



SINTEF

Report

Material recycling and reusability of lifting slings

Materialgjenvinning og ombruksmuligheter for lastestropper

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SUMMARY

This project, funded by Handelens Miljøfond with support from industry partners and a sling producer, explored how synthetic lifting slings used in Norwegian construction can shift from single-use disposal toward circular practices. Although technically durable and recyclable, most slings are discarded after one use, generating unnecessary plastic waste, pollution, and GHG emissions. The study mapped current flows and user approaches, highlighting major barriers such as fragmented practices across the supply chain, lack of formalized procedures and systematized processes, and high recertification costs compared with the low purchase price of new slings. Although not fully circular, best practices already exist such as established collaborations between suppliers and contractors for returning and sorting routines enabling partial reuse and recycling. Innovations like mobile scanning for sling “activation” related to new uses, digital documentation, and monitoring of slings across their useful lifetime, as well as higher recycled content of slings material represents proactive measures that set the basis for circular solutions. Coordinated stakeholder action, formalized systems, and integration of circular goals into management practices are crucial to make reuse and recycling both practical and economically viable.

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Table of contents

1	Background	5
2	Literature review	5
2.1	Plastics and waste management frameworks	5
2.2	Circularity in the Norwegian construction sector	7
3	Method	10
4	Results	11
4.1	Data collection from project participants and other relevant actors	11
4.1.1	Material composition, product specifications, and standards	11
4.1.2	Quantities consumed, current practices, resource streams and management	14
4.1.2.1	Steel Suppliers	14
4.1.2.2	Contractors	14
4.1.2.3	Waste and resource management	17
4.2	Material flow analysis of synthetic lifting slings	21
4.3	Life Cycle Assessment of synthetic lifting slings: the impact of GHG emissions.....	23
4.3.1	Production (A1 – A3).....	23
4.3.2	Transport (A4).....	23
4.3.3	Handling (A5)	24
4.3.4	Use (B1 – B7).....	24
4.3.5	End-of-life (C1 – C4).....	24
5	How to achieve circularity with more reuse and recycling of synthetic lifting slings?	27
6	Conclusions	28
7	References	29

1 Background

The **material recycling and reusability of lifting slings** project was financed by Handelens Miljøfond with the contribution of several industry partners such as: Norsk Stål, Contur, Retura, Smith Stål, Stålforbundet, Anlegg Øst Entreprenør AS, Isachsen Anlegg, Hæhre Entreprenør, Johs. J. Syltern AS. A main producer of synthetic slings (AGON) also participated by providing key information.

The focus of the project was on synthetic lifting slings made of fibre plastic used for material deliveries in the construction sector. In Norway, a huge proportion of technically usable synthetic lifting slings – designed for material recycling, are often used once and discarded as non-recyclable waste. Through this project, a group of stakeholders came together to address the same problem: the large number of lifting slings discarded each year in each construction project, which are difficult to upcycle in today's Norwegian market. A better understanding of the system was obtained through mapping current practices, material flow and environmental impact, practical or cultural barriers, and opportunities for increased circularity.

The aim of the project was to build a knowledge base for developing solutions that reduce virgin plastic use in lifting slings. This can be achieved by increasing material recycling and reuse, while also encouraging circular design and new services. This report summarizes the results and discussions collected during the project implementation period.

2 Literature review

2.1 Plastics and waste management frameworks

Fibre plastic slings for lifting or securing loads are lightweight, corrosion-resistant, and cost-effective solutions. However, the use of virgin plastic in their production poses environmental challenges. They are made from plastic polymers like Polyethylene Terephthalate (PET), and poly Polypropylene (PP), and Polyethylene (PE) that ensure safety operations by preventing loads from shifting during transit and by reducing the risk of accidents caused by falling or shifting products during handling and lifting of heavy materials. These materials are made of fossil fuel-based resources which contribute significantly to Greenhouse Gas (GHG) emissions across their lifecycle [1].

For packaging, plastic is the most carbon-intensive material and recycling of plastic waste is approximately five-times better than incineration with energy recovery. To reduce the reliance on fossil fuels, bio-based polymers are expected to gain more attention in the near future, but still they have not fully scaled-up in the market [2].

In the academic literature there is lack of evidence on the environmental impacts of lifting slings, while there is a greater focus on plastic packaging for different industries (food, automotive, retail, other consumer goods) and categories such as, carrier bags, transport boxes, wrappers and pallets [3][4][5]. Similar conclusions are drawn for different types of plastic packaging, such as the recommendation to 'reuse as many times as possible before disposal.' However, applying this principle is not as straightforward for load-handling or lifting accessories.

Few studies investigate the impacts of waste management of plastics. Incineration with energy recovery is the process of burning plastic waste to derive heat. The heat is either used directly to heat buildings or used indirectly to produce electricity. While plastics have the highest net calorific value¹, it also has the highest carbon emissions [6]. The downside of this process is that not all of the toxic emissions can be captured from the fumes thus posing environmental and health risks. Other major recycling processes focus on the

¹ Net calorific value of a waste fraction is an important factor when considering the energy produced by waste-to-energy.

mechanical recycling of plastic waste, but this process is limited by the sorting and degradation of plastics during the process. Mechanical recycling refers to the use of separation techniques, crushing, heat and extrusion to melt used plastic waste down and produce recycled plastic pellets. Alternative process can be the chemical recycling or depolymerization, among others. Chemical recycling processes consists of breaking down plastics into their basic building blocks which can then be reused to make new plastics [7].

Landfilling and natural degradation processes are environmentally unacceptable for plastics waste management [8]. Plastic persists in the environment for centuries due to their remarkable resistance to natural degradation processes. PET can remain intact for over 70 up to 450 years in natural settings, while for PP and PE the estimation of degradation times ranges from 10–20 years to 500–1000 years [9]. Other sources reported that such plastics do not degrade at all [10] [11]. Instead of complete decomposition, these plastics often fragment into microplastics, creating persistent environmental pollutants. The UNEP's 2021 assessment "From Pollution to Solution" indicates that mechanical fragmentation (breaking into microplastics) dominates over chemical breakdown, contributing to the accumulation and contamination in marine and terrestrial ecosystems.

The Waste Framework Directive (Directive 2008/98/EC) sets the basic concepts and definitions related to waste management [12]. The first version of the Waste Framework Directive consisted of a five-steps waste hierarchy indicating the order of preference for managing and disposing of waste (Figure 1). It places prevention, reuse, and recycling above other recovery options. Waste disposal (landfilling) is the very last measure.



Figure 1 - Waste management hierarchy. Source: Directive 2008/98/EC on waste.

In 2019 a new waste management hierarchy was published [8] including social, economic and logistic considerations with the objective to foster a transition towards circularity. With the new mental frame set by the Circular Economy thinking, a new hierarchy is needed to change the mindset from waste management to resource management (Figure 2). The Zero Waste hierarchy has 7 steps, two related to products and 5 related to waste. The driving force of the hierarchy is not only the safe disposal of waste but also to ensure that the value of our resources is preserved in the economy for the new generations.



Figure 2 - Zero Waste hierarchy. Source: Zero waste Europe and Zero Waste International Alliance.

It is widely recognised that continuing in a business-as-usual scenario for plastic waste management is no longer an option. A plastics circular economy is an alternative economic model for plastics which moves away from the current take, make, waste model. In a plastics circular economy, plastics and plastic use is better designed so that it does not become waste and instead is reused, recycled or composted [13]. A circular economy of fibre plastic slings must keep valuable plastic products in the value chain. To this, existing methods should be improved, and new methods should be developed.

2.2 Circularity in the Norwegian construction sector

A mapping of circularity in construction [14] showed that the Norwegian construction industry was around 7% circular in 2023, according to the calculations of FutureBuilt's circularity index. Projections show that circularity could be around 14–42% in 2030 and 34–71% in 2050, however such percentages are contingent to the implementation of political and structural measures and changes.

Figure 3 show the proportion and type of waste treatment in construction activities such as new construction, rehab, demolition from 2013 to 2023 according to Statistics Norway (SBB). The three big categories are accounted by material recycling (46,6%), energy recovery – as the combustion of waste to produce heat and electricity (25,4%), and landfill (24,5%). This reflects significant progress toward sustainable resource management and supports the transition to a circular economy in the construction sector. With continued investment in recycling infrastructure and innovation, reliance on landfill could be further reduced, driving the industry toward greater resource efficiency.

