Nordic Council of Ministers

PRODUCT-SERVICE SYSTEMS IN THE NORDICS

Paving the Way for Circular Business & Sustainable Consumption

Table of contents

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1. EXECUTIVE SUMMARY AND KEY FINDINGS

Nordic businesses are increasingly exploring circular business models, while policymakers and public institutions in the region are prioritising the transition to a circular economy. This shift aligns with the Nordic vision to become the most sustainable and integrated region by 2030, delivering environmental, social, and economic benefits. Transitioning to a circular economy requires a fundamental departure from the traditional linear "take-make-waste" model, moving instead towards models where products and materials are used longer, creating value in innovative ways.

One promising approach for advancing circularity is the adoption of Product-Service-System (PSS) models. In these models, businesses retain ownership or control of products throughout their lifecycle, creating incentives for durability, quality, and extended use. This shift allows products to serve multiple users over a longer period, maximising their utility and reducing the need to produce new goods. By implementing PSS models, businesses can create new revenue streams through services such as rentals, repairs, and maintenance. Consumers, in turn, benefit from greater flexibility, improved access to high-quality products, and lower total ownership costs while contributing to a more sustainable system where fewer resources are wasted.

Despite the potential of PSS, broader implementation in the Nordics remains limited. While examples like car-sharing, facility management, and workwear rental services have gained traction, small and medium-sized enterprises (SMEs) and startups face significant challenges in scaling these solutions to achieve economic viability. Barriers include the deeply rooted culture of ownership, gradual adoption of sustainable consumption patterns, and market conditions that still favour traditional ownership models. Additionally, limited cross-border knowledge sharing and inconsistent industry collaboration slow the widespread adoption of PSS models and circular practices in the Nordics.

From 2021 to 2024, the project **"Product-Service Systems in the Nordics – Paving the Way for Circular Business and Sustainable Consumption"** has explored whether, when, and how PSS models can succeed in a Nordic context, delivering both resource efficiency and economic benefits. Through active stakeholder engagement – including 16 pilot projects across the Nordics – and comprehensive literature reviews, the project assessed key barriers to adoption, assessed the sustainability potential of PSS models, and provided actionable recommendations for their practical implementation. Moreover, the project aims to enhance regional cooperation by facilitating the exchange of insights and best practices, accelerating the adoption of PSS models and building synergies to overcome market and cultural barriers.

This report examines the conditions necessary for PSS success in the Nordics, highlighting key opportunities, challenges, and relevant policy frameworks. It provides specific recommendations for key stakeholders – businesses, policymakers, public institutions, and financial actors – who play a vital role in advancing the adoption of sustainable PSS models. Based on the project's findings, 13 key insights have been identified, offering a deeper understanding of how PSS models can enhance resource efficiency, promote circularity, and drive sustainable economic growth while addressing the barriers that need to be overcome for their widespread adoption.

Key findings

Targeted measures and policy support

A comprehensive policy approach and targeted measures are needed to incentivise PSS adoption and promote circular business models

Effective policy interventions are essential for creating a competitive landscape that supports circular business models, including PSS. Although PSS is recognised in EU and Nordic circularity strategies as key to advancing the circular economy, many policies fall short of translating this recognition into concrete, actionable measures. A more strategic and coordinated policy framework is needed – one that not only acknowledges PSS but also implements targeted actions to drive adoption. Current Nordic policies often lack the specificity and coordination needed to drive widespread change. For instance, Sweden's regulation on alternatives to single-use takeaway packaging has spurred investment in PSS and attracted B2B customers for reusable packaging. However, these efforts have not yet led to significant shifts in consumer behaviour or substantial environmental outcomes. This underscores the need for a strategic approach, combining targeted incentives for PSS with broader policies that promote resource efficiency and sustainable consumption.

The need for a green tax shift

Shifting the tax burden from labour to natural resources would further support PSS development, especially in the Nordic countries where high labour costs make services such as repair and maintenance expensive. By reducing labour taxes and increasing taxes on virgin resources, the cost of labour-intensive services – integral to PSS models – would decrease. Additionally, offering tax incentives, such as VAT reductions for repair, rental, and leasing services, would make circular service-based models more affordable and attractive to consumers, driving their broader adoption.

A "green tax shift" from labour to natural resources would encourage service-based business models

The role of EPR schemes

Implementing Extended Producer Responsibility (EPR) schemes can be a powerful tool for promoting circularity. By placing financial responsibility for end-of-life product management onto producers, EPR promotes the development of products designed for longevity, reuse, and recycling. However, for EPR to be fully effective, it needs to be complemented by other policy measures, such as policies targeting consumer behaviour or other stricter regulation on waste management. A coordinated approach across the Nordic region, integrating EPR with incentives for circular design, resource efficiency, and waste reduction, will create a more comprehensive shift towards sustainable business models like PSS.

EPR schemes can encourage reuse and waste reduction, supporting PSS adoption when combined with other policies

PSS success in the B2B sector

PSS models have shown some success in the B2B sector across the Nordic countries, although scaling remains a challenge due to various barriers. While economic viability is more easily achieved in B2B settings – thanks to economies of scale, long-term contracts, and TCO considerations – PSS adoption is still limited by factors such as market readiness, resistance to change, and the complexity of implementing new business models. The upcoming mandatory sustainability reporting requirements do, however, increase the appeal of PSS solutions, especially those that can demonstrate clear environmental impact reductions, giving businesses an additional incentive to adopt these models. B2B also allows for more efficient customer acquisition, as one contract can serve multiple end users within a company, unlike B2C models, which typically engage customers individually. However, despite these advantages, scaling PSS even within B2B remains difficult. To fully unlock the potential of PSS, significant efforts are needed to overcome these barriers and expand its reach into B2C and B2G markets, where changing consumer habits and rigid public procurement processes pose additional challenges.

PSS models have a higher success ratio in B2B markets due to economies of scale and more efficient customer acquisition

Scaling vs. personal touch

Many PSS services attract customers through a 'personal touch' - characterised by trust, personalised service, and flexibility – an aspect that is especially important for SMEs. Many Nordic PSS providers seek to expand their operations. However, scaling up while maintaining this connection can be challenging, as it requires significant resources and risks losing close customer relationships. As this personal connection is often a key reason customers choose PSS solutions, providers, particularly SMEs, need strategies to preserve it as they grow. An alternative solution is to expand PSS services by replicating successful models in other locations or market segments.

A highly personalised service is a selling point for many PSS, but makes it difficult to scale operations

Collaboration and knowledge-sharing

Enhanced collaboration between PSS providers – whether within the same product category or across different sectors facing similar challenges – can unlock significant synergies. Knowledge-sharing and best practice exchanges are essential for overcoming common barriers, such as scaling operations and developing effective customer engagement strategies. Greater collaboration can also lead to standardisation within sectors, making it easier for businesses to integrate PSS models into their existing frameworks. This collective effort will help PSS providers expand their market presence and innovate more rapidly, driving the broader adoption of circular business models.

Stronger collaboration and knowledge-sharing between PSS providers can help overcome common challenges and drive innovation and scalability

Environmental potential of PSS

PSS holds the potential of minimising environmental impact by decoupling resource use from economic growth. PSS aims to fulfil consumer needs using fewer products, thereby reducing resource consumption and waste generation. By adopting circular economy strategies, PSS providers can lower the use of virgin materials, decrease energy consumption, and minimise pollution and greenhouse gas emissions, contributing to improved resource efficiency and sustainability. This shift towards a service-based economy can promote the dematerialisation of society, where services, rather than physical goods, are central to economic growth. The three main types of PSS models – product-oriented, use-oriented, and result-oriented – offer varying levels of sustainability benefits, all with the potential to contribute significantly to environmental goals. However, unintended consequences must be considered.

PSS hold the potential for reducing resource use, emissions, and waste

Possible negative impacts

To fully realise the environmental potential, it is crucial to critically assess positive impacts and possible unintended consequences of the PSS, such as induced impacts and rebound effects. Induced impacts might occur through additional processes within the system, such as increased transportation, product maintenance, or the production of capital goods. Rebound effects – both direct and indirect – can also arise when the efficiency of a system leads to increased consumption, either within the PSS or in other areas. For example, services can increase the affordability of certain products, inducing increased consumption. PSS models rely heavily on user engagement, and their environmental performance is influenced by how users interact with the system, e.g. whether consumers return products as intended, or increase overall consumption of services. As a result, unintended or undesirable consumer behaviour can reduce or offset the potential environmental gains.

Potential drawbacks like rebound effects must be evaluated to maintain sustainability

Mitigating unintended consequences

Induced impacts and rebound effects are often difficult to predict, especially during the use phase, but they can be estimated through the use of tools such as Life Cycle Assessments (LCA). LCAs help PSS providers evaluate potential negative consequences and identify strategies to address them. Key aspects to consider in an LCA assessment include the functional unit and scale of the system, realistic assumptions on consumer behaviour, the number of products required, the rate of product loss, what the system replaces, and whether additional processes may lead to negative impacts. Conducting customer surveys and gathering user feedback are critical in assessing actual environmental impacts and potential unintended effects during the use phase. These findings can then be accounted for in the PSS design and implementation.

LCA helps to assess environmental gains and the effects of unintended consumer behaviour. Findings can be included in the PSS design and implementation

The social value of PSS models

Beyond their environmental advantages, PSS models can provide substantial social value for both consumers and local communities. Many PSS offerings, particularly membership-based rental models, foster a sense of community, while others offer personalised customer service experiences. The shared and more intensive use of products allows PSS providers to offer services at lower costs compared to traditional product sales, making certain products more affordable and accessible to consumers who might not otherwise have access. Additionally, because PSS models often rely on labour-intensive services such as repair and maintenance, they create valuable local employment opportunities. Highlighting these social benefits can help PSS providers attract customers who prioritise both social and environmental impact, reinforcing the market appeal of these models.

PSS models often provide added social value through personalised services, local employment, and fostering community engagement, further boosting their appeal

Changing the culture of ownership

One of the primary challenges facing the widespread adoption of PSS models is the ingrained cultural preference for ownership, which affects individual consumers, businesses, and public actors alike. Although certain PSS models, such as car leasing, have become widely accepted in the Nordics, many product categories face resistance due to emotional attachment, perceived convenience, potentially higher long term costs or concerns over control or safety. The success of PSS models hinges on shifting consumer behaviour and attitudes towards the concept of access over ownership. This can be achieved through clear communication of the benefits – such as cost savings, flexibility, and reduced environmental impact – along with addressing any potential drawbacks. Changing these deeply held preferences is key to unlocking the full potential of PSS in both consumer and institutional markets.

Changing cultural preferences from ownership to access is key to PSS success

The financial challenges

Innovative funding solutions and government support are needed to scale PSS, especially for SMEs

Overcoming financial barriers is critical to scaling PSS models, particularly for SMEs. Many PSS businesses face challenges in securing stable cash flows and aligning high upfront investments with long-term revenue generation, which can be at odds with traditional financial metrics. Financial institutions must innovate in how they assess the value and risk associated with circular business models, adopting approaches that account for the long-term value of PSS. Governments can play a key role by offering financial instruments that share investment risks, such as loan guarantees or co-investment schemes. Such support will provide the necessary financial backing to scale PSS models and embed them more deeply in the market.

Leveraging public procurement

Flexible procurement processes can unlock public sector adoption of PSS models

Public procurement holds immense potential for stimulating the growth of PSS models. While there are no significant legal barriers to adopting PSS in Nordic countries, many public institutions have yet to integrate PSS into their procurement strategies outside of sectors such as ICT and mobility. Complex procurement rules, lack of knowledge, and rigid framework agreements often hinder the adoption of innovative PSS models in public institutions. Addressing these challenges will require better training for procurement officers, increased market engagement, and the development of more flexible procurement processes that encourage the adoption of circular business models. Public institutions, by leveraging their purchasing power, can lead the way in promoting sustainable consumption and production patterns.

2. PSS IN THE NORDICS

This report marks the culmination of three years of dedicated research into the potential of Product-Service Systems (PSS) in the Nordic region. The aim is to explore when, how, and under what conditions PSS models can deliver resource efficiency and economic value.

The concept of PSS, which combines products and services with a degree of provider ownership, has been recognised as a powerful strategy for advancing the circular economy (CE) and improving resource efficiency (Reigado, 2017). Industries can implement circular principles and unlock new value-creation opportunities by emphasising the continued use of products through maintenance, leasing, or repair services. However, while PSS offers a promising pathway toward a more circular and sustainable economy, the success of these models is not guaranteed. Their ability to reduce material consumption and generate economic gains depends heavily on careful business model design, practical measures to curb resource use, and widespread consumer acceptance.

In the Nordic context, the adoption of PSS remains understudied (Hernandez, 2019). Although the region is often seen as a global leader in sustainability, limited penetration of PSS models across industries and countries reflects an untapped potential. Barriers such as a lack of cross-border knowledge sharing, inconsistent industry collaboration, and underutilisation of synergies persist. This report aims to bridge these gaps by examining the conditions necessary for PSS to thrive in the Nordics, providing a detailed analysis of the opportunities, challenges, and policy frameworks that can support PSS development and adoption.

Our aim is to contribute to a deeper understanding of how PSS can be harnessed to deliver both environmental benefits and economic growth. By fostering collaboration between Nordic industries and sharing best practices, this project seeks to chart a roadmap for scaling PSS models aligned with the region's strong commitment to sustainability and circularity. The insights in this report are intended to guide policymakers, businesses, and stakeholders in unlocking the full potential of PSS in the Nordic region.

2.1 About the project

In August 2019, the Nordic prime ministers and the Nordic Council of Ministers set forth a vision for the Nordic region to become the most sustainable and integrated region in the world by 2030. This vision centres on three key pillars: a green Nordic Region, a competitive Nordic Region, and a socially sustainable Nordic Region (Nordic Council of Ministers, 2019). Circular business models and innovation pathways are critical

components in realising this vision, as they foster resource efficiency, economic growth, and societal sustainability while reducing environmental impacts and promoting a more resilient economy.

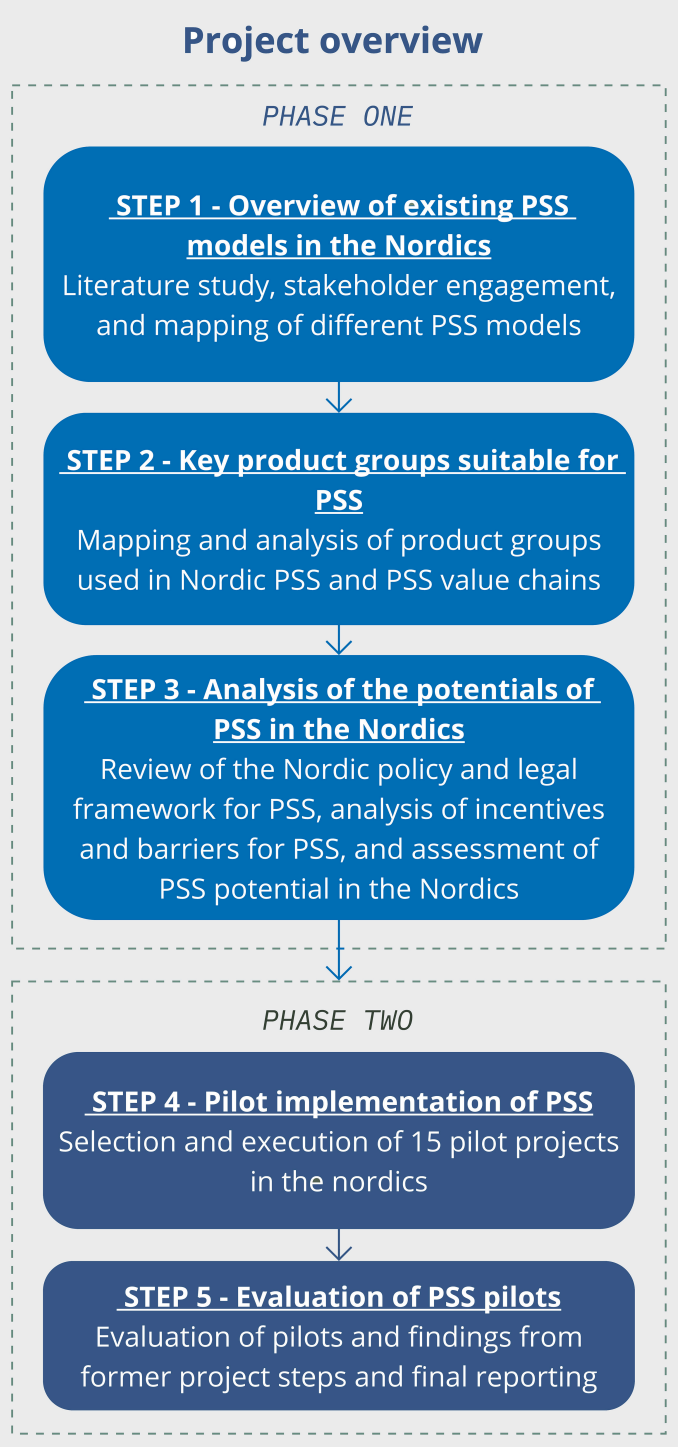

Figure 1: Project overview.

In support of this vision, the Nordic Council of Ministers launched the project **"Product-Service Systems in the Nordics – Paving the Way for Circular Business and Sustainable Consumption"** in November 2021. The project's purpose is to explore how, when, and under what circumstances PSS models can succeed in the Nordic context, delivering both resource efficiency and economic gains.

The project is structured into two phases with five key steps (illustrated in Figure 1).

- **Phase One** involved creating an overview of existing PSS models and identifying key product groups suited to PSS in the Nordic region. This phase also identified barriers to PSS adoption, including cultural, technical, economic, and regulatory challenges, and provided tools and recommendations for PSS providers. Twelve significant barriers and suggestions for improving regulatory frameworks to support PSS growth were highlighted.
- **Phase Two** focused on the selection, execution, and evaluation of 16 pilot projects, each representing different stages of PSS implementation across the Nordic countries.[1].These pilots were designed to test the feasibility of PSS models and their potential to deliver resource efficiency and sustainability outcomes. The projects spanned various industries and product groups, offering valuable insights into the practical challenges and benefits of PSS. This phase aimed to empirically validate the findings from Phase One, assess the scalability of PSS models and refine strategies for their implementation.

Phase Two also linked the empirical findings from the pilots to broader EU and Nordic strategies, offering a comprehensive analysis of how PSS models can be aligned with existing policy frameworks to drive sustainable business practices in the region.

This report integrates insights from both phases to provide a detailed understanding of the opportunities and challenges associated with PSS adoption in the Nordics, offering a roadmap for scaling these models to achieve both environmental and economic benefits.

1. An overview of the 16 pilot projects, including key activities, product categories, and lessons learned is provided in Annex 1.

2.1.1 Report structure

The report is structured in the following chapters:

Table 1: Structure of the report.

2	Regulatory framework for Nordic PSS models	This chapter provides an overview of current EU and Nordic action plans, strategies, and economic incentives supporting PSS development. It evaluates technical criteria, cultural barriers, and assesses if the current regulatory framework effectively addresses these challenges.
3	Introduction to PSS models and product groups	This chapter introduces established PSS business models, market trends, and perspectives. It also offers insights into tendencies across Nordic PSS models by product group, providing a broad overview before delving into detailed analyses.
4-13	PSS product groups and pilot findings	Each of these chapters focuses on one of the ten most relevant product groups in the Nordics, with insights into their subcategories. The chapters include theoretical and analytical introductions, followed by in-depth, empirically informed analyses of pilot-tested product categories, examining key drivers, barriers, and environmental potential.
14	Sustainability potential of Nordic PSS models	This chapter discusses the sustainability potential of PSS models, drawing on both theoretical insights and empirical data from the 16 pilot studies. It explores potential benefits, as well as risks, disadvantages, and unintended consequences associated with PSS implementation in the Nordic region.
15	Drivers and barriers to achieve the sustainable PSS model	This chapter explores challenges such as cultural attitudes toward ownership, financing, procurement, technology development, and documentation requirements.
16	Conclusions and recommendation	The final chapter summarizes findings and presents recommendations for three stakeholder groups: 1) Businesses exploring PSS development, 2) Policymakers promoting PSS adoption, 3) Public institutions seeking PSS solutions, 4) Financial actors improving financing access for PSS. The focus is on key enablers to support PSS development and the transition to a circular economy in the Nordics.

2.2 Defining product-service systems

Product-Service Systems (PSS) represent a shift from traditional product ownership towards more integrated, service-based business models. Several related concepts are used interchangeably, including Product-as-a-Service (PaaS) and Product-Ownership Model (POM), each reflecting different approaches to servitisation (Kim, 2019). These models share the goal of providing value through services rather than product ownership, with PSS encompassing the most comprehensive transformation towards sustainability.

- **Product-as-a-Service (PaaS)**: PaaS focuses on providing products as services, like Software-as-a-Service (SaaS), where customers pay for usage rather than ownership. It's commonly used in cloud computing but lacks the deeper systemic changes needed for sustainability, as seen in PSS.
- **Product-Ownership Model (POM)**: In POM, the provider retains ownership of the product and offers services such as maintenance and repairs. While it extends product life, it maintains the traditional ownership structure and does not fully integrate service solutions like PSS.
- **Product-Service System (PSS)** integrates PaaS and POM into a holistic approach, rethinking the entire product lifecycle, from design to disposal. It entails a systemic transformation of business operations, from cash flow and product design to supply chains and customer relationships, marking a full transition from linear business models to circular ones.

This report adopts PSS as the primary framework for examining sustainable business models, offering a broader perspective on how servitisation can contribute to a more circular economy.

2.2.1 The product-service systems archetypes

Despite multiple definitions in circulation, no universally accepted characterisation of PSS exists. One of the most frequently cited definitions comes from , who defines PSS as combinations of tangible products and intangible services designed for their joint capability of fulfilling specific needs while generating value. Tukker's framework breaks PSS into three primary orientations:

- **Product-Oriented Models:** These focus on selling tangible products with added services like maintenance and warranties. The core business remains product-based, but services enhance the customer experience and extend product life.
- **Use-Oriented Models:** Here, the product remains owned by the provider, and customers access it through leasing, renting, or sharing. This model promotes resource efficiency and longer product lifecycles by ensuring that the provider maintains responsibility for the product's condition and performance.

- **Result-Oriented Models:** Here, the focus shifts to delivering a specific outcome or performance rather than a physical product. Customers pay for the result, while the provider determines how best to achieve it, often without a predefined product being involved. This approach shifts the emphasis from owning or using a product to simply receiving the desired service or function.

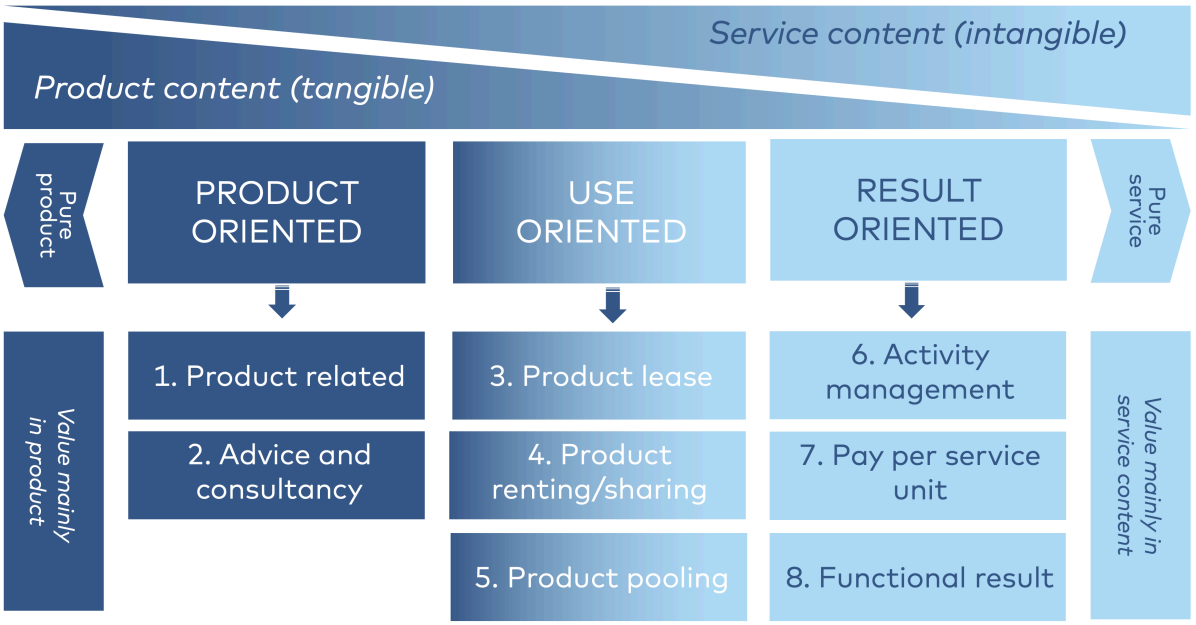

Figure 2: Eight archetypical models of product-service systems based on Tukker 2004. Adapted from Tukker (2004): Eight Types of Product – Service System: Eight ways to sustainability?

Tukker further expanded these orientations into eight archetypical models to capture the diverse ways PSS can be structured. Each archetype offers a different combination of economic, environmental, and service-related impacts, allowing for a more nuanced understanding of how PSS can be applied across various industries. These archetypes will be used throughout the report to explore how PSS can be applied in various industries and how each model influences environmental impact and value creation.

3. REGULATORY FRAMEWORK FOR PSS

The Nordic countries are recognised as global leaders in advancing circular economy (CE) initiatives underpinned by ambitious national policies and strategies. These strategies frequently emphasise the importance of circular business models as essential drivers of the green transition. However, despite this forward-thinking approach, the market penetration of circular business models remains relatively narrow, largely concentrated in areas such as waste management and the production and utilisation of secondary raw materials.

Other types of circular business models, such as PSS, continue to represent only a small fraction of the economic and material turnover (OECD, 2019). While certain PSS, like car-sharing platforms, have seen rapid growth, they still operate primarily within niche markets. For the Nordics to fully transition to a more circular and resource-efficient economy, there needs to be a broader adoption and integration of alternative business models, including PSS. Public policy can facilitate this shift, providing the necessary frameworks and incentives to scale PSS models more broadly across industries.

Policymakers can support the PSS development and implementation through indirect and direct interventions. Indirect support comes from general policy measures that create favourable conditions for PSS, while direct support involves adopting policies specifically tailored to promote PSS initiatives (Clemente et al., 2018). Thus, governments and public institutions can influence the demand for innovative business models through various instruments, including the implementation of national strategies, action plans and roadmaps; the introduction of new regulations, standard and control mechanisms; economic incentives such as tax breaks; subsidies and public funding programs; dissemination of knowledge through campaigns and labelling schemes; and direct public sector purchasing.

This section briefly discusses how policies can help to promote broader adoption of PSS in the Nordics. It offers a high-level overview of policy frameworks rather than a detailed analysis of specific PSS models in the Nordic countries.

Given this report's scope, exploring every possible variation is not feasible. However, the specific policy barriers and enablers identified through the pilot projects provide valuable insights into the existing policy landscape in the Nordic countries, which are discussed in more detail in the product-specific sections of this report. These examples illustrate the current challenges and highlight potential avenues for policy interventions that could support the scaling of PSS across the region.

3.1 Strategies and action plans to support PSS development

Overarching strategies and action plans at both the EU and national levels play a crucial role in shaping the vision and direction for the development of our economies and societies. Both at the EU and national level in the Nordics, PSS is increasingly mentioned in strategies aiming at resource efficiency, such as circular economy strategies. The following section provides a more detailed overview of the relevant strategies. To limit the scope, only strategies that directly reference PSS are included at the EU level while all key circular economy strategies are considered at the Nordic level, even if they do not directly address PSS.

3.1.1 Strategies at EU level

While there is no dedicated strategy for promoting PSS at the EU level, the concept – also often referred to as Product-as-a-Service (PaaS) by EU institutions – is explicitly mentioned in several recent EU strategies and implementation instruments under the European Green Deal. Most prominently, the New Circular Economy Action Plan (CEAP) seeks to incentivise product-as-a-service and similar models (European Commission, 2020). This inclusion reflects the EU's recognition of PSS as a key model for accelerating the transition to a more sustainable and circular economy.

However, despite this strategic recognition, there remains a significant need for further support to promote and implement PSS across the EU effectively. The current gap between high-level strategies and on-the-ground execution suggests that additional targeted measures are required to ease the transition from policy to practice. To illustrate the growing emphasis on PSS within EU strategies, the following table provides an overview of key EU strategies explicitly mentioning PSS, highlighting their role in advancing the European Green Deal objectives.

Table 2: Overview of EU strategies, year of adoption, and related PSS-references.

EU Strategy	Year	PSS-reference
European Green Deal (EGD)	Adopted in December 2019	The EGD aims to support new business models for a clean and circular economy and indirectly refers to PSS: **"New business models based on renting and sharing goods and services** will play a role as long as they are truly sustainable and affordable."
New Circular Economy Action Plan (CEAP)	Adopted in March 2020	The new CEAP mentions PSS several times. The EC commits itself to "incentivising **product-as-a-service** or other models where producers keep the ownership of the product or the responsibility for its performance throughout its lifecycle".
EU Chemicals Strategy for Sustainability	Adopted in October 2020	The strategy names PSS as relevant new business models: "Beyond the role played by technology, innovations in business models can be an important driver for the green transition of the industry producing and using chemicals. Opportunities to shift from traditional production and use of chemicals to **chemicals-as-a-service** should be explored and promoted.
EU Strategy for Sustainable and Circular Textiles	Adopted in March 2022	The strategy names PSS as relevant new business models in the textile sector: "Re-shaping the purchasing habits of consumers is difficult unless companies provide for new circular business models, such as **product-as-a-service models**, take-back services, second-hand collections and repair services".

3.1.2 Strategies at Nordic level

In the Nordics, the Nordic Council of Ministries has set out a Nordic Vision for 2030, addressed in the Action Plan 2021 to 2024. The Nordic Region aspires to become the world's most sustainable and integrated region, based on three dimensions: a green, competitive, and socially sustainable Nordic Region (Nordic Council of Ministers, 2019). PSS is not specifically mentioned in the NMR's strategy, but the action plan seeks to promote circular business models more generally and foster innovation to achieve this vision. Likewise, the Nordic countries also developed national strategies for promoting a more circular economy.

In **Denmark**, a national strategy for circular economy (Miljø- og Fødevareministeriet og Erhvervsministeriet, 2018) was launched in 2018, including initiatives to strengthen enterprises as a driving force for the circular transition and changing consumption patterns through a circular economy. In the strategy, PSS is mentioned several times to increase material efficiency and the utilisation rate of products through shifting consumption patterns of leasing and sharing products or buying a service instead of a product. In 2021, the strategy was followed by the Danish National Waste Prevention and Management Plan 2020–2032 (Miljøministeriet, 2021) with policies and initiatives promoting CE at different stages in the value chain. The plan further highlights circular business models, such as PSS models, as important for reducing waste generation and improving resource utilisation. However, the Danish strategy and action plan do not include any specific measures to promote PSS. In light of Denmark being one of the first countries to reach World Overshoot Day, Danish environmental NGOs call for an ambitious national strategy for a circular economy with concrete targets for reducing resource consumption (Larsen et al., 2024).

In **Sweden**, a national strategy for the transition to circular economy was adopted in 2020 (Regeringskansliet, 2020), which was followed by a circular economy action plan and an action plan for plastics in 2021 (Regeringskansliet, 2021a, 2021b). The Swedish strategies and action plans identify plastics, textiles, renewable and bio-based materials, food, the construction and property sector and innovation-critical materials and minerals as key sectors. Furthermore, they cover the entire product lifecycle and include innovation and circular business models as focus areas, amongst others. While Sweden is generally considered a frontrunner in terms of eco-innovation, which is greatly supported by government policy, the Swedish Action Plan has been criticised by the European Commission for its lack of a concrete timeline for implementation (Nordic Council of Ministers, 2022).

In **Norway**, a national strategy for a green, circular economy (Reynolds, 2021) has been adopted in 2021. It includes specific action points for the sectors identified with high circularity potential: the bio-based sectors; the process industries; construction and buildings; and service industries, including retail and wholesale trade (Ministry of Climate and Environment, 2022). While the strategy does not include direct references to PSS, it

includes a more general commitment to support the development of innovative business models to use resources more efficiently, including the service industries.

In **Finland,** the first roadmap to a circular economy was published in 2016 and followed by an updated version 2.0 in 2019 (Järvinen et al., 2019). The overall vision is to achieve a carbon-neutral society by 2035; whereby sustainable products and services and the sharing economy are mentioned to keep materials circulating longer and to reduce natural resource use. The strategy includes a clear commitment to move away from ownership-based consumption models, towards the use of services on product sharing, renting and recycling (ibid.).

In **Iceland,** the national strategy "Towards a circular economy" with an integrated waste prevention programme was published in 2021 (Umhverfis– og auðlindaráðuneytið, 2021). The Icelandic strategy incorporates circular economy principles by prioritising material efficiency and promoting sustainable consumption practices, such as opting for services over products, favouring sharing instead of ownership, and repairing items rather than discarding them. Although the strategy explores innovative methods to maximise material use, reuse, and longevity, the primary approach remains reducing the overall consumption of materials, particularly targeting materials like plastics and paper (Steingrímsson, 2022).

Table 3: Overview of Nordic national circular strategies and action plans and related PSS-references.

Country	Strategy / Action Plan	PSS reference
Denmark	Danish strategy for circular economy (2018)	The strategy repeatedly mentions PSS as a way to foster more resource-efficient consumption and production: "By leasing and sharing products – or **buying a service instead of a product providing this service** – it is possible to increase the utilisation rate" and "Enterprises may create more value from the same volume of materials, for instance through more efficient use of materials in their production, sharing economy, remanufacturing, and **product-as-a-service models under which they sell the access to using products**, while the enterprises maintain ownership of them."
Denmark	Danish action plan for circular economy 2020–2032 (2021)	The Action Plan mentions PSS to increase resource efficiency: "Circular business models such as rental, **product-as-a-service service** and sharing economy, use the same materials and products over and over again, often with a smaller environmental and climate footprint than traditional business models."
Iceland	Icelandic strategy towards a circular economy (2021)	The strategy includes a focus on adopting sustainable consumption practices, such as opting for service-models instead of products.
Finland	Finnish roadmap to the circular economy 2.0: The critical move (2019)	The roadmap includes a clear commitment to move towards PSS-models: "Instead of ownership, consumption will be based on the **use of services**: on sharing, renting and recycling."
Finland	Finnish strategic programme to promote a circular economy (2021)	The programme repeatedly mentions service models and aims to support their development: "We will develop economic incentives that support the sparing use of natural resources, reduce carbon dioxide emissions and promote the widespread use of **circular economy service models**"
Norway	Norwegian strategy for a green and circular economy (2021)	No direct reference to PSS, but a more general commitment to foster innovative circular business models.
Sweden	Circular economy: Strategy for the transition in Sweden (2020)	The strategy includes PSS in a section on digital innovation for circular products and services: "Digital and data-driven innovation creates new technologies and services. They can contribute to the transition **by the replacement of products with services** or by it becoming easier to reuse or **share products** and services."
Sweden	Circular economy: Action plan for the transition in Sweden (2021)	The action plan mentions alternatives to ownership-based models as a way to foster a more resource-efficient economy: "Reusing products, **rent, share or lease instead of buying new** can contribute to more sustainable consumption and reduced greenhouse gas emissions, among other things, by using products used longer and more efficiently."

The overarching assumption reflected in all strategies is that Nordic societies and businesses must rethink the design and use of products and services and reconsider how value is generated in economic activities. Some strategies explicitly highlight PSS as examples of circular business models that enhance resource efficiency. However, while acknowledging the potential of PSS in national strategies is crucial, more concrete policy initiatives are necessary to create conditions that allow PSS to effectively compete with traditional business models. This will involve developing sector-specific strategies and action plans, as well as implementing systematic approaches to establish the framework needed for a transition from linear to circular production models.

3.2 Economic incentive: levelling the playing field

Business models designed with circularity in mind typically demand fewer virgin resources and generate lower environmental impacts than their linear counterparts, which follow the traditional "take-make-dispose" model of production and consumption. However, linear business models maintain a competitive advantage by benefitting from low-cost raw materials and externalised environmental costs. These externalities, such as pollution and resource depletion, are not reflected in the pricing of products or services, which undermines the financial viability of more sustainable, circular PSS models. Policies can thus help to ensure that the full environmental costs of production and consumption are reflected in market prices, creating a level-playing field between linear and circular business models (OECD, 2019).

To bridge this competitive gap and encourage the transition to circular business practices, economic incentives are needed. Key policies such as Extended Producer Responsibility (EPR) schemes and shifts in tax structures can create a level playing field by internalising environmental costs, incentivising innovation in sustainable design, and promoting the adoption of PSS models. This section explores the role of EPR schemes and other fiscal measures in driving PSS competitiveness and fostering circularity at both the EU and Nordic levels.

