utilizing materials in their original form without altering their composition. It represents a significant conservation measure for both energy and resources. Additional details on reuse can be found in Appendix A.
M - 6	*Detect the construction activities that can admit reusable materials from the construction*	Detecting the activities throughout the construction of the network energy that can incorporate reused cable.
M - 7	*Use of reclaimed materials*	Reclaiming materials involves the reuse of materials that were previously used in other construction projects. According to the Oxford Dictionary, "reclaim" means to retrieve or recover something that has been lost or given. In the context of cables, this refers to retrieving and reusing cables from previous waste, including scraps, leftovers, and old cables.
M - 8	*Reuse of off-cut materials*	Off-cut materials refer to the scraps, in this context cable scraps. Re-using the small scraps in other sections of the construction decreases the final waste generated on-site. Residuals of cut materials are generated by six components presented in Appendix J.
M - 9	*Maximization of on-site reuse of materials*	

Table 1- Components with the respect measures for successful on-site waste management.

COM-4	***Materials Logistics Management***	Effective material planning, understanding inbound and on-site material movements, and efficient storage practices are crucial in minimizing errors in material handling, thereby reducing waste (Ajayi et al., 2017).
M - 10	*Use of safe materials storage facilities*	The implementation of adequate storage can help reduce waste generation because no damaged material will have to be disposed of.
M - 11	*Adequate materials delivery and movement*	Involves processes related to procurement, delivery, storage, and transportation of materials that become waste. Clear and efficient methodologies help identify sources of waste generation and enable corrective actions (Ajayi et al., 2017).
M - 12	*Central areas for storage*	Central storage areas can enhance other measures such as preventing material loss through theft or damage, encouraging waste segregation, increasing the efficiency of material planning and use.

3. Research Objective

The research objective is to analyze how effectively surplus cable during the construction of energy networks is managed, applying the framework developed by Ajayi et al. (2017). Given the problem statement, regarding surplus cable waste in energy network construction, the framework developed by Ajayi et al. (2017) appears suitable for evaluating the current on-site waste management effectiveness in this sector. Their research offers insight and measures that can serve as an ideal situation for successful waste management practices. By applying the framework derived from the literature, the research aims to evaluate and compare the waste management practices employed by Siers and Alliander. This analysis will focus particularly on cable waste management on-site, aiming to identify strengths and weaknesses in current practices.

The scope of waste examined will be limited to the physical surplus generated on-site, specifically focusing on leftover materials discarded during the construction phase. This includes old cables extracted from the ground, unused leftover materials, and cut-off cables, collectively referred to as surplus cables. The research will investigate the entire lifecycle of these cables on the construction site, including their procurement, delivery, utilization, and disposal processes.

Through this practice-oriented research, insights into existing strategies for managing surplus cable in energy infrastructure construction will be gained, facilitating effective improvements in waste minimization. This analysis is crucial for supporting Siers and Alliander in achieving environmental objectives, including reducing carbon emissions and enhancing sustainability throughout their supply chain.

4. Research Questions

From the components of the framework by Aliya et al. (2017), 4 research questions were developed to reach the research objective as presented in Table 2.

Table 2- Research Questions per component

Component	Questions
Contract Management	What are the contracts and regulations between the stakeholders about waste management?
Waste Segregation	How is waste mitigated on-site?
Material Reuse	How is waste managed on-site for potential reuse?
Materials Logistics Management	What are the material logistics on-site?

5. Methodology

The investigation utilizes various forms of qualitative data: literature, on-site observations, documents, policies, and interviews with professionals from different areas of the supply chain. During the data collection, interviews were conducted in an informal approach, lasting between 30 to 60 minutes. This type of approach of interview asked questions in a conversation to get an overall sense of the interest and work in the company. The questions asked through the meeting were tailored to the expert's position and expertise, and aligned with the framework structure. Specific questions corresponding to each measure of the framework are outlined in Appendix C2.

This approach allowed professionals to discuss topics freely and provide detailed perspectives. Additionally, employees with similar positions, for example, the circular manager from Alliander which is involved in the procurement and CSRD development, the project controller from Siers also responsible for the CSRD, and the CSR(d) manager from TKF were asked the same question to compare data.

Depending on the logistics, meetings occurred in the company or via virtual platforms like Microsoft Teams. With consent from the interviewees, sessions were recorded and transcribed to ensure the accuracy and completeness of information. The participants were also requested to provide documentation such as contracts, presentations, reports, and spreadsheets, which were reviewed and categorized based on their relevance to the framework measures (Appendix D1).

The research is based on qualitative data, which involves organizing data from various sources (interviews, documents, policies, and observations) into groups based on the measures from the framework. Thematic analysis was implemented by reading through the data set and clustering data into measures. Once the data was clustered into the different measures chosen from the framework, it became possible to determine which measures were being practiced by Alliander and Siers in the construction of energy networks. This process allowed for a detailed understanding of current waste management practices and helped identify areas for improvement.

To validate the conclusions, triangulation was applied to ensure consistency across different data sources. This validation method involved finding two or more sources that will describe the same idea (e.g., Interviews 2, 8, 10, and 11, corroborated by Site Visits 1 and 2, noted the existence of designated waste sorting areas on projects).

After implementing the thematic approach to illustrate the on-site waste management measures currently in use, a comparative method was applied. The measures from the data set were compared to the ideal construction practices to evaluate the effectiveness of waste management in the context of an energy network. For instance, if the literature and the paper by Aliya et al. (2017) described Measure 2 as “properly managing integration throughout the supply chain ensures all workers have aligned performance and optimization targets,” the way the supply chain worked together through the development of the CSRD (Sustainable Report) was compared. Additionally, statements such as “including recycling as a shared goal across the supply chain” and “integrated supply chain is necessary to prioritize recycling in waste management activities” were compared to the content of documents and interviews. This involved examining whether the workers had aligned performance and optimization targets, recycling as a shared goal, and prioritizing recycling in waste management within the project. Finally, conclusions were drawn on whether the projects by Siers and Alliander adhered to these principles.

Table 3 summarizes the information gathered from each participant and the data source of each measure. Further details on the documents and policies analyzed are presented in Appendix D.

Table 3- Data Collection

		Measures											
Position	***Company***	1	2	3	4	5	6	7	8	9	10	11	12
Logistic Service and Planner [1]	Alliander			✓	✓	✓				✓		✓	
Team Leader [2]	Siers	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
CSR(d) Manager and Account Manager [3]	TKF		✓					✓				✓	
Logistic Administrator [4]	HKS					✓		✓	✓			✓	
Project Controller [5]	Siers	✓	✓	✓									
Purchaser [6]	Siers	✓	✓	✓									
Project Manager Large Projects [7]	Siers	✓	✓	✓			✓	✓		✓		✓	✓
Project Manager [8]	Alliander		✓	✓	✓	✓	✓		✓			✓	✓
Circular Manager [9]	Alliander	✓	✓	✓	✓	✓		✓		✓		✓	✓
Team Leader Work Manager [10]	Siers				✓		✓		✓	✓	✓		
Regional Manager [11]	Siers	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Documents (Appendix D1)		✓	✓			✓	✓	✓		✓	✓	✓	
Policies (Appendix D2		✓	✓	✓				✓					
Site Visits													
Medium Voltage Project [1]				✓	✓	✓	✓				✓	✓	✓
Large Scale Neighborhood Project [2]				✓	✓	✓	✓		✓	✓	✓	✓	✓
Logistic Center Alliander [3]		✓	✓	✓		✓			✓		✓	✓	

6. Results and Findings

This chapter will present the comparison between the ideal type situation of waste management in literature, with the case study of constructing energy networks. Each category elaborates on the components 1-4 from the network with their corresponding measures. Then a conclusion on the waste management of energy projects between Siers and Alliander can be drawn from the results.

6.1 Component 1, Contact Management

Contract Management associates measures that concentrate on the development of documents and policies that will propel targets to minimize waste generation on-site.

Measure 1- Waste Target set for sub-trades

In the construction of energy networks, sub-trades, after being rendered to subcontractors, refer to a group of workers responsible for specific tasks in the project. These subcontractors can vary; for instance, Siers may act as a subcontractor under Alliander, responsible for on-site construction, while excavators may be subcontractors under Siers. Each operates under respective contracts. According to the literature, Measure 1, aims to assess whether clients provide documents or legal requirements to their contractors regarding waste. These targets can range from waste reduction objectives to initiatives promoting waste reduction.

Working Contracts for Sub Trades

Alliander typically works with a comprehensive contract with Siers, integrating logistics, cable routing, and engineering designs. In these situations in which Siers is following the plan step by step, it is because Alliander does not have enough capacity to achieve a project (Regional Manager, Int 11).

Siers engages subcontractors using two distinct contractual models, which are chosen based on the project type. In one contract, subcontractors are compensated based on the length of cable laying per day. Alternatively, subcontractors can be paid hourly, providing more flexibility in their work schedules. This arrangement significantly impacts waste management practices since workers' priorities differ based on their compensation structure. Subcontractors' inventions by cable length may prioritize speed and efficiency.

A three-step contract is adopted by Sies, integrating network owners' requirements obtained during tendering with their specific conditions for executions, named “Special Conditions for Execution of Works” (Appendix D1.1). The contract stipulates conditions for waste disposal and treatment (Appendix F), emphasizing material reuse and waste segregation being promoted by the client and contractor. The document further outlines requirements for waste management compliance set by the main client (network owner), such as segregating waste into waste skips, and surplus cables required to be returned to Alliander; this was confirmed by interviews (Int 2, 9, and 11). No detailed waste targets are presented in these documents. Additionally, the literature suggests that incorporating incentives or penalties related to waste management in contracts could potentially enhance efforts to reduce waste, and such provisions are not included for subcontractors in these arrangements.

Legal documents that focus on waste management within the “Special Conditions for Execution of Works", present the expectations of the sub-trades on waste treatment. While these documents encourage waste management, they do not specify explicit targets for waste reduction, reuse, or recycling. Contractual variations influence waste generation on-site, with varying payment methods.

Measure 2- Recycling target to be set for every project

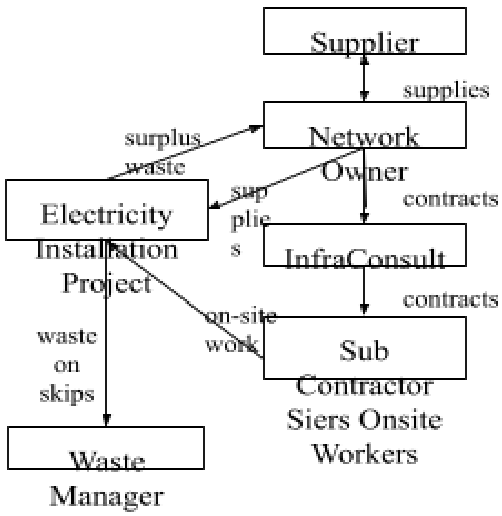

Figure 3 - Supply Chain Construction of Energy Networks

This measure aims to analyze if stakeholders in the supply chain (Figure 3) set recycling goals in the project. Companies focusing on environmental practices can raise awareness and ensure all parties are conscious of material use (Al-Hajj & Iskandarani, 2015).

The relationship between recycling and waste management is explained in Appendix A.

Targets in Projects

When discussing project targets, managers often emphasize safety, revenue, quality, and costs, but do not mention recycling or waste management. None of the managers were aware of any specific recycling targets for their project. Even the Project Manager for larger projects described that there are no goals related to recycling, highlighting that the primary focus is delivering the project to the client. According to insights from the Regional Manager and Project Manager (Int 8), project success is primarily measured by safety and revenue outcomes.

Dutch Regulations Followed by the Stakeholders in Supply Chain

Common policies used by everyone in the supply chain include environmental legislation outlining waste management protocols, aligned with the Waste Framework Directive (Appendix A). The CSRD is another mandatory document for non-governmental organizations in the Netherlands, requiring them to report on sustainability practices, including their recycling methods.

The environmental considerations are "obvious", with aims aligned with Sustainable Development Goals (SDGs) (Regional Manager, Int 11). Both companies use these goals; Siers measures their Corporate Social Responsibilities (CSR) with SDGs, while Alliander describes their environmental goals with the SDGs in their annual report. Alliander and Siers produce monthly reports on their waste flows, aligned with the Environmental Plan. These reports classify waste to promote proper recycling by detailing what materials are accepted in each waste skip.

Furthermore, Alliander's waste management aligns with the Netherlands National Waste Management Plan (LAP3) (Circular Manager, Int 9) (Appendix E3 presents the three relevant chapters of the document). These policies focus on waste collection, recycling, incineration, and landfill activities. The conditions are followed by the recycling processors of cables. This is a procedure rather than a goal for a project.

The conditions for Acceptance from the Netherlands, the recycling methods for metals from cables include:

1. Recycling Aluminum: The main component must be aluminum, with no other
2. non-ferrous materials mixed in. Attachments of iron, rubber, or plastic are accepted but should be free from other waste.
3. Mixed Scrap Metals: These can include ferrous and non-ferrous materials. They may contain copper, aluminum, and steel in certain thicknesses.
4. Scrap Metals: These should be free from other waste when disposed of in the metal contains. The copper content should be at least 28% of the material for this.

Summary

None of the documents or interviews indicated specific recycling targets for the projects between Siers and Alliander. What is currently done with recycling, is following the regulations and laws prescribed by the government. Regarding the waste processor, HKS is responsible for the recycling of the metals in the capsules. However, recycling is not a target set by any client.

M3- Making sub-contractors responsible for waste disposal

Waste disposal involves collection, transportation, and disposal (e.g., landfill). Based on observations and interviews, different subcontractors handle the waste disposal on-site. According to the literature, successful waste management involves the meticulous documentation of waste flows and the use of checklists. Measure 3 will investigate who is responsible for waste disposal and whether weather checklists and waste disposal records are being applied.

Subcontractors are responsible for handling on-site waste disposal. Workers are expected to dispose of waste materials into designated skips and return any surplus cable left on reels to the network owner. The returned materials are documented in the "Material Bon" by Siers, specifying the materials that are returned. Specialized waste processors handle the processing of the collected waste. Pre Zero processes nonmetals and non-ferrous electronics, while HKS processes metals for recycling. HKS is particularly responsible for non-ferrous materials such as aluminum and copper, which serve as the conductors in cables. Cable weighing and sorting typically occur at the waste processor's facility, as explained by HKS's Logistic Administrator.

For the registration of waste, tools such as material checklists are not implemented. This lack of tools results in the absence of official checklists and documentation on material use and disposal. According to the team leader, the recording system of the cables is done once or twice a week by a Siers representative through the GPS Click. Waste is weighed and recorded by workers at project completion, as noted by the Logistics and Service Planner. These records are compiled into documents such as monthly reports with HKS and Alliander's annual waste disposal spreadsheet.

The procedure for on-site waste disposal varies depending on the project size and type. Workers dispose of old cables and scraps into the corresponding waste skips. When a skip is full or the project is over, the project planner contacts the waste processor via phone or email to arrange pick-up. The responsibilities of the waste processors are often outlined in contracts, resembling a subcontractor relationship. Pre Zero processes nonmetals and non-ferrous electronics, while HKS processes metals for recycling.

Subcontractors seem mostly responsible for on-site waste disposal. Workers follow client instructions to dispose of materials into designated skips and return surplus cables on reels. The waste processor, acting as a subcontractor of Alliander, is responsible for the procession of cables.

6.2 Component 2, Waste Segregation

Waste segregation is a mandatory on-site practice enforced by both the network owner and waste processors to facilitate the recycling and reuse of materials. Governmental policies mandate the maximal separation of cables into reusable materials. According to the team leader and the regional manager, incorrect waste segregation has not been an issue in their projects.

Measure 4- Dedicated Space for sorting waste

In the energy network projects carried out by Siers and Alliander, evidence showed that there was a dedicated space to sort waste. This area was separated from the construction zone, and its location depends on the availability of space near the project site, the surroundings, and the willingness of nearby residents to allow equipment placement (Int 8, 10, and 11). Finding a suitable location for this area can be challenging, especially in cities, due to potential opposition from residents or legal restrictions on where containers and waste skips can be placed. As a result, this space is often situated far from the construction site, complicating the mobility of materials to the construction site.

On-site, waste cables (including scraps, leftover cables, and old extracted cables) are collected in smaller trucks or vehicles and transported to a designated area (Appendix G and H present pictures and observation notes on-site visits 1 and 2). In this dedicated space, workers are responsible for disposing of the cables into metal skips or storing leftover cable reels. This area is exclusively used for the delivery, transport, storage, and disposal of materials from the construction site. This was seen in both site visits where the storage location was located in a separate area and expressed by. The storage and segregation area is outlined in Appendix G2.