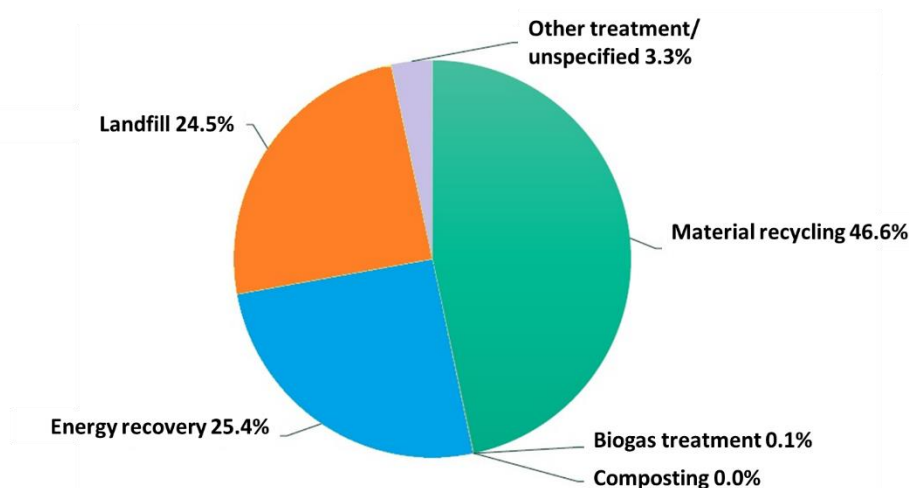


Figure 3 – Waste Management Construction Activity 2013-2023. Source: Statistics Norway (SBB)

A 2025 report on circularity [15] indicate that Norway must set clear sectoral targets to advance circularity and reduce material consumption. It must be supported by multi-stakeholder collaboration and robust monitoring. A system change happens through the interaction of three levels.

A top-down level means large-scale external forces that shape the environment in which a system operates, such as political shifts, economic cycles, demographic changes, or environmental trends. These forces put pressure on existing systems to adapt. For example, policymakers should enable businesses to adopt circular practices by addressing financial and regulatory barriers, making secondary materials more competitive and incentivising circular business models. This alongside policies that prioritise maintaining and extending the lifetime of existing materials.

A bottom-up level means the innovation through emerging new technologies, practices, business models, and ideas that can challenge or replace existing ways of doing things such as startups, pilot projects, or research breakthroughs. These innovations can grow and start to align with or disrupt the existing system, especially when external pressures make the old ways less viable.

A middle level is the current system, as the established way of doing things including rules, norms, institutions, and infrastructures that define the system itself. It can be in the form of market structures, industry standards, laws, or cultural norms. The system tends to resist change, maintaining stability. But under enough pressure from above (external forces) and below (innovation), it can shift.

Therefore, a system change does not come from just top-down policy or bottom-up innovation alone. It is the interaction between external pressures (by opening “windows of opportunity” for innovations), existing system and adjustments (by adapting and absorbing some innovations while discarding others), and emerging solutions or innovations that drives transformation (by reshaping the system when the external pressures make old solutions less viable).

Research plays a critical role in understanding and addressing system changes and trends. A 2024 report [16] on human impacts on the environment highlights that Norway’s material footprint is among the highest globally. The construction industry has a significant environmental footprint, responsible for 30% of Norway’s material footprint, 23% of its carbon footprint, and 26% of total waste generation in 2022 [15] [17]. Economic fluctuations, along with challenges such as the covid-19 pandemic from 2019 to 2022, have influenced the construction industry’s business as usual. Construction is among the industry sectors with the greatest potential for circular innovation [16].

Construction projects in Norway are governed by national and local regulations. In recent years, there has been a strong focus on climate action and the energy transition, and more recently, circular economy principles have gained increasing attention. For example, the technical requirements for construction (Byggteknisk forskrift, TEK 17) set standards for GHG accounting, energy flexibility, and circularity. New requirements emphasise material mapping, reuse, waste sorting, and design for disassembly. In addition, certification schemes such as BREEAM-NOR and Svanemarket are widely used to promote sustainability in the built environment. Circular principles are further reinforced through initiatives like FutureBuilt which encourage innovative and resource-efficient construction practices.

In 2024, climate and environmental considerations must account for 30% of the evaluation criteria in public procurement. However, there is no guarantee that circular solutions will be prioritised. In parallel, Norway's National strategy for a Green, Circular Economy and Action Plan for a Circular Economy are aligned with the EU Green Deal and the Circular Economy Action Plan. Among the seven priority value chains identified by the EU, the built environment holds a prominent position—and Norway is committed to adopting EU regulations and directives in an effort to harmonise policymaking in the industry. The European framework for advancing circularity in construction is built on four key pillars: the Energy Performance of Buildings Directive (EPBD), the Construction Products Regulation (CPR), the Eco-design for Sustainable Products Regulation (ESPR), and the Waste Framework Directive (WFD). Such directives and regulations do not specifically target plastics although the ESPR and the WFD establishes eco-design requirements for all physical products and end-of-waste criteria that applies to plastics. Additionally, the EU Taxonomy and the Corporate Sustainability Reporting Directive (CSRD) are expected to impact the Norwegian construction industry by setting clear sustainability and reporting standards.

Norway's adoption of EU regulations related to the environment is extensive. In this sense, it can be assumed that the EU's Packaging Product Waste Regulation (PPWR) may impact the internal market. The PPWR was released in January 2025, and it is a legislative framework by the European Union aimed at reducing the environmental impact of packaging and packaging waste. The term “fibre plastic lifting slings” is not specifically mentioned but it can be assumed to be under the category “Textile - Natural and synthetic textile fibres” referred to in Article 6. The re use targets establishes:

“From 1 January 2030, economic operators that use transport packaging, or sales packaging used for transporting products, including for products distributed via e-commerce, within the territory of the Union, in the form of pallets, foldable-plastic boxes, boxes, trays, plastic crates, intermediate bulk containers, pails, drums and canisters of any size or material, including flexible formats or pallet wrappings or straps for stabilisation and protection of products put on pallets during transport, shall ensure that at least 40 % of such packaging in total is reusable packaging within a re-use system. From 1 January 2040, those economic operators shall endeavour to use at least 70 % of the packaging referred to in the first subparagraph in a reusable format within a re-use system.”

Also, the PPWR highlights that packaging designed for material recycling (this is, resulting secondary raw materials that are of sufficient quality when compared to the original material that they can be used to substitute primary raw materials) shall be collected separately and sorted into specific waste streams and recycled at scale. States shall reduce the quantity of plastic packaging waste generated and reduce the consumption of single-use plastics, fostering recycling and circular economy as well as preventing their disposal in landfills or incineration. The recycling targets indicate that by 31 December 2025, 50 % by weight of plastic materials contained in packaging waste generated should be recycled, while 55 % by 31 December 2030.

3 Method

The project's working plan consisted in five activities: (i) data collection of synthetic lifting slings from participants and literature review; (ii) Material Flow Analysis of synthetic lifting slings; (iii) Life Cycle Assessment to investigate the GHG emissions of synthetic lifting slings; (iv) interviews with participants and relevant actors; (v) development of report summarizing the results and discussed opportunities for improvement. The project was coordinated by SINTEF. The participants were: five suppliers of construction elements (steel or concrete), five contractors, the Norwegian steel association and one waste management company. Participants were had a key role in the provision of quantitative and qualitative data such as quantities consumed, common practices and logistics, waste and resource management, transport modes and distances, as well as expectations about potential circular solutions.

A dialogue was also established with the manufacturer of synthetic lifting slings to investigate the material composition, associated criteria and regulations, and current barriers and opportunities for reuse and recycling.

From September 2024 to June 2025, monthly meetings were carried out with all participants to discuss the progress and outcomes of the planned activities. Individual meetings were also conducted during the project period to explore in depth certain practices and collect specific data. All interviews and questionnaires were supported with pictures of the slings focus of this study to avoid misunderstandings. The empirical data and associated calculations are representative of the conditions prevailing during the project period in which the information was collected. The results are dependent on the information provided from participants.

For activity (i) a literature review was conducted to explore material composition, waste management frameworks, and relevant standards. The review included academic and industrial publications, popular science sources, as well as European and Norwegian regulations. Subsequently, an Excel form was created for each group of participants and sent electronically. A list of specific items was requested to better understand the quantities consumed, current practices, and resource streams and management including logistics, waste handling, sorting and return schemes, recertification and recycle processes. Relevant actors in the values chain (i.e., the Norwegian Labor Authority, certification bodies, waste treatment companies, and governmental agencies) were also consulted about particular aspects mentioned by the project participants such as, regulations, inspection and certification systems, waste and resource management.

Activity (ii) consisted in the development of a Material Flow Analysis. Data gathered in activity (i) was crucial for setting the basis of the analysis. Individual meetings with participants and questions sent via email were undertaken to investigate the flows and quantitative data more in depth.

For activity (iii) a Life Cycle Assessment (LCA) to investigate the GHG emissions of synthetic lifting slings was conducted. The data gathered in activity (i) and (ii) was used to build the life cycle inventory data. A couple of meetings with participants and questions sent via email helped in the revision and collection of key information.

LCA is a standardized methodology, defined by ISO 14040 and ISO 14044, for assessing the environmental impacts of a product, process, or service throughout its entire life cycle. This approach considers all stages, from raw material extraction to end-of-life disposal, to provide a holistic view of environmental performance. In this study, the LCA focuses on synthetic lifting slings used for the deliveries of steel and concrete elements to construction sites. The impact of GHG emissions was assessed, as the primary indicator of Global Warming Potential and expressed in kilograms of CO₂ equivalent (kg CO₂ eq.). The functional unit was defined as 1 ton of *Endless* slings from AGON producer. Three variations of the same product were assessed such as 100% polyester (virgin material), 10%, and 25% of recycled polyester primarily from PET bottles.