Extended Producer Responsibility (EPR) schemes can incentivise the adoption and growth of PSS models. As the (financial) responsibility of the end-of-life treatment of products is placed on the producer, PSS models offer a solution for increased waste prevention and product reuse, e.g. through maintenance and repair services. This responsibility encourages circular design innovation, as well as reuse and remanufacturing, levelling the playing field between linear and circular business practices – and potentially creating new business opportunities for PSS models.

3.2.1 Extended Producer Responsibility (EPR)

EPR at EU level

Many EU Member States already have established EPR schemes in various sectors, and recent EU policies have now called for mandatory and harmonised EPR schemes across the EU. Following the Packaging and Packaging Waste Directive, all EU Member States are already required to introduce EPR schemes for packaging by 2024. Furthermore, the EU is currently revising the Waste Framework Directive (WFD) to better align it with the EU's circular economy objectives. The proposal for the revision provides for harmonised extended producer responsibility (EPR) schemes for the textile sector that would require fashion brands and textile producers to cover costs for textile waste management.

While EPR schemes have historically focused on covering waste management costs, the EU is working to expand their scope with measures like modulated fees. The idea is that fees can be reduced for products that follow eco-design guidelines, such as repairability or durability. However, there is a risk of losing the incentive for businesses to put fewer products on the market, and it is thus important that the fees are not reduced overly much so that PSS models remain economically viable (Christiansen et al., 2021). Furthermore, there are also proposals to replace traditional EPR schemes with "Producer Ownership schemes," where producers retain some ownership throughout the product's lifecycle (Stena Circular Consulting, 2022).

POLLUTER-PAYS-PRINCIPLE

As the EU continues to refine and expand EPR schemes, the underlying philosophy aligns closely with the broader polluter-pays principle. The polluter pays principle is at the core of EU environmental policy, seeking to hold polluters accountable for the environmental and social damages that they cause. This is enacted through forcing polluters to pay compensation for those environmental and social damages that they cause, whenever damages cannot be avoided.

A report for the European Commission (2021) shows that many opportunities are still missed to make polluters pay and that a more rigorous application of this principle could produce positive macroeconomic benefits for the EU economy (European Commission, 2021). Across all pollutants (air, GHG, water, waste, water scarcity and biodiversity loss), in all EU MS and across all economic sectors polluters continue to externalise costs, leaving the taxpayer to pick up the bill. The report proposes a general tax shift from labour to the environment and believes this will help address the issue. Inconsistent application of the polluter pays principle across EU environmental policies and actions has also been confirmed by the European Court of Auditors (European Court of Auditors, 2021).

EPR at Nordic level

The Nordic countries have implemented mandatory EPR schemes across a diverse range of product categories and waste streams, such as cars, tyres, electronic goods, packaging, pharmaceuticals and batteries, for many years, except for Denmark, where EPR schemes were only recently introduced (Nordic Council of Ministers, 2024c).

In line with the European Commission's proposal to introduce mandatory EPR schemes for textiles, Sweden has been the first Nordic country to pass EPR rules for textiles and clothing, putting the financial and operational responsibility of textile waste collection and management on Swedish textile producers. However, plans to introduce a clothing and footwear tax to reduce hazardous chemicals and minimise environmental impacts have been abandoned (Conde et al., 2022).

As highlighted in a recent Nordic Council of Ministers report (2024c), the Nordic countries face different challenges in successfully implementing EPR systems. For packaging EPR schemes, issues include administrative burdens, unclear definitions of producer obligations, limited enforcement and sanctions, and minimal impact on encouraging product design improvements. In Norway, for instance, the EPR for plastics has been criticised for providing insufficient incentives to create a circular value chain for plastic packaging within the current framework. The report suggests that EPR should be integrated with other policies to create a more comprehensive approach to promoting a circular economy (Nordic Council of Ministers, 2024c). Sweden, for example, has recently passed a regulation on mandatory reusable options for takeaway, further discussed in section 6.1.1 of this report.

Likewise, in Denmark, the implementation of EPR for packaging, already delayed, is facing calls for further postponement by the collective schemes. They cite excessive bureaucracy, unclear guidelines, and last-minute regulatory changes as key reasons for the requested delay (Nielsen, 2024). These challenges, seen in both Denmark and Norway, point to a broader need for improved coordination and more streamlined processes across the Nordic region. As the Nordic countries continue to refine their EPR schemes, it will be essential to address these operational issues to ensure that the intended environmental benefits of EPR, including promoting circular business models like PSS, can be fully achieved.

3.2.2 Shifting the tax burden from labour to natural resources

Taxes and subsidies are powerful regulatory tools facilitating market development and driving circular business models. Tax exemptions, reductions, and financial support for innovative business practices can provide crucial economic incentives to implement circular strategies. However, misalignments in policy – especially the current tax structures – can also obstruct the emergence of circular models, such as PSS.

An economy that favours product-life extension is inherently more labour-intensive than one based on the linear model. Services like repair, maintenance, upgrading, and remanufacturing of products require more human input than highly automated processes like mining and manufacturing (Wijkman & Skånberg, 2020). Thus, shifting the tax burden from labour to natural resources could provide the necessary economic incentives to support circular business models.

Taxes and subsidies at EU level

At the EU level, there is a general misalignment between taxation and environmental objectives. As noted in a report by the Club of Rome, modern EU tax systems impose high rates on employment while leaving the use of natural resources tax-free or even subsidised (Wijkman & Skånberg, 2020). This encourages businesses to exploit natural resources instead of investing in human labour for circular activities like repair and maintenance.

There are no EU-wide rules on the taxation of personal income since these fall within the competence of the Member States. The coordination on income tax is primarily focused on eliminating tax obstacles to cross-border activities, and the income tax rules by EU Member States have to respect the free movement of workers, services and capital (European Commission, n.d.-c).

The EU has introduced mechanisms like the Carbon Border Adjustment Mechanism (CBAM) and the EU Emissions Trading System (ETS) to address environmental concerns, but these are not direct taxes and focus more on carbon emissions rather than resource use. To better align taxation with circular goals, further exploration of environmental tax reforms is necessary.

Taxes and subsidies at Nordic level

In the Nordic countries, the high wage levels make it more expensive to repair or maintain products than to purchase new ones, which undermines the business case for circular models like PSS. High labour costs, partly due to significant taxation on labour income, contribute to this imbalance. In 2021, Denmark (24.7%), Norway (19.7%), and Sweden (21.3%) all generated a substantial share of their tax revenue from personal income taxes and social security contributions (Fíonta, 2023), making it difficult to shift towards more labour-intensive circular models.

The Circularity Gap report for Sweden recommends a "green tax shift from labour to virgin resources" (Conde et al., 2022). Similarly, research on how to implement a larger environmental tax reform in Finland suggests lowering income taxes to mitigate increased carbon taxes – and that new tax revenue derived from emissions can be used to lower labour taxes for low incomes more than those of higher incomes, to reduce income inequality (Tamminen et al., 2019).

Denmark already has mechanisms in place to offer incentives for businesses to employ people who are unable to work full-time, due to impairments. Employers can get the

wage costs partially covered through subsidies. A similar approach could be applied to support circular businesses by subsidising the labour costs involved in repair and maintenance services (Yrjö-Koskinen et al., 2019). Already today, many examples exist of companies that have a strong focus on circularity and social aspects alike, such as the Danish lighting company Fischer Lighting, which has successfully combined circularity with social employment goals by refurbishing old luminaires and providing jobs for individuals who might otherwise struggle to find employment.

Tax incentives for circular services

In Sweden, the government has implemented several tax incentives to promote a more circular economy. These measures included reducing the VAT for repair services from 25% to 12% and further lowering it to 6% in 2022 for the repair of household goods such as bicycles, clothes, and shoes. However, in 2023, the VAT was reverted to 12% (Finansdepartementet, 2022). Additionally, tax deductions were introduced to repair white goods, allowing consumers to deduct 50% of the labour costs, up to a maximum of 25,000 SEK per year (or 50,000 SEK for individuals over 65). This deduction was applied directly by service providers, who could subtract the amount from the customer's invoice.

Despite these initiatives, the Right to Repair campaign has reported that the impact of promoting repair services has been limited. Several factors contributed to this, including the exclusion of electronic goods like TVs ("brown goods") from the tax benefits, the administrative burden placed on service providers, and the fact that only individuals who earn enough to file taxes benefit from the deductions. Moreover, these measures fail to tackle the root issue of cheap new products entering the market, which continues to undercut the demand for repair services (Ganapini, 2023). As a result, while well-intentioned, these tax incentives have not fully achieved their goals of promoting repair and extending product lifecycles.

Across the Nordic countries, different tax models have been established by governments targeting short-term renting of private cars. In Norway, private car owners can earn up to 10,000 NOK tax-free annually from renting out their cars to private customers (The Norwegian Tax Administration, n.d.). In contrast, in Sweden, a different tax system has been established with 13 SEK pr driven miles tax-free when renting out a private car to private customers (GoMore, n.d.). The Danish tax model differentiates fossil fuel from electric, hydrogen or hybrid cars. Private owners of gasoline-fuelled cars can earn up to 11,500 DKK tax-free through short-term renting on an established platform. In contrast, private owners of electrical, hydrogen or hybrid cars can earn up to 21,600 DKK tax-free annually through short-term renting on established car renting platforms to private customers (Skat, 2024). In contrast to Norway and Sweden, the Danish tax model might succeed in encouraging private car owners who intend to short-term rent their car to opt for an electric, hydrogen or hybrid car instead of a fossil-fuelled car.

In the broader Nordic context, reduced tax rates on circular services or tax breaks for sharing platforms could enhance the benefits of the sharing economy and PSS models.

For example, the Circularity Gap Report for Norway suggests providing tax incentives like VAT exemptions or tax refunds for shared goods (de Wit et al., 2020), making sharing and service-based models more economically viable.

In summary, shifting the tax burden from labour to natural resources can create significant incentives for circular practices by lowering the cost of labour-intensive services like repair and maintenance. With their high labour taxes, Nordic countries are well-positioned to explore such reforms, which could help level the playing field for circular business models like PSS while supporting broader social and environmental goals.

3.2.3 Public funding for PSS development

In addition to economic incentives to create a more level playing field between linear and circular business models, such as PSS, direct financial support for innovative business models through public funding can be an important driver for PSS development. However, It is beyond this project's scope to present all public funding programs supportive of PSS at the EU level and within the Nordic countries. A few selected programmes explicitly incorporate PSS within their objectives and activities are presented in the following.

Public funding at EU level

The EU has long provided funding for knowledge generation, the exchange, and the uptake of best practices on circular business models. One example is the European Circular Economy Stakeholder Platform, which facilitates the exchange of best practices, knowledge, and strategies for implementing PSS. The platform brings together stakeholders across sectors to promote circular economy principles and highlights successful PSS models, offering valuable resources for those looking to adopt similar approaches (European Union, 2024).

Moreover, the EU's Horizon and LIFE funding programs have substantially supported PSS pilot projects across Europe. For example, Horizon provided funding for a project on resource-efficient circular product-service systems. Notably, in its recent call for proposals, the LIFE program has incorporated PSS as a specific objective (ECIEEA, 2024), reflecting an increased focus on scaling PSS models and exploring their potential to contribute to the EU's sustainability goals. These projects serve as important test beds for scaling PSS models and exploring their viability in different contexts.

In addition, EU programs like Horizon Europe and LIFE have provided substantial financial support for CE business models and PSS initiatives. For instance, Horizon has funded projects focused on developing resource-efficient circular product-service systems (ReCiPSS, n.d.), encouraging the creation of scalable PSS models. With its recent calls for proposals, the LIFE program has explicitly included PSS as a strategic objective (ECIEEA, 2024), reflecting the EU's increased focus on scaling PSS models as part of its broader sustainability goals. These programs serve as essential platforms for

testing and refining PSS models in various sectors, contributing to the overall transition toward a circular economy.

Public funding at Nordic level

In the Nordic Region, public funding is also seen as a critical enabler for the growth of PSS. Nordic PSS providers have emphasised that access to traditional financial sources, such as venture capital and loans, remains limited for PSS ventures, which often require long-term investments. Therefore, public funding programs are essential to create a supportive ecosystem for PSS development and scaling as discussed in section 16.2.

In the Nordic Region, Denmark leads with multiple funding opportunities. Programs like SMV Grøn support small and medium-sized enterprises (SMEs) in adopting greener, more circular business models, while Grøn Cirkulær Omstilling (GCO) offers financial and advisory support for companies implementing circular economy principles, including PSS. These regional programs are critical in fostering innovation and scaling PSS solutions within the Nordic economies.

In the broader Nordic Region, funding specifically targeting PSS projects or companies offering PSS solutions remains limited. In Finland, the Bio and Circular Finland Research, Development, and Innovation Program supports companies focused on bioeconomy and circular economy solutions, aiming to enhance their competitiveness. In Sweden, the Mistra Programme promotes robust environmental research, while the Re:Scource Programme works to increase the competitiveness of companies by fostering and funding sustainable and resource-efficient solutions. In Iceland, an Innovation Fund exists, but its scope does not align with the needs of PSS providers.

3.3 Technical criteria and reporting standards

Another characteristic of PSS – like other circular business models – is the need for increased collaboration within and across value chains. The supply chain of PSS needs to include actors at several stages of the life cycle, creating additional challenges for managing the supply chain (Lingegård, 2020). For example, PSS providers that offer maintenance and repair services depend on the availability of spare parts from manufacturers and/or sub-suppliers. Thus, design decisions by traditional manufacturing firms can have implications for the feasibility of product life extension activities and other services offered further downstream.

To address these complexities, there is a growing need for standardisation and unified reporting frameworks on sustainable business practices. Such frameworks would facilitate better coordination across the value chain, ensuring that all actors align their practices with circular economy goals and contribute to a more transparent and efficient system.

3.3.1 Standardisation and reporting at EU level

In its pursuit of a more transparent and accountable corporate environment, the EU has introduced key regulations such as the EU Taxonomy for Sustainable Finance and the Corporate Sustainability Reporting Directive (CSRD). These initiatives aim to steer the EU towards its climate and environmental objectives by promoting sustainable finance and enhancing transparency in corporate practices.

The EU Taxonomy provides a unified definition of sustainable activities, including PSS, which it recognises as a sustainable business model (European Commission, 2023a). By defining PSS as a sustainable activity, the Taxonomy offers clear guidelines for structuring such activities, encouraging businesses to align their practices with circular economy principles. However, the Taxonomy's criteria can be complex and challenging to implement, potentially creating barriers for smaller enterprises that lack the resources to navigate these regulations effectively. While disclosures are only mandatory for large companies that fall under the scope of the Non-Financial Reporting Directive, it is intended to also benefit SMEs whose business models are based on green activities (European Commission, n.d.-b).

In parallel, the CSRD strengthens sustainability reporting by requiring companies to disclose information on environmental, social, economic, and governance factors. This includes specific requirements related to resource use and circular economy practices, encompassing PSS activities. While these disclosure requirements are designed to enhance transparency and accountability, there is concern that the increased reporting burden might disproportionately affect smaller businesses, which may struggle with the administrative demands of compliance.

Table 4: Overview of EU policies, year of adoption, and related PSS-references.

EU Policy	Year	PSS-reference
EU Taxonomy for Sustainable Activities	Entered into force in July 2020	Annex 2 of the Taxonomy defines PSS as a sustainable activity. **Product-as-a-service** and other circular use- and result-oriented service models *Description of the activity*: Providing customers (physical person or legal person) with access to **products through service models**, which are either **use-oriented services**, where the product is still central, but its ownership remains with the provider and the product is leased, shared, rented or pooled; or **result-oriented**, where the payment is pre-defined and the agreed result (i.e. pay per service unit) is delivered.
Corporate Sustainability Reporting Directive (CSRD)	Entered into force in January 2024	The Disclosure Requirement E5-2 on actions and resources related to resource use and circular economy includes PSS: (i) value retention actions (maintenance, repair, refurbishing, remanufacturing, component harvesting, upgrading and reverse logistics, closed loop systems, second-hand retailing), (ii) value maximisation actions (**product-service systems**, collaborative and sharing economy business models), (iii) end-of-life actions (recycling, upcycling, extended producer responsibility), and (iv) systems efficiency actions (industrial symbiosis).

The Ecodesign for Sustainable Products Regulation (ESPR) (European Commission, 2024b) is another recent example of EU policy fostering circular consumption and production by improving product standards. The ESPR focuses on extending product lifecycles by introducing energy efficiency requirements and addressing environmental impacts through material efficiency, durability, reusability, upgradability, and reparability standards for all product groups (excluding perishable items like food and medication). For PSS models, which often rely on extending product life through maintenance, repair, and reuse, the regulation aligns with their core business principles. By promoting sustainable and circular product design, the ESPR could make it easier for PSS providers to source spare parts and perform repairs, as more products will be designed to meet these sustainability requirements from the outset.

In addition, the ESPR introduced the Digital Product Passport (DPP), which contains vital product information, such as performance, traceability, technical documentation, and user manuals for repair. By making this information more accessible to stakeholders

across the value chain, the DPP could significantly reduce technical obstacles for PSS models. For instance, PSS providers could use the DPP to track a product's repair history, enabling faster diagnostics for future repairs and evaluating product performance throughout its lifecycle.

However, there are still uncertainties surrounding the ESPR's implementation, as the first product requirements are expected to take effect in 2027. Key details, such as how DPP information will be made available to professional actors and consumers, are yet to be decided. The ultimate success of the ESPR will hinge on its execution, including effective market surveillance mechanisms (ECOS, 2024).

3.3.2 Standardisation and reporting at Nordic level

The Nordic countries are in the process of implementing the newly adopted EU regulations, as well as preparing for upcoming EU regulations that are likely to have a strong impact on the framework conditions in the Nordics. For instance, **Denmark** is implementing the CSRD Directive, mirroring the EU requirements and phased implementation. However, Danish authorities seek to expand the scope of organisations covered by the mandatory reporting requirements beyond what is requested at the EU level, including large enterprises such as commercial foundations, cooperatives, and state-owned public limited companies (Hasselbalch, 2023). In **Sweden**, a government proposal to delay the national implementation of the CSRD provoked some confusion among businesses, which were already preparing to report on their 2024 data (SustainLab, 2024). This case illustrates, that there are still many uncertainties regarding the process and effects of the implementation of these new technical standards and reporting schemes.

In support of these regulations, tools like the Danish Klimakompasset and other resources enabled by Nordic policies can assist PSS companies in navigating sustainability requirements. Klimakompasset, for example, helps businesses measure and manage their carbon footprint, providing guidance on assessing climate impact and identifying reduction strategies. This can be particularly beneficial for PSS companies, often in need of assistance calculating the environmental benefits of their business models. Similarly, the Swedish government initiative Fossilfritt Sverige provides sectoral roadmaps for transitioning to a fossil-free economy, e.g. tools and strategies for businesses to reduce fossil fuel dependency and move towards climate neutrality (Sveriges Miljömål, n.d.).

The Nordic Circular Economy Playbook provides a practical framework for businesses looking to integrate circular economy principles into their operations. It helps companies identify circular opportunities, optimise resource use, and improve product design for sustainability. For PSS companies, this playbook can guide their business models toward greater resource efficiency and reduced environmental impact. For further tools and resources to aid companies in achieving these goals, explore the guide Pathways to Circular Business – 15 Tools and Guides for Product-Service System Innovation.

3.4 Cultural barriers – Enhancing consumer interest in PSS

A significant challenge to the widespread adoption of PSS is consumer behaviour, particularly the strong cultural preference for ownership and the often low appeal of service-based offerings. Even when PSS models are cost-competitive over the full product lifecycle, many consumers still prefer to purchase inexpensive, low-quality products that are easily accessible. This tendency to favour ownership and disposable goods creates a barrier to the growth of PSS, relying on longer-lasting, service-oriented consumption. To overcome this, policy initiatives must not only support the economic and environmental benefits of PSS but also actively promote consumer interest and trust in these alternative, resource-efficient consumption models.

3.4.1 Consumer perspectives at EU level

The EU has launched several initiatives to promote sustainable consumption and empower consumers for the green transition. In May 2024, the Right-to-Repair Directive was adopted to encourage product repair over replacement. This legislation aims to make repairs more accessible, transparent, and attractive to consumers by implementing key measures such as (European Council, 2024):

- A legal guarantee favouring repair over a replacement. Consumers can now only ask for a replacement if the repair is more expensive;
- A European quality standard for repair services; and
- An online repair platform that connects consumers with local repairers and sellers of refurbished goods.

While the Right-to-Repair Directive does not directly challenge traditional ownership models, it enhances repairability, indirectly supporting the growth of PSS. By making repair services more accessible and promoting longer product lifespans, PSS models can offer product use as a service and benefit from the reduced need for product replacement. However, the directive has faced criticism for only covering products under Ecodesign criteria and for ambiguous definitions – such as what constitutes a "reasonable price for spare parts" – which could create loopholes (Rezende, 2024).

Repair-related requirements are also integrated into the EU Ecolabel, a voluntary product label for goods and services that meet high environmental standards. For instance, EU Ecolabel criteria for electronic displays mandate that products must be repairable, spare parts must be available for at least eight years, and producers must offer a three-year warranty at no additional charge (Šajn, 2022). Furniture products require spare parts to be available for five years, while footwear manufacturers need only inform consumers about the environmental benefits of repairing their products (Šajn, 2022). Like the Right to Repair, the EU Ecolabel does not directly promote PSS but encourages a broader shift toward higher-quality, repairable products and environmentally conscious consumption. Furthermore, the EU Ecolabel offers discounts to SMEs and micro-enterprises (EU Ecolabel, 2024). These discounts can provide financial support to PSS businesses, many of which are SMEs, by making certification more affordable and helping them demonstrate their commitment to sustainability.

To further empower consumers and prevent greenwashing, the Green Claims Directive (GCD) was proposed in March 2023. The GCD aims to establish clear, reliable, and verifiable criteria for companies' environmental claims about their products and services, complementing the EU's efforts to foster trust in sustainable consumption models (European Commission, 2023b). In theory, this could help inform consumers about the environmental benefits of PSS. However, many PSS businesses find it difficult to pursue verification processes due to the complexity and cost of assessing the environmental impact of service-based models compared to traditional products. This could limit their ability to promote their services as environmentally beneficial (European Commission, 2023b).

3.4.2 Consumer perspectives at Nordic level

Similar to the efforts at the EU level, there has been attention by policymakers on how to foster sustainable consumption practices, and how to prevent greenwashing.

Already in 1989, the Nordic Swan Ecolabel was established, as a voluntary scheme for certification within the Nordic countries. Currently, more than 25,000 products are certified within a wide range of product groups (Svanemærket, n.d.-a). The Nordic Swan also includes certification for "Textile Services", such as laundry and rent of textiles, washing and delivery of clothes, and textiles for hospitals and hotels (Nordic Swan Ecolabel, n.d.-b). Thus, it directly offers a certification for PSS models, recognising them as an environmentally friendly alternative to ownership-based models or the use of disposable items. There are currently 117 textile services certified, including services offered by the Lindström Group, the largest PSS provider in Finland (Svanemærket, n.d.-b). However, when discussing the topic of ecolabelling with other PSS providers in the Nordics during the course of this project, it was considered valuable in some cases, but also an expensive and inconvenient process (Egebæk et al., 2023). More recently, the Nordic Swan Ecolabel also introduced reduced fees for SMEs and micro companies (Nordic Swan Ecolabel, n.d.-a), following the efforts of the EU Ecolabel to reduce challenges for these companies to obtain certification for their products and services.

Furthermore, the Nordic countries are also pursuing national efforts to prevent greenwashing and to protect consumers better.

In **Denmark**, the Danish Marketing Practices Act establishes guidelines for good marketing practices (Forbrugerombudsmanden, n.d.). For PSS, the sections addressing misleading actions and omissions are most relevant, especially in the context of environmental marketing. The Danish Consumer Ombudsman has noticeably increased the focus on the prevention of false green claims since 2021, leading to Denmark's first greenwashing conviction (Osbæck, 2022) – and other convictions have followed since (Dijk, 2024). In response to this, a comprehensive guide on environmental marketing was published in 2021, distinguishing between general and concrete statements (Forbrugerombudsmanden, 2021).

In **Sweden**, the Swedish Consumer Agency (SCA) is responsible for safeguarding consumer interests, guided by objectives set by the government and parliament. Led by the Consumer Ombudsman, the SCA monitors market trends to identify consumer issues, including environmental concerns. Key legislation includes the Swedish Marketing Act (Government Offices of Sweden, 2015), which includes sections on accepted marketing practices, misleading marketing, and comparative advertising. Thus, this might be relevant for PSS providers, who often seek to compare their service-based models with other market alternatives, such as ownership-based models or single-use items.

In **Finland**, the Consumer Protection Act includes guidelines for marketing procedures, and the Consumer Ombudsman published guidelines on the use of environmentally oriented claims in marketing, which were last updated in 2019. The Finnish Competition and Consumer Authority, which is responsible for compliance with consumer laws, has recently stopped multiple companies from using environmental claims in their marketing since their claims were too vague and not it was not clear what they were based on (Aarikka & Bräutigam, 2024).

In **Norway**, the Norwegian Consumer Authority (NCA) has created a set of guidelines for companies promoting green claims to Norwegian consumers to prevent misleading practices and assist businesses in adhering to the rules established by the Norwegian Marketing Control Act (MCA) (Fobrukertilsynet, 2020). This serves as Norway's primary legal framework for consumer marketing and incorporates the EU directive 2005/29/EC on unfair commercial practices. In recent years, the Norwegian Consumer Authority (NCA) has increased its focus on fashion retailers using vague green claims in their marketing. In February 2020, the NCA issued a formal notice to 53 retailers, emphasizing the need for specific explanations when labelling products as "green," "sustainable," or "ethical" (CMS, n.d.).

In **Iceland**, the Consumer Agency (Neytendastofa) is responsible for market surveillance, and covers both aspects related to market competition, and consumer safety. This includes the prevention of unfair business practices, such as misleading marketing.

While it is important for Nordic countries to update legislation on greenwashing and hold companies accountable for false environmental claims, these efforts could unintentionally create challenges for PSS providers, particularly smaller ones. The complexity of documenting and verifying the environmental benefits of PSS models might lead to "greenhushing," where businesses refrain from fully communicating their sustainability efforts out of fear of being accused of greenwashing. This could result in smaller, genuinely sustainable PSS providers being overshadowed by larger companies with less circular business models but greater resources to promote even marginal environmental improvements.

To ensure that these policies empower consumers and support the green transition, it is crucial to address these verification challenges and complement the initiatives with regulations that enhance the competitiveness of PSS models, especially since price remains a key factor in consumer decisions.

3.5 GPP: Supporting market development of PSS models

Public institutions can directly stimulate the development of PSS models by implementing circular economy principles, such as functional requirements, in public procurement procedures. Potentially, this could provide a significant driver of market development for PSS and even contribute to cost savings (Linder et al., 2022). On a broader level, green public procurement (GPP) can serve as a model and guide for individual consumers through the dissemination of knowledge on green consumption and the acceleration of the adoption of new environmental standards (Wang et al., 2021).

3.5.1 GPP at EU level

The EU considers GPP as key for boosting the circular economy. However, so far GPP has been limited to voluntary criteria, where EU Member States can decide whether and how to apply them (European Commission, n.d.-d). Thereby, ecolabels such as the EU Ecolabel can play an important role in the development of technical specifications and award criteria. To be more effective, the EC is proposing minimum mandatory GPP criteria and clear targets for the wider uptake of GPP across Member States (Directorate-General for Environment, European Commission, n.d.). In a position paper on the revision of EU GPP criteria, Digital Europe stated that they would welcome criteria where electronic products such as PCs, displays and smartphones are purchased as services to facilitate the shift towards a more circular economy (DigitalEurope, 2020). However, significant progress is still required for public procurement to contribute to a more circular economy, and to stimulate growth in alternative business models such as PSS (Linder et al., 2022)

Moreover, the EU has supported different pilot projects on circular public procurement, which also covered aspects related to the procurement of services instead of products. For example, the Interreg project Public Procurement in the Baltic Sea Region promoted a circular procurement approach and stimulated the development of new business

models, including PSS (Interreg, n.d.). The project included public authorities, procurement officers, suppliers and policymakers from Denmark, Sweden and Latvia between 2014–2020. These pilots, which focused on circular procurement in sectors such as ICT, furniture, and playground equipment, offer valuable insights into how PSS can be integrated into public procurement processes. One of the key policy recommendations of the project is to "buy services or product-service systems instead of traditional products" (Interreg, 2020). Similarly, the ProCirc project in the North Sea region, including actors from Denmark, Sweden and Norway, aimed to create knowledge on how circular procurement contributes to resource efficiency and reduced emissions across industries. The project offers guidance and tools for various stakeholders and published a guide on circular public procurement, that includes different PSS models (Interreg, 2022).

3.5.2 GPP at Nordic level

Across the Nordic countries, public procurement is recognized as an important tool for driving innovation and the promotion of environmentally friendly consumption and production. In the following, key strategies and legislation is briefly presented:

In **Denmark**, a strategy for green public procurement was published in 2020, covering both the procurement of goods and services (Ministry of Finance, 2020). The strategy includes the development of guidelines to assist public procurers in using the possibilities for green public procurement offered by the Public Procurement Act. While not directly addressing PSS, the strategy also includes the development of guidelines for product life extension, such as requirements for extended product warranties and repair.

In **Finland**, the National Public Procurement Strategy was established by the Finnish government in 2020 (Valtiovarainministeriö, 2020). The strategy serves mainly to increase the effectiveness of public procurement but also seeks to improve social and environmental sustainability through the purchasing of high-quality products and services. As part of this initiative, the network-based competence centre KEINO was launched to develop and implement innovative public procurement systems in Finland, including learnings on PSS and other alternative business models. However, KEINO is no longer operating (Keino, n.d.). The Public Procurement Act (1397/2016) also supports innovative and sustainable procurement practices, covering PSS (Oy, 2024).

In **Norway**, the government published an Action Plan to increase the share of green public procurement and green innovation and a new procurement regulation in Norway include more environmental provisions and possibilities to promote innovation (The Norwegian Agency for Public and Financial Management, 2021). For electronics, the strategy specifically mentions leasing or buying second-hand as an alternative to buying new, thus encouraging alternative business models such as PSS.

In **Sweden**, the National Public Procurement Strategy includes goals on public procurement supporting innovation and promoting alternative solutions that are more environmentally responsible (Regeringskansliet, 2015). The Swedish Procurement Agency

was created in 2015, and is responsible for supporting and overseeing the implementation of the strategy. The Swedish Public Procurement Act was adopted in 2016, also including the promotion of environmental considerations, but these are not mandatory (Lewis & Machlowska, 2022).

In **Iceland**, a national policy on sustainable procurement was adopted in 2021, followed by an action plan for 2021–2024. According to the action plan, the Central Public Procurement Authority Ríkiskaup will take measures to include mandatory environmental criteria for certain products and services (Government of Iceland, n.d.).

All of the Nordic countries have strategies and legal frameworks in place to support public procurement practices in line with social and environmental goals. However, there is often a gap between the ambitions of national plans and the resources and capacities allocated to the implementation, as found in the case of Sweden (Lewis & Machlowska, 2022). In the case of the procurement of product-as-a-service, this project equally found existing practices and cultural norms as the main barriers. Many PSS providers in the Nordics are thus hesitant to enter the B2G markets since they perceive it as inaccessible due to their distinctive business models. Experiences on PSS in public procurement in the Nordic countries are discussed in more detail in the section 16.3 and 16.4.

4. INTRODUCTION TO PSS MODELS AND PRODUCT GROUPS

This report provides an overview of PSS models in the Nordic region and identifies key product groups relevant to further PSS development. These product groups are categorised into distinct clusters covering a wide range of sectors, such as transportation, textiles, and packaging, reflecting how PSS can touch nearly every aspect of daily life for Nordic citizens.

Each product cluster presents different PSS alternatives, targeting specific needs and transforming traditional consumption practices. Some clusters focus on replacing single-use products, such as packaging, while others aim to transition ownership-based models into service-based solutions, like tool or clothing rentals. The markets for these PSS models vary: some are predominantly B2B (e.g., heavy machinery), others B2C (e.g., casual and special occasion clothing), while certain categories, such as computers and smartphones, overlap between B2B, B2C, and B2G.

Across all product groups, the models illustrate a potential to increase resource efficiency, reduce waste, use sustainable materials, and lower CO_2e emissions. Common services include product repair, refurbishment, take-back options, and extended warranties, which help extend product lifespans. In the product-specific sections of this report, we provide in-depth analyses of the current conditions of PSS in these sectors and highlight existing drivers and barriers for further development. However, the environmental benefits of these models depend heavily on specific use cases and logistical arrangements. A key part of this project involved evaluating how effectively these models can meet environmental goals and contribute to advancing the Nordic countries toward a more circular economy. The report section 15 provides a more conclusive assessment of PSS models, their environmental potential, and possible rebound effects.

The figure below provides a comprehensive overview of key product groups for which PSS models are offered across the Nordic region. Each category is broken down into specific sub-groups, where PSS models can replace traditional ownership with service-oriented solutions. These product groups and sub-groups were selected through an extensive mapping of more than 300 Nordic PSS solutions and categorised acordingly.

Following the categorisation, each product group was assessed based on its social, economic, environmental, and innovative potential and suitability for the Nordic market. Evaluation criteria included parameters such as market size, material consumption, Nordic market spread, adoption of innovations, replication potential, and both social and environmental impact potential (Egebæk et al., 2023). Through ongoing evaluations and iterations that reflect updated insights into these parameters, the following product groups and categories have emerged as key focal points in the PSS in the Nordics project.

Figure 3: Overview of product groups relevant to PSS in the Nordics.

4.1 Well-established PSS models

Before delving into product-specific sections, this chapter highlights a number of successful, well-established PSS models in sectors where they are already deeply embedded in the economy. Though not the primary focus of this project, these models offer valuable lessons for unlocking the potential of PSS in other sectors or product categories.

The concept of PSS is not new, even if the terminology is relatively recent. For decades, business models such as car leasing, laundry services, and shared workspaces have existed. Initially driven by profitability and service provision, these models can also integrate sustainability practices, optimising resource use and reducing waste. Service-based models offer economic advantages, including increased customer retention, personalised solutions, and product longevity (Baines & Wilson, 2007). This ability to stay flexible when considering the customer's needs increases user satisfaction while positioning these businesses as forward-looking, responsive entities in a rapidly changing marketplace (Kjær et al., 2018).

For example, Lindström, a Finnish company that has been operating for 175 years, originally produced textiles but shifted to a workwear rental service in the 1950s in response to a shortage of textile products (Lindström, n.d.-a). Today, Lindström operates globally and brands itself as a sustainable textile service. Their B2B rental model includes washing, maintenance, repairs, renewals and storage. With recent acquisitions of Cintas, the world's largest textiles services company, and Alsco's operations in Shanghai, Lindström's growth has the potential to reach new heights as it expands into the Asian market (Lindström, n.d.-a).

Another well-established and rapidly growing PSS is the car share business concept. ShareNow, a car share business, has seen huge growth in its European market and, since 2015, has expanded its operations to 16 cities worldwide with an estimated 3 million users (Li et al., 2021). Despite some setbacks during the pandemic, their recent acquisition by Stellantis (Free2Move) in 2022 has allowed them to expand their fleet of vehicles across Europe. The growing development and implementation of the car share market both in the Nordics and around the globe is attributed to its convenience and flexibility compared to public transport (Li et al., 2021). Despite competing with traditional car ownership and the many other forms of transportation offered in major cities, the market for care sharing is expected to grow substantially between now and 2030. Since 2019, car ownership has steadily declined across the European market (Díaz et al., 2021) , and car-sharing services such as ShareNow have established themselves by targeting the high ownership costs for vehicles, MOTs, high fuel prices, availability of spare parts, etc. While sustainability may not be at the centre of car-sharing PSS models, it can bring environmental benefits to the mobility industry by reducing traffic, pollution, and oil dependence, especially with the ongoing growth within the electric vehicle market (Li et al., 2021). Read more about car-sharing systems in chapter 5.1.

Finally, facility management businesses such as Coor have quietly employed PSS business models for years. The Swedish enterprise has provided cleaning and catering services since 1998 and has successfully competed and replaced in-house management systems for decades. Management services such as the one Coor provides offer flexible solutions that can be adapted and integrated to meet the needs of the customer on a case-by-case basis. Activity outsourcing models such as cleaning allow facility management companies to employ new technology that reduces resource use (such as water and chemical cleaners), which would be too expensive for individual businesses to use (Tukker, 2004a). Despite a dip in growth due to the COVID-19 pandemic, the market for facility management PSS is expected to continue to grow from 290.4 billion USD in 2022 to 426.6 by 2030 (Fortune Business Insights, n.d.). The growth of these services has been attributed to increased tourism within the EU and new technologies for cleaning and facility management services.