However, an operational field is not always available because not all projects need a large area for waste disposal. In certain cases, waste is not sorted on-site due to the minor scope. When there is a small cyclic work, all waste is stored in Siers' bus and transferred to the headquarters of Siers. Once there, the materials are sorted into the network owner bins (Team Leader Work Manager, 10).

Regardless of the project size, there is a dedicated space for sorting waste. For large-scale projects such as the one visited, there is a dedicated space of land where waste skips, offices, parking, and storage units are located. If the project is smaller and dedicated space for storage or skips is needed, a smaller van transports the waste to a Siers' headquarters where it gets sorted in a specific area with waste skips from the network owner.

Measure 5- Provision of waste skips for specific materials

Waste skips for the material are ordered depending on the project. As mentioned beforehand waste skips are not always ordered, it depends on the scale of the project and skips are not necessarily on-site, but in the designated space.

The Project Planner is responsible for ordering waste skips based on the waste processor preferred by the network owner (Team Manager, Int 2). The common tool between stakeholders to order the waste skips which are through portals from the waste processors. Appendix I provides detailed information on the different portals from Pre Zero, HKS, and between Allainder and Siers. To order the appropriate skip size, Siers will estimate based on the length of cable work from the cable plan. Alliander makes an order from the HKS portal based on the length of cable extracted from the ground order skips. The type of materials expected to become waste is based on the project specifications.

The Team Leader mentioned that while skips can be emptied or changed upon request during the project, it's uncommon to change midway. This consistency is because the types of material used and disposed of during energy network construction remain the same throughout the project. Furthermore, from interviews and site visits, there was an estimate of three waste skips per project, one designated for cables. The cable skips are used to dispose of all types of cable, including scraps from new cables and old cables.

Ordering during the construction of energy networks is possible as expressed by the Team Leader. Throughout the project, the project managers onsite or the representatives from Siers can email or make calls when a skip has to be emptied and/or changed. However, it is uncommon to change the type of skips in the middle of the project according to the Team Leader. This is because the type of materials that are used and disposed of during the construction of an energy network does not vary with time.

During the construction of energy networks, waste skips are allocated specifically for different materials. The order is based on the projected waste volume on a project, from which one skip is dedicated to cables, including scraps and old extracted cables. For smaller projects that do not have on-site waste skips, the waste is transported to Siers' headquarters for further segregation.

6.3 Component 3, Material Reuse

Siers and Alliander prioritize using cables that are as long as possible to minimize connections and reduce the risk of network problems (Int 2, 7, 9, 10, 11). Connecting multiple short lengths of cable to create a full cable is avoided to maintain network stability and integrity. There is a general rule allowing low voltage cables a maximum length of 500 meters and medium voltage cables a maximum of 1000 meters. This approach makes the reuse of cables challenging which is why cable reuse can occur by reusing the cable materials or long unused cables in other projects.

Measure 6- Detect the Construction activities that can admit reusable materials from the construction.

This measure will analyze the activities involved in the construction of energy networks, with a focus on experts identifying potential opportunities for cable reuse.

The construction process for all network projects follows a standardized procedure:

1. *Excavation*: Trenches are excavated according to engineer specifications detailed in technical drawings.
2. *Cable Laying*: New cables are pulled into the trenches and laid next to the old cables.
3. *Cable Connections:* New cable connections are securely wrapped with impermeable material, adhering to design specifications.
4. *Substation Connection:* The new cable is connected to the substation, while the old cable is disconnected from the grid, ensuring continuous energy supply.
5. *Cable removal:* The old cable is removed by cutting it into smaller pieces to comply with legal requirements and facilitate handling due to the substantial weight of cables. The decommissioning process for the old cable varies based on factors such as alignment with drawings, whether the cable feeds from both sides of the transformer and the presence of the connections through the main cable.

The activity of cable laying to introduce reused cables is more delicate due to the mentioned risks by the experts. The risk of network malfunction outweighs the benefits of reusing cables in the network (Project Manager Large Projects, 7). The primary risk is related to the length and number of connections required to achieve the desired length, not necessarily because of the age of the cable. However, this is the only activity in which surplus waste (with adequate length) is implemented back into the system. More on the process will be discussed in Measure 7.

Measure 7- Use of reclaimed materials

The reclamation and reuse of cables in the construction of energy networks would be analyzed by focusing on the newly purchased cables, and the recycling of cables that reclaim raw materials.

Sustainable Material in Cables Purchased

Alliander aims for energy efficiency and sustainability, targeting 45% circular procurement by 2027. The goal is driven by the material demands during the energy transition and energy demand for the future. Therefore, Alliander prioritizes materials with high recycled content for their networks, evaluating the environmental impact based on recycling percentage and reusability.

During the tendering process, Alliander challenges suppliers to use renewable materials in their products, as claimed by the Circular Manager. This practice helps save CO_2 and provides circular benefits for all stakeholders. To ensure purchased materials are circular and contain the correct components, Alliander uses a Material Passport. This document, requested from all suppliers, tracks the circulatory purchases. Network owners such as Alliander, Enexis, Gasunie, and Stedin use this tool, with varying requirements based on the company.

The material passport provides a clear picture of the raw material composition and whether the product can be recycled or reused at the end of life. More on the sections and details of the document can be seen in Appendix K. Suppliers are required to fill out the table with information before orders are made to evaluate whether the materials used in the products align with Alliander's requirements.

Recycling Cable to Reclaim Raw Materials

As discussed in Measure 2, Alliander recycles its cables with HKS, ensuring metals in cables are recovered and converted into usable metal again. A legal contract between HKS and Alliander mandates that 100% of waste is sent to HKS. However, workers such as the Logistic Service Planner [Int 1] declare what is waste at the end of a project.

The processing of ferrous and non-ferrous materials begins by shredding the cables. Metals are extracted from the shredded residuals with magnets to sell the metals to smelters. This way, raw materials are extracted and promoted for reuse.

Summary

Reclaiming in several ways is achieved with the cables used for the construction of energy networks. Alliander is responsible for purchasing these assets, which is why they make it a priority to buy cables that have restored materials. Additionally, they challenge their partners to also use assets with recycled components. Furthermore, the unused materials are recovered from the construction sites to reuse them in other projects. Recovering material can be a type of reclamation. Finally, recycling of cables to recover metal is assured by Alliander sending their waste to HKS.

Measure 8- Reuse of off-cut materials

The goal of Alliander and Siers is to minimize the number of connections to ensure a stable energy supply. Off-cut material happens during the connection between cables, which are also described as scrap cables. These short lengths of cables are mostly disposed into the cable skip. Experts advise against reusing these cables because they are often too short to be useful for new installations and pose risks of future breakdowns and operational disruptions.

Measure 9- Maximization of on-site reuse of materials

Experts advise against reusing old cables. Instead, the focus is on managing leftover lengths and ordering materials in precise amounts. Reusing short cable lengths and leftover cables is handled carefully, but the primary goal is to reduce the initial provision of materials to minimize waste. This proactive approach in logistics, engineering, and management practices aims to enhance efficiency and sustainability in energy network construction.

The leftover cables are sent to Alliander as discussed in the past measures. Only if the surplus cables are still on the reel, the material is received in the logistics department to prioritize their reuse. The Circular Manager highlighted during Site Visit 3 that retired assets still on reels are particularly valued, according to the annual report, to €1.85 million saved from collected materials, €850,000 of which were reused. Recovering the surplus cables on reels has indicated a 45.95% reuse from returned assets. For a smaller amount of surplus in reels, as mentioned in Measure 6, Siers operates their warehouse to reuse reclaimed materials from other projects.

To ensure surplus cable is reused, Siers' workers also store leftover cables at Siers' headquarters for future projects. Typically, leftovers are sent to the network owners, but with Alliander's agreement, they can be kept by Siers for reuse in other projects or emergencies. This practice of reusing cables is the only one employed by professionals in these projects (Team Leader and Regional Manager, Interviews 2 and 11). However, the reuse of cables is not always successfully done. This is proven by the amount of new, unused cables that are disposed of per quarter of the year by Alliander in their "Incurant" waste calculation.

6.4 Component 4, Materials Logistic Management

The focus of this measure may not explicitly aim to reduce waste, but to generate emphasis on proper handling of materials and raise awareness about responsible resource management.

Measure 10 - Use of safe materials storage facilities

Proper storage practices are essential for preventing damage or theft of valuable materials, such as cables, which are high-cost materials with valuable components. Ensuring proper storage minimizes waste and reduces the need for additional supplies.

The Team Leader and Regional Manager discussed the implementation of storage facilities near construction sites. These areas are fenced and equipped with 24/7 camera surveillance for added security. As mentioned in Measure 4, a designated space within the project area is allocated for material storage.

This setup ensures that materials, including cables, are protected from damage and theft. Effective storage not only guards against physical damage but also shields cables from environmental factors like UV rays, which can degrade their quality over time. Special covers are used to preserve cables exposed to sunlight, as explained in Int 2 and 11 and confirmed during Site Visits 1 and 2 (see images in Appendix G and H).

The importance of preventing damage during storage was emphasized in interviews (e.g., Int 1, 2, and 11). In the event of damage during storage, Siers assumes responsibility for any cable losses. The proper handling and protection of cables are randomly inspected by the Network owners to ensure that storage practices comply with standards. The Logistic Service and Planner described that the random checks minimize risks associated with material handling.

In conclusion, proper storage units and locations are effectively managed in the construction of energy networks. Workers are conscious of the importance of properly storing and protecting cables. Alliander conducts random checks to ensure compliance with storage standards. Additionally, facilities such as the lockable containers that are protected by fence and security also ensure adequate storage.

Measure 11 - Adequate materials delivery and movement

This measure will analyze the delivery and movement of materials during the construction of the energy networks. It covers the transportation from storage units to construction sites and the back-and-forth movement of surplus materials between Siers and Alliander.

The process of cable movement starts with Alliander purchasing cables from suppliers each quarter of the year, based on projected needs for upcoming projects in the energy network (Int 3). These projections are developed by tendered projects from Alliander. Once ordered, materials are delivered to Alliander's logistics center, and stocked. When InfraConsult receives a tendered project, the engineered cable plan is specified, detailing the type and quantity of cables needed. Project planners request the necessary cables through a portal with Alliander (Appendix L). The order includes specific data and location details for delivery and is recorded in the 4P software used by Siers.

Ordering errors occasionally occur due to design changes or incorrect underground cable data. Experts note that while these errors do not necessarily impact waste generation, proper cable planning can integrate design changes effectively. Additional cable required due to routing changes can usually be managed with existing project materials, though priority orders to the network owner may be necessary for extra supplies. Changes in materials and orders are documented in Siers' 4PS Windows system, allowing to track deviations in orders.

Cable delivery to the storage location typically occurs at the beginning of projects (Regional Manager, 11). Although early delivery can facilitate timely project commencement, it sometimes requires rushed installation of security measures, generating additional costs. Project complexity and type, influence material delivery and movement. Medium voltage projects, for example, often involve longer cable lengths and fewer connections, resulting in less waste and fewer cut-offs. This was visible in Site Visit 1 where a main medium cable was replaced. These projects typically use a single type of cable delivered directly to the site.

During site visits, it was noted that storage sites varied in proximity to the work area depending on the project's magnitude. For instance, in a medium voltage project, the storage site was situated at the beginning of the construction site, whereas in a neighborhood project managed entirely by Siers, the storage site was within a 10-minute walking distance. In both cases, materials were transported using smaller vehicles like trucks, ensuring they were delivered efficiently to the work area. After project completion, the surplus material is sent back to the logistics department (Circular Manager, Int 9).

In conclusion, adequate material delivery and movement are generally achieved, despite some issues with unexpected early deliveries. Materials are typically asked to be delivered at the start of the projects with the use of a portal. When the storage location is far from the construction site, workers transport materials and waste using additional vehicles.

Measure 12 - Central areas for storage

Centralized storage areas play a crucial role in facilitating efficient material management on construction sites. When these areas are strategically located, they minimize the need for workers to travel back and forth, optimizing productivity. An analogy drawn by a Siers project manager related this setup to Formula 1 pit stops; where seamless logistics ensure that materials and tools are readily available to mechanics without delay, enabling quicker operations.

Experts note that there isn't a standardized procedure for selecting storage locations. Instead, availability of space and compliance with local regulations specify where sites can be established. Legal restrictions and community preferences often deny placing containers or storing materials within residential areas. This results in necessitating storage sites to be located outside communities to maintain aesthetic standards and resident well-being.

In summary, while centralized storage areas enhance material handling efficiency, their location impacts logistics and operational costs. Balancing regulatory requirements, community considerations, and logistical needs remains a challenge in ensuring effective material management on construction sites.

6.5 Framework Analysis

The research objective is met once the analysis using the framework demonstrates the efficiency of the current waste management practices in the construction of energy networks in the Netherlands. With the collected data and results discussed in the findings, an ideal perspective on successful on-site waste management is presented parallel to the energy network projects.

Ideal Framework		*Energy Network Projects*
1	*Contract management*	**No**
M - 1	Waste target set for sub-trades	**No.** Uses Special Conditions for Execution, where there is a Disposal and Treatment section. The conditions aim to set targets but are vaguely specified.
M - 2	Recycling target to be set for every project	**No,** but based on governmental documents; Environmental Management Act, Waste Policy and National Management Plan 3, and Corporate Social Responsibility.
M - 3	Making sub-contractors responsible for waste disposal	**Yes,** Workers are responsible for throwing the waste in the skips. After skips are full the responsibility passes to the waste processors. There are recordings of the waste and returned materials.

Ideal Framework		*Energy Network Projects*
2	*Waste segregation*	**Yes**
M - 4	Dedicated space for sorting waste	**Yes,** in a devoted space with the waste skips.
M - 5	Provision of waste skips for specific materials (waste segregation)	**Yes,** ordered through portals to the waste processor. Different skips depending on the suspected waste are ordered and delivered before the start of the project.

Ideal Framework		*Energy Network Projects*
3	*Material reuse*	**No,** but Both companies prioritize the reuse of unused materials from other projects, yet the disposal of new materials remains an issue, occurring every quarter. Recycling of waste is consistently performed, and occasionally, experimental projects are developed using reused materials.
M - 6	Detect the construction activities that can admit reusable materials	**Yes,** activities such as laying down and connecting cables have been tested to find where reused materials can be used.
M - 7	Use of reclaimed materials	**Yes,** recycled materials that are circular are purchased **but** are not necessarily the best for long-term efficiency.
M - 8	Reuse of off-cut materials	**No.** However, cut-off cables have been used on Siers' solar park connections.
M - 9	Maximization of on-site reuse of materials	**Not completely.** Both companies aim to reuse materials from other projects. However, challenges arise with optimizing reuse and handling custom-made cables.

However, claims about reusing old cables and short cable scraps in the network should be further investigated. Another concept that needs innovative solutions is refurbishing cables, which is currently not practiced by anyone in the supply chain. If cables can be re-joined to form a specific length, scraps can be fully reused.

	Ideal Framework	*Energy Network Projects*
4	*Materials logistic management*	**Yes**
M - 10	Use of safe materials storage facilities	**Yes.** Materials are properly stored and taken care of.
M - 11	Adequate materials delivery and movement	**Yes,** materials are adequately delivered on-site and moved daily from the storage to the construction site. The movement depends on the schedule and action planned for the day. **However,** deliveries sometimes occur earlier than needed, causing logistic problems. The delivery could be more efficient with the implementation of the Just-In-Time method, but the network owners currently prefer not to use this type of delivery.
M - 12	Central areas for storage	**Yes, considering** the limitations on finding a suitable free area. Regulations and laws make it hard to find a central location, therefore it is mostly chosen because of availability.

7. Discussion and Recommendation

Based on evidence from the study, seven out of twelve measures are considered to be achieved, this means that the success is 58% on the waste management. The data show that the on-site waste management in the construction of energy networks has room for improvement. Considerable improvements can be implemented to achieve full success. This chapter will discuss the findings and provide innovative solutions that could be implemented to reduce waste on-site.

7.1 Component 1- Contract Management

Measure 1- Waste Target set for sub-trades

There are no comprehensive documents outlining waste targets for on-site workers. From out of the 34 documents reviewed, contractual agreements between stakeholders potentially hold crucial information on waste management targets. However, due to confidentiality and time constraints, a detailed analysis of these contracts was not feasible.