The system boundaries were set as cradle-to-grave, encompassing raw material production, manufacturing, transport, use phase, and end-of-life management. The use phase (B1-B7) includes recertification to evaluate the influence of extended product use on overall environmental impact (Figure 4).

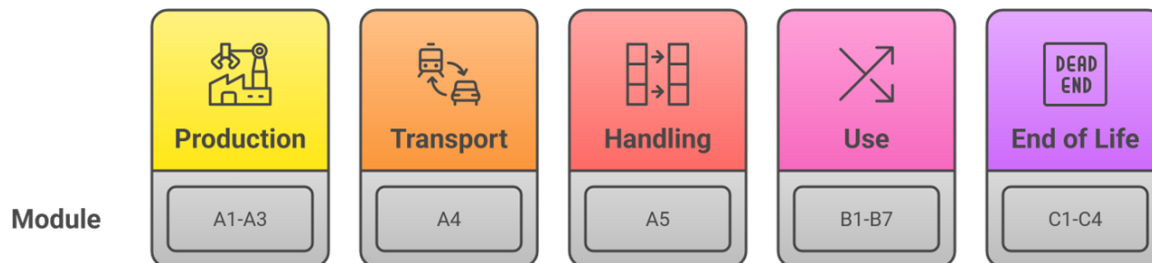


Figure 4 – System boundaries for GHG emissions calculation of synthetic lifting slings

The Life Cycle Inventory data consisted of European impact factors for virgin polyester and recycled polyester from PET bottles, fossil fuel vessel (transportation from Asia to Europe), and waste treatment (incineration, recycling, landfill, and land use impact). Norwegian impact factor for EURO 6, diesel trucks and electricity from European mix.

In activity (iv) a semi-structured questionnaire was developed for each group of participants to cover the perspectives of consumers, users, producers, and waste handlers related to current practices and improvement opportunities for increased circularity. Before the interviews, the questionnaire was distributed digitally offering the option to respond to each question and facilitate further discussions with participants.

Activity (v) refers to the development of this report summarizing the methodologies, data collection, and results.

4 Results

4.1 Data collection from project participants and other relevant actors

4.1.1 Material composition, product specifications, and standards

The slings explored in this project are used for material deliveries in the construction sector. They are made of plastic fibres due to their strength and durability. Three main types of synthetic lifting slings were identified as being used by the participants: *Endless*, *Reinforced Endless*, and *Round*. Around 90% of the total of slings consumed by participants are *Endless* type. The producer is a Danish company and one of the largest suppliers of lifting slings in Scandinavia. The slings can be delivered in box or pallets.

Endless are flat slings that is joint at ends (Figure 5). It is an affordable alternative that is often used where there is a large consumption of slings and where these are delivered to the customer. Three versions of the same product are commercialized: one made of 100% virgin polyester, and another two made of polyester (virgin material) and 10% or 25% of recycled polyester primarily from PET bottles. They come in different lengths and be chosen according to the working load limits; one for 1000 kg and the other for 525 kg.



Figure 5 – Endless slings. Source: AGON.

Reinforced Endless is a strengthened version of the endless slings but with longer life but with an additional cost of around 30 %. (Figure 6). This type of slings is based on a patent-protected system, developed by AGON, which makes the reinforcement particularly resistant to sharp edges and wear. Three versions of the same product are commercialized: one made of 90 % PET (virgin material) and 10% recycled from PET bottles, and another two made of polyester (virgin material) and 10% or 25% of recycled polyester primarily from PET bottles. The working load limits is 1000 kg.



Figure 6 – Reinforced Endless slings. Source: AGON.

Round slings are made of woven textile threads providing the lifting capacity and surrounded by a bag that provides durability (Figure 7). They have long life, especially when they are fitted with double outer bags. Three versions of the same product are commercialized: one made of 100% virgin polyester, and another two made of polyester (virgin material) and 10% or 25% of recycled polyester primarily from PET bottles. They come in different working load limits such as 1000, 2000 and 3000 kg and multiple lengths.



Figure 7 – Round slings. Source: AGON.

The slings are CE marked and approved in all EU and EEA countries and can be delivered to the goods and reused at the customer. The slings are produced according to EN1492-1 (*Textile slings - Safety - Part 1: Flat woven webbing slings made of man-made fibres for general purpose use*) and EN1492-2 (*Textile slings - Safety - Part 2: Round slings made from man-made fibres*). These standards encompass design and manufacturing requirements, safety factors, testing procedures, marking and labelling, instructions for use, inspection and examination criteria. For webbing slings and round slings made from fibres, the standard requires a minimum safety factor of 7:1. This means the minimum breaking force must be at least seven times the stated working load limit.

The control of slings must follow a specific safety criterion. The first use of slings is documented to keep track of later uses. The lifetime of technically usable slings is 12 months. Examination of slings must be carried out at every use. Slings showing one or more of the following faults must be taken out of service, such as: missing label, date expired or lack of date marking, cuts or stretching, contaminated with chemical substances, solar UV degradation (bleaching), knots or holes on the sling, welding spray, heat exposure, wear marks, or acid burnt. A main inspection must be conducted at least every 12 months. The use of slings with a date that is over 12 months old and that were not subjected to the mandatory annual inspection, should never be used. It must always be stated in the sling documentation when it last underwent the mandatory annual inspection.

The EN1492 standard places significant emphasis on the role of the competent person throughout the lifecycle of lifting slings. A competent person is defined as: *“a designated person, suitably trained and qualified by knowledge and practical experience, a with the necessary instructions to enable the required tests and examination to be carried out.”*

According to EN 1492, D.4, Examination and repair: *“Examination periods should be determined by a competent person taking into account the application, environment, frequency of use and similar matter, but in any event, slings should be visually examined at least annually by a competent person to establish their fitness for continued use. Records of such examinations should be maintained. Damage slings should be withdrawn from service. Never attempt to carry out repairs to the slings yourself.”*

The producer provides to customers a quality management system including test certificates, user manuals, discard criteria guidance and QR documentation system. All slings are therefore equipped with a QR code through which relevant documentation can be accessed directly using digital devices such as smartphone or tablet (Figure 8). Each production batch has its own ID and thus a QR code. The users have easy access to the information of each sling by monitoring the number of uses along slings lifetime such as production, commissioning, and annual inspection dates. It enables to keep track on reuse control cycles, allowing to register the first use after the annual inspection and ensuring other 12 months lifetime.



Figure 8 – QR documentation and quality system provided by the slings producer.

4.1.2 Quantities consumed, current practices, resource streams and management

The scale of synthetic lifting slings consumption varies between suppliers and contractors, according to the information provided. These products arrive in Norway directly from Asia via freighter ships, entering through container ports in the Oslo area before distribution to various steel supplier locations throughout the country.

4.1.2.1 Steel Suppliers

Steel supplier “A” buy approximately 500 tons annually, while Steel supplier “B” consumes around 4.5 tons per year, illustrating a more than hundredfold difference in usage patterns.

The waste generation numbers show a concerning picture of current disposal practices. Steel supplier “A” revealed that 89 tons are sent to residual waste annually. From that, about 4,7 tons are directed to recycling plants per year, resulting in 1% recycling rate.

Steel supplier “B” reported that approximately 70 to 75 tons of slings are sent to residual waste annually. Such amount includes materials shipped from construction sites and other sectors. Steel supplier “B” achieved around 4% recertification rate, equivalent to approximately 3 tons per year (currently, *Reinforced Endless* slings is the only type being recertified).

The suppliers have a formalized return systems which implies that those slings which seems visibly useful and in good conditions must be sorted into their own fraction in dedicated container or bags.

4.1.2.2 Contractors

Construction contractors exhibit varying approaches to sling management. Contractor "1" reported the consumption of 6 and 10 tonnes of synthetic lifting slings solely from steel deliveries in two different projects. The management of slings at construction sites varies from project to project. A main influencing factor is the location of the project which sometimes determine the choices about suppliers and logistics based on proximity or regional circumstances. Two different approaches from two distinct projects of the same contractor (1) were examined.

One of the projects had 180 000 m² and consisted of the expansion of an industrial facility located in western Norway. About 6 tonnes of synthetic lifting slings were received at the site from a steel supplier (a different company from the suppliers involved in this project). After use, contractor “1” reported that the slings were sorted into their own fraction and discarded in containers. It means that the slings are not mixed with other

types of residual waste. Since the steel supplier did not have a sling return scheme, all the discarded slings were sent to a regional waste management facility (a different company from the one engaged in this project). Such company was contacted to investigate more in depth the downstream solutions. They answer was:

"...here at X, another company (a large-scale national recycling and waste management company) operates the sorting plant. All mixed waste that comes in is sorted and handled by them. You should therefore contact them instead."