These examples demonstrate that PSS is not a theoretical concept but a practical, competitive alternative to ownership-based models. Companies like Lindström, ShareNow, and Coor have thrived by focusing on customer convenience, flexibility, and resource efficiency – qualities that resonate with evolving consumer preferences. These businesses, while not always founded on sustainability principles, have contributed to changes in consumption patterns, which optimise the use of resources, and extend product lifecycles. The widespread adoption of these PSS models has been largely motivated by material shortages, economic challenges, and consumer convenience rather than sustainability alone. So, while PSS models have already proven their competitiveness and adaptability, their future growth in other sectors – and their potential to support a circular economy – will depend on both market dynamics and the proactive role of policy in encouraging sustainable business practices.

4.2 The Nordic PSS landscape

While well-established PSS solutions demonstrate the viability of PSS models in the Nordic market and their potential for global expansion, most Nordic companies – whether linear, circular, or PSS-based – are SMEs. Over the course of the project, more than 300 PSS solutions were identified and analysed over three years. Through over 100 interviews, five national workshops, and two joint Nordic workshops, an extensive dataset was developed, highlighting trends in PSS across a diverse range of companies, from start-ups to well-established firms, both small and large. The project analysed emerging challenges and enablers, along with the rise of new PSS solutions and the exit of others from the market.

4.2.1 General tendencies for Nordic PSS

The extensive mapping of PSS cases in the Nordics reveals some general trends. Use-oriented PSS models are generally the most common and well-known among consumers. B2C and B2B are the primary target markets across product groups. In the Nordic countries, newer PSS companies (established within the last five years) predominantly serve B2C markets, while older PSS companies often cater to both B2C and B2B markets. This shift suggests that PSS solutions are becoming normalised for consumers, with greater acceptance of service agreements for maintenance and repair or even the idea of not owning products at all. However, PSS adoption within B2G remains limited, as public procurement rarely integrates PSS models.

Most PSS providers in the Nordic region are small and medium-sized enterprises (SMEs), and many do not manufacture the products they offer. Nonetheless, these providers tend to prioritise durable, repairable products in their procurement processes, particularly in use-oriented models. While some providers maintain close relationships with their suppliers, they often have limited influence over product design. Providers that manufacture their own products through PSS models often introduce radical innovations that disrupt the market and significantly reduce environmental impacts.

Across the product groups, the PSS providers consulted have expressed a desire to support the Nordic regions' development towards a circular economy. Their main motivation lies in creating models that increase product utilisation, addressing issues like short usage periods or underused products. Interestingly, many of these businesses adopted circular economy principles without consciously identifying their models as PSS, meaning that sustainability emerged organically as part of their value proposition.

Despite their potential, several SMEs discontinued operations during this project, highlighting the significant challenges of the start-up phase. Use-oriented PSS models require large initial capital investments, primarily to build stock. Many providers struggled to secure financing, making it difficult to sustain their business models. These challenges, along with the costs of developing digital administrative systems like inventory tracking, add further pressure on emerging PSS businesses. However, once established, most

providers report that these challenges diminish over time (learn more about financing PSS in chapter 16).

Few PSS providers have conducted comprehensive environmental impact assessments, largely due to the complexity and cost of such evaluations. However, existing assessments indicate that PSS models can deliver substantial environmental benefits if certain conditions are met. Factors such as product return rates, transportation logistics, and what the PSS solution replaces (e.g. if car-leasing replaces public transport) significantly affect the overall sustainability of PSS models. For example, a reusable packaging service could offer significant environmental advantages. Still, if customers fail to return the packaging or if transportation costs to recover the items are too high, the benefits may be negated (learn more about potential environmental impact in Chapter 15).

4.2.2 Target markets

As PSS models continue to evolve in the Nordics, understanding their target markets is key to addressing both sustainability and economic viability. PSS is being adopted across various sectors, with distinct challenges and opportunities in each market. These markets – B2C, B2B, B2G, and B2B2C – affect how PSS models are designed, implemented, and received:

- **B2C (Business-to-Consumer):** Companies directly serve individual consumers. This market is often characterised by flexibility, shorter product life cycles, and a growing acceptance of shared or leased services over ownership.
- **B2B (Business-to-Business):** PSS providers offering services to other businesses, often through long-term contracts. The B2B market is established but slower to adopt radical innovations due to conservative industry practices and liability concerns.
- **B2G (Business-to-Government)**: Companies offer services to public institutions. B2G holds strong potential due to governments' significant buying power, but PSS adoption remains limited as public procurement processes rarely integrate service-based models.
- **B2B2C (Business-to-Business-to-Consumer):** A hybrid market where businesses serve other companies that ultimately provide services to consumers. This market is complex, requiring careful coordination between all stakeholders.

Table 5 explores the key product categories within Nordic PSS, highlighting the most prominent target markets and additional insights into how these markets influence both sustainability and business performance.

Table 5: Overview of product categories and target markets.

Product category	Target market	Additional insights
Transportation	B2C, some also B2B	PSS models such as Mobility as a Service (MaaS), peer-to-peer sharing, and product pooling are gaining traction. In the Nordics, pooling/sharing models are particularly popular, especially for cars and bicycle solutions. These models cater to the growing consumer preference for access over ownership in the category, though sustainability may not always be the primary focus. Instead, convenience and cost savings often drive adoption, while sustainability outcomes depend on usage patterns and integration with broader environmental goals.
Packaging	Mostly B2B and B2B2C	The packaging sector is primarily dominated by start-ups founded in the 2020s, with the exception of a few long-established companies in the freight segment. This category typically involves low-value products, often designed to replace single-use items. A key challenge is encouraging the return of low-cost products, as small deposit fees often discourage consumers from returning them. Despite this, there is significant potential for scaling circular systems, though achieving consumer engagement remains a key hurdle.
Machinery & Tools	Primarily B2B	The B2B market for machinery and tools is mature, but conservative users and safety concerns – especially in B2B2C settings like tool libraries – pose barriers to adoption. Liability issues are key challenges, but the economic and environmental benefits of leasing or sharing high-value tools remain strong in industrial contexts.
Household Appliances & Furniture	Mostly B2C	B2C PSS providers are gaining traction by offering flexible, non-ownership models for household appliances and furniture. B2G markets show growing potential as governments and institutions seek sustainable, cost-efficient furnishing solutions. B2B providers, particularly in office furniture leasing, have proven to be more financially viable.
Products for Children	Primarily B2C, dominated by micro-companies	PSS models for children's and maternity products are well-suited due to the short usage periods as children grow. However, many providers in this sector, often start-ups, have shut down operations over the course of the project due to significant challenges. Limited funding, high operating costs, and the need to offer a wide range of products to meet diverse consumer preferences make profitability and scalability difficult, especially for smaller, micro-companies. Despite these hurdles, PSS models in this sector hold strong potential for sustainability by reducing waste and promoting product reuse.

Textiles	Strong presence in both B2C and B2B	In the textile industry, B2B PSS providers are typically larger, more established companies, while B2C providers are often smaller micro-companies with shorter lifespans. Many of these smaller B2C textile PSS providers have shut down operations over the course of the project, facing challenges such as limited funding, high operational costs, and the increasing demand for fast fashion. However, the rising interest in circular fashion and rental models offers a potential pathway to address these sustainability challenges and promote more durable business models in the sector.
Seasonal & Special Occasions	B2C and B2B, though B2C faces more difficulties	B2C PSS providers for seasonal goods and special occasions are often start-ups and struggle in B2C markets due to high costs related to logistics and customer service. B2B providers have more stable models, and the environmental impact could be reduced by focusing on reuse and rental, particularly for items that are infrequently used.
Electronic Equipment & Solutions	Primarily B2B and B2G	Leasing models in electronics are gaining traction, particularly in the B2B and B2G markets. Most PSS providers of computers and smartphones in the Nordic region are larger, well-established companies. However, significant barriers exist, such as legal complexities around ownership and liability, as well as concerns about data security. Overcoming these challenges could unlock further growth in the sector.
Buildings	Primarily B2B, with some B2B2C and B2G	The buildings sector's diverse ownership models prompt PSS providers to target a mix of B2B, B2B2C, and B2G markets. Sustainable building services, such as energy-efficient retrofits and green construction materials, appeal to businesses and governments aiming to achieve environmental goals. However, the variety in ownership structures creates added complexity for deploying PSS solutions in this sector, making it challenging to implement consistent models across different stakeholders.

In the Nordics, PSS models are generally more established in B2B markets, particularly in sectors like machinery, workwear, and buildings, where companies tend to be larger and the market more mature. While PSS providers often face financial challenges, mainly due to substantial upfront investments and slow returns, long-term contracts in B2B settings can help convert these investment costs into manageable operational costs, which is attractive from a financial standpoint. B2B clients typically take a calculated approach, valuing the reduced risks, convenience, and the shift from capital expenditures to operational costs offered by PSS models.

Additionally, B2B models often benefit from offering a smaller, more uniform product range, simplifying the message and reducing complexity. Their focus on functionality and ease of repair streamlines maintenance, extends product lifespans, and enables more efficient logistics. For example, transporting workwear in bulk for businesses lowers emissions and costs per unit compared to B2C models, which typically involve individual shipments. Additionally, B2B models offer convenience to companies, allowing them to outsource operational tasks like managing workwear and focus on core activities.

In contrast, B2C-oriented PSS models must cater to a wider range of consumer preferences, requiring a diverse product selection that increases procurement and maintenance costs. While B2C models can capture niche consumer segments by appealing to emotions, ideals, and personal preferences, they often face more operational complexities. Each market offers distinct advantages, but providers must tailor their strategies to balance operational complexity with market expectations.

4.2.3 Nordic frontrunners – transcending common barriers

Through extensive analysis of both successful and challenged PSS solutions and providers, several trends have emerged among Nordic PSS frontrunners that have managed to transcend common barriers (further discussed in section 16). While these insights are not a one-size-fits-all solution, as PSS models differ across product groups, target markets, value chain collaborations, and communication strategies, they offer useful guidance on business model approaches that have helped Nordic PSS providers overcome obstacles. These trends are organised according to the three overarching categories of PSS: product-oriented, use-oriented, and result-oriented.

Product-oriented PSS models

Product-oriented models in the Nordics tend to have lower visibility, as they are often communicated as an add-on to existing products or services, such as product sales or combined with other PSS models. These models focus more on the product itself and less on associated services. Although product-oriented PSS models generally offer lower environmental impact potential compared to other types of PSS, they can still deliver meaningful environmental benefits when strategically implemented. These models often sit at the intersection of traditional linear models and newer circular models, making them somewhat familiar but still novel to customers. As a result, the economic risks of product-oriented PSS models tend to be lower than those of other PSS categories.

Key strategic activities adopted by Nordic product-oriented PSS models:

- Providing **advice, guidance, and directing** the customers towards procurement of products with less environmental impact, greater durability, repairable products, etc.
- The inclusion of **extended warranty or similar guarantee solutions** in the value offer
- Inclusion of **post-sales solutions**, e.g. repair and maintenance services to extend product life, reducing the need for product manufacturing or product take-back, ensuring resale or proper waste handling
- **Fixed pricing** on added-value service pre- and post-product-sales makes the economic costs predictable and manageable for the PSS providers. Further, this approach to pricing enables clear communication with customers, supporting trust in the systems.

- **Utilising in-house staff** for maintenance and repair services reduces costs compared to outsourcing, e.g., if these activities are done in close proximity to the point of sale.
- **Modulation of added-value services** based on the product price. In practice, this would mean that more expensive/high-quality products are granted an extended amount of services, motivating product sales, while low-quality products come with less added-value services.

Use-oriented PSS solutions

Use-oriented PSS models typically offer a balanced value proposition, combining both tangible and intangible aspects related to product usage. These models are the most common in the Nordics, and throughout the project, extensive data has been gathered on their successes and challenges. Use-oriented PSS solutions hold significant potential for reducing environmental impact, particularly when the focus is on sustainable product selection, high return rates, and responsible consumption behaviour.

However, their economic viability varies widely. Some use-oriented PSS businesses go bankrupt within a year or two, while others have thrived in the Nordics for over a century. The sustainability and success of these models depend heavily on product choice, efficient logistics, and consumer engagement.

Key strategic activities adopted by Nordic use-oriented PSS models:

- **Convenient product (return) systems**, motivating customers to access and return the products of the PSS solutions. This reduces the need for extensive product stock and transportation and increases the recirculation product use rate throughout its lifespan.
- **Clear consumer guidance** on proper product use, along with an emphasis on the environmental benefits of responsible usage, improves product durability and reduces the need for repairs, spare parts, and premature replacements. For example, providing washing guides for textiles helps extend their lifespan, minimising wear and tear and ensuring products remain in use for longer periods.
- **Producing or prioritising products** designed for durability, ease of repair, availability of spare parts, and effective tracking helps ensure sustainability, especially in cases of poor return rates. Inclusion of durable products made for reuse, where spare parts are available, where repair and maintenance are conductible, and where product tracking (e.g., if there is a poor return rate) is possible.
- **Prioritising or producing products** designed for reuse that are durable, repairable, and supported by the availability of spare parts ensures a longer product lifecycle. These products should also be easy to maintain, with built-in tracking systems to monitor usage and return rates, especially when return rates are low.

- **Clear value propositions** tailored to specific target groups enhance customer retention, satisfaction, and willingness to pay for the service, fostering stronger customer relationships.
- **Applying diverse revenue streams** by, e.g. combining subscription models with additional on-demand services. This helps generate steady income from multiple sources, ensuring financial sustainability for maintaining product stock, wages, and operations.
- **Offering flexible prices** based on the length of product use, especially in the product-rental and -leasing models. There is a tendency for B2B and B2G customers to want insights into Total Cost of Ownership (TCO) and prices flexible enough to accommodate a reduction of TCO compared to product sales. For B2C customers, the focus should rather be on reduced costs achieved in product rental and leasing, e.g. lower costs/day with long-term compared to short-term rental, as this is more relatable and easier for B2C customers to understand.
- **Offering flexible pricing** based on product use duration, particularly in rental and leasing models. B2B and B2G customers often seek insights into Total Cost of Ownership (TCO) and prefer pricing structures that reduce TCO compared to product sales. For B2C customers, the focus should be on simplified cost savings, such as lower daily rates for long-term rentals, which is more relatable and easier to understand than TCO calculations.

Result-oriented PSS solutions

Result-oriented models, which focus more on services than products, are fairly common in the Nordics. However, their long-term success is challenging to predict due to their intangible and highly varied value propositions. The environmental impact of these models also differs significantly, depending on the nature of the result delivered and the resources involved (e.g., products, materials, flora, or fauna). Similarly, the economic viability of result-oriented PSS models is highly dependent on the specific solution offered. Successful examples often involve expensive, innovative technology development, services that support critical societal functions (e.g., infrastructure maintenance), or services that ensure compliance with regulations for manufacturing companies.

Key strategic activities adopted by Nordic result-oriented PSS models:

- **Documenting cost savings** for customers, often using TCO calculations, which helps secure long-term agreements, especially in B2B and B2G markets. This also underscores the environmental benefits alongside financial savings, improving customer retention.
- **Leveraging customer feedback and data-driven insights** to tailor services more precisely to customer needs, strengthening relationships and increasing the likelihood of contract renewals.
- **Timely maintenance and repair**, as PSS providers handle the products directly. This

ensures high product utilisation and extends product lifespan, significantly reducing operational costs for the provider and the customer.

- **Managing the entire product lifecycle**, including end-of-life processes. PSS providers extract additional value, reduce waste, and improve environmental performance by reusing, remanufacturing, or recycling product components.

With this overview of the Nordic PSS landscape, we will now explore the ten key product groups that highlight how PSS models are applied across various sectors. Each product group presents unique challenges and opportunities, providing insight into how PSS models are evolving and adapting to market needs. The following sections will examine these groups in more detail, focusing on the specific dynamics, successes, and barriers encountered within each.

5. TRANSPORTATION

Transportation plays an essential role in society and the economy, affecting efficiency and accessibility, all while being the key source of environmental pressure, consuming one-third of all final energy in the European Union (Klychova et al., 2020; Salvucci et al., 2019). Besides contributing to climate change, air pollution and noise, transportation takes up large strips of land, contributing to the fragmentation of habitats and urban sprawl (European Environment Agency., 2020). Current tendencies in the global transportation market revolve around privatisation, income diversification, utilising public-private partnership mechanisms, infrastructure, and agglomerated approaches to business model formation (Vinichenko, 2021). Mobility as a Service has gained more focus (Alexiou, 2021; Wolters Kluwer, 2021), indicating that PSS solutions in transportation have a window of opportunity to achieve stability in the market. (European Environment Agency., 2020). Current tendencies in the global transportation market revolve around privatisation, income diversification, utilising public-private partnership mechanisms, infrastructure, and agglomerated approaches to business model formation (Vinichenko, 2021). Mobility as a Service has gained more focus (Alexiou, 2021; Wolters Kluwer, 2021), indicating that PSS solutions in transportation have a window of opportunity to achieve stability in the market.

Transforming transportation is a crucial energy challenge in the Nordic region to achieve the climate targets set by the Nordic governments (Hansson, Karlsson, et al., 2019). The transportation sector represents a significant source of GHG emissions and other pollutants in the Nordic region, accounting for 20–35% of the countries' total GHG emissions (Laine et al., 2018a). The European Union's common target to reduce GHG emissions from the transport sector by at least 60% from 1990 levels by 2050 (European Commission, 2011) has been implemented in Denmark, Finland, and Sweden (as members of the EU,) with each country setting its own national and city-level GHG emission reduction goals for the transport sector (Laine et al., 2018a).

At the same time, the Nordic countries are considered pioneers in deploying sustainable energy technologies relevant to the transportation sector, with some of the Nordic capitals considered global leaders in sustainable urban transportation (e.g. Copenhagen's bike lanes, Oslo's electromobility and Stockholm's public transportation) (Salvucci et al., 2019). In 2019, Finland, Sweden, Denmark, and Iceland signed a declaration to collectively work toward carbon neutrality, further increasing the attention on decarbonising the transportation sector in the Nordics (Mordor Intelligence, 2021).

Path-creation policies are predominant in the Nordic policy mixes on transportation. Policies focusing on transportation in the Nordics often rely on creating new policy pathways for mobility, but transport regime-sustaining policies are also standard due to public and market pressure. Therefore, Nordic policy actions for mobility are developed in a push-pull environment, resulting in, at times, internal paradoxes in mobility-related actions (Kotilainen et al., 2019). The Nordic region can become a frontrunner in solving climate challenges related to the transportation sector. Still, the deployment rate of low-carbon technologies and fuels needs to be accelerated for this to be achieved. Improved policy measures are essential to decarbonise areas such as freight transportation in the Nordics (Hansson, Karlsson, et al., 2019).

The Nordic countries have explored several transport innovations and are regarded as international pioneers in electric vehicles, electrified roads, and the Mobility-as-a-Service model. A transnational study on sustainable future transportation in the Nordics concluded that attention should be given to how key innovations can be commercialised and deployed. There is a need to increase the understanding of the role of new business model innovation in supporting transport innovation (Hansson, Karlsson, et al., 2019). Despite some successes, the overall picture indicates many ongoing opportunities, with initiatives often being superficial, for example, not extending beyond the coordinated provision of information. There is also evidence of weak coordination and duplication of effort, for instance, between public transport authorities (local, municipal, and regional). At the last-mile level, the emergence of e-scooters has been the most visible move in the personal mobility market over the past few years. However, the steep upward trend in e-scooter use has stalled somewhat due to increasing safety and nuisance concerns. There is a need to increase the understanding of the role of new business model innovation in supporting transport innovation

The need for sustainable mobility solutions is continually on the rise. PSS solutions can integrate sustainable principles in the use and design phase of passenger transportation (Beella et al., 2010) and new opportunities in the logistic management and supply chain configurations (Pan, 2019), as seen with the Nordic freight transport, consisting almost solely of PSS solutions.

To understand the dynamics and potential of sustainable transportation in the Nordic region, we have mapped the use of four key product types: bicycles, cars, scooters, and boats. These categories represent a broad spectrum of mobility options in Nordic countries. Each product group offers unique insights into the challenges and opportunities of implementing PSS models in the transportation sector.

We have chosen to focus our pilot projects on bicycles better to understand the business models for PSS in this category. Bicycles are particularly promising due to their existing integration into the Nordic transportation culture, low environmental impact, and suitability for short to medium distances. Furthermore, the rapid growth of bicycle PSS models in the Nordics (and the EU) underscores their potential to significantly contribute to a more sustainable transition of Nordic urban mobility. This growth trend provides a

rich field for studying the dynamics of PSS implementation and scaling possibilities. Through detailed investigations in pilot projects, the aim has been to analyse and refine these models, enhancing their overall efficiency, accessibility, and environmental sustainability.

5.1 Passenger Cars

Cars remain a significant mode of transportation in the Nordic countries and a large contributor to greenhouse gas emissions. In the EU, passenger cars are responsible for 16% of total CO_2e, largely due to the use of fossil fuels in the use-phase of the vehicles (European Commission, n.d.-a). Despite more sustainable alternatives being available, such as biking and public transportation, it is likely that cars will remain a significant transportation mode in future.

The World Economic Forum and Accenture have developed a taxonomy for increased circularity in the car industry, together with 40 industry actors, in recognition of the need to increase sustainability. The taxonomy describes how PSS solutions play a key role in increased circularity across the various parts of the value chain of cars. It defines smart mobility and as-a-service solutions for vehicles and their parts to be in the upper levels of the taxonomy – assuming urban and rural implementation alike – but also recognises the role of leasing solutions in the first steps towards greater circularity (World Economic Forum, 2020). The role of PSS solutions in securing more sustainable vehicle fleets and mobility in the EU is also mentioned in the EU Circular Economy Action Plan (Nordic Council of Ministers, n.d.-a).

In some Nordic countries, with Finland as a global frontrunner, Mobility-as-a-Service (MaaS) models have been developed, where PSS solutions for cars are seamlessly integrated with other solutions such as public transport and bike-rental to provide a comprehensive model (Future Mobility Finland, n.d.). MaaS models hold the greatest potential for circularity, as reflected by the car industry's circularity taxonomy, where the models sit at the top. However, MaaS models are notoriously difficult to develop. Developing MaaS models requires the collaboration of multiple public and private actors on many complex elements, including revenue sharing, infrastructure planning, and data integration (Swedish Energy Agency, n.d.). A recently concluded Nordic practical research effort investigated and developed recommendations for developing MaaS solutions for cross-border mobility. It highlights the criteria and next steps necessary for developing viable solutions. These are also relevant for more general implementation of MaaS models in the Nordics (Nordic Council of Ministers, 2024a) and can be supplemented by previous Nordic research and recommendations based on an analysis of drivers and barriers for MaaS in Nordic countries (Laine et al., 2018b).

Many other PSS solutions are available for passenger cars today – not least provided by new startups. These include both use-, product-, and result-oriented models that target B2B and B2C markets, with some extending to B2G. Well-established models include ride-hailing services (taxis), short-term renting, and operational leasing. Newer models are becoming more prevalent, such as peer-to-peer apps for ridesharing and carpooling, private product pooling models for car rental, and flexible pay-as-you-go sharing services (Kurpiela & Teuteberg, 2023).

The mapping of Nordic cases in this project suggests that the use-oriented PSS models, especially pooling/sharing models, are predominant and typically utilise smartphone applications for easy access. Pay-as-you-go services are also common, often combined with subscription or pre-paid minute packages to reduce costs. The newer PSS models, such as pay-as-you-go models, are primarily available in the larger cities in the Nordics, but many providers are gradually expanding their reach (Egebæk et al., 2022).

The market penetration of PSS car solutions varies across the Nordic countries with each model facing unique challenges in the various contexts. However, there is no recent comprehensive overview of the presence and success of the different PSS models across the Nordics. A 2017 report on the Nordic sharing economy identifies several empirical examples of PSS models for personal transportation with and without drivers (Skjelvik et al., 2017a). Our investigation shows that some of these models have ceased to exist, other currently existing services are not included, and others on the list have expanded in market prevalence. Generally, the market for PSS car models is likely growing as customers seek more flexible solutions for personal mobility. This includes a growing market for operational leasing of electric vehicles (EVs), with private consumers shown to be twice as likely to choose leasing over ownership when shifting to EVs (McKinsey & Company, 2023). In Sweden, for example, approx. 70% of newly registered EVs are leased rather than owned (Trafik Analys, 2022). This is a highly relevant trend, considering the EU ban on sales of new cars and vans with combustion engines from 2035 (European Commission, 2023d).

According to the literature, car-sharing services can positively and negatively impact CO_2e emissions (Ceschin, 2013a; Kuntzky et al., 2013). Car-sharing services integrating the newer and more energy-efficient vehicle fleets are particularly effective at reducing CO_2e emissions (Ahonen et al., 2023). The most impactful features of car-sharing services include a decreased need to manufacture new cars and a reduction in total vehicle kilometres travelled, which diminishes the overall environmental footprint (Chen & Kockelman, 2016; Jung & Koo, 2018). Well-implemented car-sharing services can significantly reduce both car ownership and the distance travelled by vehicles, contributing to a substantial reduction in emissions (Chan & Shaheen, 2012; Nijland & van Meerkerk, 2017).

However, the transition from private car use to shared vehicles introduces a modal shift effect, where some of the mobility previously served by private cars is replaced by other forms of transport, such as public transportation. To some extent, this effect can offset the benefits of emission reductions provided by shared cars (Amatuni et al., 2020). Conversely, some of the mobility previously managed by public transportation might be replaced by car-sharing services, potentially increasing total emissions (Arbeláez Vélez & Plepys, 2021; Jung & Koo, 2018; Skjelvik et al., 2017b).

While the modal shift effect brought on by car-sharing services introduces complexities in measuring their overall impact on emissions, connecting these findings to broader trends in transportation habits is crucial. Despite the increasing availability and utilisation of PSS models, private car ownership remains the most common practice for using passenger cars in the Nordics.

The modal shift effect brought on by car-sharing services introduces complexities in assessing their overall impact on emissions and highlights the need for a deeper analysis. Despite the increasing availability and utilisation of PSS models, private car ownership remains the predominant mode of transportation in the Nordics. Continuing to explore and understand these dynamics is vital for shaping future policies and practices that effectively balance personal mobility needs with environmental sustainability goals.

5.2 Scooters

E-scooters have become increasingly prevalent as a B2C last-mile transportation solution in Nordic urban areas. Their rapid introduction has significantly impacted urban infrastructure and prompted various regulatory responses due to concerns over public safety and urban clutter. In cities like Helsinki, Oslo, Copenhagen, and Stockholm, the overwhelming presence of e-scooters has resulted in regulations such as nighttime bans and restrictions on the number of scooters permitted. This response was driven by safety issues, with numerous incidents leading to injuries and, in some cases, fatalities, prompting calls from medical professionals and public health officials for more stringent controls (Dodds, 2021a; European Commission, n.d.-e; Meaker, n.d.; YLE, 2021). PSS providers with electric scooter solutions, such as Tier, have supported limitations and regulations of the market and call for tenders to enable parking infrastructure and accessibility, as seen in Paris, London, and New York (Dodds, 2021b).

The environmental impact of e-scooters, often marketed as a green alternative to traditional urban transport methods, is also under scrutiny (Tier, n.d.). While the emissions during use phase are relatively low, the overall environmental footprint is significant. This impact primarily arises from the production, collection, and charging processes. A 2019 Life Cycle Assessment (LCA) highlighted that manufacturing accounts for about 50% of an E-scooter's greenhouse gas emissions due to the materials used, such as aluminium and battery components. The user phase emits about 47% of the

total impact, mainly due to the collection of the e-scooters in fossil-driven vehicles, charging and short lifespan of shared scooters, in some cases due to vandalism (Hollingsworth et al., 2019).

A 2019 Life Cycle Assessment (LCA) highlighted that manufacturing accounts for about 50% of an e-scooter's greenhouse gas emissions due to the materials used, such as aluminium and battery components. Operational impacts, including the use of fossil-fuelled vehicles for scooter collection and the energy used for charging, contribute substantially to their environmental burden.

Research, such as a study from North Carolina State University in 2019, has indicated that e-scooters produce more emissions per passenger mile than buses, e-bicycles, and traditional bicycles. The e-scooters are, however, a more sustainable alternative to a short car trip. Data from French cities suggest that e-scooters typically replace walking or public transport (in total 74% of the uses), while only 8 % displace car trips (Perry, n.d.).

Despite these challenges, e-scooters still present a potential reduction in urban transportation emissions if they replace personal car travel (Hollingsworth et al., 2019). The true environmental benefits of e-scooters hinge on optimising their collection and charging systems and extending their operational lifespan. This improvement can mitigate some of the negative impacts and enhance the positive contributions of e-scooters to urban mobility solutions. As such, the debate continues on how to best integrate e-scooters into the urban transport ecosystem in a way that genuinely contributes to sustainability goals.

5.3 Boats

The Nordic countries, characterised by their islands and coastal geography, rely heavily on maritime transportation of passengers, goods, and commodities (Oceana, 2021). This dependency has given rise to a wide array of maritime PSS solutions, from leisure trips to essential personal transport, embodying the region's deep-rooted maritime culture.

Historically, maritime transportation has been a staple in the Nordic region. Modern developments have introduced PSS models that offer day trips on small boats for both consumer (B2C) and business (B2B) markets in Nordic harbours and canals. These services typically operate on use-oriented models, such as rentals or pooling, often requiring memberships for access.

The environmental implications of these PSS offerings, particularly leisure boat trips, raise critical questions similar to those of other transport models. One such question is whether these services reduce the need for boat production and ownership or merely shift the demand. While PSS solutions expand access to maritime experiences to a broader audience, potentially democratising waterborne leisure activities, they may

inadvertently increase overall material and energy consumption. However, boats utilised within these PSS frameworks are likely to achieve higher usage rates, enhancing value creation and potentially offsetting some environmental impacts.

Regarding the environmental impact of PSS solutions providing boat trips for enjoyment, the question of whether the PSS solutions actually replace any production and purchases of boats arises as with the other transportation models. The PSS solutions for boat trips for leisure could add to the consumption of materials and energy since the boat trips become available to a broader consumer group that would otherwise not have the means to access a boat. While this provides more equality in consumption patterns, the overall material and fuel consumption could increase. On the other hand, the boats produced are more likely to have a greater utilisation with PSS business models, with more significant value creation. Depending on the PSS provider's approach to the acquisition of the boats, the design phase and the maintenance and energy source of the boats, environmentally sound solutions can be provided for "enjoyment" boating. Still, the opposite can be just as likely.

The sustainability of these boating experiences heavily depends on the providers' strategies concerning the acquisition, design, maintenance, and energy source for the boats. While PSS can offer environmentally friendlier boating options, achieving these outcomes is highly contingent on the implementation practices of the service providers. Therefore, the environmental benefits of leisure boating PSS models are not guaranteed and can vary widely based on operational execution.

5.4 Bicycles

Bicycles are a cornerstone of sustainable urban transportation in the Nordic countries, with cities like Copenhagen, Oslo, and Stockholm globally recognised for their extensive bike lane networks and high cycling rates. The well-developed cycling infrastructure in the Nordic region supports year-round cycling, making bicycles a practical and environmentally friendly mode of transport. PSS solutions for bicycles have been introduced in more than 700 cities worldwide, with more than 2,000 bicycle-sharing programs in service (Shui & Szeto, 2020). They are widely acknowledged for reducing car use and fuel consumption, promoting green travel, and improving traffic efficiency. They are widely acknowledged for reducing car use and fuel consumption, promoting green travel, and improving traffic efficiency.

SIRQEL (est. 2022, Norway):

Operates a subscription-based model aimed at reducing the overconsumption of children's bicycles (and later adult bicycles) and the associated waste.

The company offers long-term bicycle rental, including continuous maintenance, primarily serving the private market in Norway.

In the Nordic Region, PSS models for bicycles are increasingly prevalent, especially in urban areas, where they contribute to more sustainable mobility. Use-oriented models dominate, including:

- Short-term rentals, popular in cities for commuters and tourists, allowing for on-demand access to bicycles at low costs.
- Long-term leasing, where customers can rent bicycles (including cargo and electric bikes) for an extended period, often includes maintenance and repair services.
- Bike-sharing systems, which allow users to pick up and drop off bikes at designated stations, commonly integrated with city transport systems. These programs are particularly prominent in cities like Copenhagen and Stockholm, promoting flexibility and reducing car dependency.

RENT A BIKE & OUTDOOR
(est. 2019, Faroe Islands):

Rent a Bike & Outdoor offers short- and long-term bicycle rentals and guided tours to cultural and historical sites. Its primary customers are tourists and local businesses, and the company aims to promote cycling culture and sustainable mobility in the Faroe Islands.

Additionally, **electric bicycle rentals and leasing models** are gaining traction in the Nordic region, providing access to more expensive, higher-quality products. This makes cycling an attractive alternative to car ownership, particularly in urban areas where parking savings further enhance the appeal. These models often include comprehensive service packages, such as maintenance and theft protection, ensuring the longevity of the bicycles and minimising waste.

5.4.1 Drivers and barriers

Bicycle-sharing and rental models are widely regarded as low-cost, low-emission solutions that align with the Nordic countries' ambitious climate goals. They are praised for supporting societal mobility equality through increased access, reducing emissions, and promoting health benefits. However, different PSS configurations for bicycles come with both minor and major challenges (Egiguren et al., 2021). For instance, studies show that these solutions do not always accommodate diverse user groups (Breengaard et al., 2021), limiting their broader adoption. Another study highlights how PSS solutions for bicycles have resulted in massive investments, unreasonable distribution of bicycles, and significant disruption and stress to urban governance due to "bicycle cemeteries" and immature technologies for recycling the waste from these cemeteries.

A recent study on bike-sharing in Milton Keynes in the UK indicates that bike-sharing usage peaks significantly during the summer months compared to winter, indicating a strong dependency on weather conditions. Additionally, bike-sharing was more frequent on weekdays than weekends, with two prominent peaks during morning and evening hours, suggesting that commuters, rather than recreational users, primarily drive bike-sharing. These insights suggest that the success of PSS models in promoting bike-sharing may depend heavily on local commuting patterns and seasonal variations, adding complexity to their broader implementation in urban areas (Dzięcielski et al., 2024)

Three PSS providers of bicycle renting and leasing solutions have participated in the project pilot programme: Sirqel, based in Oslo, Norway; Rent a Bike & Outdoor, based in Tórshavnar, the Faroe Islands; and Liisabike, based in Copenhagen, Denmark. The pilot projects focused on identifying economic barriers, such as access to loans and insurance, increasing customer appeal for PSS solutions, and assessing the environmental impacts of different transport modes compared to bicycles.

Cultural drivers and barriers

While cycling is deeply embedded as a cultural norm in most Scandinavian countries, this is not the case in places like the Faroe Islands, where the pilot company Rent a Bike & Outdoor operates. Introducing a bicycle rental PSS in the Faroe Islands also aimed to shift local perceptions of cycling as a viable mode of transport. A key focus of the pilot project was understanding customer perceptions of the rental service using a mobility-oriented PSS framework. Overall, customers appreciated the user-friendly system, high flexibility, and personal customer service. However, these benefits for customers also

presented challenges for the provider, as maintaining high levels of service and flexibility required significant resources.

The study examined the dynamics between customer and provider perspectives. Customers were drawn to the business model's lack of insurance requirements, flexible service, and high levels of support. However, from the provider's standpoint, these benefits led to increased maintenance costs, resource use, and operational instability. On the customer side, key barriers to adopting the PSS model included a desire to own the bicycles, a limited product selection, and perceived high costs. For the provider, however, the narrow product range simplified maintenance, and higher prices were necessary to cover administration, repairs, and customer service costs.

Customer interviews revealed additional experience-based benefits, particularly for tourists. Rent a Bike & Outdoor enabled tourists to explore the Faroe Islands with greater freedom and engagement compared to traditional transport options like cars or buses. Customers valued the slower pace of cycling, which allowed them to interact more closely with the surroundings and locals, offering a unique, immersive experience.

> ”
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> *With the bike, I was able to stop and talk (...) with locals and learn about the country I visited*
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> **– Interview 2024, PSS customer**

However, a survey conducted with existing and potential customers identified some barriers to bicycle rental. About 70% of respondents noted concerns over availability, fearing that their preferred bike might not be available when needed. Additionally, 50% found rental options more expensive than purchasing a bike, while 30% were reluctant to rent due to the lack of ownership. These responses indicate a prevailing culture of ownership, with many customers (particularly locals) still hesitant to embrace the full benefits of rental solutions.

Economic drivers and barriers

A common challenge for all pilot companies is the high cost of product acquisition, which limits their ability to quickly meet customer demands, offer a broad product range, and scale operations. Although securing loans or funding might seem straightforward, the pilot projects revealed the difficulties small businesses face in obtaining financing, particularly for newer, less common models like PSS.

The loan application process credit assessments, bank meetings, and extensive documentation consumes time and resources, with many applications rejected without explanation. Small and medium-sized enterprises (SMEs), which dominate the PSS bicycle solutions consulted during the project, are particularly vulnerable due to weaker

financial structures, lower capitalisation, and fewer financing options compared to larger firms.