Wang et al. (2014) stated that the key lies in how to drive people and incentivize them through short-term benefits. The literature recommends this approach but is not applied to the workers on-site in the construction of the energy networks. On the other hand, incentivizing the workers is the type of monetization stated in the document (Purchaser and Project Manager Large Projects, Int 5 and 7). Monetization can generate prioritization of activities to earn as much profit as possible. The target of on-site workers depending on having a contract that pays by length compared to the workers that get paid by hour can generate different behavior on-site.

For the workers that are paid by length, it is disposable that their target is speed, which can lead to prioritizing using a new reel with more reels to complete a section faster even if two reels are possible to be used (Project Controller, 5). Conversely, hourly workers may exhibit greater conscientiousness in material handling and waste management. While some interviewees suggest a relationship between time management and waste generation (Int 5, 6, 8), others do not see a direct correlation (Int 11). It is possible that time management can be related to waste generation on-site; it is something that has been brought up as a relationship by some interviewees (Int 5, 6, and 8) but others believe it does not have a direct relationship (Int 11).

To promote waste reduction among subcontractors, interviews with the Project Controller and Purchaser (Int 5 and 6) proposed setting waste generation objectives for sub-trades and offering incentives like bonuses. A recommended approach could involve rewarding subcontractors economically if the total waste generated is ≤10% of the total material ordered, with the reward proportional to the waste reduction achieved (e.g., 2% waste generates a 0.98 reward). Such incentives can encourage material efficiency and problem-solving among workers, thereby reducing unnecessary waste generation on-site.

As mentioned in the results, the only document encountered that addresses waste disposal and treatment agreements between site workers and the client is the Special Conditions contract with subcontractors. The conditions lack concrete instructions for implementation such things as “reuse of materials and waste quantities” and “limit waste flow”. When setting clear objectives regarding waste reduction, these can ease workers to find a way to reach these targets. It can be argued whether or not these are goals for the workers on-site to reduce waste and be conscious of waste generation. Waste is stated, but there is also no way to measure if the target is achieved or not, that is to say, what is expected from the workers to accomplish the statement.

Additionally, under the fourth condition of the Disposal and Waste section, subcontractors are obligated to provide copies of reporting forms in compliance with the Environmental Management Act. This indicates that Siers expects subcontractors to adhere to environmental regulations, as stipulated in Appendix E and corroborated by the Circular Manager (Int 9). The document covers general provisions like duty of care, dumping bans, use of a national waste management plan, reuse, prevention, recycling rules, waste shipments, and regulations for every waste stream. Siers and Alliander ensure subcontractors comply with Dutch policies and regulations through these conditions.

Measure 2- Recycling target to be set for every project

In Alliander's and Siers' annual reports and development of CSRD, waste management is tackled in the form of waste reduction and recycling. Evidence presented how companies work on their waste management independently. Both companies achieve over 90% recycling, as stated in the portals and Annual Reports. The recycling is facilitated by the company's waste processors. However, specific recycling targets or objectives for individual projects are not explicitly outlined and could help reduce CO2 emissions. However, the measure aims to promote collaboration within the supply chain.

Recycling in projects primarily relies on the waste processor chosen by Alliander, HKS, which is legally authorized to process cable waste. However, HKS processes only what is provided in the designated metal skips on the project. There are no specific project-level recycling goals; procedures for recycling are outlined but not targets.

Stakeholder collaboration within the supply chain includes adherence to the Greenhouse Gas (GHG) Protocol, integrated into the CSRD. This protocol assesses emissions across three scopes: direct emissions, upstream emissions (involving activities like capital goods, purchased goods and services, transportation fuel, and operational waste), and downstream emissions (related to production, distribution, and end-of-life treatment of products). Consequently, waste management practices within the supply chain significantly influence each company's carbon footprint. Each participant in the supply chain depends on the waste management practices of others. For example, Alliander's annual report identifies their primary emission source originating from purchased assets, particularly related to the extraction of raw materials used by suppliers in cable development (as discussed in Interview 3). Therefore, recycling targets set respectively for a project should be an important implementation. This can also help subcontractors to compromise with reducing waste on-site.

While companies prioritize transparency in emissions reporting and communication, specific reduction targets are not discussed. Interview 3 highlights that meetings between TKF and Alliander to formulate their CSRD typically end with a general encouragement to reduce emissions without setting explicit targets.

Measure 3- Making sub-contractors responsible for waste disposal

Waste disposal is composed of different activities, from which the on-site workers are required to collect waste and waste processors transport, recycle, and dispose of the waste. The process of waste disposal in Siers projects is logically organized and established by the client. While material handling is not typically the responsibility of the workers, they are trained to effectively use materials (Regional Manager, 11). Workers are accustomed to following instructions to place materials in designated skips and waste processors to dispose of or recycle. Each subcontractor is clear in their position regarding waste disposal, but there is always someone who has a role.

Documentation on material usage and checklists for waste disposal is not done specifically on-site by the workers. This concept of monitoring inflow and outflow materials can help identify construction activities that are utilizing more material than normal and understand overall material usage and inefficiencies.

7.2 Component 2- Waste Segregation

Consistent waste segregation and disposal practices facilitate recycling, which is the responsible activity for waste processors chosen by the company. Both of the measures were possible to see through the different sources, from which the evidence indicates waste segregation is properly applied in the construction of energy networks.

All experts interviewed about this measure agree that having different skips is essential and allows workers to understand what waste goes where and to be sure to give it to the right processing company so they can recycle. It was also brought to the attention that there are project leaders who are more cautious with the revision of proper waste disposal and segregation. In the large-scale neighborhood project, a Siers representative would check the skips daily to make sure that what was being disposed of was in the right place and qualified as waste. Additionally, waste segregation is double-checked by the waste processors. If there is a location in which the waste is not being segregated properly, then the processor will give the network owner a working solution.

Measure 4- Dedicated space for sorting waste

This measure is accomplished adequately, considering how there is always a dedicated space where workers can segregate waste. There is no general rule on how many skips there should be on site. It is important to think about simplicity and not overcrowding the space dedicated to all the transportation and overall material handling (Team Leader and Regional Manager, Int 2 and 7). This was observed in the site visits from which it was also possible to see that the area for sorting waste distributed space for workers to easily dispose of, allowing the managers to go thoroughly in the skips and ensure that all the materials being disposed of are actual waste and are in the correct skip.

Measure 5- Provision of waste skips for specific materials

Evidence demonstrated that there are waste skips ordered for the segregation of materials. They are ordered based on the project's specifications through the portals, from which there is a possibility to choose different waste types (Appendix I). Literature expresses that reuse and recycling are achieved when there are clearly labeled skips and bins. (Al-Hajj & Hamani, 2011). This was also applied on-site as observed in Vist 2 (Appendix G3).

Having an accurate estimate of what type and size of waste skip is needed was also performed by Siers. This is important to control the unnecessary transport and labor needed when skips are ordered. In a general sense, having specific waste skips does not allow effective waste segregation if they are not necessary or if there are unnecessary skips in the space. Therefore, demonstrating that this measure is accomplished the right way.

When non-ferrous streams of waste such as copper and aluminum are separated from the rest of the waste, there is a possible 91% environmental benefit due to the raw material saved. This is properly done on-site by having the cables specifically disposed of in one skip. Segregating waste eases waste processors to support the prevention of scarcity in materials and reduce CO2 emissions released when new materials are manufactured (Logistic Administrator (Int 4).

7.3 Component 3- Material Reuse

M6- Detect the activities that can admit reusable materials from the construction

Currently, the primary activities focus on reusing materials involving connections and repurposing cables in other projects. The potential for utilizing unused materials, such as scraps, requires further investigation.

Based on expert opinions and site visits, reusing old cables is not feasible. Typically, these cables have been in the ground for around ten years and are near the end of their service life. Using old materials can result in a high risk of destabilizing and damaging the networks. The quality of the same cannot be assured, making them a liability. The topic of cable reuse was discussed in all the interviews that have been checked in Table 3 with the data collection.

Specific attention has been given to connection activities, exploring ways to facilitate material reuse. For example, during Site Visit 2, a storage container was used for sorting surplus materials that were unused or accidentally disposed of by workers after completing an area of the project. Loose connection components were organized into packages containing all the small parts needed for one cable connection, re-introducing reused materials back into the system. Although this is not a common practice, it can be implemented in the future to ensure reuse of surplus materials.

The approach of collecting the connections surplus waste inspired the project manager to develop a simpler connection system. Using a new apparatus that will change the connection procedure. Such innovations arise from the freedom to explore and improve standard practices, potentially leading to new solutions for reusing materials in the future. This simple approach by the working team in Visit 2 was possible due to their freedom in logistics and planning (Project Manager Large Projects, Int 7). This can also reveal that maybe a collaboration between Alliander and Siers for the logistics and overall planning can help with implementing new practices. Rather than following what is prescribed by Alliander, implementing new experiments such as containers and new technologies for connections can be beneficial for both companies.

Alliander has tested a new methodology for the connection activity by making pre-connections at the storage area of the project. This approach significantly reduced waste due to more meticulous work. Although this method does not currently use reused materials, it could potentially incorporate leftover cable lengths for pre-connections in the future.

Measure 7- Use of reclaimed materials

The metals reclaimed by the waste processors are not directly sold to suppliers; instead, they are sold to smelters who produce recycled metals. Suppliers then have the option to use this recycled metal or not. This decision is driven by the need for a large amount of disposed cables to make metal extraction efficient for smelters (Account Manager, Int 3). Consequently, cables are handed over to a separate company that collects the required amount for smelters, rather than being returned to suppliers for reuse.

The concept of refurbishing cables has not been extensively investigated. Due to the contract between Alliander and HKS, cables are not returned to the supplier to explore possibilities of regenerating cables from scraps. This contractual arrangement limits opportunities for refurbishing and reusing cable materials, leaving the focus primarily on recycling processes managed by smelters.

Measure 8- Reuse of off-cut materials

The cause of the residual lengths is an issue stemming from the cable length and connection design (Schaap et al., 2022).

The analysis of waste management has proven that reusing cables is sensitive. However, the project on the solar farm from Siers proves that cut-off new materials can be reused. This can open a conversation on how it is possible to use the off-cut materials for other things that engineers are thinking about. In a general sense, the thought of using the off-cuts is thought to be used as the main line, which is stated to be a risk to the quality of the network. However, there can be other purposes for these off-cut materials. Maybe not even for the same project, but in other types of projects.

To find a new purpose for these scraps, it is necessary to divide them in the segregation process. Scraps are thrown away no matter the length, so there could also be a set standard. For example, the minimum length that can be separated from the rest of the cable waste could be more than 20 meters. It is interesting to observe that HKS logistics state that it is not necessary to separate the waste from old and new, although it can be useful. Further segregation is done in the HKS headquarters where experts sort the recyclable materials for their waste processing. However, it is possible to experiment with how to reuse off-cut materials in hand with the topics talked about in Measure 7 with refurbishing cables.

Measure 9 - Maximization of on-site reuse of materials

Custom cables become a significant waste because their unique details prevent them from being reused in other designs (Project Manager, Int 7). Multiple ways to order a cable can also lead to challenges in reusing such cables. The procurement of uncoded and incomplete materials, referring to items not in their original packaging or leftover pieces that cannot be returned to logistics, exacerbates this issue. The team aims to find new purposes for the reclaimed materials but is limited by the uniqueness of the ordered cables. Custom design lengths contribute to significant waste, as evidenced by the Strategic Resource Management (SRM) Logistics document and statements from the Circular Manager. In 2023, Alliander disposed of new, unused cables, referred to as “incurant” (Appendix D1.7). That is why standardization of materials can help with maximizing the reuse of leftover cables.

Although methods have been implemented to maximize on-site reuse, different practices can be improved based on observations and proposals from workers. For example, ideas for future-proof infrastructure could prevent current problems from recurring or introduce new approaches to speed up the energy transition and achieve the Netherlands' forecasted goals for 2050.

During a discussion with one of Alliander's Project Managers devoted to sustainability and innovation, an idea emerged related to waste disposal of cables from solar farms. Solar farms have a life cycle of around 15 to 20 years, while cables have 40 to 50 years. Experts have noted that old cables are typically not reused. However, after a solar farm is no longer serviceable, the cables, still potentially serviceable, will be dismounted and become waste. The suggestion is to implement medium voltage cables back on towers instead of underground. Above-ground cables simplify maintenance and replacement processes, allowing for easier assessment of material condition and determination of specific lengths needing replacement. Neighboring countries such as Germany and Belgium already employ this method. This approach could potentially reduce waste and improve the efficiency of cable usage.

Additional observations both from the Site Visit 3 and the interviewee (Project Manager Large Projects, Int 7) evidentiated that cables are maximized for reuse when projects are on a larger scale. In medium voltage projects, leftover cable reels are more common due to section-based designs. Once a project is completed, the leftovers are either sent back to Alliander or disposed of. However, in large-scale projects lasting three-quarters of a year with reconnecting 70,000 houses, surplus cables can be reused throughout the project. Demonstrating that larger projects have a higher potential for material reuse compared to smaller projects. This way of organizing materials can be considered by the network owners. Aligning projects based on the material type and length could be a potential idea on how to ensure the reuse of materials, hence finding a maximization on reusing the surplus materials.

Measure 10- Use of safe material storage facilities

Various measures are in place to protect cables and other materials with safe storage facilities. Additional safety measures are implemented on-site and by network owners to ensure proper storage and material use. Experts have highlighted that material damage is uncommon and materials are rarely rendered unusable due to improper storage. However, damage can occur when cables are pulled into underground holes. Despite precautions, it is challenging to visually inspect underground conditions, which can lead to scratches in the cable. In such cases, the damaged section of the cable is replaced entirely to maintain network quality. This reveals a challenge on-site that generates unexpected waste, as damaged cables must be disposed of.

Measure 11- Materials adequate delivery and movement

Ordering of Cables

Experts (e.g. Int 7, 9, 10) and the document by TKF on connectivity solutions, state that optimizing the ordering process can directly reduce the need to purchase materials and increase the reuse of leftover cables. Views differ among workers regarding the logic of the current ordering system. Some believe that adjusting this process could reduce workload and decrease CO_2 emissions by 19%. However, Alliander defends this approach, citing benefits such as rationalizing the tendering process and mitigating past issues with material shortage through increased capacity. Bulk purchasing every quarter also allows Alliander to negotiate better prices with suppliers.

The company defends its strategy of building stock as a precaution against shortages to ensure projects are developed without delays. However, experts from Siers and TKF argue that surplus materials can be significantly reduced through precise ordering. They suggest that orders should be with specific lengths; not the exact length because of the risk of unsuitable lengths. Engineers can calculate a 2% margin from the cable lengths of the project to ensure there are no shortfalls in the connections. Orders should be done with specific and needed lengths and no significant surplus can become waste.

Despite this proposal, no actions have been taken to implement it. The traditional mindset, as explained by the project manager from Alliander, is that if a company can afford to build stock, it should maximize its inventory. Recognizing the issue through stakeholders, a recommendation to the network owners on preference for maintaining stock is questioned. However, an alternative if Alliander wants to still proceed with stocking up with material could be to cut the cables in the logistics department of Alliander. The necessary lengths per reel will have only the necessary material, reducing waste on-site and the need for transportation of the leftover material. This approach would effectively reduce waste while respecting Alliander's preference for stock.

Further recommendation on the delivery and stock of supplies was offered by TKF to another network owner, Enexis. The proposed idea is to deliver the cables directly to the project site instead of storing them at Alliander's logistics center. This Just-In-Time delivery in hand with a new reel design (Appendix M) focuses on a sustainable ordering and delivery approach, aiming to reduce surplus cable. According to TKF’s proposal, the new design could reduce unused cable waste by 91% and cut carbon emissions from transport by 31%. Additionally, if this new approach is implemented, delivery and transportation will be simplified while reducing costs.

Recording Waste

Proper planning and efficient handling ensures minimal waste and timely project execution. Siers and Alliander have a clear ordering and material movement that has worked. Tools like portals facilitate organized delivery, and documentation helps track the ordering and return of materials, ensuring accountability and efficiency in projects.

Understanding the flow of assets within the supply chain is critical for effective waste management in cable handling. The documentation indicates that this process has been effectively managed, although further improvements in material movement can enhance efficiency. Analyzing how materials move in and out of construction sites can provide insights into areas where material handling may need improvement to reduce waste. Recording material usage through the project could offer an overview of how materials are utilized and disposed of, aiding in the detection of activities that can admit reused materials.