An interview was held with the suggested waste company. The questions were related to downstream solutions of synthetic lifting slings and material flows. The answer was:

"...we have no source sorting solution and no functioning downstream solution for lifting slings. It mostly comes in as mixed residual waste, but here too it represents a problem as it can stop the grinding process. So as of today, lifting slings are in a way "unwanted" and expensive. That said, the volumes are also vanishingly small, so there is no real problem."

The good practice of Contractor "1" in sorting the slings into their own fraction loses its effectiveness once the slings arrive at waste management companies that do not have downstream solutions. Consequently, the slings previously sorted at the construction site (Figure 9) end up being mixed with residual waste for subsequent incineration at the waste treatment facility.



Figure 9 – Slings sorted into their own fraction at construction site. Source: Contractor X.

The other project had 468 000 m² and was located in southeastern Norway. It consisted of a bus route including a road, bridge and culverts. Around 10 tonnes of synthetic lifting slings were received at the site from steel supplier "B" (one of the suppliers involved in this project). In this project, approximately half of the slings (5 tonnes) were sorted for reuse or recycle (via return scheme) while the rest were sent to disposal for incineration given the discard criteria. The visibly useful slings were delivered to steel supplier "B" which classified the slings for recertification or recycling. If slings are suitable for recertification they must be inspected by a certified body to guarantee that slings can be reused, by extending their useful life for another 12 months. If slings are not suitable for recertification, they are sent to a waste treatment company in partnership with recycling plants.

In this case, the good practices of Contractor “1” and Steel supplier “B” – sorting the slings for subsequent recertification and recycling following a return scheme, comes into effect due to a formalized system. Both contractor and steel supplier collaborate together, assuming a key role in the circularity of slings by taking responsibility and ensuring that the slings can be incorporated into subsequent lifecycle stages.

Figure 10 illustrates an example of the joint efforts between the supplier and the contractor under a returning scheme that facilitates further handling and inspection. For more information about the best practice, visit the link: <https://www.smithstal.no/article/nyheter/resertifisering-av-stropper-baerekraft-i-praksis-med-positiv-bieffekt>



Figure 10 – Example of best practices from a steel supplier and contractor in sorting slings under a return scheme. Source: Smith Stål and Brødrene Ulveset.

Contractor "2" reported that 182 tonnes were sent to a waste facility in one project, with lifting slings mixed with residual waste streams. The project consisted of 15 km of new highway with parallel local roads. The contractor also expressed concern about the amount of sling being discarded and noted that the company adopted a sorting practice:

"...we have started sorting out this fraction now. Collecting defective loading slings in pallet frames in the warehouse at the project."

The challenge arises when the slings leave the construction site and are delivered to waste treatment companies with no downstream solutions. Contractor “2” pointed out:

"...X, which is a recycling company, only accepts loading slings as part of the residual waste fraction."

Similar to the first project example described for Contractor “1”, Contractor “2” also demonstrates commendable diligence by sorting slings into a dedicated waste fraction. Without an integrated end-to-end recovery system, coordinated action across the entire waste chain, even more robust on-site sorting practices and return schemes, the whole system fails to deliver environmental value.

4.1.2.3 Waste and resource management

Three different end-of-life stages for synthetic slings were identified, such as slings processed as residual waste, for reuse, and for recycling.

(i) Slings processed as residual waste

Depending on the project location or specific circumstances, discarded slings may be sent directly to large-scale national waste facilities or first to a regional waste management company, which subsequently forwards them to the national facilities.

A national waste treatment company which received the discarded slings from one of the contractors participating in this project was interviewed. The explanation given demonstrate, to some extent, the common challenges faced by waste companies without downstream solution:

“...syntenic lifting slings are tough and difficult to grind. They also easily get tangled on grinder shafts and create large repair and maintenance costs. This also applies to all ropes and nets. It is some terrible stuff if this gets tangled on the shaft, it spins around and “glues” itself onto it. There are probably few syntenic slings in Norway that go directly to incineration. Most incinerators (which have silo reception) also have grinders where the waste must be ground before the waste is loaded into the combustion chamber. And they have the exact same “challenge” with slings getting tangled up on the shaft during grinding. If the slings had been easy to grind, I’m guessing most of them would have been incinerated.”

It means that synthetic slings are not burned directly, not because the material cannot burn, but because waste incinerators shred most waste first, and the equipment cannot process them easily. Due to recurrent mechanical problems, the company described the following approach:

“.. so these (syntenic lifting slings) are picked out from the residual waste if they are uncovered and placed in a container intended for landfill. If clean/sorted slings/ropes come in, these are placed directly in the same container. When there is a full load, this is transported to a landfill. We deliberately use the authorities' terms associated with waste management. That is, landfill where the waste is buried in an approved landfill as final treatment.”

The current mechanical issues result in the slings being sent to landfill for burial, which is the least preferred alternative from a circularity perspective, although waste is safely and legally buried in a regulated landfill as the ultimate method of disposal.

(ii) Slings processed for reuse

In Norway, the Labour Inspection Authority (Arbeidstilsynet) sets the requirements and criteria for the inspection of lifting slings. According to national regulations, slings may only be recertified by a competent enterprise, rather than by a competent person as stated in EN 1492. A competent enterprise must be certified by a certification body, which in turn is authorized by the Labour Inspection Authority.

Participants of the project argued that the Norwegian methodology for annual inspection of lifting slings discourages its reuse. The increased bureaucratic complexity through the involvement of multiple agents and the total costs for recertification are the main reasons.

Slings producer and suppliers believe that the control structure represents regulatory and legal barriers that hinder the circularity of synthetic lifting slings. Participants also compared the Norwegian annual inspection system with its implementation in other Nordic countries, such as Denmark (Figure 11).

In Denmark, the Danish Working Environment Authority mandates that inspections and approvals for reuse must be conducted at least every 12 months by competent persons, according to the standard EN 1492. Some providers of lifting slings execute inspections and recertifications, with accredited service technicians who are continuously educated and trained. The recertification process includes visual inspection or non-destructive testing.

A set of Danish suppliers and contractors were contacted to investigate more in depth the recertification processes and reuse practices, but they declined to participate.

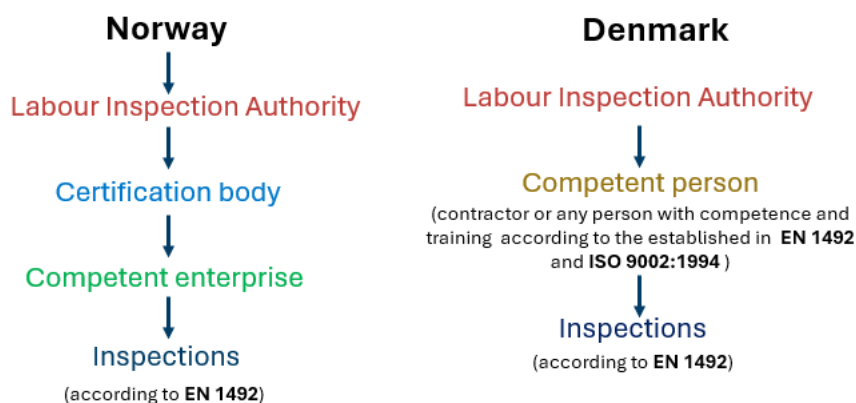


Figure 11 – Comparison of the inspection and recertification system between Norway and Denmark.

Source: Data collected from producer, the Norwegian Labour Inspection Authority and the Danish Working Environment Authority.

Participants also pointed out to the economic challenges that hinder slings reuse in Norway. The main constraint is that the process of recertification is more expensive than buying new slings. The duration of the recertification process can take weeks, depending on the volume. For example, to rectify 400 pieces of slings, the total cost is around 15000 NOK. The price of each recertified sling is about 40 NOK, excluding handling and transportation. The examination and recertification process, excluding administration, handling and transportation, can take about 15 hours if two people are involved.

The unit price of a new sling varies between 10 to 20 NOK, depending on the volume and exchange rates, and including VAT and transportation.

From the participants perspective, the feasibility of slings reuse in Norway is limited by the increased bureaucracy and duration of recertification and high cost when compared to the purchasing new slings. It results in huge amounts of slings being discarded indiscriminately per year (between 75 and 89 tons).

According to the slings producer:

“...the company highly benefit from this situation in Norway - both commercially and financially. However, the company is committed to values that promote a more sustainable society and environment and considers the efficiency in resource utilization as important as financial gains.”

Also added:

“...because lifting slings are cheap there is no financial reason to inspecting them carefully. Instead is better to discard them with a generous hand and buy new one so that all safety requirements are met.”

“...every time a lifting sling can continue in use instead of being discarded, the GHG emissions are reduced, which is in line with today's focus on the environment. The inspection and recertification system enforced in Norway, also prevent this.”