Interviews with a Norwegian financial institution also revealed that proving the value of PSS models in financial terms is a barrier. These businesses struggle to demonstrate their commercial viability using traditional banking frameworks, which are better suited to linear business models where asset depreciation is easily calculated. For Sirqel, documenting the retained value of their bicycles after their rental lifecycle was problematic despite having an established partnership with a company that systematically buys used bicycles. Although Sirqel's business model is financially sound, the lack of clear metrics for evaluating bicycles' resale or reuse value hindered their ability to secure loans.

Additionally, the extensive documentation requirements – such as long-term projections and detailed product data – present another challenge. Circular businesses, which operate with longer product life cycles, challenge traditional loan evaluation processes. While Nordic financial institutions have been slow to adapt to these new models, countries like Germany and the Netherlands have shown greater flexibility in supporting circular businesses, offering more favourable financing options.

This research also revealed that the Nordic micro-mobility sector, which includes many of these PSS companies, is characterised by frequent market entries and exits. Even larger, well-funded firms consistently struggle to achieve profitability. For example, one of Denmark's leading operators has reported ongoing double-digit losses over the past few years, while smaller companies face financial deficits despite receiving significant investment. The reasons for this persistent lack of profitability are not entirely clear but may include high operational costs, market saturation, and fluctuations in demand due to seasonal variations. More in-depth analysis is required to fully understand the financial challenges facing this sector.

Overall, these findings underscore the need for systemic changes in the financial sector to better support circular business models. For companies like Sirqel and Rent a Bike & Outdoor to grow and succeed, Nordic financial institutions must adjust their loan approval criteria to focus more on the long-term sustainability and retained value of circular products. This shift will likely require political and regulatory support to encourage greater investment in green and circular business models.

Technical drivers and barriers

The pilot companies face a range of technical challenges, both internal and external. Internally, they struggle with operational documentation, such as tracking rentals, managing maintenance and repairs, and handling waste efficiently. Externally, they are hindered by broader infrastructure issues that do not adequately support PSS models, limiting their potential to scale and serve diverse customer needs.

Rent a Bike & Outdoor uses an analogue system to track bicycle rentals, making inventory management difficult, especially during peak tourist seasons in the Faroe Islands. Sirqel faces issues in obtaining financing, which requires comprehensive documentation of products and financial projections. Both companies struggle with integrating digital systems for tracking rentals and operations, a common issue identified among SME PSS providers. A technical solution for registration, monitoring, and documentation of business operations could help streamline operations, reduce resource use, and facilitate financing and partnerships. Without them, these companies face higher operational costs and difficulties in scaling.

Rent a Bike & Outdoor also encounters challenges related to the underdeveloped cycling infrastructure in the Faroe Islands. Since cycling is not yet a common mode of transport in the region, issues such as a lack of road safety information for cyclists and poorly marked routes create difficulties for customers. Some customers expressed concerns about the lack of signage and information regarding which tunnels were safe for cycling. To promote cycling as a viable transport option, the company will need to collaborate with policymakers to push for better infrastructure and safer roads for cyclists.

5.4.2 Environmental potential

The environmental potential of bicycle PSS models is most significant when they effectively reduce car dependency, promote long-term use of bikes through maintenance and repair, and avoid the pitfalls of oversupply and poor waste management. However, to fully realise these benefits, the integration of sustainable practices in the management of these systems, along with supportive infrastructure and responsible consumer behaviour, is crucial. Bike-sharing systems not only cut CO_2e emissions and fossil fuel use but also encourage healthier lifestyles and lower urban pollution levels.

Studies evaluating long-term environmental benefits, such as those from New York City's bike-sharing system, reveal significant impacts. Over four years, the system saved 13,370 tons of oil equivalent and reduced 30,070 tons of carbon emissions and 80 tons of nitrogen oxides, highlighting its contribution to urban sustainability (Y. Chen et al., 2022). In other studies, the environmental impact varies depending on factors like infrastructure, user behaviour, and the extent to which these systems replace car travel (Fishman et al., 2014).

By maximising the use of bicycles through sharing and leasing, PSS models can reduce the demand for new bike production, which cuts down on raw material extraction and energy use. This is especially relevant for electric bicycles, which require more resources to produce but can offer greater emissions savings over time if maintained well.

While environmental impact assessments were not central to the two pilot projects, a literature review was conducted on CO_2e emissions across transportation lifecycles. Although bicycles typically have low CO_2e emissions, the production and end-of-life

stages particularly for e-bikes still generate emissions The literature review suggests that end-of-life emissions could be reduced through reuse and recycling initiatives, which could involve outsourcing or reselling materials. Additional recommendations include using spare parts made from secondary materials, repurposing parts from decommissioned bikes, and partnering with local organisations to repurpose unavoidable waste, such as for children's crafts in daycare settings (Baird & Pedersen, 2013; Buberger et al., 2022; Chen et al., 2020; García et al., 2022; Mahesh & Ramadurai, 2017; Qiao et al., 2017; Roman et al., 2023).

5.4.3. Conclusions

Bicycle PSS models in the Nordic region hold potential for sustainable urban transport by reducing new bicycle production, lowering resource use, and cutting carbon emissions through broader access to low-emission options. Short-term rentals, long-term leasing, and bike-sharing systems extend bicycle lifespans by incorporating maintenance and repairs, which helps reduce waste and improve resource efficiency.

Studies indicate that, when adopted at scale, these systems can significantly impact urban sustainability, promoting a shift away from car dependency, reducing traffic congestion, improving air quality, and encouraging healthier lifestyles.

However, scaling bicycle PSS faces challenges. Financial barriers, especially for small businesses like Sirqel, make funding difficult due to the complexity of circular business models. Additionally, limited cycling infrastructure in some regions, such as the Faroe Islands, and a preference for bicycle ownership can limit the growth of rental and sharing programs.

6. PACKAGING

Packaging is an essential part of daily life, serving functions like product protection and reducing food waste. However, its widespread use, especially of single-use plastic packaging, has severe environmental impacts. This includes the pollution of ecosystems, for example, creating serious problems for marine environments (European Environment Agency, 2021). Today, single-use items like cups and food boxes are among the most common plastic pollutants found in nature (Oceana, 2021). The rise of disposable packaging is driven by lifestyle changes, such as the demand for convenience meals, takeaways and the growth of e-commerce and home deliveries. This trend is expected to continue, increasing packaging consumption and exacerbating its environmental problems.

In response to the growing demand, use, and waste of packaging, the EU revised the Packaging Waste Directive (94/62/EC) in 2018, obliging all Member States to introduce Extended Producer Responsibility (EPR) schemes for packaging by 2024 (Directive (EU) 2018/852). A more recent proposal from the EC aims to harmonise EPR requirements across EU member states to make them more effective. Further measures to combat plastic waste include banning certain single-use items in the EU (European Commission, 2022b).

With pressure from EU regulations and an increased focus on the negative environmental impacts of single-use packaging, PSS and Reusable Packaging Systems (RPS) (Long et al., 2020) can be considered solutions for closing the loop on packaging, thereby effectively contributing to reduced emissions from production and waste reduction. In some cases, RPS has been used for several decades, such as the Euro pallet or the well-established deposit return systems for bottles in many European countries, including the Nordics (Sensoneo, 2024). These successful examples illustrate that changing consumer behaviour is possible if financial incentives are provided. Additionally, the standardisation of products, along with the development of infrastructure and collaboration among market actors for return, collection, and redistribution, has been crucial to their success (Christoph et al., 2023).

In this project, we explored novel PSS solutions for packaging, covering a range of products and markets. Public attention often focuses on innovative ways to reduce plastic waste from consumer goods since this problem is highly visible. However, it is equally important to develop alternative models for the reuse of packaging in the B2B sector, where substantial opportunities for waste reduction exist, as shown in the example of Euro-pallets. Unlike other product groups, packaging typically lacks user interest in retaining ownership, presenting unique challenges for PSS providers. Packaging is often seen as disposable without value since it is frequently provided

at little to no cost to the consumer, such as single-use takeaway packaging or parcel packaging. euro

In the B2B sector, such as the pilot case of Looping's reusable transport packaging, the business model is straightforwardly B2B. The success of such systems depends on creating a business case appealing to logistics PSS providers, who are the direct users of these solutions. In the other cases, like the two pilots of Re-Zips' reusable packaging for parcels and Kleen Hub's reusable cups and food containers for takeaways, the business relationships remain primarily B2B, as these PSS providers collaborate with online retailers, takeaway vendors, and other businesses. However, these products are ultimately used by end consumers. Therefore, these solutions must not only be attractive to businesses participating in the reuse system but also to end consumers, requiring a double value proposition. Furthermore, this requires active engagement in communicating the benefits from the participating partners to their customers.

6.1 Plastic and single-use packaging

Plastic and single-use packaging are pervasive in modern consumer culture, particularly in the food and beverage industry, where convenience often takes precedence over sustainability. Single-use packaging, such as plastic cups, food containers, and cutlery, is designed to be disposed after use, leading to significant environmental challenges. Single-use cups are, for example, often a mix of fibre and plastic, making them difficult to recycle, with most ending up in general waste – or littered in the environment (EPECOM, 2019).

Efforts to address these issues include promoting more durable and multi-use reusable packaging solutions. Such systems are increasingly seen as a way to reduce the reliance on single-use packaging and minimise environmental impacts. By establishing reuse systems, reusable packaging can be circulated among consumers, significantly lowering waste generation and resource consumption. Packaging-as-a-service providers offer integrated solutions for managing reusable cups, including collection, inventory management, and re-circulation, aiming to make sustainable packaging convenient for end-users and participating take-away providers such as cafés and restaurants.

Reusable alternatives are most commonly seen in the context of coffee cups, and the Nordic countries are ranked amongst the highest in coffee consumption per person (Statista Research Department, 2024). However, the waste problem extends far beyond. In 2022 alone, around 843 million disposable cups and 681 million disposable food boxes were placed on the Swedish market, according to the Swedish Environment Agency (Håll Sverige Rent, 2024). The market potential for reusable solutions spans a wide range of takeaway packaging used in restaurants, cafés, shops, petrol stations, hotels, event venues, and offices. Despite this, the adoption of reusable packaging systems is lagging, and existing systems have not yet been scaled to a national level across any of the Nordic

countries. Where providers do exist, they tend to operate on a smaller scale, often in niche markets, and have yet to achieve the scale necessary to significantly reduce single-use packaging.

In the Nordic region, Sweden currently leads the market for reusable packaging services. The dominant player, Panter, operates a digital return system for reusable containers across roughly 800 takeaway locations. Several start-ups have emerged in the Nordic circular packaging market, offering various solutions such as app-based systems for deposit and returns, reusable cups and food containers, and washing services. However, many of these companies face challenges in expanding their operations. Low consumer adoption and reduced profit margins during COVID-19 have hindered their ability to scale effectively. As a result, in June 2024, Kamupak, the Finnish market leader for reusable packaging solutions, and &Repeat, Sweden's largest startup for circular packaging, announced their closure less than a year after merging in an effort to establish a dominant Nordic provider of circular packaging solutions (Santos, 2024).

KLEEN HUB (EST. 2020, DENMARK)

Kleen Hub offers a reusable packaging system to help take-away providers reduce single-use plastic waste. Through Kleen Hub's technology, participating restaurants and cafés can provide reusable cups linked to customers' payment cards, eliminating the need for an app or deposit. Customers are only charged if they don't return the cup to a participating partner.

In Denmark, Kleen Hub and New Loop are the main operators, providing services primarily to festivals, office buildings and a few cafés using branded cups in closed-loop systems. In January 2024, Aarhus launched a city-wide pilot project introducing a reusable cup system with return stations across the city and more than 60 participating cafés (Rotake by Tomra, 2023). While the ambition is to expand the system to include other packaging types, the long-term success of this project remains uncertain.

Norway lags behind in adopting reusable packaging systems, with only a few locations in Oslo participating in Europe's biggest reuse system operated by the German company Vytal (Vytal, n.d.). Stavanger and other Norwegian cities are part of a municipality-driven project to reduce litter and explore experiences from other European cities to minimise single-use cup consumption (Pedersen, 2024).

Iceland currently lacks reusable cup systems. Travel blogs advise visitors to bring their own reusable mugs, as most establishments only offer paper or plastic cups, even for dine-in customers (Local Guide, n.d.) .

6.1.1 Drivers and Barriers

Regulatory drivers and barriers: Policy efforts do not (yet) translate into desired results

There is a growing emphasis on reducing waste from single-use plastics at European, national and local levels. The EU's single-use plastic directive sets the framework for national legislation and municipal initiatives across the Nordics, such as pilot projects for reusable cup systems in Helsinki and Aarhus. The EU is actively working to significantly reduce packaging waste by 2040 (European Commission, 2024c) through measures such as banning certain single-use plastic items, reducing consumption via product labelling, setting national reduction targets, and implementing extended producer responsibility (EPR) programs.

Nordic countries are in the process of implementing the EU Directives with varying levels of ambitions in their efforts to curb plastic waste. While all Nordic countries have incorporated plastic waste reduction into their national strategies, only Finland and Sweden have set specific national targets. Finland aims to reduce the consumption of single-use plastic packaging for food and beverages below 2022 levels by 2026 (Ministry of the Environment – Finland, 2018). More ambitiously, Sweden seeks to cut the consumption of single-use cups and food containers by 50% by 2026 (compared to 2022). As of January 2024, Swedish legislation requires businesses that sell more than 150 takeaway items per day in single-use packaging to offer reusable alternatives. (The Swedish Environmental Protection Agency, n.d.).

Other European countries are taking similar steps. In 2023, Germany introduced comparable regulations, while the Netherlands opted for a mandatory fee on single-use plastic cups and food containers (RVO, n.d.). However, despite these policy initiatives, the adoption rate of reusable packaging solutions remains disappointingly low, even in countries with mandatory regulations for reusable takeaway packaging. Service providers in these markets initially experienced a surge in new business customers and investments following the introduction of the new legislation. However, this momentum has since slowed (WWF Deutschland, 2024). A recent study on the effects of the new regulation in Germany shows that the reuse share increased from 0.7% in 2022 to 1.6% in 2023 (WWF Deutschland, 2024). While this represents doubling the reuse rate, the overall percentage remains very low. One major barrier has been the lack of enforcement, which has led many businesses to scale back their efforts to provide reusable options due to minimal regulatory oversight. Simultaneously, the total amount of packaging waste has continued to rise, highlighting the ineffectiveness of current policy efforts in driving meaningful change (WWF Deutschland, 2024).

In Sweden, many companies are still hesitant to fully comply with the new regulations, waiting to see whether authorities will enforce them with sanctions. So

far, fines have rarely, if ever, been issued. According to interviews with reuse providers, even many businesses that offer reusable packaging alternatives fail to actively promote these systems to their customers. The current regulation mandates that companies offer reusable alternatives. Still, it does not provide incentives for either businesses to encourage their use or consumers to choose them, especially since single-use packaging remains available at no additional cost.

Some experts argue that the policy is ineffective in its current form and call for stronger measures, such as introducing a mandatory fee on single-use takeaway packaging – similar to the approach taken with plastic bags (WWF Deutschland, 2024). Furthermore, the experiences from Sweden and Germany show that the lack of enforcement and controls hinders the successful implementation of the existing legislation. The current policy efforts in Sweden and Germany have led to a situation where companies subscribe to the regulation mainly to meet legal requirements. Some even use the subscription as a greenwashing tactic without meaningfully reducing their reliance on single-use packaging, according to some of reusable-packaging providers interviewed for this project. They expressed frustration over, that their business model is contributing to this inefficient use of resources under some circumstances.

> ”
>
> *Policy cannot only rely on the reuse providers and restaurants to provide the solution, if we are to have a chance of meeting the political goals on reducing single-use consumption*
>
> **– Anna Lindvall, Panter (reuse provider)**

This regulatory challenge is closely tied to economic aspects, as the current infrastructure is designed for single-use items. Waste management systems are efficient, keeping streets clean and ensuring trash is processed without direct cost to the end consumer. To truly shift toward reusable systems, funding and focus would need to transition from waste management infrastructure to reuse infrastructure. Without this shift, the adoption of reusable packaging will remain limited.

Cultural drivers and barriers: Discrepancy between consumer values and action

Despite widespread awareness of environmental issues, there remains a significant gap between consumer values and actual behaviour when it comes to adopting reusable packaging systems. According to a user survey and interviews during the Kleen Hub pilot project, waste reduction is the primary motivation for consumers to use reusable packaging. Over 80% of respondents cited waste reduction as the main advantage, surpassing even financial incentives like receiving a 10% discount on their drink when choosing a reusable cup.

The Nordic countries have a strong foundation to build upon, particularly with the success of deposit-return systems for bottles, which have cultivated a cultural recognition of the value of reusable containers. (Pedersen, 2024). However, despite this cultural groundwork, many consumers try reusable cup systems only a few times before reverting to single-use packaging. This indicates that these systems struggle to create sustained behavioural change. A likely explanation for this drop-off is the perception that reusable systems are burdensome. In contrast, single-use packaging is associated with convenience, especially since the waste management process remains largely invisible to consumers. This aligns with findings from interviews with larger providers in Sweden and mirrors the experiences of reuse providers in Germany, where similar challenges with consumer retention have been observed.

Field research at Coffee Collective shows that nearly all users were introduced to the Kleen Hub system through staff or signs and posters at the participating café. Staff mostly tries to introduce the system in the mornings to regular customers and does not have the time for this on the weekends when the café gets very busy. This highlights the importance of frontline staff in actively promoting reusable alternatives and guiding customers through the process, such as answering questions about how to return the packaging – but also, that educating customers is additional work that requires extra time.

In Sweden, the new law mandating reusable options requires businesses to make these alternatives visible to customers, but this was not supported by a wider public campaign to raise awareness about the new regulations. While reuse providers like Panter supplied communication material to restaurants and cafés, they lacked the financial resources for wider promotional efforts, such as social media campaigns or public advertisement. As a result, many customers remain unaware of the regulation or are unsure where they can request reusable options since they are not visibly promoted in most locations.

Technical drivers and barriers: The lack of standardised systems

A major challenge in adopting reusable packaging systems is the lack of standardised solutions across the market. The fragmented landscape, dominated by small start-ups, creates difficulties for reuse system providers, participating businesses, and consumers. Customers often find it inconvenient to download multiple apps or sign up for systems that only function in a limited number of locations. Additionally, the absence of standardisation in cup sizes, washing systems, and tracking technology makes it harder for providers to scale their businesses effectively.

For participating companies, being part of a larger, standardised reuse network could increase the appeal of reusable options for their customers. However, many businesses hesitate to adopt standardised reusable cups that circulate between cafés and restaurants, as this limits their ability to include custom branding. This is one reason some establishments, like Coffee Collective, choose to offer their own reusable cups rather than join a broader network.

User interviews at a Copenhagen café revealed that the use of reusable cups is mostly limited to customers who live nearby or are on a walk, where they can conveniently return the cup after use. Otherwise, the perceived barriers to participation become too high. Most operating return systems have very few return points, making customers reluctant to commit to the process, even if they are supportive of environmentally friendly solutions in general.

> ”
>
> *I considered using it, but it's too difficult for me to return it. I would 100% use it if I could return it close to my home*
>
> – Coffee Collective customer

Furthermore, the inconvenience of carrying the cup after finishing a drink, especially if it lacks a leak-proof lid, adds to the reluctance. These practical challenges highlight the need for more accessible and standardised systems to make reusable packaging a convenient and attractive option for both consumers and businesses.

6.1.2 Environmental Potential

The primary environmental benefits of a reusable cup system are reducing the need for new production and minimising waste. However, reusable cups, typically made from higher-quality, resource-intensive materials, often require more resources and energy to manufacture than disposable options. For these cups to become environmentally preferable, they must be reused multiple times, factoring in the material, weight, reverse logistics of transport and washing, and the technology needed to operate the system.

LCA research from East Asia supports these findings, showing that rental systems for reusable cups generally outperform disposable alternatives across most environmental impact categories (Greenpeace, 2023). However, experiences from the Nordics and other European countries indicate that achieving widespread adoption of reusable systems remains a challenge, which limits their overall environmental impact.

In addition to the environmental benefits, pilot interviews and field studies reveal that reusable cup systems offer distinct operational advantages for businesses and customers. For participating cafés, restaurants, and other venues, these systems can streamline inventory management and reduce storage needs by distributing reusable items across network partners. The technology within the system also facilitates impact data collection useful for ESG reporting. From a consumer perspective, beyond environmental benefits, customers appreciate the enhanced taste and experience of using reusable cups over disposables, as found in field research at Coffee Collective. Additionally, choosing a reusable option can give customers a sense of contributing to a larger environmental cause, enriching their overall experience.

Life Cycle Assessment of a reusable cup system

As part of the pilot project, Kleen Hub's reusable cup system underwent a Life Cycle Assessment (LCA) to evaluate its sustainability potential as a PSS. Several critical parameters were tested and analysed, including return rate, product technical lifespan, and the additional capital goods/technical equipment required to operate the system effectively. The key assumptions used in the LCA are outlined in Annex 2.

To evaluate the system, the functional unit (FU) was based on one year of servings of hot, to-go beverages at a café in Copenhagen, equating to 13,036 servings annually (or approximately 36 servings per day). According to data and assumptions provided by Kleen Hub, each reusable cup was estimated to have a technical lifespan of 200–300 uses and a return rate of 98%, equating to a loss rate of 2%. Using the formula for calculating the required number of products to fulfil the functional unit (RF = (FU/NU) + (FU/NU)*LR*(NU - 1)), the Kleen Hub reference flow was:

RF = (13,036/250) + (13,036/250) * (0.02) * (250-1) = 312 Kleen Hub cups

Since single-use cups cannot be reused, the total number needed to meet the functional unit (FU) is simply the total number of servings: 13,036 single-use cups.

The study results highlight key hotspots in the PSS model and provide insights into the sustainability potential of the Kleen Hub system compared to the single-use alternative. Figure 4 illustrates the stages included in the assessment, along with the percentage contributions to the reference flow's overall emissions. The largest contributors to emissions are the production and incineration of cups lost in the system. Additionally, the operations phase – which involves a tablet used in cafés for cup rental and returns, energy consumption for running the tablet, and data storage – also significantly impacts emissions. Within this phase, the tablet alone accounts for most emissions, confirming the assumption that capital goods can substantially impact the system's overall emissions.

Other capital goods, such as dishwashers and production equipment, were excluded from the assessment as they are not solely dedicated to operating the Kleen Hub system. Unlike in other LCAs for PSS, transportation contributes minimally to overall emissions. This is because transportation was only considered in the production and distribution phase, and it was assumed that cups would primarily be returned by bike or on foot. The decentralised washing approach within the Kleen Hub system further reduces transportation-related emissions.

This finding indicates that if washing and servicing of PSS products are centralised, or if distances for returns are reduced, the sustainability potential of PSS models could be even higher.

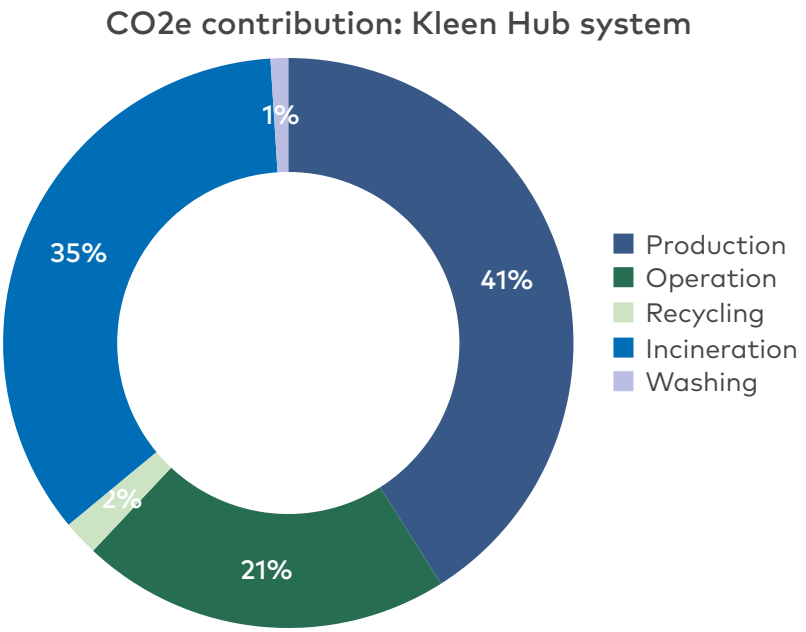


Figure 4: Overview of the percentage contribution to overall emissions from each lifecycle phase and process.

The effects of variations in return rate and technical lifespan were examined, as these are critical assumptions for the PSS. Analysis showed that changes in the return rate had the most significant impact on overall results, as even small changes in the return rate directly influence the number of products needing production. Additionally, higher loss rates increase the likelihood of cups being waste-managed by users. In this study, it was assumed that cups lost within the system would be incinerated. However, this assumption may oversimplify reality, as actual waste management by end users – such as home reuse, recycling, public trash disposal, or littering – has not been investigated.

Figure 5 illustrates the impact of key assumptions, showing that use rate (or technical lifespan) has a smaller effect on the results if the return rate remains consistently high (set at 98% in this study's reference flow). In contrast, changes in the return rate itself have a substantial effect on overall environmental impact. For example, if the return rate decreases from 98% to 95%, total emissions double – even though the technical lifespan of each cup is still 250 uses, as established in the study's reference flow. This finding underscores the return rate as a key factor when evaluating the environmental impact of packaging, as it determines the number of products needed to maintain the system's function and is central to most PSS business models.

In the Kleen Hub system, a lower return rate significantly affects the number of cups that must be produced and the number that end up managed as waste outside the system assumed here to mean incineration. Consequently, maintaining a high return rate minimises production demands and associated emissions. Furthermore, waste

management options are also impacted. In the Kleen Hub case, discarded cups are recycled by the producer. When cups are not returned, the user determines the waste management of the cups, making it difficult to control the plastic material's final disposal.

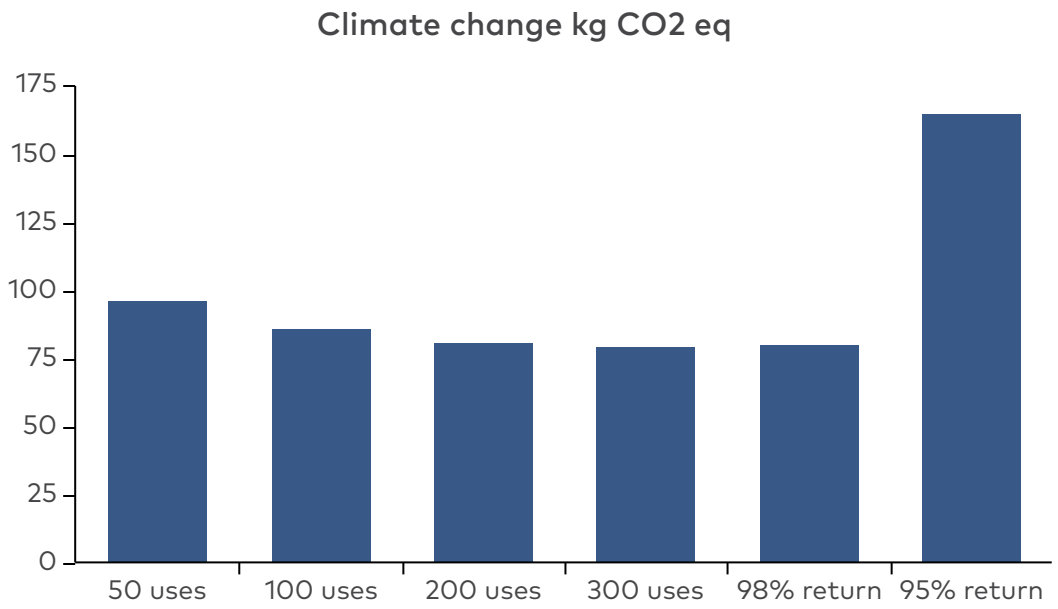


Figure 5: Impact of different number of uses and return rate of reusable cups.

Focusing on the return rate, the break-even point of the two reference flows is investigated. This investigation is based on the assumptions and system boundaries from the reference flow of the Kleen Hub study, meaning that the technical number of uses is 250, including production, transportation, operation, washing and end-of-life. Figure 6 illustrates CO_2e emissions at various return rates compared to the single-use alternative. This comparison shows that lower return rates lead to significantly higher emissions. The break-even point –where reusable cups match the emissions of single-use cups – occurs when the return rate is between 60% and 70%.

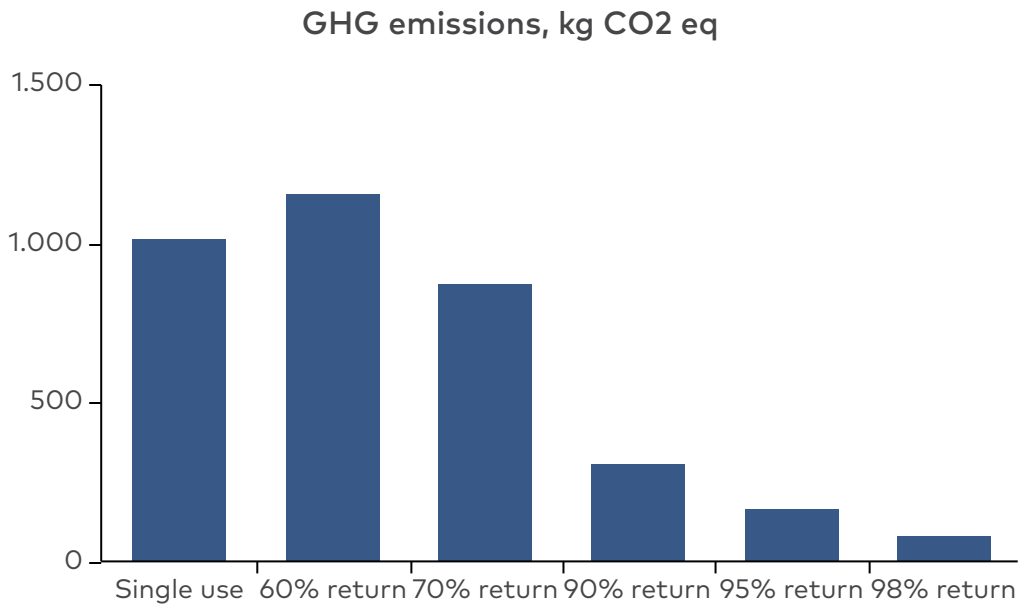


Figure 6: Impact from different return rates when compared to single-use.

6.1.3 Conclusions

Our research confirms that reusable cup systems have strong environmental potential if they achieve high return and usage rates. However, the market conditions for reusable packaging service providers in the Nordics remain challenging. Even in Sweden, where specific policy measures have been introduced to facilitate the shift from single-use takeaway packaging to reusable alternatives, adoption has been slow.

Current policy efforts must be complemented by measures that make reusable systems economically viable as they struggle to compete with the low costs of single-use packaging. Consumer adoption is still lagging, and reuse systems are often limited to regular customers who have been properly introduced to the concept.

While customers generally recognise the importance of reducing plastic waste through reusable alternatives, significant barriers to behavioural change remain. To drive wider adoption, it is essential to expand the number of return points and reduce the fragmentation of reuse systems across regions or countries. Additionally, efforts from staff at participating venues to introduce and promote these systems are crucial. For businesses to engage in these efforts, reusable alternatives must be more attractive and cost-effective for B2B customers.

6.2 E-commerce

Across the Nordic countries, the e-commerce sector has grown significantly, making it one of the leading markets in Europe in terms of online purchases per capita (Ecommerce News, 2023). This trend highlights the need for more sustainable packaging and logistics solutions as e-commerce continues to expand. Nordic e-commerce businesses vary widely in size, organisation, and product offerings, influencing their selling and packaging practices. Some use large online marketplaces, while others integrate e-commerce with physical stores or operate purely online. Packaging processes also differ, with some companies using fulfilment centres while others manage packaging in-house. Although comprehensive data on e-commerce packaging in the Nordics is limited, estimates for Denmark suggest that the sector generates significant amounts of packaging waste, including cardboard, paper, and plastic (Petersen et al., 2023). These estimates are based on assumptions and available data, making precise calculations challenging. Additionally, the practice of over-packaging, such as unnecessary fillers or excessive material use, remains difficult to quantify (Petersen et al., 2023).

RE-ZIP (est. 2020, Denmark):

RE-ZIP specialises in producing durable and reusable packaging for e-commerce.

RE-ZIP rents out e-commerce packaging to web shops, where consumers can choose to have their goods delivered in RE-ZIP reusable boxes and bags. Customers receive their orders in RE-ZIP packaging and return these at the local mailbox or pick-up point. The packaging is sorted, cleaned and reused.

Reusable packaging solutions and PSS business models have not been a major part of e-commerce, posing possible barriers to implementation. But, as the e-commerce sector grows, so does the need for and importance of reducing the impact of e-commerce packaging.

6.2.1 Drivers and barriers

Regulatory drivers and barriers

As with the remaining product categories for packaging, the revised Packaging Waste Directive (94/62/EC) and the Directive (EU) 2019/904 on the reduction of the impact of certain plastic products on the environment is expected to have a significant impact on the demand for reusable e-commerce packaging. However, according to RE ZIP, web shops do not wish to charge the consumers for packaging. Thus, they see a need for a tax on single-use packaging in e-commerce to create the necessary economic incentives. Furthermore, it is expected that regulation on mandatory ESG reporting such as the

CSRD will make it easier for RE ZIP to document and report on the environmental benefit of their packaging solution.

Cultural drivers and barriers

Although there is a growing trend for consumers to consider the environmental impact of their choices, a significant challenge remains: customers are not accustomed to paying for packaging in e-commerce. Most consumers do not want to pay extra for sustainable solutions and consider it a responsibility of the companies to shift to more sustainable practices (Rashmi, 2023). This makes it difficult for RE-ZIP to persuade larger web shops to either cover additional costs related to packaging or pass these costs on to the consumer, by charging them extra for packaging. Since single-use continues to be available at very little cost, it is thus challenging to create an economically viable business model based on reusable packaging.

Moreover, the return rate is a significant aspect of the environmental impact associated with RE-ZIP's products, making it essential to ensure consumers return the packaging. However, this presents challenges since consumers must change their behaviour regarding returns and not simply dispose of the packaging as usual. Having to remember to return packaging can be perceived as a burden since it requires extra time and effort from customers.

Technical drivers and barriers

For its reusable packaging system, RE-ZIP needed to build a supporting infrastructure, develop apps, and create new products. This process posed several technical challenges, as nearly all packaging in the e-commerce sector currently relies on single-use products. A priority for RE-ZIP was to develop durable, high-quality products that could be reused many times. However, the first prototypes were so well-made that customers often kept them rather than returning them, as they found the bags appealing.

Additionally, the initial bags required at least 50 reuses to outperform single-use alternatives environmentally, due to the heavier materials used. In subsequent product development, RE-ZIP created a lighter product made primarily from cardboard and paper, with only a small amount of rubber. This adjustment reduced the environmental impact by lightening the materials while maintaining durability for multiple reuses.

6.2.2 Environmental potential

The environmental benefits and consequences of RE-ZIP products have been examined during the pilot. This study showed that RE-ZIP has the potential to significantly reduce CO_2e emissions, waste amount, and water consumption compared to single-use packaging. The most critical assumptions and the goal of the assessment is available in annex 2.

The primary purpose of the RE-ZIP pilot was to develop a calculation tool based on LCA, making it possible for RE-ZIP to calculate its actual environmental footprint for the

metrics of kg CO_2e, m^3 water, and kg waste. The functional unit was *1 m^2 of packaging to contain and protect dry goods during transportation and storage for one delivery.*

As RE-ZIP rents out two different types of e-commerce packaging with different sizes, two functional units have been used in the assessment:

- *1 m2 of **hard case** packaging to contain and protect dry goods during transportation and storage for one delivery*
- *1 m2 of **soft case** packaging to contain and protect dry goods during transportation and storage for one delivery*

A hypothetical scenario was created to examine RE-ZIP's overall environmental performance, calculating the impact of 300 RE-ZIP cardboard packages. By the reporting time, 200 initial packages had been returned and reused, while the remaining 100 packages had not been reclaimed. Diagram ## presents the results, showing that the RE-ZIP scenario emits 50% less CO_2e than the single-use cardboard alternative if 2/3 of the 300 packaging are reclaimed.