Records of material use throughout the project are generally not applied, according to the (Team Leader, Int 2). Instead, Siers’ workers conduct random checks using the Click software to record the installed cables. Based on the length recorded, it is possible to know how much material has been used. However, the recording does not specify how the material was used or what was disposed of.

In Interview 7, the alignment of materials with project activities was discussed. The expert explained that in large-scale projects, workers have started planning material containers for specific activities on-site. These containers hold the necessary materials for specific periods of work. Pre-planning and aligning materials with specific tasks could be considered for future projects to enhance proper material use and increase efficiency.

Measure 12- Central areas for storage

In many energy network construction projects, having a central storage area is often unavailable and not possible. Finding a suitable space, especially in neighborhood projects, is challenging due to inflexible policies and regulatory requirements for storing in public and private spaces. Consequently, storage locations and waste skips are chosen based on available and adequate sites. This often results in less-than-ideal locations in terms of accessibility and compliance with regulations.

As a result, materials must be transported daily to the work site, which adds logistical complexity and may lead to increased costs. Given these constraints, it might be more beneficial to focus on enhancing efficiency through new methods of material movement, rather than in a centralized storage. Exploring innovative approaches to material handling and transport could potentially mitigate logistical challenges and optimize project efficiency.

8. Limitations and Recommendations

8.1 Theoretical Limitations and Recommendations

Utilizing a framework developed for waste management on construction sites in the context of energy networks required adaptations. While this framework was suitable for measuring waste management across four components aligned with the waste hierarchy (reduce, reuse, and recycle), it may not have been an ideal fit for the unique challenges within the energy network.

Further investigation into the measures was necessary to understand the framework, though some had to be taken literally. The framework included 12 measures but lacked detailed qualifications to conclude whether the measure was achieved ideally. For instance, measure 7 on the use of reclaimed materials can be interpreted in various ways. The literal definition of “reclaim” involves retrieving materials for reuse. In this research, it was not interpreted to include the recovery when returning of surplus unused cables, but it could be understood differently. Similar issues arose with measures 10 and 12 regarding the adequate delivery and movement of materials and central areas of storage. This investigation simplified them into the inflow and outflow of materials for a better analysis. Interviewees also found it challenging to define or consider what an ideal central area is, and what is maximization.

Component 1, measure 2, emphasizes the importance of recycling for every project. However, literature, observations, and interviews indicate that recycling should be a last resort for waste minimization. Surplus waste can be prevented on-site by shifting to ordering specific lengths and just-in-time delivery of materials. This could be a future focus for waste minimization. Finally, conducting further research on a Pareto analysis of the different types of material ordered and used from Alliander's suppliers could provide a detailed analysis for the company for effective ordering and supplying.

Finally, in sub-chapter 2.1, the measures that were discarded due to time constraints and studying physical waste measures could provide insight into the bottlenecks that are happening in the construction of energy networks. The 12 measures were developed before the data collection began and topics such as following the drawings and the prevention of over-ordering materials were brought up in different locations. The measure of over-ordering and building material is a very controversial topic that was discussed by all interviewees and should have research of its own. It is possible that solving this measure could make a difference in the industry.

8.2 Practical Limitations and Recommendations

The research conducted was based on qualitative data and could be improved. More precise data could have been obtained if the same positions within Alliander and Siers were interviewed. Although this was the goal, certain roles like Project Controllers and Team Leaders were not interviewed. Interviews with subcontractors on-site, which were not done due to language barriers, could provide valuable insights.

Some interviews had incomplete transcripts due to technical difficulties. One was recorded halfway in another language, requiring audio review during coding. Others were conducted through email due to language barriers so the interaction was lost, this is important considering that when having a meeting the conversations would flow naturally, and valuable information was obtained from it. Consistency in interview methods can help with better overview and data accuracy. Additionally, it would be recommended to do the coding with software so the analysis is more accurate and specific.

A significant limitation was not being able to analyze documents due to confidentiality. For example, contracts between Siers and Alliander were not available for review. To have an insight on how much cable is purchased and how much cable is disposed of can help to better understand qualitatively the waste management of cables. These documents were not available for this investigation but could serve as good qualitative additional data.

Different types of projects and contracts can generate an extensive amount of data and potential confusion. Since projects are managed differently, with variations in contracts, logistics, and areas for waste segregation, it might be more effective to analyze waste management on a per-project basis. Then this can help to determine the bigger picture of whether waste management is efficient and successful.

More site visits are recommended to gain a better understanding of material movement and disposal. Observing a project site consistently for a week could reveal patterns valuable for measuring against the framework measures.

Conclusion

In the Netherlands, the energy sector is being pressured to reach a 100% renewable energy source by 2050. This change requires a reconstruction of the current infrastructure and electrification, where old cables are being disposed of and a new energy network is being constructed. Waste management in this sector has not been thoroughly analyzed. To investigate such, the framework developed by Ajayi et al. (2017) on Critical Management Practices Influencing On-site Waste Minimization in Construction Projects was applied to the construction of energy networks.

With different sources of data collection, from interviews with different experts in the supply chain, governmental policies, company documents, and construction site observation, a qualitative data set was developed. With the application of thematic analysis, the data was grouped into twelve measures relevant to the physical waste management on-site and the construction of energy networks. Triangulation was then applied for validation of the current waste management in the projects constructing energy networks between Siers and Alliander. demonstrated that 7 out of the 12 aligned with the ideal waste management situation. While there are areas for improvement in the remaining 5 measures, it is evident that current projects and experiments on-site aim to reduce waste and ensure adequate waste management. Some measures can be considered more than ideal, such as the use of reclaimed materials. Despite organizational issues with reusing surplus cables, there is a priority on using sustainable assets that contain recycled materials.

Companies tend to focus more on their tasks within the supply chain rather than on the project's overall waste management. This is also reflected in legal documents, where waste goals and recycling targets are not in an ideal situation. Although there are conditions for waste disposal to the subcontractors, there are no specific goals for workers regarding waste, no incentives or penalties to reduce waste, and no main targets for recycling materials in the project. This reveals that the component of contract management can be improved to ensure that everyone in the supply chain is committed to waste management and reduction.

Waste segregation on-site is a major accomplishment in constructing energy networks, with dedicated spaces for this activity and different waste skips for each waste stream. Material logistics management is also appropriate in these projects, with proper storage facilities focusing on protecting materials. Workers on-site and from Alliander constantly ensure that materials are properly stored and used. However, while the delivery and movement of materials are generally well-managed, there are issues with early delivery, and the process of material movement can be improved for more efficiency.

Significant improvements are needed in material reuse, particularly through experimentation and innovation. While reusing cable scraps and old cables is currently prohibited, there are efforts to rescue long lengths of leftover cables from one project and use them in another. In the big picture, two out of the components for effective waste management are properly applied during the projects to construct energy networks.

Despite the industry being managed by seven network owners across the country, this paper only focused on the projects between Alliander and Siers. The waste management practices in these projects are found to be adequate but leave room for improvement. The substantial amount of material disposed of every quarter and the significant waste generated on-site can be reduced.

Collaboration throughout the supply chain can lead to more effective waste management and minimization. To make a real impact, everyone involved in energy network construction projects must contribute by deviating from standard approaches and embracing innovation to reduce on-site waste. Crucially, improvements can be made in the ordering and delivery system, finding new technologies for connections, refurbishing cables, and developing methods to maintain network quality as more connections are made, among other initiatives mentioned. Furthermore, it is also important to focus on reducing waste generation to achieve real waste minimization, rather than merely finding methods to preserve raw materials and avoid unnecessary material production.

The use of waste processors by the companies ensures that nearly all the waste is recycled, with 90-96% of the on-site and company-generated waste being recycled with the help of HKS, Pre Zero, and Renewi. While it is advantageous to have specialized companies handle specific waste streams, like HKS recycling metals in cables, it can also be a limitation. This specialization can cause Siers and Alliander to be unaware of the total waste generated as an industry. This compartmentalizes and complicates the identification of patterns of bad waste management and to pinpoint sources of issues.

Data collected also presented the need for experimentation and innovation, where new ideas and technology from different employees should be exposed to each other. Prioritizing collaboration to improve efficiency and reduce environmental impact, should be done per project, not per company. Workers are coming up with ideas and solutions, and they should be further encouraged to develop and implement these ideas. Innovation programs and contests within the companies can uncover interesting solutions to current waste management problems. However, incentives must be provided to encourage employees to keep innovating and engineering. Developing new approaches and methodologies can drive the creation of future-proof infrastructure, preparing for future challenges and easing the way for the next generation to be developed.

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Appendix

Appendix A- Waste Hierarchy and Waste management

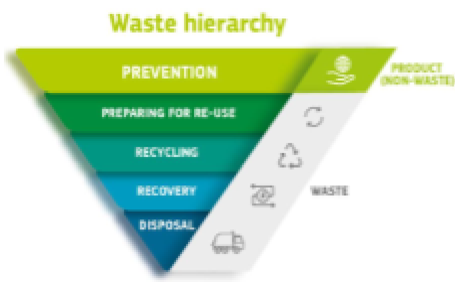


Figure A1- European Commission Waste Hierarchy

Figure A2- Lansink Ladder

In the construction industry, *waste management* involves minimizing the amount of materials that end up in landfills and sending recyclable recovered resources back to production processes for material reuse (Kubba, 2010). Managing waste enclose reducing, reusing, and recycling (3Rs) (Minelgaitė & Liobikienė, 2019).

The waste hierarchy is the first step in waste management, serving as a tool for waste minimization (Minelgaitė & Liobikienė, 2019). Figure A1 illustrates the European Commission's waste management principles through a waste hierarchy. Figure A2 presents the Lansink Ladder of the Netherlands' recycling website. The ladder is a crucial component of a sustainable circular economy, adopted in the European Waste Framework in 2008 (*Ladder van Lansink - Rangorde van Afvalverwijdering*, n.d.). This hierarchy depicts levels of waste management, starting with waste reduction as the most beneficial method and concluding with waste disposal as the final option.

According to Ray (2019), recycling and reusing in the construction and demolition industries save energy while minimizing greenhouse gas emissions. Benton (2014) adds that although waste ends up in landfills due to overconsumption, waste minimization is possible through reducing and reusing strategies.

Reducing the amount of materials needed for projects generates less waste at the end of construction (Zorpas, 2020). This strategy can be achieved by separating waste generated during construction, providing financial incentives to subcontractors to be conscious of waste, and establishing contractual procedures to decrease waste and ensure consistent on-site waste management.

Reusing materials involves utilizing them in their original state without altering their composition. Storage facilities that retain unused material from previous projects should consider these items for reuse in future projects. This strategy eliminates the need to order additional materials, reducing surplus waste.

Recycling materials involves forming new products while preserving the material itself. This step follows prevention and preceded disposal in the waste hierarchy models. Papadaki et al. (2022) state that recycling waste can decrease negative environmental impacts by 22%. Various processes renew the materials in the cables, depending on the plant from the network owner or supplier.

Appendix B- Waste Effective Site Management from Literature

Component labelling and its associated criteria.

S. No.	Extracted and rotated components	Eigen value	% of Variance	Factor loading	% Weighting within group
COMP – 1	*Contract management*	9.474	35.174		
M – 2	Waste target set for sub-trades			0.734	19.3
M – 3	Recycling target to be set for every project			0.538	14.2
M – 13	Follow the project drawings/designs			0.885	23.3
M – 18	Ensure fewer design changes during construction			0.898	23.7
M – 27	Making sub-contractors responsible for waste disposal			0.742	19.5
COMP – 2	*Waste segregation*	8.096	29.985		
M – 15	Preventing waste mixture with soil			0.729	19.6
M – 16	Providing bins for collecting wastes for each sub-contractor			0.564	15.2
M – 17	Dedicated space for sorting of waste			0.777	20.9
M – 19	Setting up temporary bins for each building zone			0.812	21.8
M – 23	Provision of waste skips for specific materials (waste segregation)			0.837	22.5
COMP – 3	*Materials reuse*	4.975	18.427		
M – 1	Detect the construction activities that can admit reusable materials from the construction			0.582	13.3
M – 7	Use of reclaimed materials			0.778	17.8
M – 10	Reuse of off-cuts materials (such as wood)			0.661	15.1
M – 11	Use of demolition and excavation materials for landscape			0.748	17.0
M – 25	Soil remains to be used on the same site			0.701	16.0
M – 28	Maximisation of on-site reuse of materials			0.910	20.8
COMP – 4	*Materials logistic management*	3.377	12.507		
M – 4	Use of safe materials storage facilities			0.662	17.6
M – 5	Prevention of over ordering			0.651	17.4
M – 6	Prevention of double handling of materials/Logistic management to prevent double handling			0.783	20.9
M – 20	Adequate site access for materials delivery and movement			0.920	24.5
M – 22	Central areas for cutting and storage			0.736	19.6

Figure B1- Components and Measures for successful on-site waste management (Ajayi et al., 2017) Table 4, pg 335.

Appendix C - Interviews and Questionnaires

C1- Expertise of the position

According to the job description from WijTechniek (2024), a project manager from Siers is responsible for managing and organizing the underlying team while aligning with the unit's objectives. Alongside the team, the manager ensures safety, quality, planning, financial status, and team organization. They manage risks and opportunities for current and potential projects. Additionally, internal developments and innovations are communicated and applied within the company.

Logistics Service and Planning (Alliander) [Int 1]: Material recording and logistic planning of material collection after project completion.
Team Leader (Siers)[Int 2]: The interviewee works on the already engineered and designed projects from Alliander, involved hand in hand with the planner of the projects. In this position, the responsibility lies in schedule, finance, and workflow for all mainline works with Siers. This individual has expertise in the material movement and on-site.
CSR(d) Manager and Account Manager Energie (TKF) [Int 3]: Responsible for the development of CSRD in the Sustainability department.
Logistic Administration (HKS) [Int 4]: Senior administration responsible for wight bridge administration of all HKS locations in the Netherlands. Within HKS and relations with Alliander, they are responsible for the logistics, administration as well as invoicing their working fee and transportation. The interviewee has a long experience in the metal recycling world and is familiar with the processing of waste, material quality, and legal regulations.
Project Controller (Siers) [Int 5]: Responsible for the implementation of predictability of project results and the financial process that could influence it. Additionally, is responsible for the implementation of the CSRD legislation for the Sieres Groep. With it, the position is also in the sustainability department where they work on how Siers can have more sustainable approaches.
Purchaser (Siers)[Int 6]: Responsible for purchasing the assets for all projects. In this case, Sier's assets are 90% worker-based. Expertise in the contracts with the people who work on-site.
Project manager of large projects (Siers)[Int 7]: Background on mechanical engineering and electrical projects. Responsible for the “Unit Project”, these are projects that have a higher budget than others. The activities that concern the person are on the design and building assignments in the project plans. The projects that the manager is working on are focused on the energy transition of the Netherlands.
Project Manager (Alliander) [Int 8]: Project manager in projects with large client consumers and the reconstruction of the network. The interviewee works in high-voltage nets (20kv) and high-voltage stations. From which the goal is to also reconstruct the current stations. Additionally, the individual is involved in innovation and sustainability projects from Alliander. Has a background study in mechanics and electrotechnics.
Circular Manager (Alliander)[Int 9]: In this position, the interviewer is responsible for stimulating the production and use of circular materials. The position belongs to the procurement department specifically working on policy and the implementation of circularity from the CSRD. The team manages the returned assets of uncoded and incomplete materials streams from the operation of projects as, the production of specific materials from the Alliander'd grid, and provisioning of temporary mid-volume stations.
Team Leader Worker Manager (Siers)[Int 10]: Responsible for developing the work plans for the mechanics to make the connections in the cables. Make sure that the tight connection with the cable is properly achieved. From its activities with cables, its expertise lies with not only the material but also the actions that are taken by the worker (mechanic from Siers).

Regional Manager (Siers)[Int 11]: Project manager in charge of the already engineered and designed projects from Siers. Responsible for four locations of Siers in the projects of North Holland and northeast of the country. Mostly on the projects of the main lines (medium-voltage) and house lines (low-voltages). In the same team as the team leader from Siers.

C2- Interview Questions Categorized to Measures

The next tables display the questions asked to each participant depending on the measure. However, some of the participants shared information from measures without being asked any specific questions.