An interview was conducted with the Norwegian Labour Inspection Authority regarding the slings inspection and recertification system. The purpose was also to obtain insights into the barriers and challenges

expressed by participants. A chief engineer from the Department of Working Environment and Regulations stated that:

“...in Norway, the concept of a “competent person” responsible for the recertification of lifting slings is not widely institutionalized within the economic sector, reflecting a cultural approach to liability and risk management. In practice, this role is generally avoided because individuals or companies carrying out independent inspections (this is outside the framework of accreditation by a recognized certification body and the Labour Inspection Authority) are reluctant to assume legal responsibility for potential serious losses (fatal accident, injuries, or economic losses due to material or equipment damaged), even when they possess the required training and technical expertise.”

It was also highlighted that the Norwegian safety culture and regulations have evolved differently from its Scandinavian neighbours (Sweden, Denmark, and Finland) due to several historical and industrial factors.

Norway's economy historically centred on resource extraction industries with inherent physical risks requiring strict safety protocols. The Oil and Gas industry led Norway to develop one of the world's most stringent offshore safety regimes. This created a robust safety culture that spread to other sectors.

Norway also adopted a "functional" regulatory approach that emphasizes performance and results rather than prescriptive requirements. This places responsibility in organizations to demonstrate safety through evidence and testing rather than just following specific rules. The representative of the Norwegian Labour Inspection Authority remarked:

“... the owner of slings is always responsible for this type of controls. A competent enterprise is not going to control slings by itself. It's owners' responsibility to deliver slings to a competent enterprise for control. If the slings do not meet safety requirements, then the competent enterprise recommend not to use it, but cannot forbid to use it. Just owner of slings and Arbeidstilsynet (Norwegian Labour Inspection Authority) can stop work with not approved equipment according to regulations concerning the performance of work § 12-5.”

This statement encapsulates the “Norwegian philosophy” in which people own the outcomes of their safety decisions. In this case, the outcomes of decision-making are embedded in a chain of responsibility rather than in individuals (i.e., the figure of competent person as described in EN 1492).

Example of slings reuse for other purposes

A meeting place was created at Åsen (Stavanger borough of Hillevåg). The project was led by the New European Bauhaus Stavanger (NEB-STAR) in collaboration between architects from Helen & Hard, students from construction at Jåttå Upper Secondary School, students from Stavanger Urban Folkehøgskole (STUF), Ungt Entreprenørskap Rogaland, Stavanger Municipality, Smedvig, and Site 4016. The meeting place was designed as site where parents can bring children and experience regenerative building processes in which reuse, and circularity are integrated. Ratchet straps that were discarded from the industry were reused to make outdoor structures and a temporary storage of reusable materials, as shown in Figure 12.

Feedback from users of the meeting place was gathered. An actor from the construction industry said:

“...using discarded ratchet straps from the industry to make outdoor furniture is brilliant. I see great potential for social entrepreneurship here. For example, could a sheltered workshop or inmates at Åna prison make ratchet strap beds instead of building pallets?”

More information about the project can be found in: <https://nebstar.eu/reports/d3-4-demonstrators-at-site-4016-version-2/>



Figure 12 – Meeting place and a temporary storage of reusable materials. Source: NEB-STAR.

(iii) Slings processed for recycling

Steel suppliers have specific environmental goals related to synthetic lifting slings, for example, that 10% of the slings shall be from recycled material. The aim to increase this gradually.

When the synthetic lifting slings are worn out, it can either be recycled to produce energy such as electricity and heat through incineration, or to produce new materials through processes such as chemical recycling. In Norway, there are no recycling plants for this type of synthetic slings, so they are recycled in different European countries such as, Netherlands, Lithuania and Spain. Asia is also an alternative.

The waste management company participating in this project is actively involved in recycling and collaborates with recycling facilities. According to them between 1000 and 1500 tons of synthetic slings are recycled per year. The company also explained:

“... such amount (between 1000 and 1500 tons) also contains mixed volumes of synthetic ropes as there is no separate scheme for this fraction in Norway.”

According to them, if sorting is done correctly almost 100% can be recycled. There can always be material damaged in smaller fractions due to pollution and wear, but it is not fully determined or clarified how much is affected. The volume (ton/year) for energy recovery is uncertain, but they assumed to be a large percentage.

The producer of synthetic slings being used by suppliers was also interviewed about their recycling practices. A common approach is the mechanical recycling consisting of breaking down the slings into smaller fibres and melting the shredded polyester to form new fibres or plastic products. The main constraints of this process are on quality, once the recovered fibres may be mechanically weaker than virgin fibres thus limiting their use in high-strength applications like lifting slings. They are then repurposed for non-critical applications, such as in the automotive industry used for acoustic or thermal insulation. Other applications can be for stuffing, or composite materials. However, these areas have small demand compared to the huge stock of recycled material. The slings producer also stated that:

“...recycling processes of synthetic slings are still expensive and sometimes more carbon intensive processes than virgin material production.”

The producer is currently participating in a pilot project together with Coca-Cola and other companies, aiming at investigating the efficiency of chemical recycling of reused PET. Nowadays, the raw material is primarily polyester from bottles and shoes, but there is potential for widely collect polyester from other products in which slings can play a key role. The material breakdown process of such reused plastic types involves chemicals. The producer has signed a non-disclosure agreement and cannot disclose details, but it is common knowledge that glycol can be used as a reactant in the chemical depolymerization of polyester. Although the pilot is under development, a set of preliminary opportunities were pointed out by the producer:

“...if chemical recycling can be done in an economically viable manner, this process will be able to replace virgin polyester 1:1 as there will be no reduction in quality.”

“...energy consumption can be significantly reduced, but not clear data was obtained until now.”

“...concerning the recycling plant capacity, it would be good if the plants can process 1 thousand ton per day, but today they only can process 1 hundred ton per day.”

Key challenges of chemical recycling of reused PET were also described:

“...preliminary studies show that the price of reused PET in the required quality is 5 to 10 times higher than the price of virgin polyester.”

“...higher GHG emissions compared to the breakdown process of virgin materials – for example, due to recycling plant remoteness. Today there are some plants in Europe, but these are not yet sufficiently developed to be an ecologically viable alternative in our opinion. It is possible to recycle economically and ecologically viable in Asia, but this requires sea transport.”

With increased policy support, investment in infrastructure, and process optimization the chemical recycling of PET has the potential to replace virgin polyester, contributing to significant reductions in the reliance on fossil-based raw materials, lower lifecycle GHG emissions and promoting circularity.

4.2 Material flow analysis of synthetic lifting slings

Figure 1312 illustrate the material flow analysis showing the origin, distribution, and end-of-life treatment of the investigated lifting slings. A combination of shapes, arrows, and colours is used to clearly distinguish between different actors, processes, and material flows. Rounded rectangles represent the main stocks. Parallelograms indicate actors within the supply chain. The orange colour indicates suppliers as participants of this project while the smaller dark grey parallelogram symbolizes other suppliers not participating in this

project. Diamonds depict decision points that separate between “Yes” or “No” outcomes, guiding flows toward different end pathways. Arrow thickness conveys the magnitude of each flow, with thicker arrows representing higher quantities in tons per year and thinner arrows for lower volumes. Arrow colours provide additional meaning such as blue for flows to waste, green for recycling, red for recertification/reuse, and yellow to depict the flows between contractors and suppliers through a return scheme (yellow dashed indicate that data is unknown).