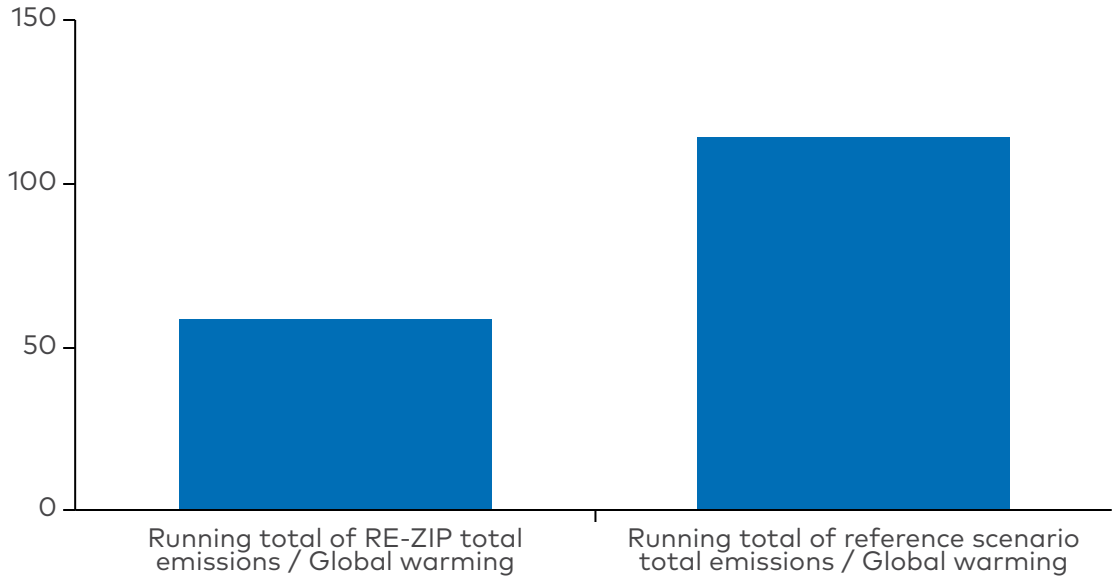


Figure 7: Results from RE-ZIP's overall environmental performance.

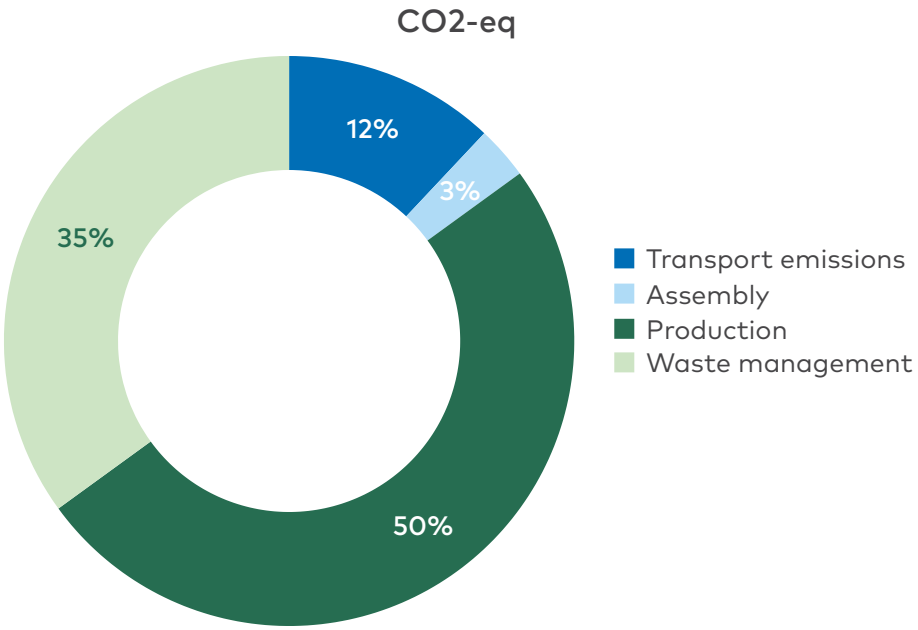


Figure 8: Emissions from different phases of the RE-ZIP system.

Investigating the hotspots of the RE-ZIP system, Figure 8 indicates that production and waste management account for 85% of emissions, and transportation accounts for 12% of the emissions in this specific scenario. This also illustrates the importance of reuse and transport distances, as reusing the products will eliminate the need to produce additional products and, therefore, the number of products discharged and transported.

Investigating the importance of the chosen g/m^2 for the single-use reference, Figure 9 illustrates major deviations between the minimum, average and maximum weight scenarios for cardboard boxes. Looking at the uncertainty margin, the RE-ZIP scenario performs better regarding CO_2e by looking at the average and maximum emissions, but not minimum emissions.

An assessment of the soft case packaging shows that this bag must be reused more times than the box to have a lower environmental impact than a single-use paper bag. Specifically, for one of the company's largest bags, it needs to be reused over ten times to achieve lower CO_2e emissions than a paper bag. This is because the soft case is made from heavier, more durable materials, which increase initial emissions but allow for multiple reuses.

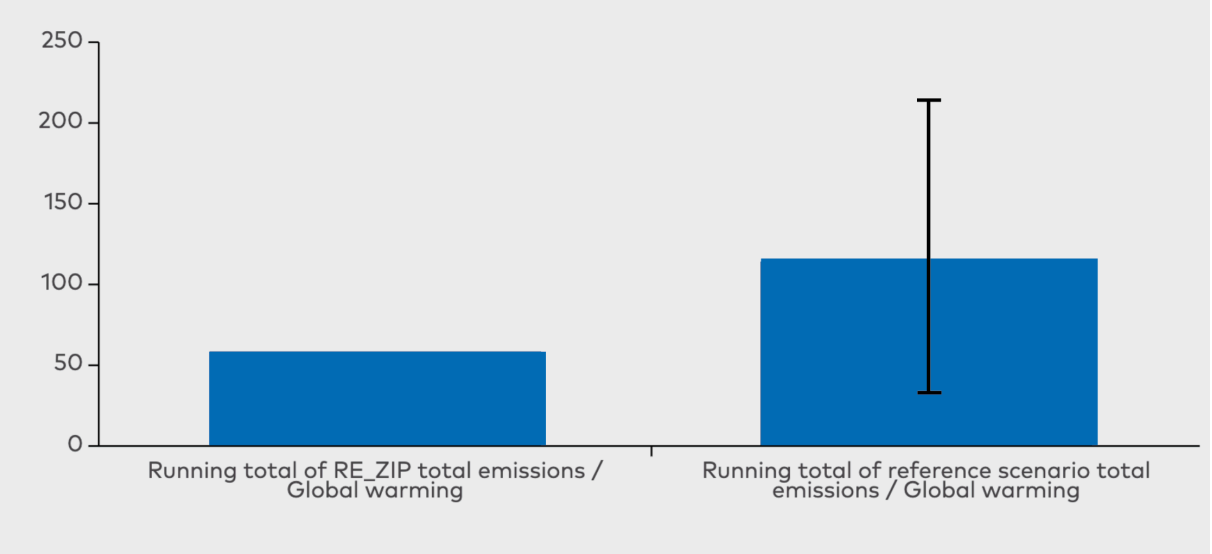


Figure 9: Comparison of RE-ZIP total emissions and Reference scenario total emissions.

Rebound effects

While reusable packaging can reduce environmental impacts and support sustainability in e-commerce, it also brings potential rebound effects. A primary concern is that both e-commerce retailers and consumers may use reusable packaging as a symbol of environmental responsibility without addressing deeper issues, such as overconsumption and high product returns. For instance, consumers may feel less guilt about frequent online shopping if the packaging is reusable, creating a false sense of eco-friendliness while consumption patterns remain unchanged. Likewise, retailers might promote reusable packaging as a sustainable solution yet overlook practices like excessive product returns, which significantly add to carbon footprints. This risk implies that reusable packaging could deflect attention from the more critical need for changes in consumption behaviour and overall reductions in consumption necessary for real environmental impact.

6.2.3 Conclusions

While reusable packaging solutions like RE-ZIP offer the potential for reducing the environmental impact of e-commerce packaging, their widespread adoption faces several challenges. The reluctance of consumers to bear additional costs means that the financial burden falls on e-commerce platforms, making these solutions economically less viable without regulatory support. Additionally, achieving the environmental benefits of reusable packaging depends on high return rates, which require significant behavioural shifts from consumers. Moreover, there is a risk that emphasising reusable packaging might overshadow the need for more fundamental changes in consumption habits, such as addressing overconsumption and reducing the high return rates of online purchases.

For reusable packaging to contribute meaningfully to sustainability, it must be part of a broader strategy that includes both policy measures and a shift in consumer behaviour.

6.3 Freight packaging

Freight packaging plays a vital role in securing goods during transport, providing protection from shocks, compression and climate conditions. Freight packaging is made of various materials, including cardboard, wood, steel, and plastic, as different types of packaging are needed depending on the type of cargo (Codot Logistics, 2024). As consumption rates rise, so does the need for freight packaging, which leads to increased emissions and resource consumption from the production process. PSS solutions can offer better utilisation of the packaging used during transportation (Hansson, Henlock, et al., 2019), thus lowering production emissions and the need for resources. While the industry is primarily based on single-use products, highly durable types of freight packaging, such as pallets, crates, and boxes, are suitable for reuse. PSS models for these products are well-established (Egebæk et al., 2022), primarily targeting the B2B market. We have explored drivers and barriers to PSS implementation in freight packaging through our pilot company, Looping.

LOOPING (est. 2017, Norway):

Looping is a company that specialises in producing durable and reusable freight packaging for construction modules, housing modules, and steel containers.

Looping rents out module covers on a subscription basis, keeping the ownership of the covers while providing their customers with the service of covered modules. They clean, repair, remake and recycle the covers when needed.

6.3.1 Drivers and barriers

Regulatory drivers and barriers

Looping is affected by product-specific regulation such as the revised Packaging Waste Directive (94/62/EC), which includes demands for reducing the use of all types of packaging, including freight packaging (also referred to as tertiary packaging) (DPA, n.d.), as well as sector-specific regulation related to the construction sector, where Looping's client base is located. These regulations were generally spoken of as a driver to increased PSS adoption in the sector. For example, in response to EU regulations, several Nordic countries require sorting and recycling of construction and demolition waste (Dansk Industri, 2022). As a result, Looping's clients look to waste reduction measures such as reusable packaging. Looping also looks to benefit from existing and future regulations that force companies to take accountability for their sustainability impact, such as the Green Claims Initiative (European Commission, 2023b) and Corporate Sustainability Reporting Directive (CSRD) (European Commission, 2022a). These regulations do not necessarily directly influence the implementation of PSS but indirectly force companies to find more sustainable solutions.

Meanwhile, regulative measures can also work against reusable packaging, e.g. regulation enforcing a certain percentage of recycled content in products (European Parliament, 2023). In this case, Looping expects single-use providers to meet those requirements easier, because of the lifetime of the product. Looping's covers need to withstand different weather conditions over longer periods of time, which necessitates materials of a higher quality, which is difficult to combine with recycled content.

Cultural drivers and barriers

According to Looping, one of the most significant cultural barriers is the conservative mindset within the construction industry. Over the years, industry players have developed habits and perceptions that they are reluctant to change, such as moving from single-use to reusable freight packaging. Many stakeholders fear that adopting reusable packaging could increase costs and time requirements. This hesitation is further amplified by the fact that many of Looping's clients already operate within the rental market and often rent out equipment themselves. While this familiarity with the rental model helps them understand the business side of Looping's service, it also makes them wary of additional costs, as they recognise that Looping must profit from the service.

However, this familiarity with rental solutions can also be advantageous, as clients already understand the rental model well. Many of Looping's clients have responded positively, highlighting potential savings in both cost and time. This indicates that broader adoption of PSS solutions in the industry may depend on early adopters setting a precedent.

> *Market maturity has been the toughest challenge for us. Construction industry is a slow mover. They won't change until they are forced*
>
> – PSS provider

An essential driver for Looping's customers in adopting and retaining the product is the option to print their logo on the packaging. Industry stakeholders view this as a significant marketing advantage, identifying it as one of Looping's key selling points. However, this feature presents a double-edged sword from a sustainability standpoint: while it encourages the shift from single-use to reusable freight packaging, it also complicates the reuse of covers with different clients. One customer expressed that, although they would not return to single-use materials, they would only use Looping's product if logo customisation remained an option. Additionally, clients find it easy to incorporate reusable packaging into their branding as a sustainability initiative.

Lastly, Looping anticipates that perceptions of environmental responsibility will evolve with the entry of a new generation into the construction sector, though such generational shifts can be gradual and are often influenced by external factors, such as economic developments.

Technical and economic drivers and barriers

A major challenge for Looping is being a first mover in the rental market for reusable freight packaging, where material options are limited. Developing new materials is costly, while competitors have a strong market presence with Polyvinyl Chloride (PVC) as a technologically, functionally and culturally established solution.

Additionally, reusable packaging requires substantial upfront investment, with high risks associated with owning large inventories. Looping does not expect to make a profit for several years, meaning they must carefully balance their strategy between investing in new products and growing their customer base.

> *We are saving so much time and reducing so much waste so that no matter if we are using the covers 2 or 5 times, it saves money*
>
> – PSS customer

A common consumer concern with subscription models is product loss, making tracking highly desirable. However, integrating tracking devices in covers faces obstacles such as high investment costs and GDPR requirements. Moreover, these devices require solutions for data collection and storage.

Regulatory requirements can help drive change by setting technical standards for packaging materials, increasing the willingness to pay for compliant products. EU directives, such as Green Claims, encourage consumers to reconsider materials, supporting Looping's business model. Another advantage of reusable packaging is time efficiency; due to Looping's design, customers require less time, staff, and resources to assemble freight covers. However, external crews unfamiliar with the covers may still need supervision, though interviews show they find Looping's covers easier to use once trained.

The payment model also affects Looping's business. According to interviews, clients on the pay-per-use model tend to monitor usage closely, which has led to improved planning on construction sites – a positive side effect. Meanwhile, clients on monthly subscriptions are generally more relaxed about tracking product use. Regardless of the payment model, clients benefit from streamlined billing, as Looping consolidates all expenses, eliminating hidden costs. Finally, the total cost of ownership for reusable packaging is lower than for single-use materials, which is a major driver for adopting PSS solutions in the sector.

6.3.2 Environmental potential

Looping looks to decrease the environmental impact of packaging by promoting reusable solutions as an alternative to single-use materials. The environmental potential of Looping's product is largely connected to reduced production of packaging materials, which in turn, also leads to waste reduction at construction sites.

As a part of the Looping pilot, a GHG calculation tool was developed to investigate the whole life cycle of the system and compare this with a single-use alternative to investigate when and if renting and reusing freight packaging will reduce the impact of packaging in the freight industry.

The functional unit of the calculation to be used in the calculation tool is one m^2 covered module for transportation or storage in Norway and Sweden for one year. This was aggregated for two years of use of packaging, corresponding to covering 16,000 modules for storage or transportation for two years in Sweden and Norway. The Looping reference flow was calculated based on the formula

$$RF=(FU/NU) + (FU/NU) * LR * (NU – 1)$$

The Looping scenario involved 4240 reusable covers used twice yearly, including maintenance, repair, discharging, and lost covers. This was calculated based on a 2% loss rate per year and two uses of the covers per year. Using the formula for calculating the reference flow:

16.000((0,02) + 0,98*(1/20)) = 240 covers lost a year = total of 4240 covers*

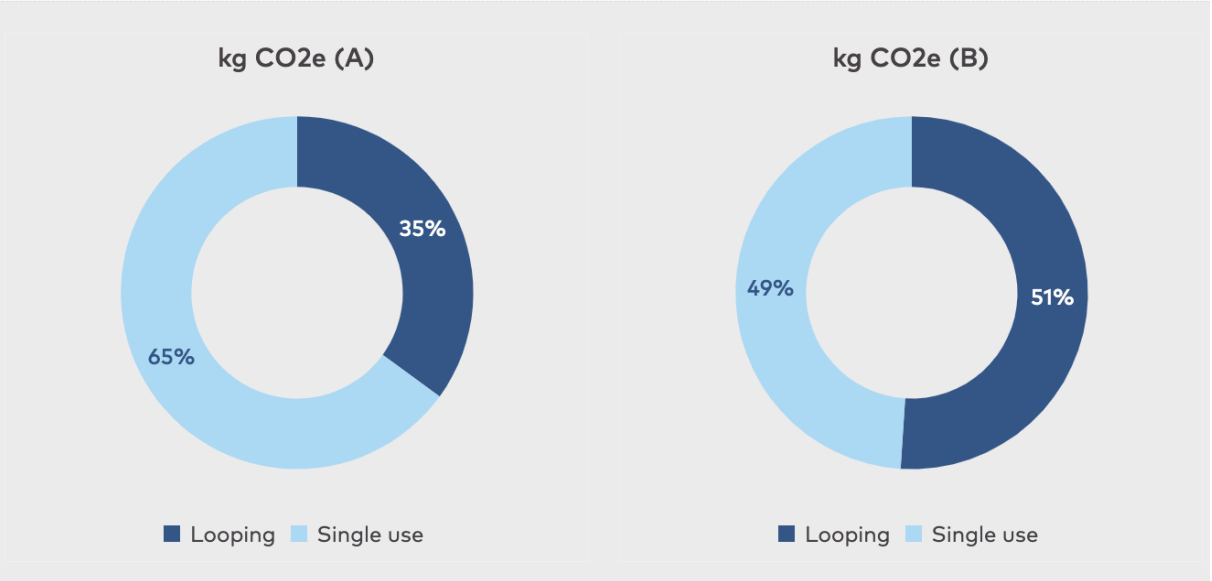
The compared reference single-use reference scenario:

16,000 times, covering the modules in single-use packaging.

The overall calculations show that after two years of use, Looping's reusable covers emit 47% less CO_2e than the single-use alternative. This is because four times more single-use packaging is required than Looping covers, which are used twice a year.

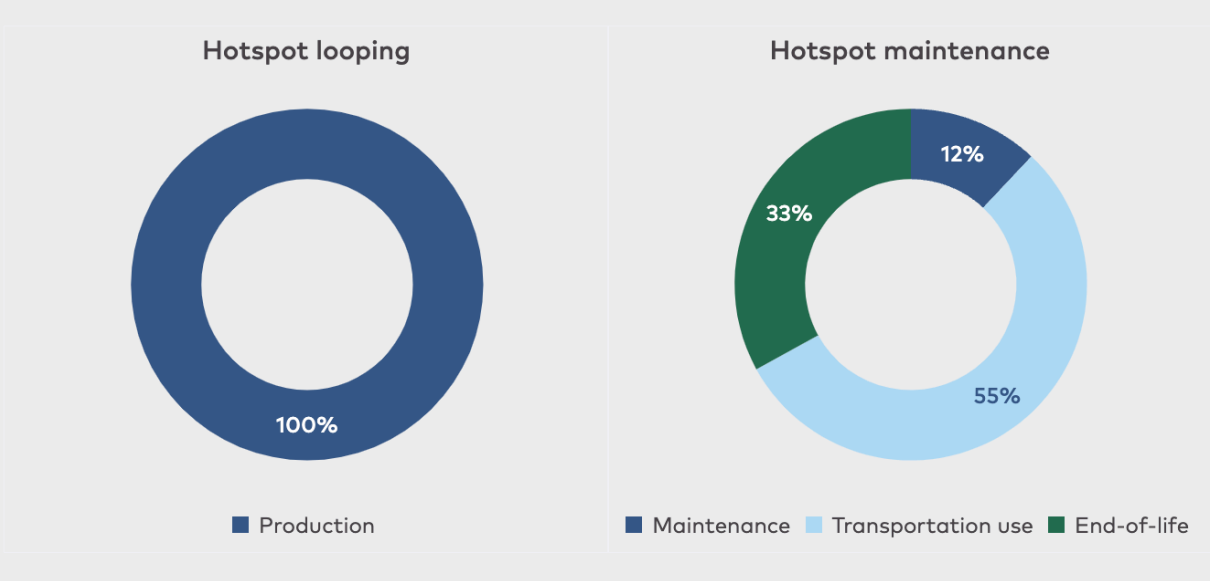
But, when evaluated over one year, Looping's covers emit more than single-use packaging, even though the covers eliminate twice the use of single-use packaging. This is because the production of the covers generates more GHG emissions than the production of single-use packaging. Therefore, a crucial factor in this scenario is that the covers are used multiple times over several years. This is typical for PSS, as the products in some systems (especially reusable packaging) are made from stronger and heavier materials than single-use materials.

Figure 10: Difference in impact, when using Looping for two years (A) or one year (B).



A hotspot analysis of Looping's covers for one year of use also shows that the vast majority of emissions are caused by producing the covers. Emissions from transportation, servicing, and waste are minimal compared to the emissions associated with production. As shown in figure 11, the production of the covers accounts for almost all of the emissions. As previously mentioned, this is a known induced impact of PSS, as reusable products are produced of heavier materials that emit more CO_2e than the single-use alternative. When looking at the hotspots in the remaining life cycle phases, another commonly induced impact of PSS is the transport emissions, having one of the largest impacts during the use phase.

Figure 11: Hotspot analysis of Looping.



Socioeconomic benefits

The reuse of freight packaging increases demand for manual labour through ongoing maintenance and repair, creating low-skilled job opportunities accessible to workers from diverse backgrounds. A PSS like Looping's can thus employ individuals who may face barriers to employment. Client interviews also reveal that the assembly process for reusable freight packaging is safer than for single-use alternatives. Nails in single-use packaging, which have posed occupational safety risks on construction sites, are eliminated with Looping's nail-free covers. Additionally, the installation process is safer, as it does not require ladders or cranes. Looping's covers fit securely on modules, reducing risk during transportation.

Despite these benefits, Looping views the conservative mindset within the construction sector as a barrier to recognising the product's socioeconomic advantages, which are often overlooked in traditional investment evaluations and criteria.

6.3.3 Conclusions

PSS models for reusable freight packaging, like Looping's, offer significant environmental and economic benefits, particularly as regulations drive waste reduction at construction sites. Looping's reusable packaging demonstrates a clear environmental advantage, with lifecycle assessments showing 47% lower CO_2e emissions after two years compared to single-use alternatives. This benefit is due to reduced material production and waste but relies on sustained, repeated use to offset the higher emissions from producing durable covers.

The conservative nature of the construction sector presents challenges, as companies accustomed to renting equipment may be wary of leasing packaging. However, this

familiarity with rental models could become an asset, as these companies already understand the concept. Another hurdle is the market's reliance on PVC, a material that is both established and often marketed as eco-friendly, making it difficult to introduce alternatives. Additionally, high initial investments are required, delaying profitability for several years.

Despite these barriers, reusable packaging has a strong business case due to its lower total cost of ownership, aligning with the construction industry's financial goals. Looping's model also brings socioeconomic benefits by creating maintenance jobs, enhancing workplace safety with nail-free, easy-to-assemble covers, and offering branding opportunities with customisable packaging. With time and committed use, Looping's model can drive substantial environmental impact through long-term adoption of reusable solutions.

7. MACHINERY AND TOOLS

In Europe, over 17,000 equipment rental companies provide a wide range of construction and industrial equipment for customers, primarily in Europe and North America (European Rental Association, 2021). In recent years, there has been a growing focus on the fact that equipment rental can offer both financial flexibility and a circular model, saving resources and CO_2e. For instance, The European Rental Association (ERA) has developed an Equipment CO_2 Calculator that can easily be used through their website to evaluate a single ownership period of one piece of equipment and, thus, to determine the climate impact of entire fleets of equipment or the total carbon footprint of all machines on a given job site (European Rental Association, n.d.).

Construction accounts for a considerable proportion of economic activity in the Nordic region (Sepponen et al., 2023), requiring machinery and tools. Repairs are often the most significant component of machinery costs, constituting around 37% of machine costs over its service life. This means that between 15% and 20% of the total equipment budget usually consists of labour for repair and repair part costs (Yip et al., 2014). A circular economy often accentuates paths for resource-efficient growth and functions as a driver for business development in the Nordic region. Political trends among policymakers, new rules and regulations can most likely not stand alone, as there is a need for substantial economic incentives for construction companies to change existing business approaches, such as financial savings of maintenance and repair (Høibye & Sand, 2018).

The construction industry dominates equipment rental, and in the Nordic rental sector, the share of rental revenues coming from the construction sector is approximately 70 % (IHS Markit & European Rentail Association, 2022). The equipment rental industry in the Nordic countries experienced growth in recent years up until the COVID-19 pandemic. The industry was growing more quickly than GDP and the construction industry, implying expansion of the rental penetration (IHS Markit & European Rental Association, 2020). Operators in this area expect an increasing proportion of their business volume to derive from services rather than goods (Wilkens, 2020). The outbreak of the Covid pandemic had a relatively mild impact on rental activities in the Nordic countries compared to other parts of Europe since almost no construction sites were shut down. Even though the markets in the Nordic countries are estimated to experience some long-term effects of the COVID-19 pandemic, the rental market for equipment and machinery is expected to continue to grow (IHS Markit & European Rentail Association, 2022).

Further cost or material use reductions can be found in proper maintenance since fuel efficiency with lower emissions in operations can be provided by keeping equipment in good condition (AE Faulks Ltd, 2021). The repair and maintenance cost creates good prerequisites for product-oriented and use-oriented PSS solutions, offering both

convenience and repair cost reductions through ownership models. Another benefit of PSS solutions for machinery and tools is enabling access to greener, more expensive options by making the products more economically attractive and affordable compared to purchasing the products. PSS solutions also lower the risks often associated with new technology, supporting the implementation of best available technology (Volvo, 2022).

Heavy machinery has the most significant environmental impact during the use phase and is significantly affected by the level of maintenance and repair (Ebrahimi et al., 2020). Meanwhile, handheld tools have a minimal environmental impact in the use phase but are often underutilised (Skjelvik et al., 2017a). This suggests a potential for PSS models on handheld tools aiming to increase utilisation of handheld tools to contribute to both resource-wise and financial savings. The following section will provide insights into existing PSS solutions in the Nordics within the product types: heavy machinery (incl. cranes), processing equipment, chemicals and handheld tools.

7.1 Heavy machinery

Growth in the construction industry of the Nordics is supported by both the private and public sectors, with the development of infrastructure, sustainable framework improvements, and residential construction, which is currently the largest market (Mordor Intelligence, 2021). Construction equipment rental is one of the most significant service sectors on construction sites in the Nordics, with the Nordic construction rental market worth more than 3.6 billion euros. High utilisation of construction capacity and labour shortage have been driving the growth in the sector. An indicator of the attractiveness of the industry is the recent acquisitions of Finnish international rental companies Ramirent and Cramo by French Loxam and Belgian Boels Rental, respectively (Pajakkala et al., 2019).

Most PSS providers target the B2B market, but some PSS models are present for heavy machinery in the B2C and B2G markets. Among the identified PSS solutions for heavy machinery, the most common is use-oriented models, predominantly rental solutions, which allow the construction industry to keep costs down on acquisition, maintenance and repair. However, product-oriented models are also standard, e.g. pure transitional services and extended warranty and preventative maintenance services. These types of PSS models can improve utilisation and prolong the lifespan of machinery, thereby reducing material inputs by decreasing production.

7.2 Processing equipment

Processing equipment is used in many sectors, from sewage treatment to food production. Depending on the function of the processing equipment, PSS can offer different solutions. Common for processing equipment is that significant investments are often needed. PSS leasing solutions provide a financing mechanism and specialised services that can be beneficial across sectors due to high acquisition costs (Klychova et al., 2020). Multiple benefits can be associated with PSS solutions for processing equipment since the manufacturers often have the best know-how on maintenance and repair, enabling reduced production of new equipment while creating continuous revenue for the PSS providers. Processing equipment is used in many sectors, from sewage treatment to food production. Depending on the function of the processing equipment, PSS can offer different solutions. Common for processing equipment is that significant investments are often needed. PSS leasing solutions provide a financing mechanism and specialised services that can be beneficial across sectors due to high acquisition costs (Klychova et al., 2020). Multiple benefits can be associated with PSS solutions for processing equipment since the manufacturers often have the best know-how on maintenance and repair, enabling reduced production of new equipment while creating continuous revenue for the PSS providers.

7.2.1 Drivers and barriers

Most identified PSS providers primarily offer processing equipment sales, with the secondary option of renting or leasing solutions to broaden their market potential by splitting up the customers' acquisition costs through leasing agreements. On this basis, the most common PSS models offered in the Nordics are product-oriented and use-oriented models. Depending on the type of processing equipment, the predominant markets are B2B and B2G. Common features among the providers of PSS solutions for processing equipment are that they are manufacturing the product themselves or are in close collaboration with the product manufacturers.

HJORTKÆR MASKINFABRIK (est. 1958, Denmark):

The manufacturing company focus on the development, sale and leasing of innovative machine and facility solutions.

The company offers long-term leasing of machinery e.g. treating sewage sludge in municipal treatment plants.

The primarily target group is municipalities and the food- and processing industry.

While PSS solutions offer more intensive and efficient utilisation of processing equipment, the economic mechanisms also provide greater accessibility. This could increase the use of processing equipment and could lead to higher emissions from the production- and use-phase, depending on the type of equipment, as many types of processing equipment have high energy consumption during their use-phase. Some identified PSS solutions have done extensive work to reduce energy consumption, while others have not. This plays a major role in assessing the environmental impact of PSS solutions.

It could be argued that some types of processing equipment can contribute to reductions of greenhouse gasses, such as in the case of sludge processing equipment, where greenhouse gasses are collected and utilised for biogas facilities. Further, some of the identified cases provide different waste treatment solutions, e.g. water purification of wastewater, targeting the B2G market. This does not, however, apply to all types of processing equipment.

Through the pilot program, one PSS provider of a processing equipment leasing solution participated: Hjortkær Maskinfabrik, located in Esbjerg, Denmark. The central focus of the pilot projects was assessing regulatory, cultural, economic and technical barriers to the uptake of leasing solutions in public procurement processes through interviews with organisations working with public procurement, experts in the public procurement field, and employees responsible for procurement at municipal companies handling and treating wastewater and sludge.

Regulatory drivers and barriers

Only a few renting or leasing solutions are used within the municipal sewage and sludge sector. It is considered a norm to buy equipment rather than to rent or lease it. Half of the interviewed public procurement actors had never developed or granted tenders for rental or leasing solutions for anything other than cars. Some public procurers have never seen an offer of rental or leasing solutions in the sludge and wastewater treatment sector and have not considered this an option.

Amongst consulted public procurers, there was a consensus that there is an evaluation bias towards prices in procurement practices. While a PSS solution for processing equipment by Hjortkær Maskinfabrik has been shown to be cheaper in the long term through TCO calculations, they appear more expensive in a short-term perspective as the leasing cost will have to come out of the municipal operation budget rather than the acquisition budget. The evaluation bias is considered a problem and a barrier to PSS solutions, as linear procurement typically requires a one-time purchase using normalised budgeting approaches. In contrast, the PSS solutions (that include continued maintenance and repair of the machinery) require continued payment from the operations budget. The evaluation bias is a problem that most public procurers are very aware of and are trying to solve. However, based on predetermined selection criteria, the

rigid evaluation process does not always give public procurers the option to take the best offer.

A general concern of non-compliance with procurement acts amongst public procurers was identified through the pilot project. While a wish to ensure compliance with procurement acts is desirable, the heightened focus on compliance was expressed to hinder the tender development process and the selection of innovative, and sometimes even sustainable, solutions. This indicates a need for increased guidance of public procurers and increased allocation of resources to immerse into sustainability strategies and evaluation processes.

Cultural drivers and barriers

The public procurers consulted had varying degrees of understanding of PSS solutions, their conceptualisation, and their benefits and pitfalls. PSS was not considered in their procurement processes for multiple public procurers because they had never been confronted with PSS solutions. However, the same public procurers were keen on learning more about PSS and how it could benefit public procurement.

The public procurers expressed challenges with implementing green public procurement, which likely impacts the breakthrough of PSS solutions to the B2G market. The challenges are not related to the availability of academic, governmental or grey literature on green public procurement but rather the availability of government-facilitated guidance for public procurement employees, resources to develop internal strategies, and internal capacity building. The pilot project indicated little time and few resources to improve the sustainability focus in the tender development and selection processes.

Economic drivers and barriers

Some public procurers expressed skepticism toward rental, leasing, and Product-Service System (PSS) solutions, primarily due to perceived cost implications. Many viewed PSS options as more expensive, citing concerns about ownership structures, as municipal companies do not retain product value with rented or leased assets. A common approach among public procurers is to favor municipal ownership for substantial acquisitions, especially when equipment is permanently installed. In the wastewater and sludge treatment sector, much of the required machinery is bolted to treatment facilities, reinforcing a preference for outright ownership over leasing or rental.

> ”
>
> *A rule of thumb is that as long as the machinery is bolted to a facility, it should be brought, not rented or leased”*
>
> **– Interview 2023, Nordic public procurer**

Financing options, such as leasing, are generally seen as economically unviable. This perception stems from the additional income requirements of both product suppliers and financiers, which add costs and make leasing more expensive than outright purchase.

Technical drivers and barriers

Criteria development in Danish public procurement processes is typically divided into three phases: 1) the economic and sustainability aspects, 2) the legislative requirements and the office work related to public procurement, and 3) the technical aspects of the operational activities of the services provided to the citizens. The technical requirements are often considered the 'minimum requirements'. When the minimum requirements are met, the price offered provides the context of the actual selection. The minimum requirements and additional criteria, e.g., sustainability included in tenders, are weighted differently, but the price is always an important parameter. While the price is still deemed the decisive factor in most tender evaluations, energy consumption, resource efficiency, and total ownership costs are gaining more weight in these processes. Some focus on energy efficiency, some on quality through market dialogue, and some on Total Cost of Ownership (TCO). Some concerns were conveyed regarding ensuring that the dynamic amount of wastewater and sludge could be treated through a PSS solution, as tenders seeking services often have a certain amount of waste treatment stated in the contract, making the selection of a PSS solution perceived as a risk.

7.2.2 Environmental potential

In 2021, Hjortkær Maskinfabrik intensified its focus on green circular transition in its company and products. Following this process, the company developed a leasing scheme for heavy processing equipment as an addition to its product sale model. The leasing solutions offered by Hjortkær Maskinfabrik have been documented to increase avoidance of new production, extend product life, improve the use-phase of the processing equipment and reduce waste generation.

Hjortkær Maskinfabrik has improved the product design, enabling a product life span +10 years longer than similar equipment, unchanged product performance throughout the life span, and energy consumption of 90–95% less than similar technology, significantly improving the use-phase consumption. Further, the improvements in the product design have ensured that 80% of Hjortkær Maskinfabrik's screw presses can be refurbished, using 20% new spare parts and that 98% of all of Hjortkær Maskinfabrik's equipment can be recycled at the end-of-life (Hjortkær Maskinfabrik, 2021).

7.2.3 Conclusions

The municipal sewage sector favours buying over leasing equipment. A bias toward short-term costs makes long-term savings from PSS less visible in public procurement processes. Concerns about compliance with procurement laws also hinder innovative or sustainable solutions, signalling a need for better guidance and resources.

Public procurers had limited exposure to PSS solutions but showed interest in learning more. Challenges in adopting green public procurement, including a lack of government guidance and resources, hinder PSS implementation. The pilot project revealed that limited time and resources are available in public procurement processes to enhance procurement sustainability.

Public procurers are sceptical about leasing solutions due to costs and ownership concerns. They prefer municipal ownership for large, bolted equipment like wastewater treatment machinery, making leasing less favoured. Financing solutions are seen as costly because both suppliers and financiers need to profit. While legally allowed, leasing is not considered sustainable and is viewed as risky and expensive in public procurement.

Technical requirements are treated as minimum standards, with price being a key factor once these are met. Although price remains crucial, factors like energy consumption, resource efficiency, and total ownership costs are becoming more important. There are concerns about using PSS solutions for wastewater and sludge treatment due to challenges with composing technical requirements in tenders. Contracts often specify fixed amounts of waste to be treated, making PSS solutions seem risky for public procurers. They doubt whether such requirements can be included in a tender targeting PSS solution.

This leasing approach reduces new production, extends product life, improves equipment efficiency, and minimises waste. Hjortkær Maskinfabrik's equipment lasts +10 years longer, consumes 90–95% less energy, and maintains performance. Additionally, 80% of its screw presses can be refurbished with minimal new parts, and 98% of its equipment is recyclable at the end of life.

7.3 Chemicals

PSS solutions for chemicals, e.g. performance-based business models, have been promoted by UNIDO since 2004. Chemical leasing models and models focusing on speciality chemicals have been established ever since (Formiconi, 2023). But still, Chemicals as a Service and other types of PSS solutions for chemical management are not well known in the Nordics. According to UNIDO, chemical PSS solutions can result in reduced consumption of chemicals and hazardous waste, better process quality, and a greater incentive for reuse and recycling of chemicals (Unido, n.d.), which could be relevant for many manufacturing companies in the Nordics.

A few Nordic providers offering PSS solutions for chemicals and chemical management have been identified, primarily in product- and use-oriented models. These solutions are exclusively targeted toward the B2B market, especially the manufacturing sector. ABB, a global company, provides a wide range of services across various industries, including the chemical plant industry (ABB, n.d.). According to ABB, the company operates with a circular business model, designing products to be durable and using sustainable materials to extend their lifespan while minimising environmental impact during production (ABB, 2023). ABB also runs a product take-back system and has implemented recycling strategies, though details about these processes remain undisclosed. Nevertheless, ABB's efforts to integrate circular strategies throughout its operations are clear, gradually developing a PSS model. This approach could serve as a model for other companies in the Nordic market, where only a few chemical-plant-as-a-service providers are currently established.