Table 2.1- Component 1, Contract Management

Position	Measure	Questions
Team Leader Siers	1	Is there any policy or regulation for the amount of waste? What are the waste management policies and contracts that you have to follow?
Project Controller Siers	1	How do subcontractors work?
Purchaser Siers	1	Are there any procedures that are expected from the subcontractors in regard to waste reduction?
Circular Manager Alliander	1	Are there any contracts with the subcontractors regarding waste? What are the waste and handling conditions for Siers?
Regional Manager Siers	1	I heard that the subcontractors usually have to provide an Environmental Management Act, is this always asked of the contractors? Is there any way in which you tell the subcontractors or workers on site what they are supposed to do with the waste?

		Does Siers have conditions on waste management placed by Liander? Are these specific or general mandatory concepts?

Position	Measure	Questions
Team Leader Siers	2	What are the on-site documentation and checklists?
CSR(d) Manager and Account Manager Energie TKF	2	What are the contracts with the suppliers and waste processors? Do you have any contact with processors like Prozero or HKS?
Purchaser Siers	2	What is the main target set for the subcontractor?
Project Manager Large Projects Siers	2	What would you say are the main targets that are set in a project? Is there a document on reducing waste by the client?
Project Manager Alliander	2	What are the targets for the contractor? What are the targets of a cabling project?
Circularity Manager Alliander	2	What are the targets of the projects? Does Alliander set waste management standards?
Regional Manager Siers	2	How would you describe the targets/ goals that are set in a project? How do you measure success in a project? What are the main priorities of the project?

		Do you think that Liander has any targets stated for waste management?

Position	Measure	Questions
Team Leader Siers	3	How do subcontractors manage the waste Do you have any policies that are given to you by Alliander regarding waste management? Such as you can not mix this cable in this bin?
Logistic Service and Planning Aliiander	3	What are the legislations that are followed in the process of waste disposal?
Purchaser Siers	3	How do you make sure they follow responsible waste disposal? How is the work with HKS and ProZero? Policy on the assets that are already in the ground? How do you educate the workers to follow what to put where in the contains?
Project manager in large Projects Siers	3	Are the workers on site aware of what their responsibilities are for waste disposal? What are the incentives for waste reduction?
Project Manager Alliander	3	
Circular Manager Alliander	3	The participant shared information on this measure but no specific question was asked
Regional Manager	3	How do you give the waste responsibility to the workers on site?

Siers		Is there any difference between when there is a subcontractor involved and when working with siers workers? How is the waste disposal expected to go?

Table C2.2- Component 2, Waste Segregation

Position	Measure	Questions
Team Leader Siers	4	How is waste produced on-site separated from the potential waste to be reused or recycled? How to know how much waste will be generated in the construction? Are the bins changed continuously throughout the project? Are there different zones on site? Are materials always measured somewhere? Where is the location and number of containers to collect the waste?
Logistics Service and Planning Alliander	4	Where are skips located? How are the collection bins?
Team Leader Siers	4	Are there only big containers or are they also smaller ones to collect temporary waste? Who is responsible for the different types of bins? Who do you work as a waste collector in what project and depending on the client? What is the portal that is used between Siers, Alliander, and Hks for the processing of the materials?

Circularity Manager Alliander	4	How is waste further segregated? When does waste come back to Alliander?
Team Leader Work Manager Siers	4	When processing the cables and getting rid of the old cables, where are the materials set aside? Are there any parameters on how the cables have to be disposed of when extracting them from the ground?
Regional Manager Siers	4	How do you decide where to place the containers and waste bins? Are there any areas to put the cut materials so they can be reused?
Logistics Service and Planning Alliander	5	How useful is the division of waste with the containers? Is there any process in the accounting of the materials where there is waste segregation?
Team Leader Siers	5	What are the main activities on site? Would you say you can use material that is left over on the reels and you have a very small amount, is it able to be reused in another part of the project? If there are small projects there are no bins?
Logistic Administration HKS	5	Are cables divided into old ones and new ones? Or is everything situated in one big container? Is it important to have this division of cables that are new and old, or does it not affect the procedures that you do? Are there instances when you have encountered materials that can be reused in the waste bins?
Project Manager Alliander	5	Do you believe that the segregation done by workers is a proper one?

		Do you think that old and new cut-off material divisions can have a big impact?
Circular Manager Alliander	5	How is the division of waste done?
Regional Manager Siers	5	Do you think that the workers ensure that waste is separated properly? Is there any way that you order as many containers as possible or do you just order from what is expected to be the waste types? ARE THE SKIPS MAXIMIZED? Do you think there should be more waste containers to properly segregate the potential reuse and recycling? Do you think that in neighborhood projects with low voltage connections, there is more waste that is produced? How well do you think that waste is segregated on-site?

Table C2.3- Component 3, Material Reuse

Position	Measure	Questions
Team Leader Siers	6	Are there possible materials that can be reused on-site? What happens with all the cables that are cut off and then the residuals, can they be used for another connection, etc? ‘ How is the material used collected in the data? How are the off-cut materials managed?
Project Manager large projects Siers	6	How can you align the activities with the waste containers?
Project Manager	6	Where could you introduce the reuse of materials?

Alliander		What are projects that you have done with the idea of sustainability and reusing? Are there checklists on site that keep track of how the materials are used and the expected activities?
Team Leader Work Manager Siers	6	What is the material flow? What is the procedure for managing the cable in the energy network construction? Are cables cut before or during the process? How are cables decommissioned? Are there any different building zones? If so, what are they and how are they organized with the materials?
Regional Manager Siers	6	What are the activities that happen on-site? Do you think that there are probable ways in which an activity can reuse cables that have been cut off and the length is appropriate?
CSR(d) Manager and Account Manager Energie TKF	7	Can leftovers be re-joined? Can you use unused scraps for something?
Logistics Administration HKS	7	How are the materials recycled? What do you do with the raw materials extracted? Do you receive any of the unused materials? The materials that you receive have to always go through a process like shredding or can they be refurbished or reused?

Circularity Manager Alliander	7	Some websites allow contractors and suppliers to set unused materials in the portal and allow the purchase of these materials, do you know about them? What is the term overhaul? Based on the definition I found online it has to do with the repairments. How is the purchasing of material?
Team Leader Siers	8	How are the materials organized on-site?
Logistic Administration Alliander	8	Is material reused on-site in any cases? Is material always transported or is there any avoidance to leave the materials on site so they can be used there?
Project Manager Alliander	8	Why are old cable cutouts not possible to be reused?
Team Leader Worker Manager Siers	8	Is it possible to use parts of leftover cables for connections or repairs on-site? Are there any rules that prohibit workers from reusing residual materials on-site?
Regional Manager Siers	8	Are the materials that have not been used in a project even reused in another project? How is the warehouse handled? Does Alliander use appropriate materials?
Logistics Service and Planning Alliander	9	Is material reused on-site in any cases? Is material always transported or is there any avoidance to leave the materials on site so they can be used there?

		Is there any way in which the waste that will be produced on-site is calculated before the construction begins?
Team Leader Siers	9	What is done with the unused materials?
Project Manager larger projects Siers	9	Why is material reuse on-site not possible? Do you believe that you can reuse material that is already in any activity on-site?
Circular Manager Alliander	9	What is the term for uncoded materials? And how are they handled? What are the issues with the standardized and custom materials, do they add more waste?
Team Leader Work Manager Alliander	9	Do you believe that reusing materials could be possible onsite? What are the strategies for on-site material maximization? What is considered an efficient use of materials? Is the amount of materials to be ordered restricted? How is the quality assured?
Regional Manager Siers	9	Can you reuse materials on-site?

Table C2.4- Component 4, Material Logistics Management

Position	Measure	Questions
Team Leader Siers	10	Are the materials kept in the storage units? Where in the construction site are the materials stored? How is the damage in storage prevented?

Team Leader Work Manager Siers	10	Are there rules or guidelines for the use of storage facilities? What are the processes for storing the materials?
Circularity Manager Alliander	10	How do storage facilities work? Is there damage in storage? Is there damage at all?
Regional Manager Siers	10	Are there time restraints on a project where workers are in a time crunch? How is the material stored? Are there ways in which the material is protected? Are there a lot of damaged cables on site? What happens with damage to storage? How are the damages prevented in the storage units?
Logistic Service and Planning Alliander	11	What are the waste measuring tools, and when are they used? How is waste measured? How is the registration of existing waste flows What is the plan for the leftovers? Transportation and delivery to the network owners? When do network owners send the materials back to the supplier? Are materials usually damaged because of inappropriate storage or transportation? When is the request for the suppliers to come pick up the containers and deliver new materials?

		What is the timetable for collection of the waste in the project?
Team Leader Siers	11	Is there any type of recording system on what is being taken out and what is being laid out? How is the waste measured per day? Who is in charge of the delivery scheduling and location? How is the delivery process of the materials? How often are the materials that you are ordering not the correct ones and you have to wait on site for the new materials? Are there issues with material damage and transportation? What happens if you are digging and you encounter a type of material that was not expected to be there? How are the materials in storage being tracked and then transported?
CSR(d) Manager and Account Manager Energie TKF	11	Is it possible for on-site delivery? Is pre-cutting a possibility? Do you receive anything from the processors? How is transportation carried out?
Logistic Administration HKS	11	How are the materials picked up from the site? Where are they stored and moved? What are the procedures for the collection of waste materials? Do you weigh the material when you receive it or once it is in the warehouse?
Project Manager larger projects	11	How are materials usually moved around the site?

Siers		How are materials organized throughout the working process? Where do you put the material facilities?
Project Manager Alliander	11	Is there a Just-in-time approach to obtaining the materials? What are some common damage issues? How do you handle last-minute changes by a client? Is it common that there are errors in the ordering? How are changes handled? Documentation on the inputs and outputs from the storage facilities, the accountant of the same?
Circular Manager Alliander	11	How is the ordering process? How are materials transported? Is there material flow? What are the inventories of unused materials?
Regional Manager Siers	11	What are the delivery methods and schedules? Do you think it is better to have things delivered just by site? Are the medium voltage projects less complicated? How do you handle last-minute changes by an engineer? Is it common that there are errors in the ordering? How is that handled?
Team Leader Siers	12	How are the storages organized? Is there any way you can plan the location of the storage units?

Project Manager larger projects Siers	12	How do you ensure that the storage of the materials is located properly? What is the reasoning behind where these containers are located? Do you have a methodology for where the materials are placed?
Project Manager Alliander	12	How are tiredness, and material organization carried on-site? Any process, regulation, etc?
Regional Manager Siers	12	How are contractors set up a proper storage area and have a practical handling of the materials?

Appendix D- Analyzed Documents and Policies

D1- Document Organization

Table D1.1 - Measure 1- Waste target set for sub-trades

Document	Stakeholder	Description
Special conditions for the execution of works.	Siers	Conditions contract for Siers Group and its operating companies. Here the expectations for the company that will work on site are presented. Usually, the contract is sent to the sub-contractors along with the clients (Network owner). These conditions are also expected to be followed by the workers from Siers if no sub-contractors are used. There are 7 main conditions: 1. Labor, safety, and the environment (contains helpful information for measure 3) 2. Disposal and treatment of waste 3. Issue of material 4. Provision of material by client 5. Purchase of materials by client 6. Executive work 7. Additional information Each of these has sub-conditions that are in Appendix

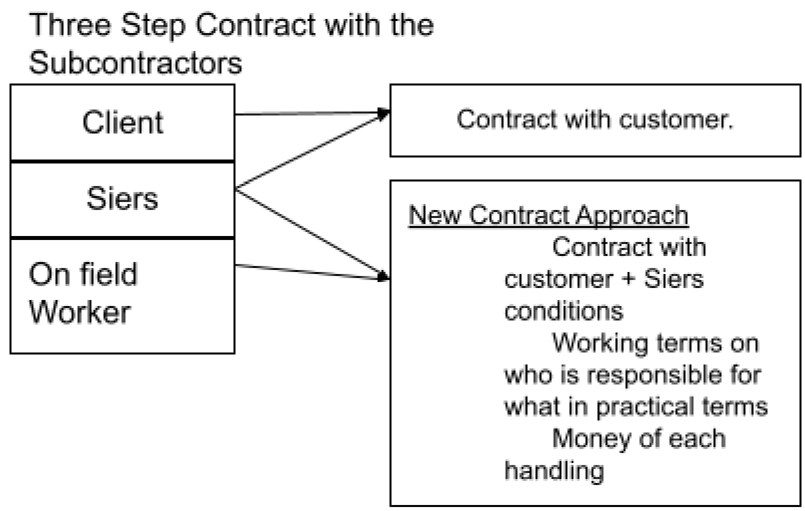
Three step contract	Siers	 **A** is legal **B** practical language that will provide what is expected by the different parties. This will prevent disagreements and miscommunication on what others are supposed to do in a project. Ex: Siers setting the traffic barriers rather than the subcontractor, this way it is clear that the subcontractor is not in charge of providing the barriers and signalization on site. **C** the monetization of all the things that are supposed to be done

Table D1.2- Measure 2- Recycling target as project

Document	Stakeholder	Description
Processing cable %	Alliander	Divisions of the different materials in a cable
SRM Logistics R&A	Liander and Processors	Serves for the logistics of all residual and waste flows in Alliander. This ensures the company matches the laws and regulations in waste, transportation, and environmental reporting. States regulations and concise things that the processors have to do with the waste that is provided to them

LAP3 Policy Sector 14	Alliander	Policies for traditional waste activities; collection, recycling, incineration, and landfill
Annual Report	Alliander	Emissions in the supply chain: Accounts for the emissions from the suppliers when producing assets, which lie in scope 3 of the GHG protocol. Allianders CO2 is mostly due to the production process of the cables while their emissions come from the infrastructure including the building and excavation which is Sier's emissions. Although the infrastructures are built for the future there are also issues with how the materials are chosen for long-term use. Some suppliers assure loss of energy due to heat as a priority but it is not accounted for in the emissions. The Netherlands is increasing the payment of CO2 production which. In the supply chain, the contractors, components, energy purchasing, and transmission tariffs are the main areas of procurement. Suppliers have a conduct code based on the OECD guidelines. Circularity: Environmental damage due to waste from Alliander is 0.1 while the procurement of materials is 36. They are measuring the negative impact on the raw material use and waste with the SDG’s 7,12,13. The impact on the purchased materials is 36.4 from which 9.95% is reduced by the recycling of the materials. Recycling is done through their waste processors. In their annual report, they state that the impact on the purchased material is lower in some years due to usable inventory.
CSRD	Siers	Core Values: Safety and keeping agreements with clients.

		Sustainability: Sustainability in business operations that connect people and the planet. To set this the UN sustainable goals (SDGs) are set into three pillars; climate and environment with SDGs 7 and 13, and vital health and future with the SDGs 6 and 9. In the future, the concept is focused on the transition to natural gas and facilitation towards energy transition. Both Siers and Alliander are directly connected with this topic. They are responsible for providing the infrastructure that will allow the energy transition. Sier's approach to an appropriate inclusion of sustainability goals is combining the thirty-one CSR to the SDGs goals. For the environmental objectives of the company, the aim is the reduction of CO2 emissions within the company. In this field, the emissions caused by transportation were the main goal in their vehicles are electric cars and HVO biodiesel. There are additional focuses for reducing the environmental impacts. In an organizational matter, Siers has an objective for gaining insight, inventory, and a design for adapted policy in the chain analysis from the equipment from third parties. The environmental accidents should be less than four while horizontal drilling will be used so excavations are not necessary. Finally, there will be site rules with an environmental toolbox. Siers believes that the most important point of attention in the sustainability goals is to properly collaborate with the stakeholders in the field. The SDGs in this section are 7, 13, and 17 of the partnership to achieve goals.
Siers Project Road Map	Seiers	Presentation of the project designs with the engineering goals and preparation for neighborhood projects. Their responsibility and procedures are done in tendered projects. Provides the steering group chain chart with the process between project teams. Here the workflow and goals are

		illustrated. It is possible to see the process and production steps while also visualizing the concepts for optimization.
Recycling Process of Cable	Alliander on HKS work	Maximization of recycling cannot be achieved due to the Dutch exports and how the cable processing labor is intensive and expensive. The process of recycling is out of scope but demonstrates the recycling purposes of Alliander.
SRM Logistics R&A	Alliander	Rest and Waste documentation. The document describes the residual and waste flows. With it, Alliander ensures matching with laws and regulations in waste, transportation, and environmental reporting. It checks with reaching sustainable and social responsibility, development, and reuse of raw materials. All waste that is generated throughout the work and waste flows must be presented to the end of the processors.