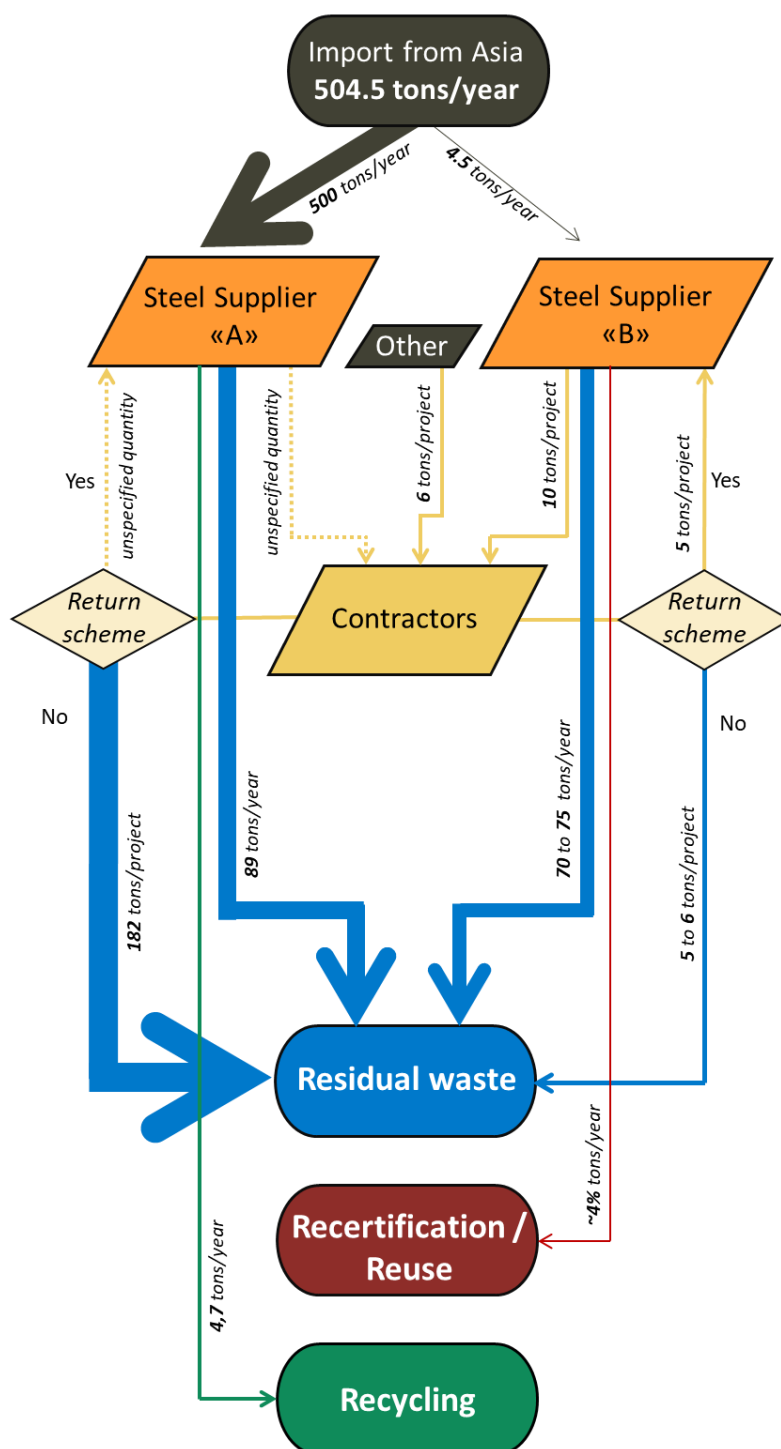


Figure 13 – Material flow analysis of synthetic lifting slings. Source: Data collected from participants.

At the top, the main input are the slings imported from Asia (504.5 tons per year) which are distributed between two steel suppliers: Supplier “A” (500 tons/year) and Supplier “B” (4.5 tons/year). These suppliers then deliver the material with slings to construction sites. If there is a formalized return practice between supplier and contractors, the slings flow back to suppliers for recertification and further reuse or for recycling when collaborations with waste management services are established. If not, the materials flow toward residual waste. A major portion ends up as residual waste, with 89 tons per year from Supplier “A” and 70–75 tons per year from Supplier “B.” According to Supplier “B,” a very small fraction is recertified for reuse, while Supplier “A” sends around 1% for recycling, all together completing a partial circular loop. When contractors do not implement a return practice to suppliers, the slings (whether separated into dedicated fractions or mixed with residual waste) are sent directly for incineration or landfilling. Overall, the figure illustrates that the majority of synthetic lifting slings are lost as waste, with a small proportion being recycled or reused. The diagram emphasizes the importance of return practices and recycling measures to reduce environmental impact and improve material efficiency in the supply chain.

4.3 Life Cycle Assessment of synthetic lifting slings: the impact of GHG emissions

The total GHG emissions of one ton of *Endless* slings varies between **3670 kg CO₂ eq. per ton** (100% virgin polyester, incineration with energy recovery) and **1466 kg CO₂ eq. per ton** (25% recycled polyester content, recertified and recycled). **The total reduction in emissions is almost 60% due to energy savings.** Recycled polyester content reduces the energy use tied to raw material extraction and refining. The processing of virgin polyester requires more energy than processing recycled PET. If the slings are recycled at end-of-life into new polyester, that reduces the need for virgin production in the next loop. Recycling also avoids incineration or other energy-intensive waste treatment.

The production of the investigated slings includes three variations in sling material composition (100% virgin polyester, 90% virgin polyester and 10% recycled from PET bottles, 75% virgin polyester and 25% recycled from PET bottles). Transportation to and within Norway, manual handling, and use (in which recertification process for reuse were accounted) were the stages with the lowest emissions. For the End-of-life, five scenarios were modelled according to the alternative waste treatments described by participants and other relevant actors, such as: (i) incineration with energy recovery; (ii) buried in landfill; (iii) recertified and no recycled; (iv) no recertified but recycled; (v) recertified and recycled.

4.3.1 Production (A1 – A3)

The total emissions from production consist of emissions from raw material extraction and production (A1–A2) of virgin polyester and recycled polyester from PET bottles, as well as emissions from slings manufacturing (A3), which includes the stitching process, other treatments, and packaging.

To produce one ton of *Endless* slings, the GHG emissions from virgin polyester are about 2200 kg CO₂ eq. per ton. When 10% to 25% of recycled polyester from PET bottles is used in slings nearly 5% and 13% of emissions are avoided per ton, respectively. The production of virgin polyester is a process with high energy intensity due to chemical transformation of crude oil and subsequent polymerization. Mechanical recycling of PET bottles into polyester is a proven and effective method for reducing environmental impact. The manufacturing process emits approximately 250 kg CO₂ eq. per ton, in average.

Overall, the production emissions for one ton of virgin polyester slings are 2450 kg CO₂ eq., while 2325 kg CO₂ eq. and 2138 kg CO₂ eq. are emitted from the production of slings with 10% and 25% of recycled polyester.

4.3.2 Transport (A4)

The transportation of slings to Norway involves two main stages: international shipping and domestic distribution. For international shipping from Asia to Oslo, the slings travel approximately 20 000 km by container vessel. This corresponds to roughly 323 kg CO₂ eq. per ton of slings. Once in Norway, distribution

occurs primarily by truck. For practical calculations, an average distance of 400 km and a 16–32 ton EURO 6 diesel truck were assumed based on the data collected from participants. The domestic transport results in approximately 25 kg CO₂ eq. per ton. The estimation of combined transport emissions is 348 kg CO₂ eq. per ton.

4.3.3 Handling (A5)

Manual handling of slings does not directly generate emissions. Any machinery used during installation is typically already present on-site for other purposes, and only a small fraction of their operational emissions is allocated to the sling installation. As a result, the associated emissions from manual handling and incidental machinery use are minimal, estimated at approximately 5 kg CO₂ eq. per ton.

4.3.4 Use (B1 – B7)

Slings that are used for 12 months and discarded as waste results in negligible emissions, estimated at 0 kg CO₂ eq. per ton.

If slings are to be used for other 12 months, the recertification process introduces additional emissions. Based on data collected from participants, recertification involves approximately 15 hours of labour for two personnel to process 400 slings, equivalent to nearly seven working days per ton. Energy consumption during this process contributes around 15 kg CO₂ eq. per ton, while transport to and from the recertification facility adds roughly 25 kg CO₂ eq. per ton. Administrative tasks further account for approximately 5 kg CO₂ eq. per ton. Altogether, the total emissions associated with extended use (only for 12 months) are estimated at 45 kg CO₂ eq. per ton.

4.3.5 End-of-life (C1 – C4)

For Scenario 1, incineration with energy recovery, there was uncertainty among participants regarding the amount of energy recovered from incineration processes. Figure 14 shows raw estimations based on data from EU waste-to-energy reports. For one ton of polyester slings, approximately 60% of emissions (800 kg CO₂-eq.) can be reduced through combined heat and power recovery mode, in addition to the reductions achieved during sling production with different material contents.

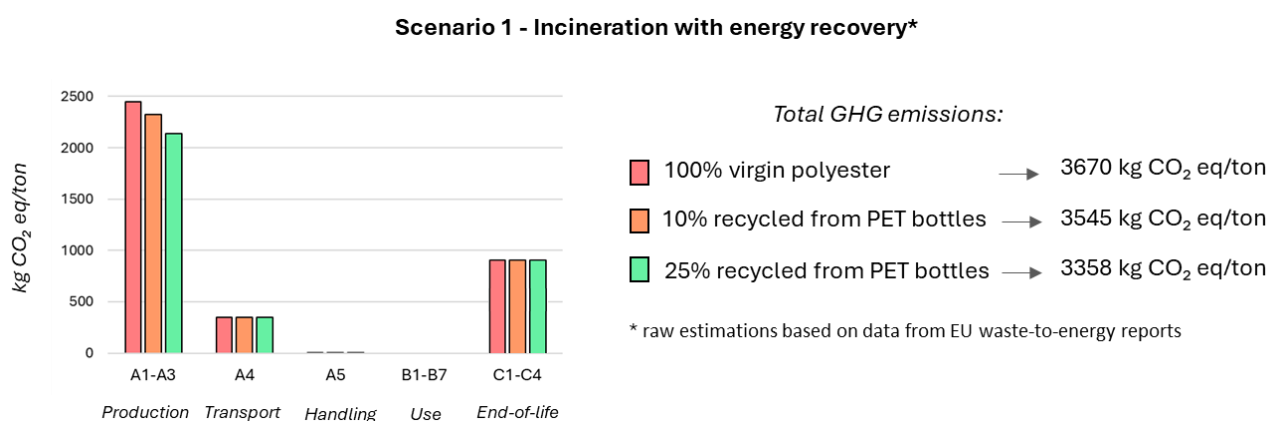


Figure 14 – Total GHG emissions from Scenario 1, over 12 months and across the three variations in sling material composition

Scenario 2, involving burial in a landfill, is not a conventional approach but is adopted by some waste treatment companies to address the recurring mechanical challenges and operational problems during the

incineration process (more details in section 4.1.2.3 – slings processed as residual waste). Figure 15 shows the total emissions including impacts from landfill and land use.