7.4 Handheld tools

Rental solutions for tools are interesting from an environmental impact perspective since most standard household tools are rarely used. A power drill is only used for around 18 minutes over its entire lifespan, resulting in the use phase of a drill contributing to only 2% of the life cycle emissions. A study of a drill rental solution showed that renting a drill six times can reduce emissions by 700 kg CO_2e in reduced material usage from avoided production (Skjelvik et al., 2017a). Therefore, PSS models for tools are an obvious solution for economical cost reductions and greater utilisation with reduced environmental impact as a result. PSS solutions for tools are prominent in the B2C and B2B markets and somewhat in the B2G market. Providers of PSS solutions for tools in the Nordics vary from small local SMEs to large globally established enterprises. Product-oriented and use-oriented models are most common within this study, although a vast range of product types and PSS models have been mapped.

Our pilot company, **Nethire**, is a Danish-based company established in 2017, which offers an online platform for short-term rental and long-term leasing of machinery and tools for craftsmen and contractors. As such, Nethire is a product-related PSS model operating mainly in the B2B market. Through their *Nethire Community* solution, Nethire aims to transform customers into *Equipment Renters*, enabling them to maximise the utility of previously purchased tools and thereby increasing their usage compared to if the tools were individually owned. The solution is currently only used by a single company, but Nethire is working on using the positive experience of their first client to expand the solution to other companies. The client has reported large financial savings from equipment sourcing, repair and maintenance, and in addition to this, there are significant environmental gains associated with the solution.

7.4.1 Drivers and barriers

Regulatory drivers and barriers

According to the EU Machinery Directive, all machinery that is sold or rented out must be accompanied by a user manual and safety guide in the language of the Member State. This practice is considerably more demanding for rental solutions, who must translate and hand out manuals and guides multiple times for the same product, rather than just once as in the scenario for equipment sellers. Rental solutions are also subject to occupational safety requirements by ensuring that rented machinery is properly maintained and calibrated. However, this exact process is Nethire's expertise, and the company can exploit economies of scale since they carry out maintenance and calibration procedures more often than non-rental solutions. Occupational safety requirements pose a larger barrier for newly founded companies or rental solutions in the C2C market, who cannot exploit the same economies of scale.

Looking forward, Nethire expects to benefit from new regulation supporting the green transition. They are not affected by construction regulation in the same way as builders, since they are subcontractors, but expect to be able to figure as a positive aspect of other companies' ESG-reports due to the environmental potential of rental solutions on machinery and tools.

Cultural drivers and barriers

The main barrier facing Nethire is having to convince a conservative industry to opt in on the culture change that it would be to engage in the *Nethire Community*. Interviews with craftsmen and executives in the industry reveal many cultural factors related to tools, which act as a barrier to PSS solutions on the area. Among these is the so-called "evaporation" of tools. According to executives, tools commonly evaporate from building sites either through theft, accident or forgetfulness, causing financial losses for companies. Nonetheless, executives are hesitant to enforce strict tracking of tools, e.g. through a rental company, as the evaporated tools are perceived as an unspoken employee benefit, and executives fear losing employees to other, less strict companies.

This implies a bottleneck in adoption of the *Nethire Community*, which would need to be opened by pioneer companies, who can show executives that the solution is not detrimental to employee satisfaction and retention. In fact, *Nethire Community*'s current client has not experienced issues with employee retention, despite concerns prior to adopting the solution.

Another factor impeding PSS solutions such as *Nethire Community* is the preference of executives to keep their tool storage in-house, as this allows for direct contact between the company and its employees. Executives fear that outsourcing tool storage to Nethire could make them lose touch with what is happening on the ground in their company and that this could negatively affect employee satisfaction and retention. Furthermore, outsourcing tool storage could lead to companies having to let warehouse workers go, which they are reluctant to do, also with an eye on employee satisfaction. A final factor related to employee satisfaction is the low IT literacy of many workers in the industry, making online platforms unappealing.

> ”
>
> *People are incredible creatures of habit*
>
> **– Construction company executive**

A further cultural factor highlighted in interviews is the correlation between work identity and tool brand and condition. Craftsmen express concern that they as *Equipment Renters* would not feel assured that tools of the correct brand and condition would be readily available. This factor is also affected by a general distrust in the tool-handling skills of other craftsmen, who are believed to not take as great care of the tools. This is despite Nethire offering maintenance and repair, meaning that the *Nethire Community*'s tools are often of better condition than individually owned tools. However, craftsmen identify paying for this service as a barrier compared to their usual practice of simply replacing tools in need of repair. If Nethire and similar solutions can find a way to communicate the advantages of professional repair and maintenance, such as increased safety on construction sites, it could be a driver to increased adoption. A further cultural driver is the fact that renting is already common in the construction industry for machines and heavy equipment, meaning that rental practices and logistics are already in place, e.g. for when companies land a new construction project. These practices could be expanded to include handheld tools. Nethire's founder also highlights a development in the construction industry from when Nethire first started in 1988, where renting was seen as a practice for "broke" craftsmen, to renting now being more common and even a "smart" solution.

Technical and economic drivers and barriers

IT is a key task for Nethire, who benefit from having worked in the area for 35 years. They can exploit economies of scale, as their many years in the industry have allowed them to develop a master database for tool administration. However, the development of the database posed a challenge to Nethire, which newly founded companies would have to be aware of. Systems, agreements and contracts need to be synchronised, which is difficult for rental solutions, who must navigate diverse pricing schemes and insurance requirements.

According to Nethire, a product's daily rental fee is generally 1% of its price, but there are many factors, which can lower or raise the price, such as the rental period and use rate of the product. High use rates and long rental periods make price estimation easier, as this allows companies to know their earnings more precisely. Furthermore, insurance constitutes a large part of Nethire's business. If a piece of machinery has more than 5 horse powers, a liability insurance is required, and this can be a challenge, as equipment renters can rent and rent out equipment through Nethire's insurance. Nethire therefore operates with an insurance scheme that allows the company to ensure a product even if it is unknown to them.

Nethire Community's client highly praises the benefits of outsourcing tool administration to Nethire, as this allows them to focus on construction matters and not spend resources on tasks outside their expertise area. Nonetheless, the path toward such symbiotic relationships between Nethire and their clients constitutes a barrier to increasing adoption of the PSS solution. Nethire needs to register their clients' tools so that they can handle administration of them, and this process was often described as time-consuming and stressful, both internally to Nethire and externally. According to Nethire, their workers need approximately 10 minutes to register a tool in their system, and as they are reluctant to hire workers who are unfamiliar with their system to perform this task, tool registration for large companies can take more than a year. This also makes the process expensive in terms of man-hours.

Nonetheless, the client highlighted savings exceeding a million DKK from the first year of being part of the *Nethire Community*, and they expect to continue profiting from the solution. This is both due a decrease in purchases of new tools, but also due to new revenue streams from renting out unused gear to other companies. Nethire expects this factor to outweigh the barriers to their solution, and now that they have a client confirming the large financial savings, they look to increase their customer base over the coming years.

> *We had twice as many tools as we thought [...] I don't understand why other companies don't want to save money*
>
> – Construction company executive

7.4.2 Environmental potential

There is a significant potential for environmental gains from increased adoption of PSS solutions related to handheld tools. Among these is a reduction of raw material consumption by reducing the need for new tools through increased use rates of tools already in existence, while PSS solutions such as *Nethire Community* can simultaneously increase the lifespan of tools through regular, professional maintenance and repair. Tools are often made with materials, which have a high environmental impact, and by not being used or properly maintained, they become obsolete before end-of-life. Furthermore, rental solutions allow for purchase of better and more durable equipment, as renters don't have to pay large sums up front for expensive equipment. When possible, Nethire pools rented tool orders together to transport many tools at once rather than having craftsmen drive to and from warehouses and stores individually, which decreases transport emissions per tool.

An environmental assessment of sharing a rolling scaffolding

As a part of the NetHire pilot, a Life Cycle Assessment (LCA) of sharing a rolling scaffolding among B2B customers was conducted. The assumptions and goal for the assessment, are outlined in annex 2.

This pilot examined the total float of rolling scaffoldings and total days of renting per year at NetHire, and the functional unit was therefore determined based on this, making it: Use of rolling scaffolds 8,406 times per year, in 15 years in Denmark. The Nethire reference flow was the production and distribution of 50.2 rolling scaffolds for rental, utilised 66% of the time, each with an expected lifespan of 15 years. This was compared with individual ownership with the assumption that these scaffolding were used 20% of the time: Production and distribution of 100.4 rolling scaffolds for private use, utilised 20% of the time, each with an expected lifespan of 15 years.

The overall result was that NetHires' rental service would significantly reduce the environmental impact of rolling scaffolding. This conclusion applies to all 16 impact categories included.

The study included a hotspot analysis of NetHire's lifecycle phases, and as presented in figure 12, transportation has the significant highest impact (looking at CO_2e emissions). This differs from the environmental assessments done in other pilots, such as to-go cups and e-commerce packaging, but aligns with research assessing the environmental impact

of PSS. One of the reasons why transportation accounts for most of the emissions is due to the product lifespan, and transportation during use will, therefore, be significantly higher than with products with a shorter lifespan. Investigating and reducing transportation emissions for these kinds of products and services will, therefore, have a significant impact on the overall performance of the system.

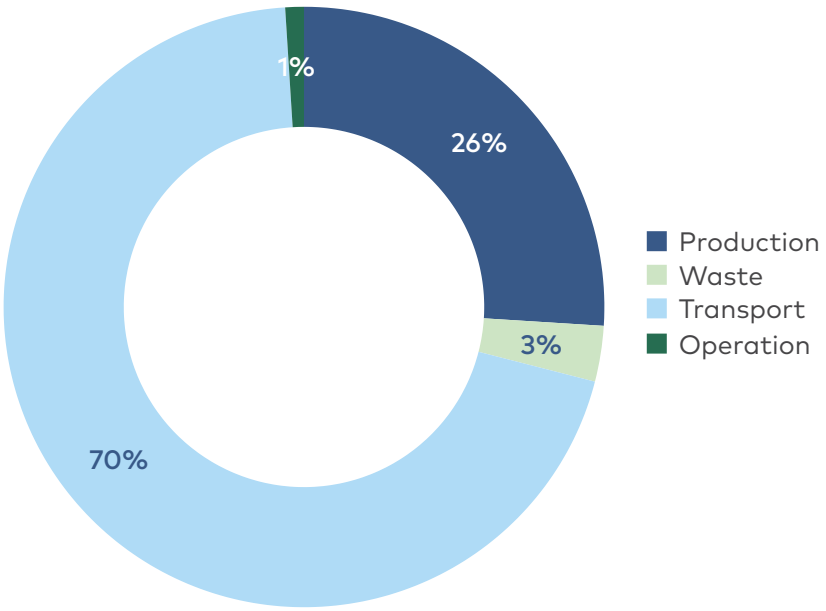


Figure 12: Hotspots of NetHire's lifecycle.

A sensitivity analysis has been performed on NetHire's transport distance. Since transport accounts for a relatively large portion of the total environmental impact, fluctuations in NetHire's transport distances also influence the overall environmental impact. The graph shows variations in transport distance of up to minus/plus 10%, with a baseline of 80 km round trip per customer. These variations strongly correlate with the corresponding total environmental impact, including the environmental impact from greenhouse gases, as illustrated in figure 13.

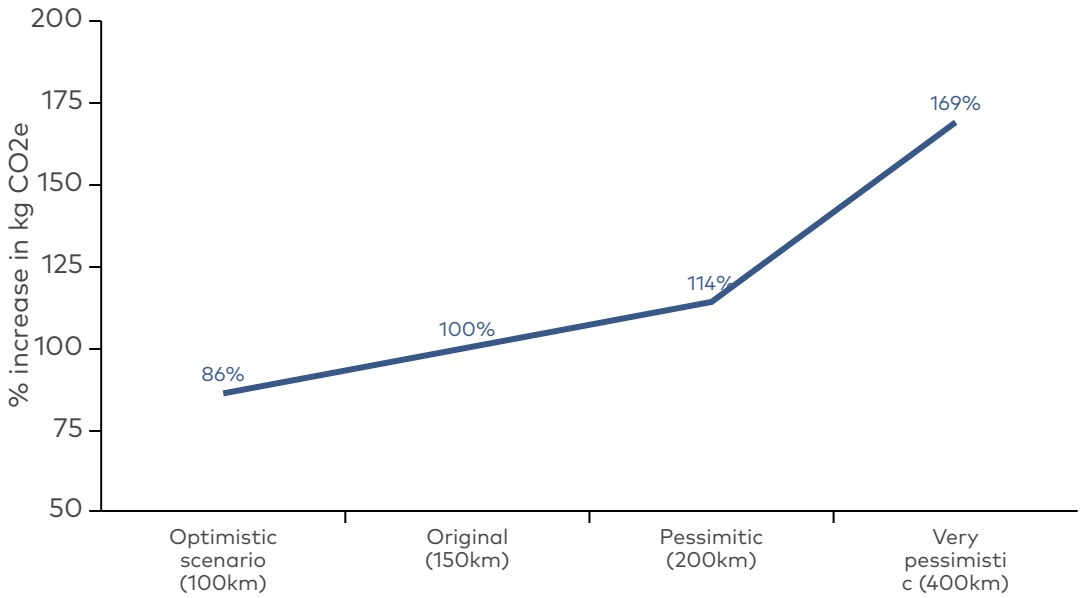


Figure 13: Impact of increased transport distances when sharing tools.

As the investigation of the utility was the most important assumption of the study, its importance was also tested. The utility rate is a well-known assumption for PSS and is important when investigating the possibility of reducing the need for production and resource use. In the case of NetHire, the utility rate was based on the number of rentals per year. A sensitivity analysis was conducted, where the number of rentals was reduced and increased. Figure 14 displays a graph indicating the breakeven for the utility compared to individual ownership, showing that NetHire can have a utility rate of 30% less than anticipated before breaking even with individual ownership. This includes the assumption that the utility rate of 20% for the individual ownership does not change; an increase of the utility rate would impact the overall impact of the assessment, making the breakeven occur earlier.

Furthermore, an important induced impact when investigating an increased utility rate is the possibility of reducing a product's lifespan. As the rolling scaffolding with individual ownership would be used less frequently, it might not wear out at the same rate as when shared. This is a general assumption when assessing products with a high utility rate (see section 15).

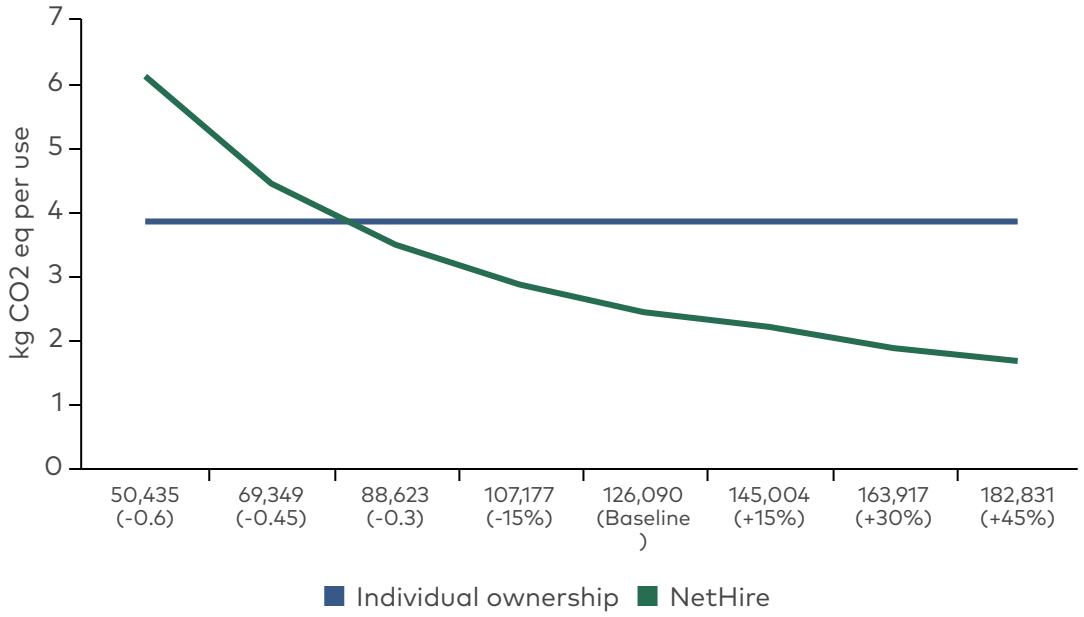


Figure 14: Overview of breakeven between rental service and individual ownership.

Rebound effects

As for most use-oriented PSS solutions, it is important to investigate whether the products that can be accessed through *Nethire Community* replace products that would have been bought and owned individually without the solution. If not, the solution risks introducing more products to the market, leading to an increase in production emissions. For example, rental solutions for scaffolding could lead to companies that previously could not afford the product taking on a higher number of projects requiring scaffolding, thereby increasing the production demand for the product, rather than substituting individually owned scaffolding with rental solutions.

Despite the potential environmental gains from collective transportation, the transport phase also poses a risk for rebound effects if the PSS solution's vehicle fleet is not up to the standards of their clients'. For example, *Nethire Community*'s client has recently introduced electric vehicles into their fleet, while Nethire employed diesel vans for transportation. This is mainly because diesel engines are more powerful than their electric counterpart, making them more suited for transporting heavy loads. Nonetheless, when transporting lighter objects, diesel powered vans lead to significantly

higher transportation emissions than electric vehicles. Furthermore, rental solutions cause an outsourcing of waste handling from the client to the PSS provider, meaning that the PSS provider must have good waste handling procedures for this not to become a rebound effect.

Socioeconomic benefits

Nethire can help smaller companies access markets that they would otherwise be excluded from by allowing them to rent their way to a broader equipment selection. Furthermore, Nethire positively affects occupational safety for workers by ensuring proper maintenance and calibration of equipment.

7.4.3 Conclusions

PSS solutions for handheld tools, like Nethire Community, present considerable environmental and economic potential but face cultural and practical barriers to adoption. Craftsmen's concerns about tool availability, brand preference, and trust in others' tool-handling skills reflect a cultural attachment to traditional, individual ownership. Executives are also cautious, fearing that a shift to shared tools could negatively impact employee satisfaction and retention. Additionally, implementing the PSS solution involves a time-intensive tool registration process, which can initially be demanding and resource-heavy.

However, once integrated, Nethire Community's client reports substantial benefits, including significant financial savings from reduced tool purchases and additional revenue from renting out unused equipment. By outsourcing tool administration to Nethire, the client also gains the freedom to focus more on core construction tasks rather than maintenance and logistics.

From an environmental perspective, PSS solutions like Nethire can lead to a reduction in raw material consumption by extending tool lifespans through regular, professional maintenance and repair. Furthermore, these solutions encourage the use of high-quality, durable equipment and reduce transport emissions by consolidating tool deliveries. If managed effectively, PSS solutions have the potential to significantly decrease the environmental impact of tool usage, making them a promising model for sustainable practices within the construction sector.

8. HOUSEHOLD APPLIANCES AND FURNITURE

The household appliances and furniture sector is a key area of consumption in the Nordic countries and is expected to grow alongside population and welfare increases. Frequent replacement of these products – both in private homes and office spaces – has led to rising waste generation, with much of it ending up in incineration or landfills (Besch, 2005).

A major environmental challenge also lies in the production of furniture and appliances, which involves high production costs and a significant environmental footprint (European Commission, 2024d). Current trends towards shorter product lifecycles, often driven by aesthetic preferences rather than actual wear, further exacerbate the environmental impact. Studies indicate that furniture alone accounts for around 10% of a net-zero building's total environmental impact, while appliances contribute up to 25% (Hoxha & Jusselme, 2017).

The need for new business models in the Nordic market is evident. While some initiatives already promote the resale of refurbished household products, incentives to design furniture and appliances for longevity and efficient end-of-life management are still lacking. PSS models could be the key to fostering more circular consumption in both B2C and B2B markets.

8.1 White goods and large appliances

White goods and or large appliances are essential in Nordic households and businesses, ranging from washing machines to larger kitchen equipment. These appliances typically consist of various materials, with metals and plastics as primary components. While recycling systems aim to reduce the environmental impact of these products, they face limitations, particularly when dealing with hazardous materials like refrigerator fluids (Bracquené et al., 2021).

PSS models present an alternative to recycling by extending the lifespan of appliances through systematic reuse. By promoting regular maintenance and repair, PSS solutions can help appliances remain in use longer, reducing the need for premature disposal. Most PSS providers operating in the Nordic region focus heavily on circular practices, incorporating repair, remanufacturing, and recycling into their business models. These services cater to both B2C and B2B markets, offering economic benefits such as reduced maintenance costs, lower CO_2e emissions, and extended warranties.

A well-known case of a product-oriented PSS is the Norwegian company Norsk Ombruk, which specialises in remanufacturing and reselling refurbished consumer white goods like

refrigerators, washing machines, ovens, dishwashers, and dryers. Norsk Ombruk retrieves products from waste streams and refurbishes them for resale. In 2017, the company reported saving 3,000 tonnes of CO_2e through its operations, although more recent data is necessary for updated environmental and economic assessments. Expanding its reach, Norsk Ombruk also operates in Denmark under the name Recirk, further embedding PSS practices in the Nordic market.

Electrolux's Appliance-as-a-Service program, launched in 2022, marks a pioneering approach in Sweden's rental market. SKB (Stockholms Kooperativa Bostadsförening) now subscribes to Electrolux's service, which includes installation, care, and repair of appliances, extending product lifespans and lowering buildings' carbon footprint. Electrolux also manages refurbishment and recycling when replacements are necessary. Though this model shows promise for promoting a circular economy, specific environmental studies on the program's benefits have yet to emerge (Electrolux Group, 2022).

However, international research, such as the Korean water purifier lifecycle assessment, has demonstrated the potential environmental benefits of such models. The study found that rental models could reduce environmental impacts by 32–37% compared to conventional ownership models, particularly by optimising maintenance schedules and use-phase energy consumption. Yet, concerns remain about resource depletion due to frequent maintenance, a challenge that PSS models must address (Chun & Lee, 2017). The study by (Sousa-Zomer et al., 2017) underscores the importance of lifecycle management in enhancing the environmental performance of PSS models within this product group. Practices such as designing for maintenance, remanufacturing, and recycling contribute to reducing resource consumption and extending product life. The emphasis on reuse and careful material selection during the product's design phase is crucial for optimizing the sustainability potential of these models.

8.2 Furniture

Furniture is a product group with significant circular potential, and PSS solutions are increasingly adopted, particularly in office environments and public procurement. These sectors see a growing trend in leasing and rental models due to their high turnover needs, sustainability goals, and budgetary flexibility. However, PSS models are still much less common in the private furniture market, which is the primary focus of the pilot projects in this study.

Currently, the Nordic market for private furniture PSS solutions is small, with only a handful of companies offering leasing and rental options to individual consumers. Most of these companies are relatively new, and many are in the process of scaling up or refining their business models. Despite this, the potential for growth in the private market is considerable, particularly among customers such as expats, students, and

young professionals, who may have short-term or flexible living arrangements. These consumers are likely to appreciate the flexibility, reduced upfront costs, and convenience offered by furniture leasing.

If PSS providers in the private furniture market can successfully scale, there is potential to significantly extend the lifespan of furniture products, reduce the amount of furniture entering the waste stream, and promote investment in more durable, higher-quality furniture. By offering access to furniture rather than ownership, these companies can encourage the development and consumption of longer-lasting products that can be repaired, reused, and eventually recycled, supporting a more circular economy.

COHABIT (est. 2022, Sweden):

Cohabit is a circular furniture rental service that offers pre-loved furniture for rent, currently operating in southern Sweden.

Their primary market focuses on individuals who move to a new city for work or study for a short period of time. The service is a circular, convenient, and cost-effective alternative to buying new furniture for short term usage.

8.2.1 Drivers and barriers

Cultural drivers and barriers

Furniture consumption is heavily influenced by personal taste and the role that furniture plays in shaping one's identity and sense of self. This leads to very specific aesthetic and functional requirements, posing a challenge for PSS models, as they often rely on standardized products and offerings. The need for tailored solutions to meet individual customer demands limits the potential for offering standard PSS packages, making it difficult to scale such services.

A growing concern in recent years is the spread of pests, such as bed bugs, through second-hand furniture. This issue is particularly worrisome for landlords, who face significant costs for pest removal and property damage, along with potential reputational risks among renters. The fear that circular furniture solutions, such as rentals, may increase the risk of pest infestations presents a barrier to wider PSS adoption. For PSS providers, demonstrating effective safety and hygiene protocols is crucial to overcoming this concern and gaining trust from both landlords and consumers. The risk of spreading pests is, therefore, a top-of-mind issue for many landlords when it comes to furniture on the property, and some express that they believe that circular furniture solutions may increase this risk.

> *Spreading of bed bugs could possibly be a barrier for furniture rental. As it is today, it is the tenants' responsibility, but who would be responsible when there is a furniture rental company involved?*
>
> – Interview with landlord

Another barrier is the general lack of awareness about the environmental benefits of renting or leasing furniture. Many consumers, when faced with a short-term need for furniture, may not realise that opting for a PSS solution can significantly reduce waste and environmental impact. Since sustainability is often a key selling point for PSS models, educating consumers about these benefits could help overcome this barrier and drive adoption.

Technical drivers and barriers

A significant technical barrier PSS companies face in the furniture sector is the lack of robust digital infrastructure to manage key operational aspects. Many companies struggle with efficient inventory tracking, processing payments, handling orders, and maintaining seamless communication with customers. This gap in infrastructure presents challenges in scaling up operations and managing the logistical complexity of circular business models.

Opportunities do lie ahead, however, as digital solutions targeted at circular companies are emerging. This includes systems for keeping stock and subscription management built specifically for circular business models (Circuly, n.d.). Also, the development of digital product passports provides a possibility to share information and promote circular furniture flows (Vinnova, n.d.).

Economic and market drivers and barriers

Economic factors are significant drivers of the attractiveness of furniture PSS models for private customers. One of the key advantages is the potential for customers to save money on direct furniture acquisition costs, as well as on related expenses such as transport, maintenance, and repair. Renting or leasing furniture eliminates the need for large upfront investments, especially for high-end, exclusive furniture items. This allows customers access to premium products without the financial burden of purchasing them outright. Additionally, PSS models remove the logistical challenges of storing furniture when not in use, offering further cost savings for individuals with temporary or changing needs, such as expats, students, or people in transitional living situations.

However, the Nordic furniture market poses challenges for PSS adoption, as it is largely dominated by affordable, flat-pack furniture options from well-established retailers. These companies offer low-cost, easily accessible furniture, creating stiff competition for

PSS providers who must differentiate by highlighting other value propositions. PSS solutions need to emphasise benefits such as convenience, higher-quality products, sustainability, and transport services to attract customers unfamiliar with or hesitant about PSS models.

Moreover, one of the barriers is the entrenched consumer mindset that is accustomed to traditional ownership models. Successfully marketing PSS solutions requires educating potential customers on the long-term economic and environmental benefits, which may be difficult given the strong brand loyalty and affordability associated with traditional furniture retailers. To succeed, PSS companies need to compete not just on price but also on added value through sustainability, product durability, and design quality.

Regulatory drivers and barriers

In general, there is little clarity regarding legal processes that apply to circular businesses, and this is also the case within the furniture sector. Many PSS providers face uncertainty regarding taxation, accounting, and legal processes due to the limited awareness and understanding of circular business models among professionals in these fields. Even experts in taxation and law sometimes hesitate to provide definitive guidance, highlighting the need for better frameworks and knowledge in circular economies.

Public procurement plays a major role in the furniture market in the Nordic region, particularly for large-scale furnishings in public spaces like schools, offices, and care homes. While public procurement policies are gradually moving toward circular models, they have yet to fully embrace PSS solutions at scale for individual housing, such as in care homes and public housing. To bridge this gap, public procurement criteria must be updated to integrate PSS providers. Furthermore, knowledge-sharing and capacity-building initiatives are essential to educate both procurement agencies and PSS businesses on how to implement circular solutions effectively within legal and procurement frameworks. Read more about public procurement in section 16.4.

Apart from moving towards purchasing furniture as a PSS solution, several municipalities in the Nordics are exploring how they themselves can become a sort of PSS provider for their public service entities by facilitatin a sort of take-back and then redistribution. By establishing a warehouse for discarded furniture and interior products and facilitating their collection and redistribution, municipalities can significantly reduce the procurement budgets for such items, save CO_2e by avoiding buying new items, and create inclusive jobs. Through the pilot study with Oslo Municipality, we found the following potential benefits for the municipality.

Table 6: Balance sheet for Oslo Municipality.

Balance sheet	
Saved costs from procurement of new items	122 mill.
Salary costs	- 42.3 mill.
Financial result	**+ 79.7 mill.**
Avoided CO_2e	2,723 ton
Number of inclusive jobs	71

More details about the pilot study can be found in section 16.4.2.

8.2.2 Environmental potential

The environmental potential of furniture PSS is apparent throughout the whole value chain, from production avoidance to extended product life and reduced end-of-life waste generation. However, these benefits depend on several factors that need to be fulfilled for the maximum environmental impact to be realised.

Avoidance of new production

The most immediate environmental benefit of furniture PSS is the potential to avoid the need for new production. By facilitating furniture reuse across multiple households or businesses, PSS reduces the demand for newly manufactured items, lowering the energy, raw materials, and emissions typically associated with furniture production. The degree to which new production is avoided depends heavily on the specific PSS model. For instance, companies like Cohabit, a pilot company in this project, source furniture from individuals and institutions that no longer need certain items, refurbishing and reintroducing them into the market. This ensures that furniture that would otherwise be discarded, such as a bed destined for incineration, gets a second life and serves multiple users throughout at least 2–4 cycles.

In contrast, some PSS models source new furniture, which reduces the potential for immediate production avoidance. However, if the furniture is high quality and can go through multiple rental cycles, it can still mitigate future demand for new items. Many PSS providers, especially those targeting premium markets, invest in high-end furniture that is both durable and aesthetically appealing, extending its life and making it attractive for repeated use. Although such products are resource-intensive to manufacture, their long life offsets their initial environmental cost.

Extended product life during the use phase

Furniture PSS also contributes to environmental sustainability during the use phase. One key driver is the flexibility offered by PSS solutions, which allow customers to exchange furniture as their needs evolve. This adaptability can help prevent unnecessary purchases of new items – and the associated waste problem. Furthermore, PSS providers typically offer maintenance and repair services as part of their business model, extending the furniture's lifespan. With access to repair expertise and environmentally friendly methods and materials, PSS companies can provide repairs more efficiently than individual consumers, ensuring that furniture remains in good condition for longer periods.

Environmental assessment of renting furniture

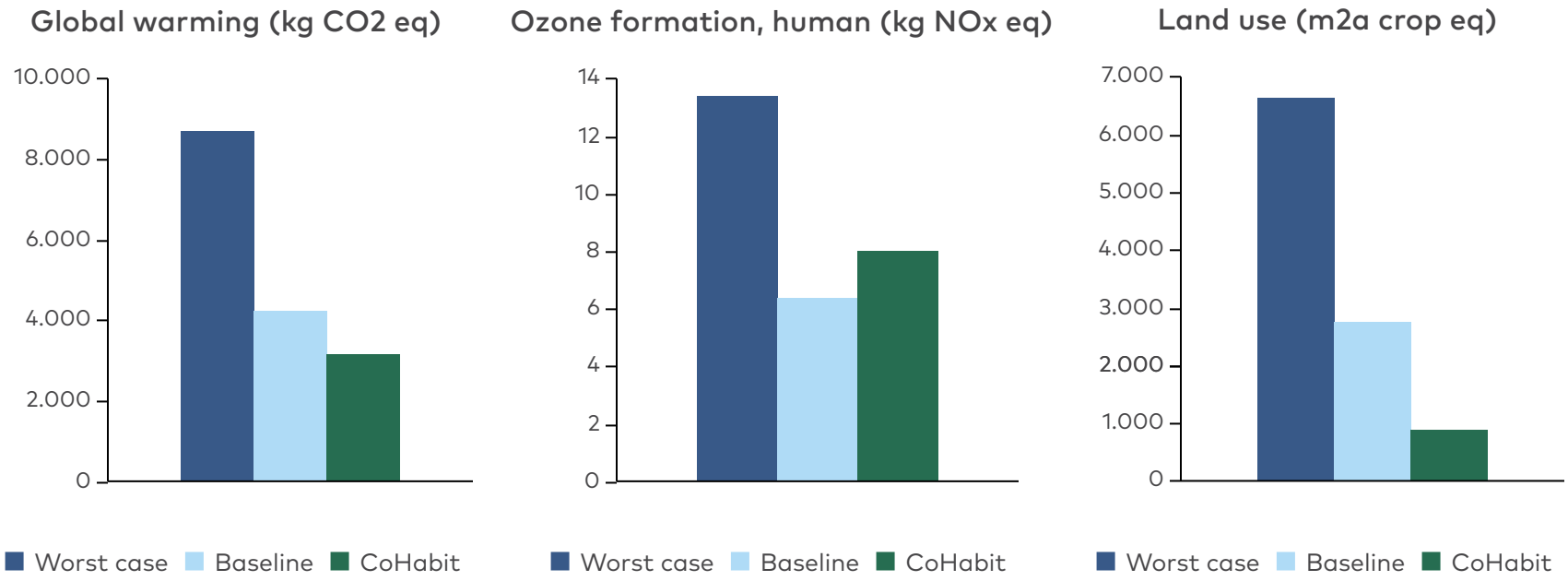
During the pilot, a life cycle assessment of CoHabit's system was conducted (Fostvang et al., n.d.).. The aim of this assessment was to investigate the number of reuses needed to reduce overall emissions and the impact of longer transport distances. The assessment is based on quantitative primary and secondary data to evaluate the CoHabit system and three pieces of furniture. The overall assumptions are documented in annex 2.

The functional unit was a bundle of clean, fully functional, neutral-looking furniture consisting of a place to sleep, sit and eat for 100 people during six months in Malmø and Lund. The reference flows needed to fulfill 100 people's need for the functional unit were calculated for three scenarios based on findings from on-site interviews with Swedish exchange students:

1. Worst case scenario: To buy new furniture and throw these out after use. Reference flow: production and disposal of 100 bundles
2. Baseline scenario: Based on on-site interviews, a baseline scenario representing the 'real' use of furniture was created and divided into the number of students who buy reused furniture, buy new furniture, or buy new furniture and throw it out.
3. CoHabit scenario: CoHabit buy reused furniture and reuses it at least seven times.

The results illustrate the importance of including user-driven reference scenarios and system boundaries. As presented in figure 15. CoHabit emits less CO_2e than the remaining scenarios. Still, the difference between the baseline and worst-case scenarios is larger than between CoHabit and the baseline scenario. Looking at other impact categories than GHG, CoHabit has higher Ozone Formation emissions than the baseline scenario, primarily due to more transportation (Fosvang et al., n.d.).

Figure 15: Comparison of Cohabit, Baseline and Worst Case. Based on work by Fosvang et al.



CoHabit transport their furniture from one storage unit near Lund in Sweden, where the furniture is cleaned and repaired before being rented out to the next student. As a part of the investigation, the impact of transportation was assessed. As presented in figure 16, the transport distances significantly impact the overall results; as the distance increases, so does the impact of CoHabit. This is due to the products being transported as the only cargo in one truck, and the CoHabit furniture, therefore, accounts for all the emissions, making this one of the largest contributors. When calculating emissions from transportation, these can be accounted for differently. When calculating emissions from the freight of products, the distance is calculated in weight/distance (e.g., kg/km), and the product only accounts for the emissions related to the transportation of the product's weight. But this is only possible if multiple products are transported in the same truck. CoHabit uses its cars and does not use existing freight groupage systems, so it accounts for all the emissions. An important finding is, therefore, that emissions from transportation are significantly larger in some PSS systems, and it is therefore important to investigate possibilities to reduce this, e.g., by groupage or decentralised storage (Fosvang et al., n.d.).