Table D1.3- Measure 3- Making sub-contractors responsible for waste disposal

Document	Stakeholder	Description
Alliander	Monthly Report HKS	Document between Alliander and HKS that provides the waste flow at the end of the month. Waste is weighted
Special conditions for the execution of works.	Siers	Section 1 This document also states the extent to which the sub-contractor is expected to dispose of waste.
Construction and demolition waste in the National Waste Management Plan	Siers	Waste streams to understand how waste is disposed of. Statement on waste segregation. Different types of waste: bituminous roofing membrane, concrete rubble, construction and demolition waste, construction and demolition waste that is non-recyclable, gypsum, mixed rubble, roof gravel, roofing waste, tar containing asphalt rubble, tar-containing roofing membrane, tar-free asphalt rubble and waste containing asbestos or if they are suspected to have asbestos.

<table>
<tr><td></td><td></td><td>The document also presents the non-recyclable materials and materials that are not permitted in these containers.</td></tr>
<tr><td>Metal
In the Waste Management Plan</td><td>Alliander,
HKS</td><td>Waste streams to understand how waste is disposed of.

Not included in the waste stream of Siers because they are not responsible for the waste disposal and processing of metal cables.

This waste stream is considered for the materials of aluminum, mixed scrap metals (ferrous materials and non-ferrous materials), non-ferrous metals, and scrap cables.</td></tr>
</table>

Table D1.4- Measure 5- Provision of waste skips

<table>
<tr><th>Document</th><th>Stakeholder</th><th>Description</th></tr>
<tr><td>Pre Zero</td><td>Siers and Liander</td><td>Portal to order size and type for the containers.

The different waste streams, containers, and actions that can be asked from the waste processor. There is also information on how to classify the waste stream with the definitions and statements of “what is not considered”.

Industrial Waste Pre-Zero (Waste stream)
<table>
<tr><th colspan="3">Prezero Industrial waste streams</th></tr>
<tr><td>Asbestos Cement Pipe</td><td>Glass bottles fur</td><td>PVC</td></tr>
<tr><td>Gas meters containing asbestos</td><td>Green waste</td><td>Rubber</td></tr>
<tr><td>Asfaltpuin</td><td>Ground</td><td>Promise</td></tr>
<tr><td>Asphalt rubble Tar-containing</td><td>Hout B</td><td>Cooking oils and fats</td></tr>
<tr><td>Bakelite & Thermoset</td><td>Wood C</td><td>Swill</td></tr>
<tr><td>Industrial waste</td><td>Coffee grounds</td><td>Textile</td></tr>
<tr><td>BSA (Construction & Demolition Waste)</td><td>Plastic plastic film</td><td>Veegvuil</td></tr>
<tr><td>Data-secure paper</td><td>Paper carton</td><td>Processing soil</td></tr>
<tr><td>Mixed plastics</td><td>PBD Plastic, Tin and Beverage Packaging</td><td>White plastic from E - meters</td></tr>
<tr><td>GFT waste</td><td>Debris</td><td></td></tr>
</table>

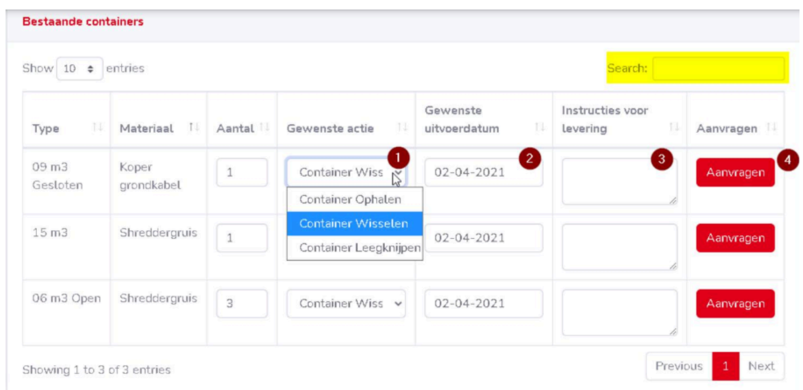
Pre-zero Service for Hazardous Waste: waste oil fuel residues, oil-containing waste, bitumen, oily filters, lubricating greases, and contaminated waste.</td></tr>
<tr><td>HKS portal</td><td>Alliander</td><td>Container portals for metals (cables)

Important to note that this is not always set onsite and sometimes there are no specific containers for the old cables to be set on.

The division of waste can be seen in the picture:</td></tr>
</table>

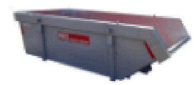
<table>
<tr>
<td></td>
<td></td>
<td>
<table>
<tr><th colspan="3">HKS Metals ferrous and non-ferrous flows</th></tr>
<tr><td>Waste transformers</td><td>Glass insulators</td><td>Copper, bronze, brass</td></tr>
<tr><td>Aluminium</td><td>Aluminum GPLK cable</td><td>KWH meters (also disassembled)</td></tr>
<tr><td>Chrome VI containing ferrous / non-ferrous</td><td>cable GPLK copper</td><td>Stories</td></tr>
<tr><td>Chrome VI containing HS masts</td><td>Oil pressure cable GPLK aluminum Empty</td><td>lead batteries</td></tr>
<tr><td>COQ installations Empty</td><td>Oil pressure cable GPLK copper Empty</td><td>Mops and trimmings</td></tr>
<tr><td>Electro motor</td><td>Oil pressure cable Vinyl Aluminum Empty</td><td>Oil pressure sleeves</td></tr>
<tr><td>Fe Gruis</td><td>Oil pressure cable Vinyl Copper Blank</td><td>Oil pressure barrels Empty</td></tr>
<tr><td>Fe scrap</td><td>Cable vinyl aluminum</td><td>Printed circuit boards</td></tr>
<tr><td>Gas meters</td><td>Cable vinyl copper</td><td>Switches and capacitors</td></tr>
<tr><td>Gas meters Smart, Lithium free!!!</td><td>cable mix</td><td>Steel / Aluminum HS lines</td></tr>
<tr><td>Cast iron</td><td></td><td>Zink</td></tr>
</table>
</td>
</tr>
<tr>
<td>Handeling JKS Klantportal</td>
<td>Alliander</td>
<td>
Manual to use the HKS portal to order waste skips.

- Action
- Container type
- Material type
- Quantity
- Desired execution date
- Instructions



(1) **Desired action**
o Container Collection
o Container Exchange
o Empty container
(2) **Desired execution date**
Here you can indicate when the collection, exchange or squeeze action should take place. A minimum date is calculated automatically, only a future date can be selected here.
(3) **Delivery instructions**
You can enter additional instructions here
(4) **Applications**
Press “Request” to initiate the action. The system sends a confirmation and the request becomes visible. The line becomes “Grey”, the action on the container cannot be performed twice.

</td>
</tr>
</table>

<table>
<tr>
<td>Waste Skips HKS</td>
<td>Alliander</td>
<td>Types of skips that can be ordered from HKS.
<table>
<tr><th>Type m^4</th><th>Information (cm)</th><th>Pic</th></tr>
<tr><td>Battery box
1</td><td>120x100x80
Ferro, non-ferro,e-scrap
Lead batteries, iron, metals</td><td></td></tr>
<tr><td>Open
4</td><td>234x150x110
ferro and non-ferro</td><td></td></tr>
<tr><td>Open
6</td><td>350x190x103
ferro and non-ferro</td><td></td></tr>
<tr><td>Closed
9</td><td>360x182x186
Miscellaneous cables and non-ferrous
2 insert hatches
Lock</td><td></td></tr>
<tr><td>Closed
20</td><td>620x250x176
Various cables w/ oil and non-ferrous
Liquid tight
Lockable
Hydraulic
Rotating lid</td><td></td></tr>
<tr><td>Warehouse 20ft</td><td>606x244x259
Lockable
Two french doors joined together short side of the sea container
Wooden floor of 3cm</td><td></td></tr>
<tr><td>Open
15</td><td>620x250x110
Ferro and non ferro
caster , izer and metal
2 doors</td><td></td></tr>
<tr><td>Open
20</td><td>Ferrous and non ferrous
Cast iron
2 doors</td><td></td></tr>
<tr><td>Open
30</td><td>Ferro and non-ferrous
Cast iron, izer, metals
2 doors</td><td></td></tr>
<tr><td>Open 40</td><td>650x250x256
Ferro and non-ferro
Iron and metal
2 doors</td><td></td></tr>
</table>
</td>
</tr>
<tr>
<td>Renewi portal</td>
<td>Siers</td>
<td>Portal for waste manager (used by Siers).

Categories on waste, on-site containers that are dependent on the waste streams, and the amount of waste generated by the</td>
</tr>
</table>

		company are presented on the website. The portal presents 94% of the recycling obtained by Siers' waste purchasing department
Valuable booklet	Renewi	The waste is recycled into new raw materials, green energy, and gray energy. The process turns waste into products following circularity.
Condition for Acceptance Netherlands	Alliander and Siers	Type of waste classified in what section? The accepted materials that lie in the category of waste management, the document sets how waste streams work. Both stakeholders can determine what skips are relevant to their projects.

Table D1.5- Measure 6- Detect the construction activities that can admit reusable materials from the construction

Document	Stakeholder	Description
Siers Project Road Map	Siers	Presents the activities on the ground, the work rhythm of construction flow, and actions on site.

Table D1.6 - Measure 7- Reuse of Reclaimed Materials

Document	Stakeholder	Description
Material Passport	Alliander	To make sure that the suppliers use sustainable products. Find if there are components in the grid that can be more green Helps in the development of the CSRD
Circular Purchasing Indicator	Alliander and TKF	Ensure the raw materials are made up of circular materials. Assure materials are circular for reuse and recycling at the end of life.
Yearly waste disposal	Alliander	Categorize waste and calculate the waste volume from the materials that have been disposed into the landfills.
Valuable booklet renewi	Siers	Provides some knowledge on the amount of waste turned to recycling materials and outputs. The segregation of environmental saving is 49% of the conservation of raw materials. Built and demolition waste is

<table>
<tr>
<td></td>
<td></td>
<td>45% raw material environmental benefit, saving 232 kgs of CO2 per ton. This is the highest waste stream from Siers (considering that when clients or on their projects Renewi is used as a processor).

Scraps of non-ferrous streams such as copper, aluminum, and bronze. They are converted into new metal products and components that can be used for other products. The environmental benefit is of 91% of raw materials saving 1876 kg CO2/ton. 96% of this waste is used on raw material, 2% on gray energy, and 2% on actual disposed residues.

WEEE has different shredded, dismantled sand sub-streams mainly of metal and plastics. These materials are suitable for recycling for the development of new raw materials at 75%, there are also savings of 1735 kg co2 / ton. The quality of the waste is very important for the materials to be used again for raw materials (metal or plastic).</td>
</tr>
<tr>
<td>Processed Cable Materials</td>
<td>Alliander</td>
<td>Excel document that provides the amount of material that is recycled. The table completely describes what type of materials is considered in what type of cable.

<table>
<tr><td rowspan="2">Cables</td><td colspan="6">Materials</td></tr>
<tr><td>Ferrous</td><td>Aluminum</td><td>Lead</td><td>Copper</td><td>Paper/ Bitumen</td><td>Plastic</td></tr>
<tr><td>Aluminum cable with ferrous sheath</td><td>yes</td><td>yes</td><td>yes</td><td></td><td>yes</td><td></td></tr>
<tr><td>Aluminum PVC cable</td><td></td><td>yes</td><td></td><td>yes</td><td></td><td>yes</td></tr>
</table>

The aluminum PVC cables (now these are the only ones used) are 100% processed and unsolvable.

Three main types of cables:
- Paper insulated cables. They have either copper or aluminum conductor
    - GPLK are paper lead cables</td>
</tr>
</table>

		- VGPLK with PVC sheath - EGPLK with polyethylene outer sheath - Bituminous layer and/or oil-containing paper for insulation - OD are oil-pressured cables and - UGD pressure pipe cables

Table D1.7- Measure8 and 9- Maximization of on-site reuse of materials

Document	Stakeholder	Description
Incurant Excel	Alliander and HKS	Material unused wasted in kg, euros, and the branch where it should be transported to There is no data on the materials that are reused and not disposed of. It is not possible to have a number of materials. They have started the recording of what is reused. There is only information on the solid data that is provided by this Excel.

D1.8- Measure 11- Adequate materials delivery and movement

Document	Stakeholder	Description
Material bon	S L	Document that registers all the returned material next to what was ordered.
Unused waste	Alainder	Excel calculation on the unused waste and waste thrown out. The cable document states the article number, description, weight, price, costs, the branch of the waste processor, the euro code followed, and the waste stream.
SRM Logistics R&A	Alliander	Rest and Waste documentation and “rules”. Also sets the requirements for the processor on waste movement and transportation. HKS has 48 hours to pick up hazardous waste. For logistics, the containers have to be easily accessible and the toll containers should be provided outside. If there is an incorrect loading and overloading of containers, the processor has the right to refuse the waste.
Waste Reports	Alliander	Each month the waste flow is recorded with the Environmental Act. Here the waste production by year is

		measured. To do so, the monthly averages are calculated for each of the projects and locations. The most common waste cables are MS and HKS.
Collecting, transporting, acting, and mediation	Alliander	Contract from the waste producer to the recipient. This document is sent by Alliander considering the collector of waste (subcontractor) and the transportation of waste (Alliander of HKS) depending on the type of waste. Collection is not the same as transportation. The collection included the temporary materials stored. Transportation is when materials are moved to a different location and have an additional fee. Once the waste processor has the waste, they are completely responsible for what they picked up. There is an agreement on the ownership of waste after waste is picked up. If there is temporary storage, it is important to have an adequate environmental permit or notify the living environment activities decree. It is important for Alliander that the processor of waste has a permit under the waste collection decree. Materials should be collected and separated as industrial or hazardous waste. The registration of these should be done on the VIHB list and used as an accompanying letter for collection. The registration on this list is formed by all the personas and companies that collect, transport, trade, or mediate waste. Permit holders should also be included in the list. Criteria of registration on the VIHB list correspond to the requirements that apply to the transport legislation of waste substances and the EU directive on transportation by road.
Disposed of Used Cables	Alliander	SRM logistics in volume, Divided by the quartile of the year and recorded in weight (kg).
Waste Volumes	Alliander	Excel sheet that calculated the kilo tons and CO2 production. The different waste streams from Pre Zero (tons)

Industrial waste - Soil	**1026.59**
Hazardous waste	0.15
Ground	1026.44
Industrial waste - Wood	**155.95**
Wood b	155.95
Unassigned	
Industrial waste - Plastic	**544.8**
Industrial waste	6.51
EPS	
Foil	6.19
Plastic	375.825
Unassigned	
PVC	156.275
Secure Data	
add to table	
Industrial waste - Metals	**0.39**
Metal	0.39
Industrial waste - Other industrial was	**3684.221525**
Industrial waste	809.67784
Construction and demolition waste	232.23
Roof waste	3.24
Foil	
Green waste	58.52
Plastic packaging waste	
Unassigned	
Paper and cardboard	321.023685
PBD	
Rubble	2259.53
add to table	
Sand / minerals	
Industrial waste - Other hazardous wa	**392.958**
Asbestos	331.94
Hazardous waste	57.298
Metal	3.72
Unassigned	

HKS

4m3 storage bins 14x	5860
Alu wire with fe sheath	511069
Aluminum refine	32446
Aluminum transformer	6640
Alu/PVC wire	38090
Alu/PVC wire (1-burner)	55913
Alu/PVC wire (3-burner)	209675
Alu/PVC wire (4-burner)	4438
Cu wire with Fe sheath	154676
Cu/PVC wire > 38% Cu	3885
Pressure regulators	9643
Electricity meters	179190
Gas meters	228520
Cast iron	3420524
Grit	306022
Resin transformer	880
Copper refine	9401
Copper refine	644
Brass	413
Oil transformers	248060
Oil transformers from burned stations	3040
Red copper mixed	36
Switch	360
Scrap	193864
Steel containers 16x	2080
Steel containers 4x	520
Transformer cores	4620
Dirt deduction	6564
Industrial waste - Other industrial waste	**13388**
Filthy	1060
Dirt deduction	4500
Waste disposal costs	7828
Industrial waste - Other hazardous waste	**144425**
Oil deduction	2100
Cu wire with Fe sheath	14660
non-chlorinated mineral oil for insulation and heat transfer	71040
SHA stripped of batteries	1265
SHA/ICT small equipment	1280
Transformers to be flushed	54080