From a GHG emissions perspective, this waste treatment method has lower releases than incineration scenarios. The potential of reduction is between 42% and 23% depending on whether the energy is recovered or not. Although slings are legally buried in a regulated landfill, the consequences of the slower (or no degradation at all) of plastics is unacceptable for the “zero waste hierarchy”.

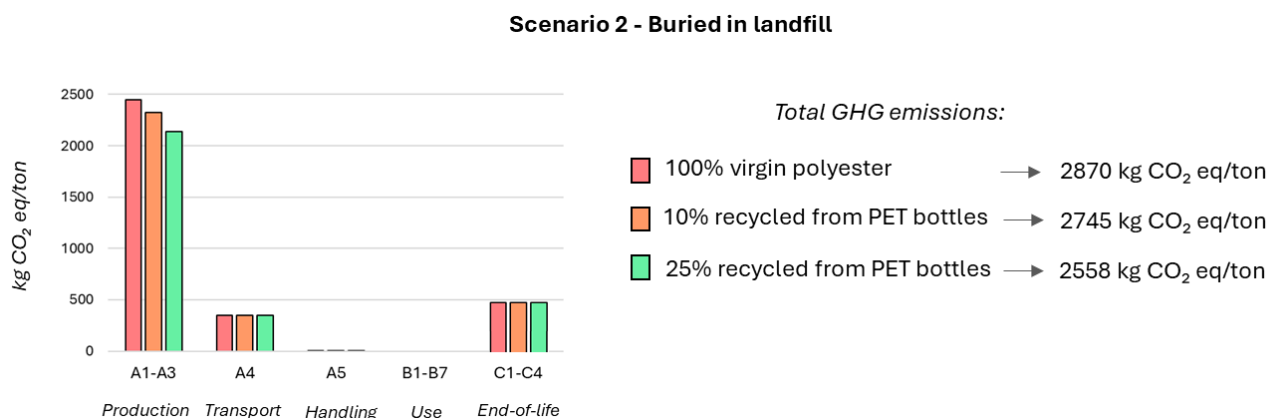


Figure 15 – Total GHG emissions from Scenario 2, over 12 months and across the three variations in sling material composition

Emissions from Scenario 3, recertified and not recycled, over 24 months. This scenario assumes a conservative practice, meaning that the use of slings is extended for 12 more months following annual inspection and sent to landfill after 24 months of usage (Figure 16). The potential for reduction along 24 months against scenarios 1a, 1b, and 2 (which are set for 12 month) are 70%, 60%, and 50%, respectively.

Recertification processes contribute with 45 kg CO₂ eq. per ton. In the worst case, slings can be sent to incineration which adds almost 500 kg CO₂ eq. per ton to the total emissions. In average, it results in more than 4000 kg CO₂ eq. per ton over 24 months.

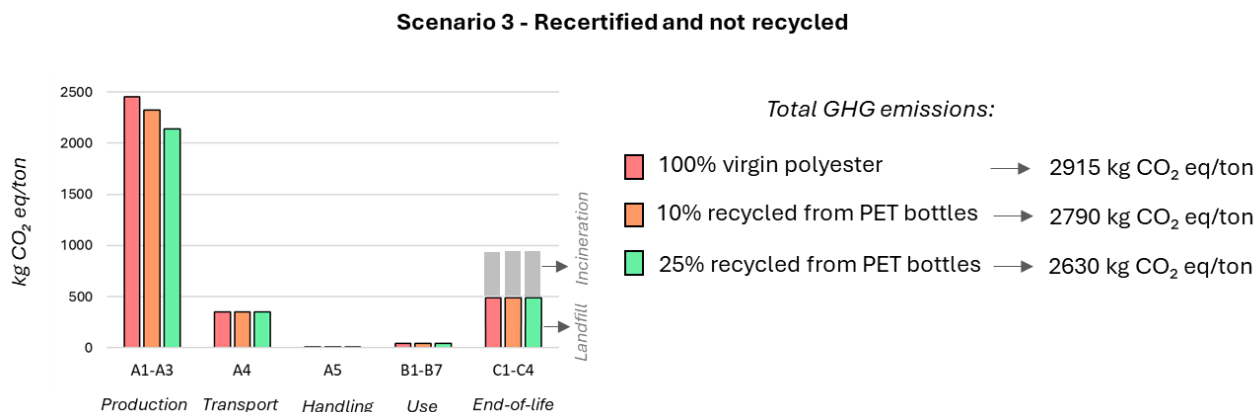


Figure 13 – Total GHG emissions from Scenario 3, over 24 months and across the three variations in sling material composition

Scenario 4, not recertified but recycled, demonstrate that emissions associated with the production, transportation from producer to suppliers, and handling of slings are partially mitigated through recycling. This scenario assumes that the slings are *not reused* after annual inspection but are sent to *recycling plants* (for mechanical recycling) within the EU. The transportation of slings contributes approximately 105 kg CO₂ eq. per ton, while the recycling process itself accounts for 770 kg CO₂ eq. per ton. Together, these steps result in a total of 875 kg CO₂ eq. per ton, highlighting the significant impact of recycling in offsetting the initial emissions (Figure 17). Further optimization of chemical recycling in polyester slings can increase emissions reduction in the future.

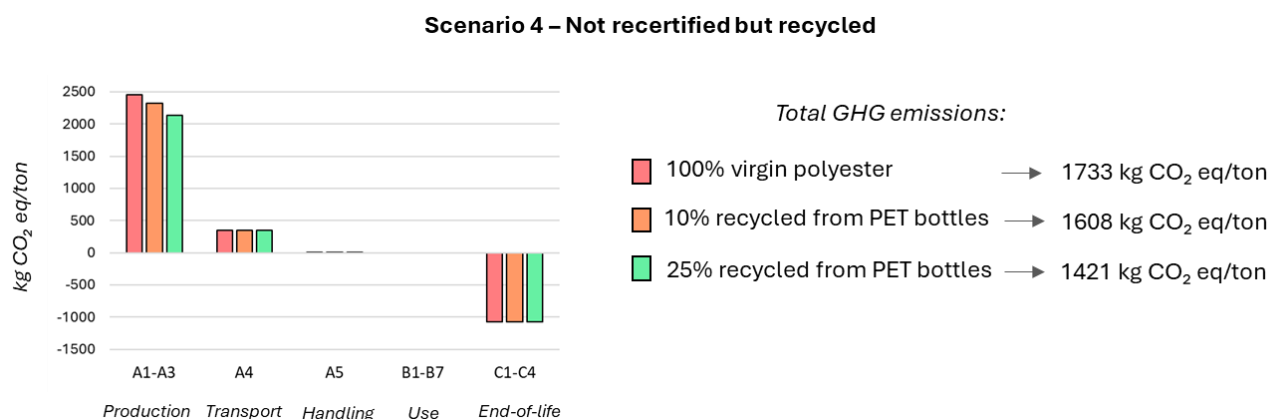


Figure 147 – Total GHG emissions from Scenario 4, over 12 months and across the three variations in sling material composition

Scenario 5, recertified and recycled, is the best approach, since it combines resource efficiency with reduced environmental impact, optimizing both material reuse and sustainability. It is assumed that the use of slings is extended for 12 more months following annual inspection and sent to mechanical recycling after 24 months of usage. Figure 18 indicate the total emissions in scenario 5 are slightly similar to scenario 4 (no recertification but recycled). The difference is that the emissions in scenario 4 are for 12 months while in scenario 5 are over 24 months.