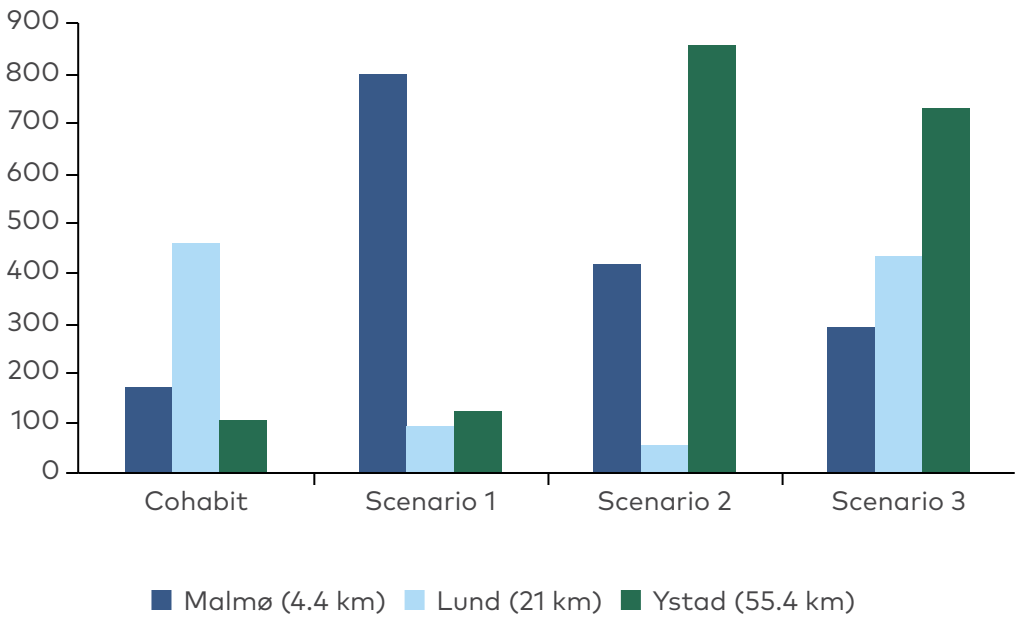


Figure 16: Sensitivity analysis of transportation. Based on work by Fosvang et al.

8.2.3 End-of-life waste reduction

One of the most compelling environmental benefits of furniture PSS is its potential to reduce end-of-life waste, a persistent challenge in traditional linear models of furniture consumption. In the linear value chain, furniture is believed to account for over 4% of municipal solid waste, and reuse rates in the sector remain low. According to Statistics from the European Federation of Furniture Manufacturers, 80% to 90% of EU furniture waste in municipal solid waste is either incinerated or landfilled, and only 10% is recycled (Forrest et al., 2017). Furniture PSS can break this cycle by extending the lifecycle of products through reuse and refurbishment, thus diverting perfectly usable furniture from the waste stream.

> ”
>
> *I don’t have to check where to leave the furniture, which I would have had to do if the furniture was bought*
>
> **– Student leasing through PSS**

With the expertise that PSS companies bring to the lifecycle management of furniture, they can ensure that when items reach the end of their usable life, they are disposed of properly. This is particularly important given the presence of hazardous chemicals in some furniture, such as fire retardants, adhesives, or heavy metals, which complicates recycling efforts. These chemicals can pose significant environmental and health risks if not handled correctly, and there is a general need for improved information transfer across the value chain (Vanacore et al., 2021). PSS providers can act as intermediaries, ensuring that important data on the materials used, including hazardous substances, is communicated to recycling facilities. This improved information flow can facilitate safer and more efficient recycling processes, contributing to a more sustainable furniture industry.

Moreover, PSS solutions eliminate or minimise the need for disposable packaging, a common issue when purchasing new furniture. With multiple rental or leasing cycles, the same furniture can be transported and installed without new packaging, reducing the vast amount of cardboard, plastic, and other materials typically used in packaging.

By managing both the use and end-of-life phases more sustainably, furniture PSS contributes to the circular economy by maintaining the value of products, ensuring they are kept in use longer, and handling waste in a way that minimises its environmental impact. This represents a shift from the traditional consumption model toward a system that prioritises resource efficiency and responsible waste management.

8.2.4 Socioeconomic and other benefits

Furniture PSS models offer socioeconomic benefits by providing access to higher-quality, aesthetically pleasing, and functional furniture without the significant upfront cost associated with ownership. This can be particularly advantageous for individuals or households with limited financial resources, as it allows for more flexible, affordable furnishing options. For instance, companies like Cohabit cater primarily to exchange students, providing an affordable, adaptable solution that fits their short-term needs.

Moreover, furniture PSS businesses like Cohabit foster community engagement and personal connections. Cohabit plays an active role in the exchange students' experience of moving to Sweden by offering more than just a rental service. The company assists with the transition by recommending other circular business solutions that might interest students and organising social gatherings. These events allow students to meet peers, share experiences and offer valuable feedback to the company on the PSS solution.

Rebound effects

One of the key rebound effects in furniture PSS models is related to transportation. Furniture used in these systems typically requires more frequent transportation than purchased furniture due to delivery, returns, and redistribution among multiple users. This increased transportation can diminish some of the environmental benefits associated with PSS, as it contributes to higher emissions, especially over long distances or if inefficient transport modes are used.

In the case with Cohabit, an LCA study of their operations found that transport was the main contribution to the company's climate impacts, responsible for 65% of the CO_2e in one rental cycle (Fosvang et al., n.d.). This was calculated under the assumption that Cohabit was responsible for 1/8 of the furniture's climate impact from production, assuming that the furniture will be circulated eight times. The cleaning procedure had an insignificant climate impact compared to emissions from production and transport. As part of the LCA study, the authors also carried out a sensitivity analysis which showed that the distance travelled to transport furniture for customers impacts the CO_2e emissions of Cohabits operations, meaning that scaling of the business to other cities affects the climate impact of the business model. Apart from transport distance, the second most important factor for CO_2e emissions was the number of use cycles that the furniture goes through, which is a well-known pattern in circular business models.

To mitigate these effects, PSS providers must prioritise optimising logistics, such as consolidating deliveries, minimising travel distances, and incorporating low-emission vehicles into their fleets.

8.2.5 Conclusions

Furniture PSS has substantial potential to promote circularity by extending product lifecycles, reducing waste, and offering flexible, accessible furnishing solutions. Barriers, such as cultural preferences for ownership and logistical challenges, remain; however, the

model offers significant economic, environmental, and social benefits. It enables access to high-quality furniture without large upfront costs and provides adaptable solutions for specific groups like students and expats. Moreover, the potential for PSS in public procurement (GPP) is promising. As public institutions increasingly adopt circular criteria, PSS models could expand, helping align procurement with sustainability goals, further driving demand for long-lasting, reusable furniture. Addressing logistical challenges and optimising transport will be critical for maximising the environmental benefits.

9. PRODUCTS FOR CHILDREN

Two main product groups are defined in this cateogry: children's clothing (including maternity wear) and toys and equipment (for children, maternity, and nursing). Companies in the Nordic market often provide products across these subcategories, even when initially specialising in one area. For instance, a company may start by offering toys but later expand to include items like breast pumps, weighted blankets, or clothing.

Examples in the category include Danish companies DearBaby, Baby BoogieWoogie, and Babysam; Icelandic companies Barnalán and Móðurást; Norwegian company SmallTrolls; and Swedish company Parently, all of which offer rentals of toys and equipment through leasing or subscription models. In contrast, children's clothing is often offered as a standalone category, as seen with Swedish company Hyber's subscription service and Norwegian company Bergans' snowsuit rental within its sales model.

As a result, children's clothing is presented separately here, based solely on existing literature, while the subcategories of toys, equipment, and maternity & nursing are analysed using literature and empirical data from pilot studies.

9.1 Children's Clothing

Renting children's clothing through PSS solutions has been steadily gaining traction in the Nordic region, where companies have offered use-oriented PSS models for over a decade. Subscription-based services, in particular, provide parents with convenient access to appropriately sized clothing as their children grow, addressing both practicality and sustainability by significantly reducing the need for frequent purchases.

Even though there are several positive aspects to sharing used children's garments, implementing a subscription model for children's clothing can present significant challenges. This is explored in a study of the former Danish children's clothing rental company, Vigga (Petersen & Riisberg, 2017) . One key challenge identified was the normative understanding of gendered clothing – for instance, blue for boys and pink for girls. Since the clothes were supplied in pre-assembled age-specific sets of various colours, and customers did not have full visibility of the products before renting, additional logistics were needed to meet customer preferences.

The study also highlights the strong emotional bonds some consumers formed with their children's clothing, which posed an additional challenge to product circulation (Petersen & Riisberg, 2017). A leasing system like Vigga depends on consumers not forming lasting emotional attachments to the garments, which could hinder reuse. To address this, Vigga redirected emotional attachment towards the community of subscribers, fostering a sense of participation in a collective movement for sustainability. By promoting the idea

of shared responsibility for the planet and providing an ongoing flow of new garments, the company aimed to reduce personal attachment to individual items while reinforcing the environmental and social benefits of their rental model.

Another study, also focusing on Vigga, explores the key factors influencing the environmental impact of its rental subscription model (Kjaer et al., 2019). The findings highlight that a significant portion of the environmental benefits depend on how consumers handle and care for rented children's clothing. Proper care can greatly extend the lifespan of the garments, which is essential for reducing their environmental footprint. To support this, Vigga partnered with Novozymes, a producer of industrial enzymes for detergents, to implement a cold-wash system that gently cleans the garments. However, this approach was challenged by customers' harsher washing practices during the rental period. In response, Vigga introduced care guides with recommended cleaning methods to help consumers maintain garment quality and extend their life. These efforts also included communication about the importance of responsible consumer behaviour in minimising environmental impact by reducing the need for frequent replacements (Kjaer et al., 2019). This initiative thereby aimed to encourage sustainable consumer behaviour and eventually contributed to extending the product's longevity.

Several studies highlight the potential for rebound effects in subscription-based models of children's products (Kjaer et al., 2019; Mont et al., 2006; Petersen & Riisberg, 2017). While renting children's clothing can offer environmental benefits, it may unintentionally lead to shifts in consumer behaviour that offset these gains. For instance, when parents save storage space by renting rather than buying, they might fill that space with other items, undermining the positive environmental effects of the rental model. Additionally, the financial savings from renting may encourage increased consumption in other areas. This rebound effect (further studied in section 15.2) has been observed across various studies on children's products like prams and toys as well, where consumers perceive rental as a sustainable action, potentially justifying additional purchases elsewhere (Mont et al., 2006). One way to overcome this barrier is to encourage more sustainable consumption patterns by educating consumers about the environmental benefits of such models and fostering a community around sustainable practices (Petersen & Riisberg, 2017).

9.2 Toys, childcare equipment, and maternity products

The Nordic market for children's and maternity products and equipment increasingly embraces circular business models, focusing on their sustainability and resource efficiency aspects. The businesses are particularly within use-oriented PSS and provide similar services like single rent solutions, monthly subscriptions and membership deals. Besides that, the services include logistics, cleaning, maintenance, repair and refurbishment of a wide range of products like entertainment blankets, books, strollers, auto seats, bikes, beds, gravity blankets, etc., emphasising convenience and product variation. These services meet the practical needs of growing children and resonate with environmentally conscious parents by extending the lifespan of high-quality toys and reducing waste.

DEARBABY (est. 2020, Denmark):

DearBaby operates on a rental-based model focused on sustainability.

It reuses toys that are typically used for short periods, reducing waste and clutter.

The company offers a carefully curated selection of toys chosen by child development experts to support children's growth in motor skills, sensory development, and cognitive progression.

DearBaby primarily serves private consumers in the Danish market.

Although some businesses still primarily operate within a traditional sales framework, some also offer rental options for specific items like breast pumps and baby scales. This shift toward offering rental services, even within conventional business models, signifies a growing recognition of the benefits of PSS and perhaps an industry-wide move toward more sustainable practices.

In contrast, the companies involved in the pilot phase of this project, DearBaby (DearBaby, 2023) and Barnalán, were founded specifically with the motivation to offer a sustainable, circular alternative to the widespread use-and-dispose culture. This vision is deeply influenced by their founders' own experiences as parents. Committed to selecting durable products that ensure longer lifespans, these companies aim to help parents choose the right products at the right time, fostering more mindful and environmentally conscious consumption.

Logistics play a central role in the sustainability efforts of both cases, as efficient transport and handling are essential to their rental models. Close collaboration with logistics partners is critical due to the substantial transportation required for delivering and returning products, and these partnerships are key to ensuring smooth operations.

Both companies maintain strong ties with their logistics providers, allowing them to meet high expectations for reliability, sustainability, and efficiency.

BARNALÁN (est. 2021, Iceland):

Barnalán offered a wide range of rental products, including beds, car seats, breast pumps, highchairs, and toys.

Products were available for individual rental, and toys were also rented through a subscription service that delivered curated toys every two months.

Each product was selected based on high quality and durability, providing an eco-friendly option that maximises usage while eliminating the need for storage and resale.

As of May 2024, Barnalán has ceased operations.

Beyond transport, cleaning, maintenance, and repair between rental periods also rely on close partnerships with external providers. The Swedish company Parently operates similarly to a retailer but has implemented a revenue-sharing model that allows manufacturers to retain ownership of certain products. This approach streamlines the maintenance cycle, ensuring products remain in top condition while strengthening relationships between brands and customers, ultimately enhancing service quality and customer loyalty.

9.2.1 Drivers and barriers

The key drivers for adopting PSS in the children's products sector include sustainability, economic efficiency, and consumer convenience. A major factor is the short lifespan of children's products, as their needs for toys, clothing, and equipment change frequently. PSS models address this by extending product life through rental and shared use, maximising item usage before they are outgrown.

Consumer convenience plays a vital role. Renting allows parents to try out items without the financial commitment of purchasing, offering flexibility and preventing homes from becoming cluttered with quickly outgrown products. According to our case studies, flexibility and convenience are identified as some of the primary drivers for customers choosing a PSS solution. Here, the convenience aspects of trying out a product without paying for its total ownership and receiving a carefully expert-selected box of age-specific toys, including prepaid return shipment, is perceived as DearBabys customer's primary motivation for choosing their solution. DearBaby states that the environmental benefit of their model is more of a positive add-on than it is their primary reason for choosing renting toys.

> *Our model makes sense for our customers. It has to be easy and make sense for them as the primary goal. Secondarily comes the sustainability aspect, which is a nice effect of our model*
>
> **– DearBaby interview**

However, while these factors encourage the adoption of PSS, significant barriers remain that complicate the business model's viability, particularly for start-ups. As with many PSS models, one of the major barriers to launching a PSS business is the significant initial investment needed to acquire inventory and build a sustainable business model. Companies must maintain a large stock of products, which presents a substantial financial challenge. This was evident in the pilot cases of this project, where DearBaby had to expand its inventory gradually, in line with cash flow, and highlighted the crucial role of funding from the Danish government and private innovation programs – without which the company would not have survived. Our study reveals that many PSS companies in this product category went bankrupt or closed down within the first years, highlighting the complex financial challenges of this type of business model.

In addition to financial hurdles, technology plays a key role in the success of PSS companies. Efficient IT systems are essential for managing subscription-based models, and both Barnalán and DearBaby have experienced difficulties in this area. Barnalán, for instance, relied on manual inventory management, which proved inefficient, time-consuming, and prone to errors. DearBaby, by contrast, secured funding to develop an IT system tailored to its business model and product range – a critical step in its survival. It is likely that Barnalán's lack of a suitable IT system significantly contributed to their decision to close, as this was cited as a major operational challenge.

A common PSS adaptation challenge that DearBaby also confirms is shifting consumer mindsets towards rental or subscription-based models. In particular, DearBaby highlights the challenges of the cultural understanding of ownership where Christmas can be understood as a barrier as many customers wants to give physical products to their loved ones. To overcome this, DearBaby introduced their webshop featuring pre-loved items, which has proven to be an effective way to address this barrier and meet customer expectations.

Another cultural issue, particularly prevailing in this product group, is customers' emotional attachment to rented children's products. A study on a children's clothing rental service revealed that customers formed sentimental connections to the products, as it reminded them of their children's growth and milestones (Petersen & Riisberg, 2017). In our case study of DearBaby, this behaviour was confirmed, as it was explained that the

company had experienced customers who wanted to buy selected pieces of toys after the renting period. Therefore, DearBaby provides its customers with this opportunity, which is perceived as a beneficial arrangement for both the company and its customers. While this solution enhances customer satisfaction, it can also be viewed as a barrier, as it potentially undermines the circular purpose of PSS solutions by encouraging product retention rather than continuous reuse.

9.2.2 Environmental potential

One of the primary environmental gains from PSS models is the reduced demand for new product manufacturing as products are systematically distributed and circulated among several users instead of only benefitting one child or family. Studies show that products like strollers, prams and bikes are often discarded after a brief period due to the rapid growth of children and changing needs, thereby presenting inefficiencies associated with short product lifespans (Kerdlap et al., 2021a).

PSS models, such as those employed by Barnalán and DearBaby, extend the usage of these products by renting them to multiple users. This sharing model diminishes the need for new products to be produced, thereby conserving raw materials and reducing emissions associated with manufacturing. For instance, a study conducted in Singapore revealed that renting prams led to 29–46% lower lifecycle environmental impacts than purchasing and discarding after the initial period of use (Kerdlap et al., 2021a). The study further showed that the most impactful scenario involved parents using a pram for three years and then passing it on to others for another three years, leading to a 50 % reduction in environmental impacts. This scenario has the most significant environmental potential, as renting out the product involves frequent heavy cleaning and transport for maintenance and between customers. Therefore, it becomes crucial for rental companies, especially those offering baby prams, to manage and limit heavy cleaning.

Extending the lifespan of children's products is another significant environmental benefit of PSS. By maintaining, repairing, and refurbishing products, PSS companies ensure that items remain in good condition for longer, increasing their overall usable lifespan (Lee et al., 2023). DearBaby also contributes to improving the environmental performance of their products during the usage phase by guiding proper use and cleaning of their products to their customers while in use. For example, detailed care instructions are given on the webpage and sent via e-mail when renting a product to ensure that the products are handled correctly, such as cleaning with a damp cloth without chemicals. This aims to optimise product longevity and functionality.

Finally, PSS models contribute to reduced waste generation by extending product lifespan and ensuring continued use, thereby minimising waste generated from discarded items. Our case studies show that products go through several stages before being sent for recycling, where both Barnalán and DearBaby clean and maintain products after each rental and have a marketplace where products that no longer meet rental standards can be purchased at a reduced price. Finally, both cases state that they strive

to minimise waste as much as possible by donating products for reuse if they can no longer be rented or sold. Companies that rent out children's equipment, such as Parently, go further by replacing broken parts that can be swapped out. They also encourage manufacturers to adopt modular design in the development phase, ensuring that products have the longest possible lifespan. This approach minimises waste, for example, by allowing a highchair to be repaired if a buckle breaks rather than being discarded. Ultimately, this strategy could potentially help reduce the need for new production (Kerdlap et al., 2021a).

Socioeconomic and other benefits

PSS for children's products offer different socioeconomic and other benefits, making them a compelling choice for consumers and businesses. By transforming the traditional product ownership model, PSS not only makes high-quality children's items more accessible and affordable but also promotes sustainable consumption and supports the development of a circular economy (Petersen & Riisberg, 2017).

One of its primary advantages is its significant cost savings, allowing parents to rent or subscribe to products without incurring the high upfront costs of purchasing. This approach is particularly beneficial for families with limited budgets or those seeking to allocate financial resources more efficiently. By lowering financial barriers, PSS models make products more accessible, ensuring that more families can afford the necessary tools for their children's development. This democratisation of access helps level the playing field, allowing all children to benefit from products that support their growth and learning, as demonstrated by cases like DearBaby and Barnalán, where families can use products only as long as needed, avoiding the financial burden of frequent replacements. At the same time, this circumstance allows parents to spoil their children without encouraging overconsumption, which DearBaby explains was one of the main motivations for founding the company.

> ”
>
> *On one hand, I have wanted to spoil my children, but on the other hand, I don’t want to encourage them to overconsume. I wanted to make it easier to spoil one's children in a responsible way*
>
> **– DearBaby interview**

Convenience and flexibility are key advantages of PSS models within children’s products. With the option to rent or subscribe to products, parents can easily adjust to their children's changing needs without the hassle of buying, storing, or disposing of items. Parents can return or exchange products as children move through different developmental stages, ensuring they always have the appropriate items. This adaptability allows families to respond quickly to changing needs and preferences, making parenting easier and more manageable. The increased flexibility also makes it

easier to live in smaller spaces, as there is no need to store products that are no longer needed or were mistaken purchases. This aspect can positively impact living arrangements, potentially delaying the need for a larger home and ultimately having a greater environmental footprint (Viegand Maagøe, 2023).

9.2.3 Conclusions

The Nordic children's product market is particularly well-suited for PSS solutions due to the rapid changes in children's needs and the short lifespan of products like toys, strollers, and clothing. Insights from companies like DearBaby and Barnalán illustrate the clear benefits of PSS, including reduced waste, extended product lifecycles, and increased convenience for parents. These rental and subscription services allow access to age-specific products, helping families avoid unnecessary purchases and clutter.

However, significant challenges remain. High initial costs for building and maintaining inventory are barriers, particularly for start-ups. Additionally, cultural preferences for ownership, especially when parents form emotional attachments to children's products, complicate the adoption of PSS. This issue can be addressed by fostering a sense of community around sustainability, encouraging customers to shift their emotional attachment from individual products to shared environmental responsibility.

Logistics, maintenance, and IT infrastructure are crucial for the success of PSS models. Efficient systems must manage product rotation seamlessly, while robust procedures for maintaining product quality through repair and refurbishment are essential. Additionally, manufacturers need to design products that are easy to repair and circulate multiple times, ensuring they can withstand the demands of repeated use. Addressing these factors is key to unlocking the full potential of PSS models. Despite these challenges, PSS offers a powerful opportunity to encourage more sustainable consumption patterns, particularly as younger generations increasingly embrace circular economy models.

10. TEXTILES

The textile sector plays a significant role in the global economy, and its consumption, especially in fashion, is rapidly growing in the Nordic countries. However, this growth has brought significant environmental consequences across the entire lifecycle of textiles, from production to end-of-life phases. Approximately 80% of the climate impact from textiles occurs during the production phase (Moazzem et al., 2022), making it a critical area for intervention.

In the Nordic Region, the average consumption of textiles is between 13-16 kg per capita annually, resulting in around 350,000 tonnes of new textiles entering the market each year. Unfortunately, only about 120,000 tonnes of used textiles are collected for reuse and recycling, mostly through charitable organisations (Fråne et al., 2017). Recognising the environmental impact of the textile sector, the Nordic Council of Ministers introduced The Nordic Textile Reuse and Recycling Commitment in 2017, which offers voluntary certification for textile collection aimed at reuse and recycling (Fråne et al., 2017). However, the reality of textile recycling is fraught with challenges. One of the biggest hurdles is the complexity of separating textile fibres, especially in blended fabrics, which complicates the recycling process (Kaipia et al., 2022). Additionally, the infrastructure for large-scale textile recycling is still underdeveloped. Many textiles contain synthetic fibres, dyes, or finishes that make it difficult to recycle them into new materials without losing quality. These limitations mean that most textiles, even when collected for recycling, are downcycled into lower-value products or are incinerated.

Thus, models extending the life span and usage of textiles are necessary. According to the Ellen MacArthur Foundation, combining resale, rental, repair, and remaking models could cut fashion industry emissions by 16% by 2030, contributing a third of the reductions needed for the sector. Efficient use of clothing from subscription-based rental models specifically can reduce emissions by 41% compared to the linear model (Ellen MacArthur Foundation, 2021b).

PSS models for textiles have been available for decades and have shown promise for economic viability, especially in markets such as the United States (Lacy et al., 2020). From mid-market to luxury goods, PSS models like rental, resale, and repair services show strong potential to not only reduce waste but also drive positive margins – particularly in the luxury sector, where these models can yield higher profits per garment compared to traditional linear models (Fashion for Good, 2021).

In the Nordic market, PSS models for workwear and household textiles are well-established and driven by demand from sectors like hospitality and healthcare. In contrast, the market for casual and festive clothing rentals remains less developed, with services mostly focused on special occasions and limited adoption of models for everyday wear. Despite this, the potential for such models to reduce the need for new clothing production and extend garment lifespans is significant, especially as consumers become more aware of sustainability issues in the fashion industry.

10.1 Workwear and household textiles

Most PSS providers in the household textile category offer comprehensive solutions, including washing and delivering textiles, primarily targeting the B2B and B2G markets. One example is Textilia, which operate in Denmark and Sweden. This company, formerly known as Danske Forenede Dampvaskerier (1958), offers industry-specific laundry and rental solutions to five market divisions, including HoReCa, cleaning, and healthcare sectors. Through its Textilia Trace system, customers benefit from digitally integrated solutions that provide easy access and stock tracking. Textilia is also committed to sustainability, with an ambitious goal to recycle 100% of its textiles by 2025 (Textilia, 2021).

Lindström, based in Finland, offers a wide range of textiles, such as mats, restaurant textiles, and workwear – the latter being the most income-generating. It has a global outreach and emphasizes a circular business model through rental, maintenance, and recycling. Providers of PSS workwear like Lindström first and foremost offer convenience, as customers are offered a total solution for the workwear. This can include personalisation, maintenance, repairs, washing, and delivery directly to staff locker rooms (Lindström, n.d.-b). Given the size and experience of companies like Lindström, the workwear market for PSS is well developed. This maturity allows them to implement sustainability strategies, such as reuse, repair, recycling, and reducing waste and water (Ellen MacArthur Foundation, 2021a).

The Danish company Gardin Lis specializes in leasing curtains for B2B and B2G markets. The company offers flexible payment options and provides take-back services for old curtains, enabling it to lease or sell reused curtains. This approach helps extend the life of curtains and prevent waste generation. Gardin Lis also stands out with its mobile "Gardinbus" service, where it visits clients to assist with measuring, selecting, and discussing leasing options (Gardin Lis, n.d.). Similar to Textilia and Lindström Garden Lis also has their own laundry and workshop for maintenance and repair of curtains.

Belle Carpets and Rugs is a family-owned product-oriented business that sell hand-knitted Oriental carpets B2B and B2C and offer repair and cleanse of the rugs to prolong the product lifetime. Belle's value proposition for businesses is to provide durable and long-lasting rugs instead of conventional rubber mats with high climate impact and short lifetime. Belle has an elaborate supply chain, for instance among nomadic tribes and villages in Iran, where the rugs are produced (Belle, 2020).

In summary, PSS solutions for household textiles in the Nordics are well-established, mainly in B2B and B2G markets. Demand for these solutions is rising, especially among industries like hotels and hospitals, due to increased focus on reducing waste and climate impact (Kumar et al., 2022). While companies like Textilia and Lindström focus on broad industry-specific textile solutions, Gardin Lis and Belle Rugs operate within a more specialized niche, focusing on the leasing of curtains and rugs. All providers share a commitment to extending product lifespans, reducing waste, and meeting recycling goals, which are vital to addressing the environmental impact of textile consumption.

10.2 Casual clothing and clothing for special occasions

B2C rental services for casual clothing are becoming increasingly common in many Nordic countries (Piontek et al., 2020), and renting festive clothing has been popular for a while. The rental services generally fall into two main categories: membership-based models with a monthly subscription, often centred around physical shops and with a strong focus on consumer education and community, and one-off rentals for special occasions, typically facilitated via social media and regular shipping services. Some established brands have also introduced in-house rental services to supplement their regular sale.

Monitoring the Nordic business landscape revealed that out of the monitored 29 rental services, all of which were founded after 2013, 12 had ceased operations before the summer of 2024. This shows a market with many newcomers and relatively short company lifespans. This was also evident in the pilot company included in this project, which ceased operations in its current form in early 2024, indicating that the current business conditions in the Nordics are still unfavourable for these businesses. The monitoring also revealed a market characterized by female micro-companies targeting female consumers.

Although clothing rental models in the Nordics are still small-scale and have not yet disrupted traditional linear models, they are beginning to challenge the demand for new clothing. Many rental members report that renting solutions satisfy their desire to renew their wardrobes without buying something new. This keeps garments in use longer, extending their lifespan and offering a sense of "newness" to multiple consumers.

10.2.1 Drivers and barriers

Cultural drivers and barriers

Studies suggest high entry barriers, such as the desire for ownership and fear of loss or damage.Additional barriers include perceptions of rentals as time-consuming or complicated as well as hygiene concerns (Bodenheimer et al., 2022). The high entry barrier was also evident in the pilot company, Vaatepuu, which offers both casual and formal wear rentals on monthly subscriptions. The company observed strong interest from its target group, with nearly 5,000 social media followers. However, this interest did not fully translate into memberships, as the pilot company had fewer than 300 paying

members. To address this barrier, many Nordic rental companies provide detailed FAQs on their websites on loss and damage, laundering, and shipping. As for hygiene, recent studies (Bodenheimer et al., 2022) and the pilot study dispute those concerns, as members of the pilot company expressed a high trust in the other members and their ability to wash and treat the clothes according to their own standards.

Technical drivers and barriers

In line with the consumer concerns mentioned above, a lack of standard policies and solutions in clothing rentals can create uncertainty and hinder scalability. Without consistent frameworks for handling aspects like rental periods, loss, and damage, customers may feel uneasy about what they are committing to (Bodenheimer et al., 2022). In the case of the pilot company, members were allowed to customise their rental periods, and issues like loss and damage were addressed on a case-by-case basis. While this flexibility worked well for long-standing members who trusted the company, it posed a barrier for new customers unfamiliar with these informal arrangements, who may expect more clarity and consistency.

VAATEPUU (2014-2024, Finland):

Vaatepuu offers clothing rental for consumers with stores in 5 Finnish cities. The clothing selection is based on sustainable high-end designer fashion brands, especially showcasing Finnish brands, with focus on casual clothing and a selection of formal and festive attire.

Clothing rental is offered a membership-based model and can participate in styling events and clothes-swappings.

Lack of financial guidance and encouragement was identified as another economic barrier for company owners, as business guidance networks seem unable to help. Another barrier is that investors struggle to understand the model and require a successful existing business case to prove that this can be profitable at scale before daring to invest. This was expressed both by PSS providers and by an investor.

> **What really makes me lose my spirit is that investors and business guidance networks no longer see any opportunities in the business model**
>
> **– PSS provider for textiles, 2024**

Economic and market barriers

Clothing rentals generally struggle to compete with fast and ultrafast fashion since there are no economic incentives for consumers to rent from fast fashion brands when they can buy them so cheaply. Rental models for casual clothing struggle specifically in the regard, as casual clothing does not retain its value as long as occasional wear (Bodenheimer et al., 2022). Lack of financial guidance and encouragement was identified as another economic barrier for company owners, as business guidance networks seem unable to help. Another barrier is that investors struggle to understand the model and require a successful existing business case to prove that this can be profitable at scale before daring to invest. This was expressed both by PSS providers and by an investor.

> ”
>
> *Investors have difficulty seeing the logic when the company is not linear and normal*
>
> **– PSS provider for textiles, 2024**

FEMININE PRODUCTS AND INVESTMENTS IN WOMEN-LED COMPANIES

Our market research shows that most clothing rental companies in the Nordics are owned by women and primarily target female consumers, reflecting broader industry trends, as women on average spend three times more on apparel than men (Brown et al., 2018). Our study uncovered several gender-specific barriers faced by clothing rental companies:

Challenges for female-owned companies: A rental company interviewee noted that potential investors focused on risks rather than expansion plans, asking questions like “Have you thought about…?” or “Do customers really like this?” This forced her into a defensive position making it difficult to highlight her business’s potential. This aligns with research showing that investors tend to ask women risk-oriented questions, while men are questioned about achievements – ultimately leading to lower funding for female entrepreneurs (Kanze et al., 2017).

Bias against feminine products and services: Gender biases affect not only the entrepreneur’s gender but also the product and target consumer. One example from the study involved a male investor showing scepticism toward a female-focused product he couldn’t relate to. This aligns with literature on the commodification of femininity, where female entrepreneurs are seen as providers of gender-specific products (Ahl & Marlow, 2021). Clothing businesses by women for women often embody commodified femininity, creating a strong identification between founders and customers, which proved to be a strong driver in the pilot

company. However, this focus can limit the scope of their businesses to gender-specific markets, making it harder to expand.

> *[The male investor] said something like, "I don't understand fashion, so I have to talk to my wife"*
>
> **– PSS provider for textiles, 2024**

Circular business models viewed as feminine: Sustainable and circular business models are often viewed through a gendered lens, with both concepts being associated with "feminine" values. This was evident in dialogues with investors about their approach to clothing rental companies, illustrated in the quote. Research suggests that women in the Nordics are more concerned with sustainability while men dominate STEM fields and green economy sectors (Sand, 2022). This gender skew can lead to investments being directed toward male-oriented solutions, potentially sidelining women-led ventures in circular industries.

In sum, female entrepreneurs in Nordic clothing rentals appear to face a triple intersection of financial barriers: being women, targeting a female audience, and building businesses on circularity values.

> *There is more doubt [among investors] in this thing with sustainability and clothes. Both circularity and clothes are sort of feminine values*
>
> **– PSS provider for textiles, 2024**

Regulatory barriers

The pilot study identified a regulatory barrier in the lack of supportive taxation policies. In Finland, selling used items is exempt from VAT, but rentals are not, placing clothing rental companies at a disadvantage compared to second-hand markets, as they must pay VAT on every rental. In Norway, a uniform VAT rate of 25% applies to all product sales, rentals, repairs, and resale, creating equal challenges for all circular business models.

Additionally, as seen with other product groups, the regulatory framework tends to favour linear business models. Cheap resources and relatively expensive labour make it more cost-effective to produce new items rather than support services like rentals, repairs, and maintenance. This imbalance creates financial hurdles for circular models that rely on labour-intensive processes to extend product lifecycles.

10.2.2 Environmental potential

Clothing rental models can potentially increase the use of items through repeated rentals to different customers (Bodenheimer et al., 2022). Studies show that renting clothing can result in lower CO_2e emissions compared to buying, except in comparative scenarios where owned dresses are worn frequently, and rental trips involve car travel. When used efficiently, subscription-based rental models can reduce emissions by 41%, compared to the linear model, according to a scenario analysis by Ellen MacArthur Foundation (Ellen MacArthur Foundation, 2021a).

A case study resembling the pilot in location, size, and product categories found that transportation had a greater environmental impact than the extra maintenance or laundry associated with rental models, particularly for formal wear requiring minimal washing (Spark Sustainability, 2022). Since formal dresses are rarely worn until their end of life, renting them tends to be more climate-friendly than renting basic wear, typically worn more often.

The pilot study also demonstrated environmental benefits. Members reported substituting new clothing purchases by renting specific outfits for special occasions or relying heavily on rental services for formal workwear. This shift helps reduce the demand for new clothing items, even though it is important to note that not all rentals substitute purchases. Additionally, members mentioned that their rental membership made them more comfortable wearing second-hand clothing, which subsequently influenced their willingness to buy second-hand items outside the rental service. Interviews also revealed that members became accustomed to higher-quality garments through the rental service, which led them to prioritise quality when purchasing new clothes. Since clothing rental models rely on the repeated use of items, they are incentivised to select higher-quality, more durable clothing, ensuring that rented garments can withstand multiple uses and maintain their appeal over time.

> ”
>
> *At age 18-20, I could not even touch clothes that others had on, now that is not a problem anymore*
>
> – User of PSS, 2024

Additionally, repairs were made to extend garment lifespans, with one case showing how local supply chains supported repairs, such as fixing a rented mohair jumper with original yarn from the manufacturer. Our analysis of the Nordic clothing rental market revealed that most companies include additional fees for repairs in their rental terms in case of damage. This suggests an intention to repair items rather than discard them, particularly when it comes to designer clothing and other high-value items rented for special occasions.

However, the analysis of Nordic clothing rental models also showed that while many companies claim sustainability commitments, few of them mention specific practices beyond the rental model, such as sourcing second-hand or surplus garments. This suggests that the full environmental potential of these companies' sustainability commitments has yet to be realised.

Socioeconomic and behavioural benefits

Interviews with members of the pilot company revealed a strong sense of community, where staff and members exchanged compliments, advice, and styling ideas. This supportive environment encouraged members to experiment with new styles and sizes, boosting their confidence. The company further fostered this community by hosting events like "hen parties" and styling salons, creating a sense of belonging that positively influences behaviour. Members often went the extra mile for one another, such as repairing garments or returning items early to benefit the next user. Despite their small scale, these community-driven rental companies have disruptive potential, as they encourage consumers to radically rethink fashion consumption and engage with fashion in a more collaborative and sustainable way.

Rebound effects and unintended consequences

However, while rental models foster positive social and behavioural change, they can also lead to unintended consequences. Some members acknowledged that their rental memberships allowed them to maintain bad habits of constantly seeking "newness," which contradicts the sustainability goals of reducing overconsumption. Clothing rental models must – at least to some extent – keep up with fashion trends to consistently offer items that customers want to rent (Bodenheimer et al., 2022). Similar to the challenge of deadstock in traditional fashion retail, rental services face the issue of avoiding "flops," or items that are rarely or never rented. However, some research suggests that excess inventory is less of an issue for clothing rental models than for fashion retailers (Jin & Shin, 2020). Conversely, "hot picks" – highly popular and frequently rented items – can equally pose challenges. Users often expect these popular items to be available when they want them and might lose confidence in the service if this is not the case (Bodenheimer et al., 2022).

However, in the case of Vaatepuu, members appeared less concerned about the availability of specific items. A sense of community enhanced the experience at Vaatepuu fostered through interactions with other members at physical stores, and not merely a transaction between users and the clothing rental company. Additionally, Vaatepuu's founder actively coordinated between members to ensure that specific items were available if someone wanted to rent them for special occasions.