D2- Policies Organization

Table D2.1 - Policies used by Alliander

Document	Concept	Measure
CSR	Corporate Social Responsibility	Recycling target to be set for every project
Integrated National Energy and Climate Plan	Set goals	Contract management
Environmental Legislation	Waste management (from the Netherlands)	Contract management
Dutch law environmental management Waste policy sheet, chapter 10	Tools for the waste management plan that regulates https://www.bodemrichtlijn.nl/Bibliotheek/beleid/beleid-van-centrale-overheid/landelijk-beleid/beleidsblad-wet-milieubeheer/beleidsblad-afvalstoffen-h95099 The processor of the cables needs to have a permit	Contract management
National Waste Management Plan NWMP3	Accordance with a statutory procedure that allows public consultation. Leads to waste policy: - Restricting waste generation - Restricts the burden of production chains on the environment - Optimisation of the use of waste with circular economy 14. Paper or plastic insulated cables and remnants Sector	Contract management

	Plan (PDF) https://lap3.nl/sectorplannen/sectorplannen/kabels/	
EVOA Importing and Exporting Waste EWSR	Waste transportation Waste shipment Regulations	Adequate material delivery and movement
Regulation of the EU Parliament and the Council on Shipping Waste	Waste list for the segregation of waste	Waste regulation but also provision of waste skips for specific materials
Monthly Report from HKS	Waste flow at the end of the month with the processors	Making sub-contractors responsible
LAP3 Policy Framework from the Waste Waste Management	Used by governments in waste management decisions and overall the policy of waste management. Policy framework - LAP3 Guideline on waste or non-waste - LAP3	Recycling target to be set for

Table D2.2- Policies followed by Siers

Document	Concept	Measure
CSDR	sustainable approach of the company	Recycling target set
Special conditions for the execution of works	Contract and requirements with the operating companies	Waste target for sub-trades
Reports on the Environmental Management Act	Document that has to be provided from the subcontractor	Contract Management

	to Siers on the conditions of disposal and treatment of waste	
NEN	For the material selection	Reclaimed materials
KOMO	Material certification	Reclaimed materials
CROW and WIBON	Excavation work requirements and policies	Contract Management
VCA Company Certificate	For the contractor to rate the client Safety and healthy working environment	Contract Management
CKB	Certificate for the cable infrastructure and pipe laying companies certification scheme. It is related to quality standards guarantees and other qualitative implementation of projects This is something that is also asked	Contract Management

Table D2.3- Policies followed by HKS

Document	Concept	Measure
WEEE	Waste electrical and electronic equipment	Provision of waste skips for specific materials

Appendix E - Dutch Policy Followed by Stakeholders

Table E1- Dutch Policy Followed by Allainder

Document	Explanation
CSR	Corporate Social Responsibility The document is mainly to set climate-neutral operations and climate procurement such that the recycling of remaining waste is 90% while having high-quality materials and maintaining a level 5 of performance ladder of CO_2 production. It provides principles for the client

<table>
<tr><td></td><td>(InfraConsultant like Siers) to have CO2 neutrality, circularity, a conflict-free use of metals and raw materials, good working conditions for everyone in the supply chain, transparency, and no use of hazardous substances.</td></tr>
<tr><td>CSRD</td><td>Corporate Sustainability Reporting Directive</td></tr>
<tr><td>Integrated National Energy and Climate Plan</td><td>Set goals for EU countries between 2021 and 2030 to reach the Paris Agreement goals. In the Netherlands, these are to take measures to reduce 49% of the CO2 emissions as well as the sustainable energy goals.</td></tr>
<tr><td>Environmental Management and Waste Policy (Chapter 10)</td><td>The Environmental Act and the Waste Framework Directive for circularity. This specific chapter is regarding the waste regulations to reach a circular economy in the Netherlands.
The document contains the general provisions of duty and care, dumping bans, the use of a national waste management plan, reuse, prevention, and recycling rules and responsibility, waste shipments, and overall rules for types of waste.</td></tr>
<tr><td>National Waste Management Plan 3 (LAP3)</td><td>As mentioned in the Environmental Management and Waste Policy, the national waste management plan needs to be included to deal with waste management depending on the waste classification.

This allows public consultation on the waste policy that restricts waste generation, the burden of production chains on the environment, and the optimization of the use of waste with a circular economy.

The framework serves as the foundation for waste management and policy implementation. It establishes minimum standards that aim to recycle the metal and plastic fractions from insulated cables. These standards specify the minimum content requirements for each material.
<table>
<tr><th></th><th>Waste / partial flow</th><th>Minimum standard for processing (and any conditions)</th></tr>
<tr><td>a</td><td>Paper or plastic insulated cables and cords and oil pressure cables</td><td>Separation into a metal fraction, a plastic fraction and a residual fraction.</td></tr>
<tr><td>b</td><td>Metal and plastic fraction obtained from a</td><td>Processing in accordance with the metal sector plans (SP12) and plastic and rubber (SP11).</td></tr>
<tr><td>c</td><td>Residual fraction obtained from a that does not contain coal tar or PCBs in a level higher than 0.5 mg/kg (as received) per congener 28, 52, 101, 118, 138, 153 and 180</td><td>Other useful application (e.g. main use as fuel).</td></tr>
<tr><td>d</td><td>Residual fraction obtained from a that contains coal tar or PCBs in a level higher than 0.5 mg/kg (as received) per congener 28, 52, 101, 118, 138, 153 and 180</td><td>Burning as a form of disposal.

Other forms of processing are only permitted if it is certain that the PAHs or PCBs are completely destroyed or irreversibly converted.</td></tr>
</table>

Waste streams are connected to each requirement. Paper and plastic insulated cables and the remnants of cables fall under categories 7A and 7B of the Living Environment Activities Decree. The decree provides</td></tr>
</table>

	environmental regulations with rules when there are harmful activities to the environment. Metal processing is once and the shredded waste should also be considered in this process.

Table E2- Dutch Policies Followed by Siers

Document	Explanation
CSR and SDGs	Siers is the first underground infrastructure company from the Netherlands to communicate their sustainability actions with SDG's. The company has thirty-one corporate social responsibilities (CSR) aligned with the United Nations goals (SDGs). The linked SDGs that are used by Siers are 6,7,9,12 and, 17. Siers set environmental objectives for CO2 reduction through awareness within the CSR.
CSDR	Corporate Sustainability Reporting Directive The report is developed for a sustainable approach to the company and framework providing sustainability data (Stertton, 2024). The CSRD goals are to provide stakeholders with transparent information on a company's sustainability.
Environmental Management Act	This is the same as the document used by Alliander and is a document that is also asked of the subcontractors who work with Siers. This way, all companies follow the basic policies and laws as expected.
WIBON and CROW	The information between businesses is exchanged in the Information on Overhead and Underground Networks Act. The WIBON is used to prevent accidents during the excavation and be sure that everything underground is recorded. The CROW is a five-phase guideline for the optimization of the risk of damage because of excavation.

Table E3- Sectors for cable waste management in LAP3

Name	Sector	Description
Metals	12	Metal straps, aluminum, copper, lead, etc. These materials have to be collected or delivered separately.
Paper or plastic insulated cables and remanets thereof	14	Metal cables covered with paper and lead, usually with oil materials, plastic-coated cables and cords, connections and end closures, oil oil-pressured cables that also can have hazardous substances
Metals with adhering oil	62	

The legal scope of the LAP:

- Conditions when grating permit
- General policy of waste separation
- Policy and licensing of collection
- Policy on storage and transshipment of waste
- Tasks and powers of various authorities involved in waste policy implementation including all the provinces and municipalities
- Eural

Appendix F- Special Conditions, Condition 2 (Disposal and treatment of waste)

Table F1- Document of Special Conditions for the execution of Works, Siers Group and its operating Companies Analysis

Special Conditions for the Execution of Works	Conditions
Disposal and treatment of waste	1. Client (InfraConsultant) and contractor (Sub-trade) promote the reuse of materials and waste quantities, and limit flows of waste as much as possible
	2. The agreed price also includes the cost of separate disposals and/or processing respectively removal and/or storage of all waste materials arising from the activities of the construction
	3. The contractor (sub-trader) makes arrangements for the removal, processing, or storage of waste in connection with his deliveries or activities, use of lockable containers, waste bins, etc. rented by him at his expense and risk.
	4. The contractor (sub-trade) provides the client with copies of the reporting forms in the context of the Environmental Management Act. The client (InfraConsultant) is entitled to: suspend payment until the obligations arising from the Environmental Management Act and/or

	other environmental laws have been met.
	5. If waste disposal is not possible at first notice from the client (InfraConsult), the client (InfraConsult) is free to dispose of the waste in question to remove the account and risk from the contractor.

Appendix G- Large-Scale Neighborhood Project Site Visit

G1- Observations and Notes

70,000 house connections in Enschede. The project is done by dividing it into substations that feed certain neighborhoods. This is a project that is being innovative and trying to find new ways to divide the organization for the construction of energy networks.

Although this project is meant to re-construct the network of a neighborhood, it is being considered as a "migration" of the old network and way of working. There used to be several network owners, around 100+ and each of them would have its way of engineering and feeding the network. This is why the project is more complex, there are very old and different cables that are being connected and changed for the new network.

In a general sense, if the old school working keeps happening and there are no experiments on how to change the way things work on-site and innovate, then there will be no difference in waste management. The goal is to have everyone in the supply chain willing to work together and consider what changes should be made for the chain to benefit.

One of the main engineering issues that have been encountered in this project is that the placement of the substations is not optimal. They should be centralized so the length of the cables is not long and there is no need for a lot of cables coming straight from one part of the substation.

This is an energy transition project which also means that the energy demand used to be average and there was no need for these big projects. The pressure is also delivering the new network that takes time and therefore speed on the work is very important. Some delays happen because of rain, which causes all the trenches to get filled with water and get soil inserted into the hole. When the trenches are filled with water and soil, the only option is to re-excavate and that is completely a delay on the schedule.

This is a big project in which the engineering and logistics are given to Siers, this is something that is also not common. However, with this organization, it is possible to encounter new ways to find effective matters. There is a big misunderstanding of efficiency and effectiveness which are important for these projects. The effectiveness is directly related to the design and engineering. This is also the starting point in which waste can be reduced and prevented.

For this project, there is a daily recording of what is found and placed on the ground which also provides the amount of material that has been used. Apart from the klick being used the proper way. The maintenance protocol is very important for this. It assures that the unknown cables that are found when there is an excavation and they are not on the map, then it is impossible to know where the cable is connected to.

Contact Management	
Making sub-contractors responsible for waste disposal	Waste is picked up by the waste processor. The old cable is disposed of in the bins. Within the neighborhood when the connections are made and there is waste generated there are bins that are later transported to the main storage stations.

Waste Segregation	
Dedicated space for sorting waste	Yes in both the main area and site site. The material controller goes every day into the bins to collect the materials that can be reused and disposed of by the other workers. They get sorted into the separated container that has the residual or leftover materials divided so they are reused. Waste controller.
Temporary bins	There are temporary bins that are placed in the neighborhoods once the construction of the network and the connections are done. The smaller waste bins are placed. The temporary bins in the different areas that are being constructed are picked up twice or once a week. This strictly depends on the type of project, bigger projects will not need the

	constant check so much.
Provision of waste skips for specific materials	For this project at this specific time of the same, there are three skips. The skips are labeled in front of the containers so it is possible to know what is what.

Material Reuse	
Detect construction activities that can reuse material from construction	For smaller connections
Reuse off-cut materials	The cut-off in the same neighborhood projects is not possible. There is a high risk that which the cable that has been cut will develop issues in the network. The risks are too high for using the cut-off materials in the network. This is why IF cables are meant to be reused they should be reused in projects that will not affect the feeding of the grid directly. What this means is that the use of these cables should not be directly into the grid. This way if one of the cables fails then there will not be a big problem in the main distribution. There was a project done in which a solar farm was constructed with cut-off cables.
Maximization of on-site reuse of materials	The reels have marks on how much length is left on the reel. This allows a proper maximization of the materials. It has been observed from the people on-site that when projects are bigger, the disposal of the cables can be less. This is because the possibility of holding the reels is longer, this means that when there is an unexpected need for 50 meters of cables, then it is possible to use what has not been used in another part of the project. The most effective way of working is when dividing the amount of needed cable by 20%

	to avoid errors and holding the corners, divided into sections of the project then carrying the bigger reels that will have left over at the end. For the longer main cables, they should be delivered in the larger and most precise dimensions. There is a way to account for the inflow and outflow of the materials. What is being used and what is not? These are called cable plans and they will provide the amount of leftovers in a part of the project. Then, it is possible to know where the leftovers can be used in other parts of the materials. This has a risk and has happened in a past project where there was a mistake in how much left over could be used. When this happened, the cable ran out and there was a need for two new reels. There was an urgent placement of products which was expensive.

Materials Logistic Management	
Use of safe material storage facilities	All storage containers are the same standard. These are the metal and properly ventilated storage containers locked. The units can not have a lower temperature of 5 degrees and in winter they are heated up so there is no material loss. They are protected by fences and have security surveillance.
Adequate site access for material delivery and movement	The site is accessible for trucks and cars that transport materials. The materials are ordered throughout the different projects that are occurring. There are also priority deliveries. Reels have to be transported by truck that has a crane installed on it because of the weight of the reels.

	The area is big enough to account for the storage and handling of several trucks at the same time and parked smaller trucks with the cables that are delivered for the project. There are always materials to use in the main storage section, however, in the buses that are going to the site, there are always other types of cables just in case. This is because of how there is always an error in the klick. There are instances in which there is another type of cable that is in the ground, and that is why there is a need for instant new materials and having to go back to the main storage delays. This backs up the need to have a central temporary storage container with adequate materials. With the kick, it is also a problem that there are cables that have not been added to the grid which can cause some other facilities and units to not have the right amount of power.
Central areas for storage	Materials are delivered on-site by smaller trucks. The material handler for the project has pre-made packages that contain the necessary for the connections on each of the houses. This is also transported to the actual site. The location of the main storage center with all the offices and the materials is not central. They are locations that are harder to find based on the restrictions of where things can be placed on the land and the resident's decisions. IDEA (same as mine): provide smaller storage that will contain the specific materials that are central in the sub-location where they have been working.

G2- Storage and Segregation area Outline from Site Visit in Neighborhood Projects

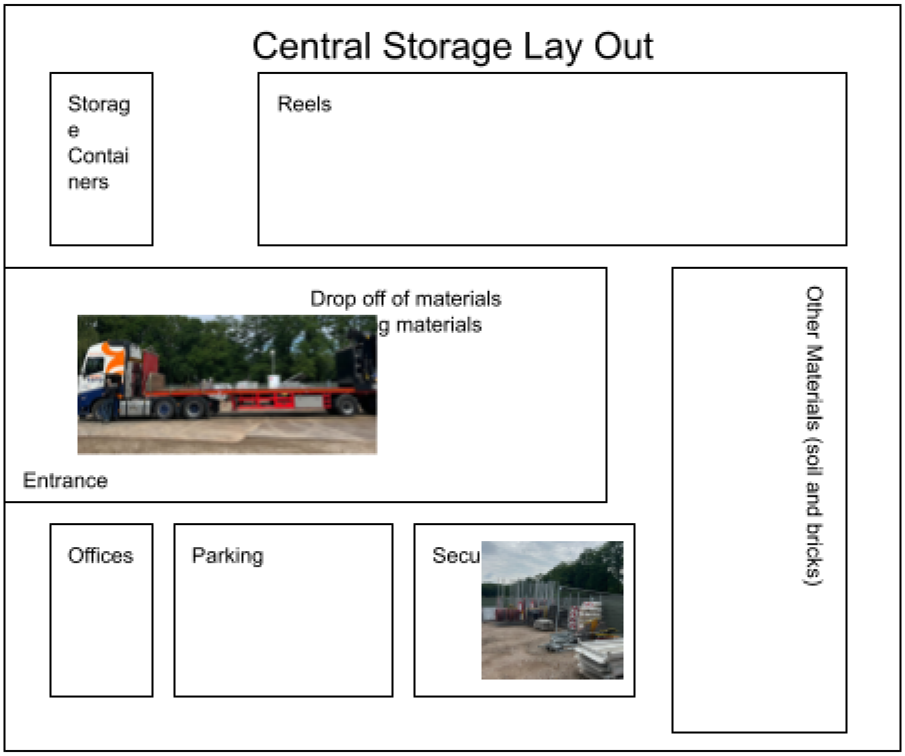


Figure G2- Central storage area lay out

G3- Images

Figure G.3.1- Waste Skips
Waste skips for different materials. Picture 1 shows how the skips are labeled in font so segregation is done properly. Picture 2 shows the skip dedicated for the old extracted cable.