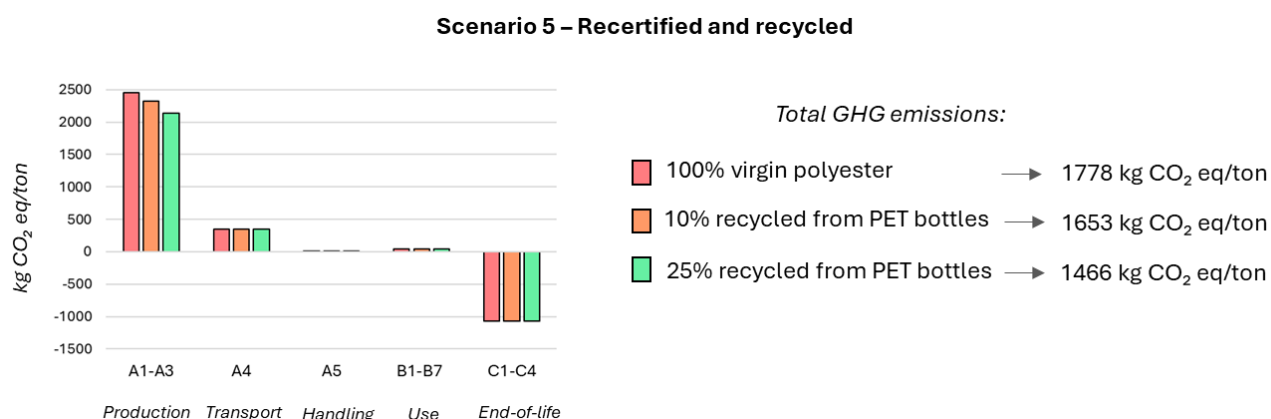


Figure 18 – Total GHG emissions from Scenario 5, over 24 months and across the three variations in sling material composition

5 How to achieve circularity with more reuse and recycling of synthetic lifting slings?

A set of barriers and opportunities for the circular transformation of slings were collected from the participants. The main barriers identified were the current fragmentation of practices and lack of formalized systems to implement return schemes and to standardize on-site sorting practices. The high costs and bureaucracy of the recertification process in Norway, when compared to the low price of slings, discourage reuse. This leads to the discard of a huge number of slings without any consideration for environmental impact. Addressing fragmentation is particularly crucial to ensure a successful circular transition. Stakeholders must be committed to drive circular practices for synthetic slings, through the systematization and assignment of roles, responsibilities, and goals. There were no established circular models identified among participants, even though circular solutions are considered positive and necessary.

Through this project, regulatory and economic barriers were identified, however, how to influence them must be further explored. Reduced the consumption of new slings and increased reuse must be another goal among stakeholders. Although there are still some challenges pointed out by participants about the recertification process in Norway, this goal can still focus on keeping them in use and find ways to return them to the economy (preferably for the same purpose the slings were created for, or other similar purposes) instead of discarding them.

Best practices were identified between contractors and suppliers involving returning and sorting practices that actually enabled reuse of a portion of slings for the same purpose they were designed for. In a lesser extent, recyclability was also recognized but the material recovery process does not achieve full circularity, as recycled content is not being reincorporated into new sling manufacturing.

Increase expertise on circular measures among stakeholders was also discussed such as training programs to improve the proper handling of slings, prevent damage, and ensure correct sorting between recyclable fractions and residual waste. The initiative also strengthens trust and collaboration between suppliers and construction companies. Goals and key indicators must be further formalised into the management systems of suppliers and contractors. For example, by increasing the adoption of slings with a certain recycled material content and better control of the quantities sent for recertification, recycling, or residual waste.

An existing opportunity considered by some contractors as an important innovation is the scanning of pallets with mobile phone to “activate” new slings for 12 months of use. Increased reusability was also not considered to create additional safety risks or lead to economic problems.

In terms of safety and quality, inspections are primarily visual and linked to the age of the slings (max. 12 months). In terms of sustainability, slings are partly reused, and a small amount go to recycling thus used slings often end up in residual waste.

Pilot-scale facilities have begun to make headway in recycling of plastic, textile, food, and other waste components. Studies show that turning waste plastics into useful chemicals could help improve current recycling methods. However, when trying to do this on a large scale (real-world waste like mixed plastics), items made of both metal and plastic, and general household trash makes the process more complicated [18]. Ongoing efforts are required to enhance the efficiency and reduce the energy demands in the recycling processes. Currently, chemical recycling of plastic waste shows significant potential to become a key method for effectively decreasing the volume of waste that are sent to incineration and landfills.

In line with [15], transforming supply chains represents a crucial pathway toward achieving a circular economy. Today, the use of synthetic lifting slings relies on international sourcing and virgin materials. By emphasizing secondary materials, regenerative resources, and sustainable sourcing practices the supply chain can be strengthened while reducing virgin material demand. The use of secondary materials in lifting slings such as PET from bottles is already a well-established practice to reduce virgin material. From a safety and durability perspective, the use of virgin material in slings is inevitable. However, the manufacturing,

disposal, or recycling of plastic materials should be as sustainable as possible. This can be achieved through the decarbonisation of processes (i.e., capturing and storing carbon), fossil fuels substitution low- or zero-carbon energy sources, and efficiency improvements to lower emissions.

Addressing the current regulatory and economic barriers described for the Norwegian sector will also require collaboration and involvement of various stakeholders to achieve a broader adoption of circular business strategy for lifting slings.

In Norway, new national rules require municipalities and businesses to separate textile waste and ensure separate collection with the aim to material recycle. Although framed as “textiles,” the obligation is technology-neutral and making it applicable to technical textiles such as polyester slings. Norway typically incorporates EU product and waste rules, part of the European Economic Area. The EU's Packaging Product Waste Regulation (PPWR) could change how slings are managed in terms of more reuse and recycled content as a plastic packaging, but not the sling's safety design, which remains under EN 1492. In May 2025, Norwegian governmental agencies were asked about the PPWR and its applicability to synthetic lifting slings. The Norwegian Environment Agency (Miljødirektoratet) said that it is a bit uncertain, and that it is possible that there will be an exception for these. The official Norwegian legal information system, Lovdata, was also consulted and they stated that the packaging regulation has not yet been incorporated into the EEA Agreement and is therefore not yet applicable to Norway. They also recommend contacting the Ministry of Climate and Environment (Regjeringen) for further information. Several attempts were made to contact the Ministry of Climate and Environment, but no response was received.

Recent initiatives, including pilot projects focusing on repairing, reusing, and recycling safety clothes, and attempts to recycle maritime ropes made of polyester fibres, have emerged. These projects have encountered challenges with recyclability of the materials. They show that active partnerships, standards, and buyers are essential for recycling technical-textile polymers in Europe. These developments are directly relevant to sling makers and users considering take-back programs.

6 Conclusions

A circular approach to the slings investigated in this project should seek the integration of environmental perspectives, safety regulations, responsibility roles and interests in the everyday practice of the main users. The project was dependent on the information provided from participants to obtain a basis for mapping flows and practices as well as exploring user perspectives for assessing circular solutions. The main limitations were related to the availability of data – either because there was uncertainty about accurate sources and quantities, or due to lack of response/decline.

This study reveals that while there is recognition of the need and potential for circular transformation of synthetic lifting slings, significant systemic barriers prevent widespread implementation of circular solutions. The primary obstacles include fragmented practices, economic, and regulatory aspects which favour disposal over reuse or recycling. Collaboration between suppliers and contractors involving return schemes and sorting is almost case-specific or context-dependent.

The fragmentation is evident, while some contractors sort diligently and some suppliers operate return schemes, the majority of slings (89+ tons annually from just two suppliers) end up as waste due to lack of coordinated downstream solutions. When the slings are sent for incineration, the waste is first shred. Most waste facilities face difficulties in processing these materials effectively due to mechanical issues - the slings jam grinding equipment and create expensive maintenance problems. This forces operators to either manually remove slings for landfilling or deal with costly equipment repairs. If slings are sent to landfill, the waste management services use the authorities' terms associated with waste management. That is, landfill where the waste is buried in an approved landfill as final treatment.

The LCA demonstrates that material composition changes (using recycled content) and end-of-life treatment are the most significant factors affecting emissions. The best-case scenario (25% recycled content with

recertification and recycling) achieves nearly 60% emission reduction compared to worst-case disposal (100% virgin plastic and incineration with energy recovery). However, today's practices predominantly follow the worst-case pathway.

The current market valuation overrides the environmental benefits and the LCA also revealed a paradox. Recertification and recycling can reduce GHG emissions by more than 150%, compared to incineration and landfilling, because it does not just reduce emissions, it creates a net negative impact that saves more than the original emissions. Yet, the economic structure actively discourages these practices. At 40 NOK per recertified sling versus 10-20 NOK for new ones, thus the system incentivizes disposal over reuse despite clear environmental benefits. Along with this, the annual inspection approach in Norway requires certified enterprises rather than competent persons for recertification, compared to other Nordic countries, such as Denmark. According to participants, it creates additional bureaucratic layers that increase costs. Together, this combination of factors hinders the widespread adoption of the circular measures.

Despite these challenges, some contractors and suppliers have developed effective returning and sorting practices that enable partial reuse. Some innovation opportunities already exist, such as mobile scanning systems for sling "activation" related to new uses or QR codes for digital documentation and monitoring of slings across their useful lifetime. The use of secondary materials like recycled PET, and pilot projects for investigating the efficiency of chemical recycling of reused PET, show promise for improving circular economy outcomes. However, isolated improvements are insufficient.

The gap between existing best practices (lower reuse and recycling rates) and the scale of the problem (hundreds of tons annually discarded) suggests that fundamental system redesign is needed rather than incremental improvements to current approaches. Circular transformation requires coordinated action across multiple stakeholders to address supply chain reconfiguration, and the systematization of existing best practices into formalized circular management systems.

Further research should focus on specific cost-benefit analyses and detailed business case developments, by gathering learning from both international best practices and exploring incentives to make circular practices viable. Stakeholder engagement should be further explored, in terms of collaboration models, industry associations' roles, user attitudes, and performance measurement systems. GHG emissions calculations could be expanded along the supply chain and updated with new inputs. Pilot program developments can be also beneficial to test circular business models.

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