Figure G3.2- Storage area

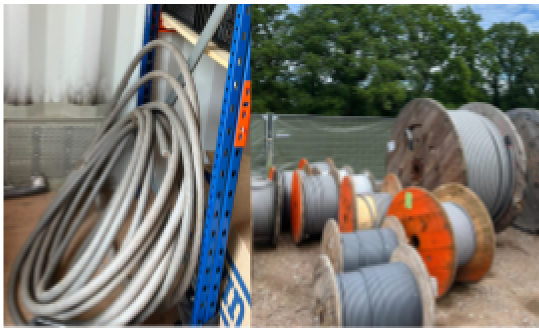


Figure G3.3- Stored materials


Figure G3.4- Storage facilities for materials

Appendix H- Medium Voltage Site Visit

H1- Observations and Notes

Subcontractors, one director from Siers, and the contract was to get paid by meters.
Duration of project: approximately 6 months
The task: laying down a medium voltage cable while the old one had to be taken out. This is because new capacity is needed.

Also had to take the old water tube (asbestos) and change it with a new tube. Not in scope but shows how it shows that they are a company who are contracted to do several things from a neighborhood. T

Old cable: 10kV 3x95AI XLPE (three cables of 95mm diameter and wrapped with PE type of plastic)
New cable: 10kV 3x240 Al and 160 PVC (3 cables of 240 mm with a PV plastic cover)

Medium and high voltage cables are DC type, then they are connected to the low voltage cable that has four phases making them into an AC type. The fact that it is AC refers to how the amount of energy that is provided comes in oscillations where there are low peaks and there is no constant voltage coming into the houses or facilities in general. The fourth phase of the cable helps regulate this irregularity. Additionally, the low-voltage cables have other four smaller cables, these are for the small connections to traffic lights or light poles that don't require as much power.

Medium voltage cables are made out of aluminum, they need to transport more energy than the amount for the cable to be copper will make it too expensive. The low voltage cables are made of copper because they are better conductors and the distances are smaller. However, high voltage cables are also copper because the power that should be transported is too high to make them from aluminum, this would mean that the diameters of these cables would be too thick and heavy for it to be handled.

Aluminum cables will need more surface area to transport energy than a copper cable would. This again, is because copper is a more efficient conductor of electricity.

There is always a transformation station that will regulate the kv that is going into the cables that are connected to the transformer.

The site is most likely going to be shared with other construction companies. In this case, there was road construction and sewage also being done at the same location.

The location was a 1km+ connection. They are done through sections, and the cable is even more than one of the big rolls that were on the site. The engineers set where to start and where connections should be made, although the goal is to not have connections it is impossible to do so because the lengths that are getting installed are long.

Process:

- Excavation
- New cable is laid completely
- Power is cut and the old cable is disconnected while the new one is connected
    - This is so no one dependent on electricity will have to
- The cable is covered with soil, the cover on top of the cable is placed throughout.
    - This is done so that when there are excavations done in the future people can see that there is a cable laying there and the excavation has to stop.
- While this happens, the old cable is also being cut and placed on the side of the excavation point where there is a small truck where the excess materials are used.
- The cables are then collected in a small wagon connected to a car and then all waste is disposed of in the skip

How the material is handled:

- The reel with 1 km is in a wagon towards the excavation starting point
- The start of the cable is placed in the beginning and rolled with the help of the steel things.
- New cable is laid down, excess is for the proper length is cut
- Connections in the areas where the engineers have drawn
- Old cut into smaller pieces to take it out
    - Everything is one waste

Contract Management

Making sub-contractors responsible for waste disposal	They are following orders of putting the waste in the containers. Liander will then pick up the things and waste will be disposed

Waste Segregation	
Dedicated space for sorting waste	There is one location in which all the containers are situated and the materials are also stored. This is in the same place in which the materials are placed.
Provision of waste skips for specific materials	This site had one bin for the waste that was taken. The skip is not covered but there are cameras for protection. There was also a paper skip Important: the skips are different for all the projects, they are known based on what the projects are the work is, and the materials that are used. In this case, the asbestos tubes were not mixed with the rest of the cables. Cables are in a different skip.

Material Reuse	
Detect the construction activities that can admit reusable materials from the construction	The reuse of the materials for the activities can not be done because of how the construction of the network happens.
Reuse of off-cut materials	The old cable is not possible to be extracted as a whole because it makes the process way harder. There is a reason why the cable that is being taken out of the ground is not able to perform what is needed or it is too old. In this case, the cable was too thin, the diameter would not hold the desired demand.

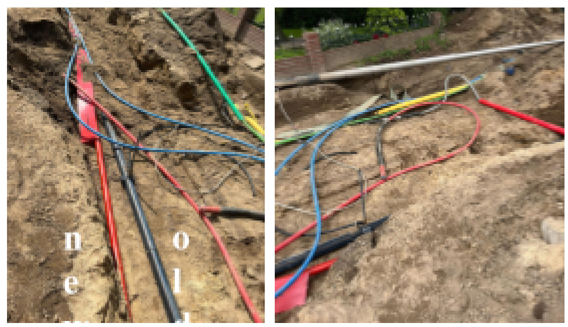
	The new cable cut-off has a small length and they are cut when doing the connections. These lengths are too small to be used, which will affect the grid.

Materials Logistic Management	
Use of safe materials storage facilities	There are four storage facilities from Siers with the equipment and materials. Additionally, there is one storage container that comes from Liander. They are protected with locks that only the workers have
Adequate site access to materials delivery and moment	Materials are stored at the beginning of the project, there could be a better location on where to situate what container. This project allowed a big space in which the materials and storage containers may be located. A lot of the material movement is done with the smaller trucks The access was easy for the trucks to reach, it was on a main road from the city.
Central areas for storage	Beginning of the project also had to share the space with other containers from the other companies working on their respective project

H2- Images

Extracted old materials were disposed into this truck which was later carried to the segregating and storage area.

Cable is attached to a wagon. These are moved with a smaller truck into the site. Cables are later pulled with steel artifacts that allow an easier pull (Image 3).
It is important to note the heaviness of the material.



During the site visit it was possible to see how the new cable was being laid next to the old cable. It was also interesting the procedure on how the the new cable is laid, protected with the plastic red rug and then covered back with soil.

Cut-off of the new cable while cable was already in the trench.

Appendix I- Waste Processor Portals

Table I1- PreZero Portal information with Siers and Alliander.

Assignment	Waste stream	Container (m^3)	Action
Sales container Rolling container Press container	Industrial Pvc pipes Asbestos Hard plastic Rubble Construction and demolition waste Wood type b Wood type c Paper Asphalt rubble with tar Asphalt rubble without tar Green waste Compostable green waste Foil	Opened: 6 10 20 40 Bigger Bag: 3	Dispose Move Switch Place

Table I2- HKS portal information

Type m^4	Waste stream	Actions
Battery box 1	Ferro Non-Ferro E-scraps Lead batteries Iron Metals	Change Collect Empty
Opened 4 and 6	Ferro Non-Ferro	
Closed 9 Two hatches and lockable.	Miscellaneous cable Non-Ferro	
Closed 20 Liquid tight, hydraulic with rotating lid and lock.	Cables with Oil Non-ferrous	
Open 20, 30, 40 Two doors	Ferro Non-Ferro Cast iron Metals	
Warehouse 20ft		

Lockable, two joined doors with wooden floor.		

Table I3- Renewi portal options

Waste stream	Action	Status
Waste and residual waste Tires and rubber (that is zero) Construction and demolition Foil and plastics Hazardous waste Wood Other Paper and cardboard Confidential paper	Change and empty Empty Collecting New container	Request Planned Executed Invoked (if waste segregation is not proper) Not executed

Appendix J- Cause of Remaining Lengths

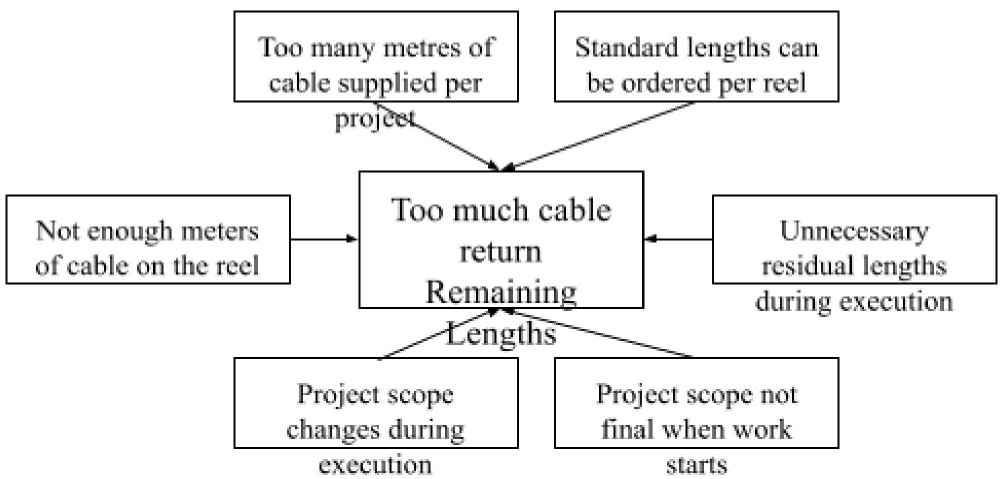


Figure J1 - Causes of residual length of cables
(Schaap et al., 2022) pg 8.

Appendix K- Material Passport

Table K1- Material Passport

Overall information (above table)	Input or calculated automatically?
General information	

Product number	Product number as used by Seller in its logistic system	Input
Summary		
Total weight	Total weight of the product	Calculated automatically
Circularity	Circularity score of the used product. Calculated as the weighted average percentage of recycled material.	Calculated automatically
Circularity total	Calculated as the weighted average of circularity scores, therefore taking into account both the percentage of recycled material and recyclable material.	Calculated automatically
Validation		
Name	Name of the person signing the passport	Input
Function	Function of the person signing the passport (Should be C-level or national equivalent)	Input
KIWA Covenant Certificate Nr	Number of the KIWA covenant certificate. With this covenant, the supplier can let an independent company confirm the correctness of the material passport	Input
Issue date KIWA Covenant	Issue date of the KIWA Covenant certificate	Input
Signature	Signature of the person signing the passport	Input

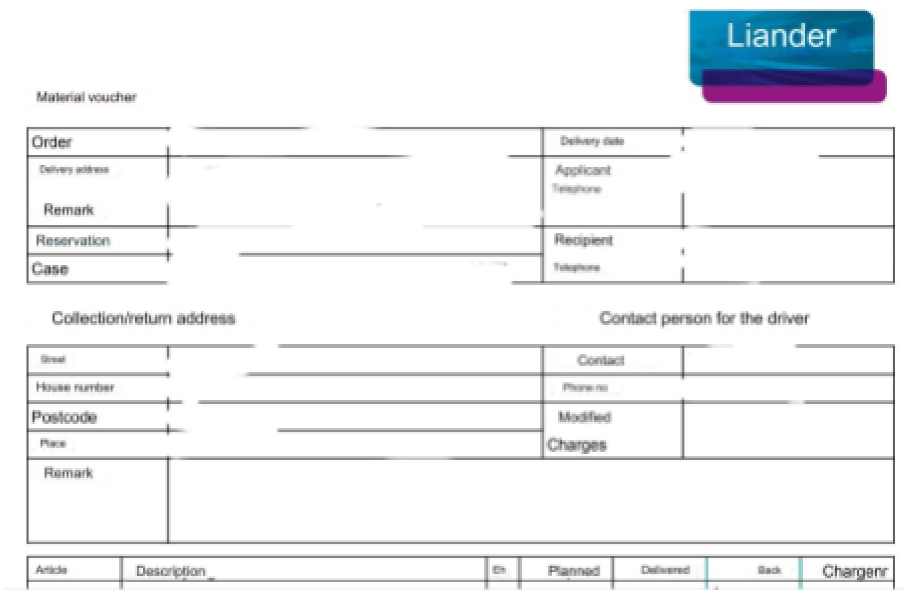
Resource information		
Material	Material selected from the list of available materials. It does include "Other" and "Unknown" but suppliers are encouraged to keep the use of those categories to a minimum. If a supplier feels another material category should be added, Alliander can be contacted.	Input
Unit	Unit for which the weight is filled in (for example M, KM, Unit)	Input

Measured Quantity	The unit of measurement used. For example, 1000 in combination with a Meter gives 1000 meters as unit of measurement	Input
Weight (g)	Weight of the material in grams	Input
Recycled (%)	Percentage of the material that is recycled/non-virgin	Input
Recyclable (%)	Percentage of the material that is recyclable. If a KIWA covenant is applicable only 0% or 100% can be used. Recyclability should be judged by current technological and economic standards. No assumptions are allowed for further innovations or market developments that would make a material stream more recyclable. If either of those two instances occur, the passport can be updated and a new iteration will be used by the buyer.	Input
Suppliers and source of the material		
Supplier/Producer (Tier 1)	Supplier/producer that supplies the material/product to the company	Input
(Base) Product	The base product that the tier 1 supplier/producer supplies to the company	Input
Supplier/Producer (Tier 2)	Tier 2 supplier/producer that supplies to the tier 1 supplier/producer	Input
Source	Source of the material used in the product, for example, "bauxite mining" or "PE recycling within the EU", etc.	Input
(Base) material	Base material used to make the material (if applicable)	Input

Resource Information (table, automatically calculated fields)		
Scores		
Circularity (%)	The circularity score of the material is based on the percentages of recycled and recyclable attributes attributed to the material. This is calculated as the average percentage of both recycled material and recyclable material.	Calculated automatically

Circular (g)	The amount of circular material in grams. Calculated as the weight multiplied by the circularity score.	Calculated automatica lly
Recycled (g)	The amount of recycled material in grams. Calculated as the weight multiplied by the recycled percentage.	Calculated automatica lly
Recyclable (g)	The amount of recyclable material in grams. Calculated as the weight multiplied by the recyclable percentage.	Calculated automatica lly

Appendix L- Materiaal Bon, Returning material document



Liander

Material voucher

Order		Delivery date	
Delivery address Remark		Applicant Telephone	
Reservation		Recipient	
Case		Telephone	

Collection/return address

Contact person for the driver

Street		Contact	
House number		Phone no	
Postcode		Modified	
Place		Charges	
Remark			

Article	Description	Eh	Planned	Delivered	Back	Chargenr

Figure L1- Material Voucher for returning unused materials

Appendix M- Can Enexis Work More Sustainability?

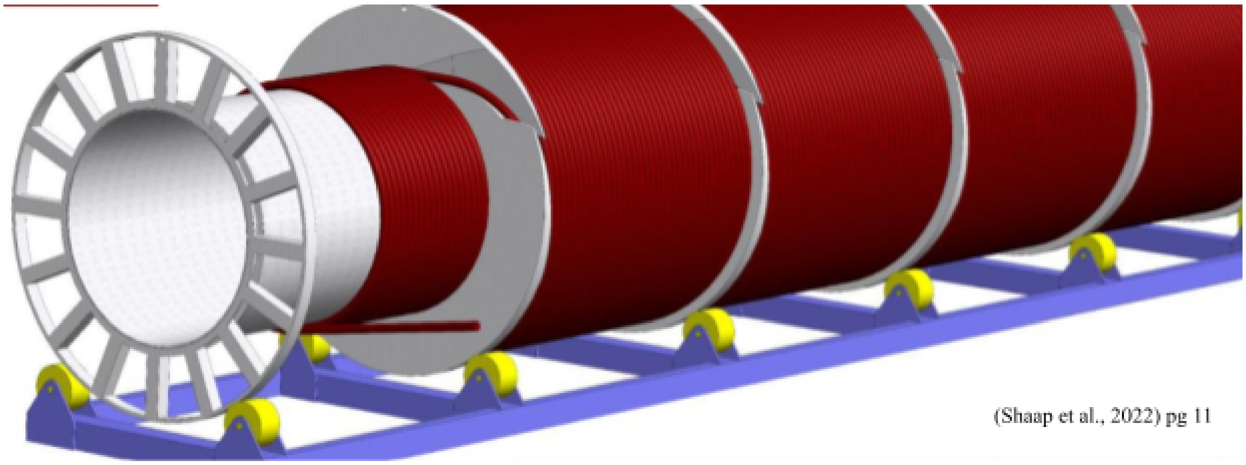


Figure M1- Design for Cable Transportation

Offered Reel Design by TKF to Enexis for easier use and transportation in order to reduce the residual lengths. The design is describes to change the delivery process, and that the contractor can provide the cable for a project to his employees (sub-contractors or subtraders).