When clothes are rented rather than owned, it can result in increased washing or dry cleaning. Most clothing rental services include a cleaning service after each rental to maintain high hygiene standards. While this feature can make clothing rental more appealing to customers, it may also lead to more frequent washing compared to

personal clothing care. Customers might not apply such strict hygiene standards to their own clothes, for example, airing them out after wearing them instead of washing them after each use.

Additionally, companies themselves may experience rebound effects in procurement. For instance, one company was founded by a woman who had accumulated too many unworn dresses, which she then began renting out – a model born from overconsumption (Sayman, 2021).

Another unintended consequence of the rental market is its impact on charity shops. As high-quality garments are kept in circulation through rentals, the availability and value of items for donation decrease, forcing charities to rethink their strategies.

10.2.3 Conclusions

This study identifies two main types of B2C clothing PSS models in the Nordics: membership-based models and one-off rentals, each distinct in terms of product categories, business strategies, consumer engagement, and levels of digitalisation. The pilot company exemplifies the membership-based model, which fosters strong customer retention and community-building, indicating the potential for reshaping consumer relationships with fashion. However, scaling these models while maintaining a sense of community and overcoming barriers such as high subscription costs remains a significant challenge.

The study finds that formal wear retains its value for longer than casual wear, making formal wear a more stable inventory to start a rental business with. It is suggested that casual wear can be added to the selection at a later point.

Despite growing public interest in PSS models, the short lifespan of many businesses highlights underlying financial barriers. These challenges are often linked to gender-related biases and the complexities of circular business models, which can cause hesitation among potential investors. Addressing these issues will require targeted funding opportunities and financial support tailored to the unique needs of circular businesses and female entrepreneurs.

By providing the right financial tools and addressing these structural challenges, the PSS market has the potential to expand, driving more sustainable consumption patterns in the fashion industry.

11. SEASONAL AND SPECIAL OCCASIONS

In recent years, the number of festivals, public events, shows, and seasonal celebrations in the Nordic countries has grown significantly, along with the number of participants (Langen & Garcia, 2009). This trend has led to various studies on these large-scale events' economic, social, cultural, and political impacts. Similarly, outdoor life and leisure activities in nature have also seen a rise, prompting studies into the environmental and economic impacts of seasonal outdoor equipment (Nordic Council of Ministers, 2014). Both large public events and the increasing demand for seasonal outdoor products play a role in shaping a country's image and its attractiveness as a tourist destination.

Research on festivals and public events has traditionally focused on their economic impact, with less attention given to their social and cultural implications (Collins & Cooper, 2017). Moreover, studies on the environmental impacts of these events are limited, leaving a significant knowledge gap. While some research exists for outdoor and seasonal products, the focus has been mostly on economic and user-driven impacts.

The category of outdoor equipment in the Nordic countries continues to expand, fueled by the growing tourism sector following the lifting of COVID-19 travel restrictions (Nordic Council of Ministers, 2023). Mass tourism, enabled by the public rights of access in the Nordic region, has made nature-based tourism highly popular (Øian et al., 2018). However, with this influx of tourists comes the challenge of preserving natural landscapes while maintaining tourism flow. As a result, sustainability has become a key focus of tourism strategies across the Nordics, with eco-conscious travel gaining traction among tourists (Øian et al., 2018).

PSS solutions for outdoor and events could offer more sustainable alternatives through rental models, reducing the need for ownership and promoting resource efficiency. Within the Nordic region, opportunities for PSS solutions are expanding, benefiting both locals and tourists (Egebæk et al., 2022). For the pilot project within this category, we have explored how rental solutions for outdoor equipment could appeal to both domestic and international tourists while also examining the barriers and benefits experienced by consumers. This research aimed to understand consumer preferences and assess market differences between the Nordic countries and the potential for expanding rental services across these regions.

11.1 Party and event equipment

In addition to outdoor gear, party and event equipment is another significant category within the seasonal product group. Rental services for party and event equipment, ranging from single-use items to large-scale essentials like tents, furniture, and electronics, are widely available for B2C, B2B, and B2G markets. The most common rental model involves short-term agreements with minimal additional services. These solutions cater to everything from small private parties to large public events (Kataria, 2021). In the Nordics, most of the PSS solutions within this product category are oriented towards the B2C and B2B markets, offering a range of solutions for sound, lights, games, activities, etc., suited for events and parties. The most common business model identified was use-oriented PSS models, typically offering rental solutions ranging from hours to weeks of product rental. Most of the PSS solutions for party and event equipment offer a spectrum of products, covering most imaginable equipment needed to throw a large party or event. However, a few are specialised in a few products, illustrated by, e.g. the Danish company A Table Story, which offers a rental solution for decorative table wear (A table story, n.d.).

Amongst the more common PSS solutions within the product category is **Party.Rent**, which is one of the largest providers of party equipment rentals across Europe, primarily serving the B2B market and catering to various event sizes. The company follows a circular economy approach, divided into three phases: development, use, and refurbishment/recycling. Party.Rent emphasises designing processes for a circular workflow, focusing on reprocessing materials and recycling raw materials to contribute to future product generations. Their pooling model allows resources to be shared among customers, reducing costs, increasing efficiency, and optimising resource use (Rent.Group, n.d.). By promoting a product-pooling approach, Party.Rent meets the growing demand for high-quality, sustainable solutions, particularly in response to the environmental concerns associated with single-use items (Kataria, 2021).

Similarly, **Barnas Dag**, a Norwegian company, offers a wide range of rental services for children's and young adults' parties, including catering equipment, sound systems, furniture, and even children's entertainers (Barnas Dag, n.d.). Barnas Dag also sells equipment, such as bouncy castles, from their rental stock or as one-time-purchase products designed for specific customer needs (Barnas Dag, n.d.).

Festkungen, a Swedish company, focuses on renting out professional sound, lighting equipment, and stages for events, along with hiring sound and light technicians. Their tailored event packages ensure that private and business customers receive a comprehensive experience (Festkungen, n.d.). Another major player in the event rental industry is Nordíc Rentals, Scandinavia's largest privately owned event technology supplier. They provide technical equipment for concerts, festivals, trade fairs, and livestreaming (Nordíc rentals, n.d.).

These examples highlight the diversity of PSS models available in the party and event equipment sector, which have been successfully operating for decades. However, this is not always the case. PUUF, a company interviewed early in the PSS in the Nordics project, were a company developing and renting out furniture for events made of reclaimed materials, such as post-consumer plastic waste obtained from companies in Copenhagen. PUUF had developed a very sustainable model, sourcing reclaimed materials, producing locally, reducing material waste, and delivering event furniture mostly through bicycle couriers. Furthermore, they received attention from many Danish universities and had customers such as the Municipality of Copenhagen. Despite their huge environmental potential, the COVID-19 pandemic stunned their rental model, hindering income on anything other than product sales.

While companies like Party.Rent and Festkungen demonstrate that PSS models in this product group can be viable and meet the demands of both private and corporate clients, the assessment of Nordic PSS solutions within this category illustrates how vulnerable these solutions can be to sudden changes in (possible) consumption behaviour, as the products do not offer essential services but rather enjoyment-based services.

11.2 Sports, camping and hiking gear

The Nordics has a broad range of PSS solutions as well as non-profit sharing solutions for sports, camping, and hiking gear. Most PSS solutions target the B2C market, specifically tourists, students, and families. The PSS solutions come in many shapes, some focusing on singular product groups, e.g. snow sports equipment or hiking equipment, and others having a broader product offering. There is a good potential for market disruption within the seasonal category, as most of the products used for outdoor activities have a relatively low use-rate, adding to a more sustainable way of travelling and participating in outdoor and leisure activities for tourists in the Nordic countries. Use-oriented models are most common among the identified PSS providers in the Nordics. Still, many providers offer either product- or result-oriented PSS solutions in addition to rental or leasing options. Most identified PSS providers offer their product services to the B2C and, to a lesser extent, the B2B market (Egebæk et al., 2022).

Very little academic work has been conducted on PSS solutions of this particular product group, and most of the studies are related to the integration of digital tools to facilitate the rental solution. The pilot projects conducted concerning this product group do, however, point to a relatively low uptake of digital solutions to facilitate the PSS solutions in the Nordic countries. While most have a website showcasing the products, and some have online booking systems, very few of the consulted PSS solutions have integrated a system to keep an overview of product stock, rental agreements, product maintenance requirements, etc.

11.2.1 Drivers and barriers

Through the pilot program, Iceland Camping Equipment Rental, located in Reykjavík, Iceland, participated in two pilot projects. The first pilot project assessed opportunities for reaching domestic consumers in the same manner as Iceland Camping Equipment Rental reaches tourists. A survey was conducted with over 1,000 Icelanders, assessing market approaches, pricing, customer segments, geographical challenges, and relevant products. The second pilot project focused on opportunities to expand Iceland Camping Equipment Rental to the Norwegian and Swedish markets, including assessments of hotspots for implementation and value chain assessments.

The surveys conducted and assessed throughout the pilot projects provided unique insights into the customers' perspectives on PSS, who are keen to use a PSS, what the customers value when engaging in PSS solutions, and what kind of products within the sports, camping, and hiking gear category they are interested in.

ICELAND CAMPING EQUIPMENT RENTAL (est. 2011, Iceland):

Iceland Camping Equipment Rental offers a rental solution for camping, hiking and leisure equipment.

The company offers short- and long-term rental of high-quality and durable products. Maintenance and repair are included in the PSS solution.

Iceland Camping Equipment Rental primarily serves tourists and locals in Iceland.

The survey with more than 1,000 Icelandic respondents showed that there is a slight preponderance of men who knew that it is possible to rent equipment (46.6% men and 38.3% women), but conversely, fewer men than women could consider renting equipment in the future (64.1% men and 76.7% women The distribution for the answer *'reducing environmental impact the respective product with a shared economy mindset*' is 46.2% women and 26.5% men. The type of products the different age groups were willing to rent differed, as 30–39-year-olds were the most willing to rent kayaks, electric bikes, skiing equipment, top tents for cars, mountain bikes, and baby car seats, while 18–29-year-olds were the most willing to rent camping and hiking equipment. Further, the respondents in the age group 30–39 years old were the ones who were the most aware of the opportunity to rent leisure and camping equipment and the most willing to consider renting these types of products in the future. The respondents over 60 were generally the least willing to rent any product examples provided in the survey.

In Norway, a survey was conducted by Ipsos on behalf of *Norsk Friluftsliv* (Ipsos, 2021), focusing on the interest in buying, renting, and borrowing used outdoor equipment. The survey shows that the age group of 25–39 years old are the most willing to buy and rent used equipment, with women being more interested in renting than men. In addition, a study shows that people between the ages of 16 and 34 have stayed out overnight in nature during 2021, while the 16–24-year-olds are the ones who have done it most often. The age group of 35–54 also stays out in nature overnight more often in 2021 than in 2007, indicating a rise in the popularity of spending the night in nature. The hammock is a specific piece of equipment that has gained popularity when staying overnight in nature (Håvard Bergesen Dalen & Madeleine Schlyter Oppøyen, 2023).

In Sweden, annual household expenditures on open-air recreation, sports, and camping equipment increased from 2008 to 2021, with the largest increase between 2020 and 2021 (Statista Research Department, 2023). This could be due to the COVID-19 pandemic and the increased interest in participating in outdoor activities. When looking at the expenditures of different age groups, the younger generations seem to spend more on outdoor equipment. In 2022–2023, people between the ages of 16–19 spent around 11,101 SEK (~ 978 €) on outdoor activities, while people between the ages of 20–29 spent around 11,283 SEK (~ 994 €). A study conducted in Sweden shows that the expenditure on products for activities such as hiking, camping, and many water-based activities was most prominent during the summer period of May-August in 2022 (Bäck, 2023), which indicates a potential option for accessing the market and offers alternative solutions such as renting.

Cultural drivers and barriers

The first pilot project with Iceland Camping Equipment Rental was centred around assessing the potential for an increased uptake of the rental solution amongst local actors to increase the market reach to exceed tourists. Even with an increased interest in renting equipment, the biggest barrier to rental services is the culture of ownership, especially among locals (be it in Iceland, Sweden or Norway), as they are more likely to own or procure the relevant products themselves when they need them. Even with additional services such as car rentals or tour packages, locals already have access to areas of interest and local knowledge about where to go and when to go there. Therefore, additional services might not be enough to spark interest in the rental service among locals as with tourists.

> ”
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> *We tried to reach more locals in the beginning but it is hard to sell to locals, it is hard to sell trips to locals.*
>
> – PSS provider

Following the assessment of the two pilot projects, it was clear that consumer-centric benefits are crucial when seeking to increase the market for a rental solution (Akbar & Hoffmann, 2018). While developing a TCO, assessing the environmental impact of the rental solution and conveying the benefits of maintenance and repair likely would benefit companies like Iceland Camping Equipment Rental; consumers will always differ based on their personal life stories, priorities, etc. (Akbar & Hoffmann, 2018). TCO and environmental impacts assessment appeal to logos and somewhat ethos, based on the presentation form. Studies done on consumers' willingness to choose a user-oriented PSS model, such as product renting, indicate that consumers are more willing to select a PSS solution if the provider satisfies their need for socialising and their desire for unique products, utilising pathos-based consumer outreach (Akbar & Hoffmann, 2018). This likely why so many of the respondents of the Icelandic survey prioritised good service over, e.g. environmental reduction potential.

THE MOST IMPORTANT ASPECTS FOR CONSUMERS RENTING CAMPING EQUIPMENT:

82.0% price of PSS
68.7% good service
68.0% quality
39.9% availability
23,1% durability
14.3% environmental factors
13.9% possibility for repairs
12.4% the business image,
12.2% certifications

(Survey, 2023)

Technical drivers and barriers

Many of the PSS solutions consulted through the second pilot project experienced challenges with the introduction of a digital administrative system for product and rental tracking. Especially in Sweden, PSS providers are challenged to develop or find a system that complies with GDPR regulations. Rental services in Norway and Sweden have developed their own tracking and return systems, often analogue ones. Other PSS providers have worked with various tracking companies. While Iceland Camping Equipment Rental have not expressed challenges with administrative systems, no one of the consulted PSS providers in Sweden or Norway has identified a tracking system that is good enough to facilitate a PSS solution efficiently.

In addition, repair activities on the products challenge many PSS providers offering camping and leisure equipment rentals. Maintenance and repair are a big part of the

added value in this kind of PSS solution, as they ensure that the products are in good shape and fit for another rental period. Depending on the quality of the products, the eco-design/design for repair or refurbishment, and the complexity of the repair of the products, this added-value service can become a great challenge from a day-to-day operations perspective. PSS providers have one of three options when it comes to repair and maintenance: 1) repair and maintenance are done in-house, a model used by Iceland Camping Equipment Rental; 2) repair and maintenance activities are outsourced; or 3) products are sold or discarded when no longer rentable. The challenge with in-house service is that it is very time-consuming and requires specific skill sets. The time that is spent repairing is time taken away from customer service and other administrative tasks. However, maintaining a product is essentially what prolongs its lifetime and keeping it from going to waste, accounting for the majority of the environmental benefits of rental solutions for camping and hiking equipment. Outsourcing repair and maintenance activities are often very expensive, which can become a significant barrier for especially SME PSS providers.

Economic barriers

Through the pilot project, it was discovered that multiple PSS solutions for camping and leisure equipment are not economically viable. While Iceland Camping Equipment Rental have been able to break through the market, many PSS providers offering a similar solution have not. These types of PSS models often require that significant resources be spent on customer service, stock administration, product acquisition and repair of the products. Since all the companies consulted throughout the project and pilot projects have a seasonally affected market, most of the PSS providers are not able to keep their staff on all year round, in addition to the administrative costs. For the companies consulted in Norway and Sweden, there is furthermore a significant competition between the for-profit and non-profit PSS solutions. According to some Swedish PSS providers interviewed, for-profit competitors had to close down after a non-profit solution offering free equipment rental was introduced to the area of operation.

11.2.2 Environmental potentials

In the Icelandic survey, the environmental impact potential of rental solutions was considered one of the main advantages of renting leisure and camping equipment for women and respondents with university degrees. However, few respondents found it to be the decisive factor when renting. This is expected to change in the near future, especially amongst the younger generations (Dragolea et al., 2023). Consumers who are highly environmentally conscious will be more likely to seek out PSS offers against all odds, while consumers who are less environmentally conscious will have a greater focus on the availability of products (Akbar & Hoffmann, 2018).

In principle, rental models of sports, camping, and hiking gear have the potential to avoid new production by increasing product sharing, extending product lifespans, and reducing the generation of waste. While Iceland Camping Equipment Rental achieve these

potentials through the procurement of durable quality products, specialised maintenance and repair practices, dismantling (for spare parts) or donations of non-rentable products to charitable purposes, many of the other consulted solutions do not achieve all or any of the aforementioned environmental benefits. The lack of environmentally sound business model practices is related mostly to economic and social barriers. The assessments have shown that the most important aspects for consumers when renting camping equipment are *price, good service,* and *product quality*. The focus on product quality amongst consumers can challenge the preservation of a holistically sustainable PSS solution for camping equipment and hiking gear, as there will be a need to replace equipment that has lost its original quality, which results in an increased product consumption or increased maintenance and repair offers, at high economic costs for the providers. However, price and quality might be closely related here since non-profit organisations in Norway and Sweden have successfully obtained used equipment (that is not always of the best quality) that is then rented for free to local tourists. This indicates that quality is valued as less important among consumers when the rental service is free because no money has been spent on the items, reducing the risk of losing money to poor or lower-quality equipment. Performance might also be relevant here since equipment of good quality may be associated with better performance, thereby enhancing the consumer's experience using the equipment.

> ”
>
> *We try to focus on being a local company. The whole idea with the rental concept is that it is good for the environment*
>
> – Interview 2024

11.2.3 Conclusions

A survey in Iceland found men were more aware of equipment rentals, but women were more likely to rent camping and leisure equipment, with 30-39-year-olds being the most interested. In Norway, younger people, especially women, showed increasing interest in renting outdoor equipment, and overnight nature stays became more popular in 2021. In Sweden, outdoor equipment spending rose during the pandemic, with younger generations leading the trend, particularly in summer. International tourists are often more inclined to use an equipment rental service because it eliminates the inconvenience of bringing lots of equipment when travelling. However, engaging with locals in an area can still be challenging for a PSS provider.

The pilot project has shown that PSS solutions for camping and leisure equipment are largely trust-based, as digital tracking systems are rarely implemented. Consumer-centric benefits are vital to growing the rental market of this product group. Consumers tend to prioritise good service, maintenance, and unique products over environmental benefits.

A significant challenge is product repair and maintenance, which is essential for ensuring equipment is in good condition for reuse. Providers typically choose between in-house repair (time-consuming and requiring specific skills), outsourcing (costly), or discarding unusable products. In-house or outsourced maintenance is vital for extending product life and contributing to environmental benefits but can divert resources from customer service.

While Iceland Camping Equipment Rental succeeded in entering the market, other PSS providers struggle due to high costs associated with customer service, stock management, product acquisition, and repairs. Additionally, the seasonal nature of the business limits providers' ability to retain staff year-round. Competition between for-profit and non-profit PSS solutions is intense in Norway and Sweden.

12. ELECTRONIC EQUIPMENT AND IT SOLUTIONS

In today's digital age, electronics play a crucial role in our daily lives. From smartphones to computers and household devices, technology is embedded in nearly every aspect of modern living. The rapid evolution of IT and digital devices has transformed the way we communicate, work, and entertain ourselves, but it has also introduced new considerations about how we manage and use electronic products.

As demand for electronics continues to rise, so does the need for more sustainable ways to manage their lifecycle. Electronic waste is a rapidly growing stream, and most electronic appliances are prematurely discarded – not due to lack of function but to being outdated. The large amount of electronic waste created threatens the environment and human health, and the amount of recyclable material that could have been utilised is striking. A record 62 million tonnes of e-waste was produced in 2022, up 82% from 2010 and on track to rise another 32% to 82 million tonnes in 2030 (Baldé et al., 2024). While the negative impacts of production and end-of-life handling of electronic appliances are vast and growing, most people are unaware of the challenges this approach to IT can create. Lack of proper recycling leads to the release of toxic compounds and the continuation of mining to produce new IT products (Bansal et al., 2016).

PSS solutions for electronics could create more sustainable consumption and usage by opening new markets for refurbished, maintained, or repaired IT. Research indicates that circular business models, especially PSS, within electronics not only lead to cost savings but also significantly reduce CO_2e compared to linear models (Lopez & Soltani, 2023).

Further, an LCA study shows that use-oriented or product-oriented refurbishment PSS solutions offer significant potential for reducing the impacts associated with terrestrial ecotoxicity, human toxicity, and depletion of mineral resources, underlining the environmental and social impact potential of electronics-related PSS solutions (Nunes et al., 2021).

In addition to the increase in use (and waste) of e-products, the amount of data needed worldwide is also increasing due to virtual worlds, wikis, blogs, e-mails, online games, traffic systems, and much more. Today, most businesses cannot thrive without entering the digital market, and cloud-based computing provides new capabilities to store, search, mine, and distribute massive amounts of data in organisations. IT integration in businesses has provided many opportunities, but these come with a polluting downside from the extraction of raw materials, production, use-phase, and disposal (Bagheri & Shaltooki, 2015).

The Nordic Region is one of the global leaders in the digital economy and an outstanding digital economy market, with more than 90% of the population being regular internet users (Christensen et al., 2018). During the pandemic, a massive uptake in streaming media was seen in the Nordics, and if following international trends, this could be the new normal (Ceci, 2022). The high GDP per capita in the Nordics enables the average person to spend more on technology than in most other regions, and statistics show that Nordic citizens are very curious about the latest technology. The Nordic region has been the starting point of globally known digital solutions such as Spotify, Skype, and Trustpilot, and the tech market is supported by Nordic governments implementing numerous policies to support tech innovation, from R&D tax credits to grants (Carlsson, n.d.).

In terms of marketing electronic products, B2B operations typically involve offers for rental or leasing alongside outright purchase opportunities. In some cases, leasing options appear to offer financing assistance but little else by way of service. Other examples feature more solution-oriented offers, perhaps facilitated by bundling across product groups, such as IT hardware being bundled with office furniture, software, or other services. In contrast, there is a weak market for leasing or renting IT equipment to private customers, with conventional retail being the typical business model, sometimes embracing reused or refurbished products. The following section will provide insights into different Nordic PSS solutions within the product types: Computers and smartphones, printers, batteries, and cloud-based solutions and streaming services.

12.1 Computers and smartphones

Computers and smartphones are high-impact products, completely essential in most people's daily lives. Although the reduced environmental impact in reuse and recycling of appliances is evident, current take-back schemes of computers and smartphones are not very effective In the Nordics, renting- and leasing solutions for the B2B market have been present for quite some time.

Among the largest market actors are BNP Paribas 3stepIT, which leases computers and smartphones to more than 3,000 companies across 11 European countries, including Denmark, Norway, Sweden and Finland. There are also many SME providers offering PSS solutions for computers and smartphones, often branding themselves as founded on circular principles. Many PSS providers offer refurbished products, arguing that the recycled materials and reused products enable significant environmental impact reductions. The company Circular Computing goes a step further by offering Remanufacturing as a Service (RaaS), with their remanufacturing process going beyond refurbishing by returning used products to their original performance. They brand themselves on up to 40% cost savings compared to brand new latest models as well as significant sustainability benefits.

Across the market, use-oriented models are currently dominant, e.g. product leasing, where some product- and result-oriented services are additional. All identified providers offer product services for both computers, smartphones, and a wider range of IT products such as monitors, cables etc. Some also provide take-back or sales of used electronic equipment. However, PSS solutions for computers and smartphones could increase a 'fast replacement' culture since these product types quickly become outdated by newer models. It is therefore essential that the provider ensures identifying relevant customers in secondary and tertiary markets to continue offering the products throughout their lifecycle in order to ensure the realisation of the potential environmental benefits of the PSS models.

12.2 Printers

The printing industry has been a long-time adopter of PSS solutions due to the increased effectiveness and efficiency of printing operations, as well as financial analyses that demonstrate long-term benefits for both manufacturers and users of printing machines. Studies show that PSS models extend the lifecycle of printing machines through improved device maintenance (Salwin, 2021). From a TCO perspective, PSS is particularly relevant for printing services, as maintenance is one of the major ownership costs for printers. In the Nordics, use- and product-oriented PSS models dominate the printing sector. However, result-oriented models – such as pay-per-print services – are more prevalent for printers than for many other product types.

The B2B market remains the primary target for PSS printer solutions, but opportunities in the B2C and B2G markets are also viable. Result-oriented models, such as pay-per-print, incentivise manufacturers to improve the efficiency of their products. This shift from selling ink cartridges to charging per copy encourages the development of more ink-efficient printers and cartridges with a longer lifespan, reducing waste and costs for consumers.

In addition to these economic benefits, PSS solutions for printers have the potential to reduce environmental impact by promoting better maintenance and repair services, leading to reduced consumption and more efficient use of machines. By handling acquisition costs and maintenance, PSS models make high-quality industrial or business printers accessible to more companies, fostering wider adoption and greater sustainability within the printing sector.

12.3 Batteries

If not properly recycled, batteries can have a significant environmental impact due to their mixed metal components and heavy metals. The Nordics have had battery taxation in place since the 1990s, along with extensive collection schemes (Nordic Council of Ministers, 2002). However, public awareness of these issues remains low, as illustrated by a survey showing that 44% of the Danish population is unaware of the 30-year-old battery collection schemes, leading to inefficient recycling rates (Elretur, 2022). PSS solutions for battery maintenance and collection could help address this issue by promoting proper disposal and recycling practices.

Among the PSS providers in the Nordics offering battery solutions, few focus on larger batteries, such as those used in electric bikes, scooters, and cars. This may be due to the challenges involved in repairing and maintaining batteries, as servicing them can be complex and costly, particularly for independent repairers (Dávila et al., 2021).

The environmental benefits of PSS solutions for batteries depend on factors such as battery type, product type, component composition, and the approach of the PSS provider. Providers offering repair and maintenance services for batteries can reduce environmental impact by lowering the consumption of scarce materials, reducing hazardous waste, and extending battery lifespans. However, PSS models that rely on battery swapping schemes – where batteries are replaced rather than repaired – may increase environmental harm by promoting higher consumption of scarce resources and generating more hazardous waste. While swapping is often faster and cheaper, it may lead to greater resource consumption unless accompanied by effective waste management. In some cases, swapping schemes can still offer environmental benefits if they prevent the full replacement of a product, such as an electric bicycle or smartphone (Mikolajczak, 2021).

The introduction of the new EU Batteries Regulation is expected to benefit PSS solutions for batteries. The regulation increases sustainability requirements across the entire battery lifecycle, including material sourcing, collection, recycling, and repurposing. Additionally, the requirement for digital product passports, set to take effect in February 2027, will enhance transparency and make it easier to offer services such as battery reuse and repair (European Commission, 2023c). This regulation could create new opportunities for PSS providers by facilitating better battery management and reducing environmental impacts.

12.4 Cloud-based solutions

With the rapid digitalisation of the Nordic countries, cloud-based solutions and streaming services have become increasingly widespread and in high demand. These services cater to both consumers and businesses, with consumer-oriented offerings typically being low-cost, mass-market solutions, while business-oriented cloud-based services focus on reliability, security, privacy, availability, and customisation. For example, streaming services like e-book platforms operate under use- or result-oriented models, depending on the payment structure, and are primarily targeted at the B2C market.

Cloud-based PSS models, such as software-as-a-service (SaaS) and data management solutions, play a significant role in the Nordic economy. Our research on software solutions shows a trend towards subscription-based service models, which offer regular updates, security, and availability. While these solutions lower material and transport needs by replacing physical copies with digital alternatives, the growing demand for data storage raises concerns about energy consumption for data centers. Additionally, a large portion of the consumed energy converts to heat, causing operational challenges such as reduced system reliability, shortened device lifespans, and increased cooling demands (Buyya et al., 2024).

Limited research exists on comparing environmental impacts between cloud-based PSS and traditional models, particularly regarding electricity and cooling demands in data centers. Furthermore, there is a need to develop future generations of cloud solutions that address the environmental and operational consequences of energy usage (Buyya et al., 2024).

13. BUILDINGS

The building sector is an essential part of the economy in the Nordic countries, with a market size of USD 235 billion in 2024, and expected to grow in the coming years (Mordor Intelligence, n.d.). However, the sector enormously impacts the climate as it is responsible for 37% of global emissions, equal to 10 gigatonnes of CO_2e (United Nations Environment Programme, 2024). The built environment accounts for over 30% of the global final energy consumption (IEA, n.d.). Moreover, it causes major negative impacts on air quality, water resources, land pollution, and biodiversity loss (World Green Building Council, n.d.).

The sector utilises large amounts of resources for new buildings and renovations, estimated to account for 50% of all extracted materials in the EU (European Commission, n.d.-f.). This results in large amounts of construction and demolition waste (CDW), such as concrete, bricks, wood, glass, metals and plastic, which accounts for more than a third of all waste generated in the EU. To ensure responsible management of CDW and to enable taking full advantage of the potential of CDW, the EU has implemented legislation to improve circularity by requiring the sector to implement various practices to increase reuse, recycling and other material recovery (European Commission, 2024a).

Circular business models provide a large opportunity to translate the challenges from the building sector into business opportunities that can support increased rates of recycling and reuse of materials (Svedmyr et al., 2024). The EU Green Deal and the Circular Economy Action Plan also describe circularity in buildings as an essential part of the green transition towards a carbon-neutral future (European Environment Agency, n.d.). These policies describe the potential of PSS solutions within the building sector to lower resource and material use, reduce CO_2e emissions and optimise energy consumption. The research conducted in this project indicates that PSS solutions can potentially drive the adoption of circular economy solutions in the built environment (Cruz Rios & Grau, 2020). Still, there is a need for further research, e.g. on how to encourage sustainable consumer behaviour (Joensuu et al., 2020).

The importance of circularity in the Nordic context is reflected by the numerous projects of Nordic Innovation, a part of the NCM, regarding circular construction (Nordic Innovation, n.d.), including the Nordic Networks for Circular Construction (NNCC), which works to create a more sustainable built environment (Nordic Networks for Circular Construction, n.d.). Monitoring the performance of private actors in taking advantage of new opportunities and complying with stronger legislation to increase circularity is one critical component of accelerating the green transition of the sector. For the NNCC, Norion has proposed 11 indicators for measuring and integrating circularity in the construction and building sector (Claësson Kaarsberg et al., 2024). Increasing monitoring efforts could also help promote PSS models and solutions in the sector.

Two examples of service models within the sector (Buildings- and Space-as-a-Service and Efficiency- and Energy-as-a-Service) are described below, followed by two other examples investigated in this project's pilot studies. However, examples have been identified during the research within numerous areas, such as cooling, heating, and facades.

13.1 Buildings and space

Buildings and spaces have long been rented out for various purposes for both individuals and private or public organisations, which can be considered a PSS solution. The business model is seen in multiple segments of the building sector e.g. within vacation, storage, residential, workspaces, facility management, and events. Service solutions are emerging throughout the sector and gaining more interest from providers and customers (Yarotska, 2023; Belt, 2023).

Buildings are now seen as a service, with construction companies as full-service providers who use Business Information Modelling (BIM) systems to design and manage information throughout the lifecycle of buildings to provide the necessary service (Wildenauer et al., 2022). Buildings are now seen as a service, with construction companies as full-service providers who use Business Information Modelling (BIM) systems to design and manage information throughout the lifecycle of buildings to provide the necessary service (Wildenauer et al., 2022). Digitisation and BIM offer new, essential opportunities for implementing and supporting circularity and PSS solutions in the building sector, which makes it likely that the market for these will continue to grow (Cruz Rios & 2020; Fargnoli et al., 2019).

13.2 Efficiency and Energy

Energy- and efficiency-as-a-service are gaining interest as pay-per-use solutions that incentivise producers to maintain, repair and design products for long-term use and reuse and reduce upfront capital investments (EaaS Initiative, n.d.; gridX, 2024). In Norway, Aneo Retail collaborated with Danfoss and provided Coop with refrigeration-as-a-service, reducing their overall energy consumption by 20% (EaaS Initiative, 2024). Another Norwegian company, Otovo, offers solar power on subscription, including a 20-year warranty where Otovo keeps ownership and responsibility of the panels and maintains and repairs them to prolong their life (Otovo, n.d.). An LCA study shows that solar panels, which are reused and complete the 30-year technical lifetime, are environmentally outperforming the benefits of recycling options and the higher-efficiency rates of new solar panels (Van Opstal & Manshoven, 2024).

The built environment provides many opportunities to implement circular business models such as PSS. The models are usually based on products designed for circularity and characterised by increased collaboration between stakeholders across the value

chain. Effective implementation of PSS in the built environment depends on the specific design, efforts to change consumer behaviour, the configuration of PSS models, and using LCAs and data to give valuable insights on optimising the design of products and systems (Belt, 2023).

13.3 Lighting

Lighting accounts for an estimated 15% of global electricity demand and 5% of GHG emissions (Ellen MacArthur Foundation, 2022). Lighting-as-a-service (LaaS) business models can help reduce waste and emissions from lighting. The core concept of LaaS is to provide lighting as a service rather than selling the equipment (lighting fixtures, consoles, control systems, light bulbs, etc.) and installation. This approach incentivises producers to offer higher quality products, as they remain responsible for maintenance and repair services throughout the product's lifecycle.

In a LaaS model, lighting is provided as a subscription-based service where customers pay a fixed fee, and the service provider ensures continuous, efficient lighting while offering a performance guarantee. This typically includes installation, maintenance, and repair of energy-efficient lighting systems during the contract period and may even include upgrades to new technology. Since the provider retains ownership of the lighting equipment, it can be upgraded, refurbished, and reused at the end of the contract, either with the same customer or a new one, depending on the product's remaining lifespan and the specific terms of the LaaS agreement (European Union, 2021).

LIGHTING-AS-A-SERVICE (LAAS)

LaaS offers a subscription-based model for the provision of light.

LaaS contracts typically run over 3–10 years, in which the service provider guarantees the light performance, and is responsible for maintenance, repair and upgrades.

The product ownership of the luminaires usually remains with the service provider, and customers pay a fixed monthly fee. In some models, other parties are involved in the financing of LaaS.

For customers, LaaS offers different benefits, depending on their financial situation. For some customers, LaaS offers an opportunity to upgrade to energy-efficient lighting by minimising the financial barriers. For others, it enables the selection of higher-quality products focusing on circular design instead of settling for less expensive LED options of lower quality. In traditional scenarios, landlords or tenants often avoid investing in long-term, sustainable lighting due to higher installation costs and uncertain tenancy

durations. Tenants may hesitate to invest in lighting without knowing how long they'll occupy the space, while landlords risk installing lighting that might not suit future tenants' needs. Thus, by lowering the upfront costs, LaaS can help customers to reduce their operational expenses through energy-efficient LED lighting and to access higher-quality lighting solutions. In some cases, third-party financiers may cover the initial installation costs, making the transition to LaaS even more accessible.

LaaS has the potential to foster a more circular building sector in the Nordics. Despite growing interest in circular construction, larger organisations – both public and private – are still hesitant to switch from purchasing lighting solutions to adopting a LaaS model (Rex & Kron, 2022). Currently, there is no established market for LaaS in the Nordic countries, but pilot projects have begun to explore its implementation, and the Research Institute of Sweden (RISE) investigated the driving forces and obstacles related to LaaS in Sweden (Hunka, 2020).

One example of a pilot project is the Swedish municipality of Bollnäs, where a LaaS model was used to upgrade public pre-schools and schools to energy-efficient lighting as part of a broader national initiative to phase out fluorescent tubes (Rison, n.d.). The service was provided by a start-up company, BrightEco, supported by Umeå's BIC Factory business incubator, with external financing from an investment firm focused on the energy transition in the Nordics (Directorate-General for Environment, European Commission, 2023). Interestingly, despite this progress, BrightEco lacks a fully functioning website, reflecting the early-stage nature of the LaaS market in the region.

13.3.1 Drivers and barriers

The key drivers for adopting Lighting-as-a-Service (LaaS) in the Nordics include its potential to reduce environmental impact, improve lighting quality, and provide a flexible solution that adapts to changing needs. Reducing environmental impact appears to be the primary motivator for stakeholders such as real estate companies and public institutions, as energy savings align with sustainability strategies and reduction targets. Additionally, the prospect of extending product lifecycles through maintenance and repair is seen as a major advantage, particularly in light of frustrations over the need to replace entire light fixtures rather than individual bulbs (interviews phase 1). New mandatory requirements on the quality of light in office spaces, such as mandatory daylight trimming, could also become a driver of LaaS, according to a Danish lighting company.

Cost savings are another potential benefit of LaaS, although stakeholders are uncertain about the economic implications. Overcoming the high upfront costs associated with installing energy-efficient lighting is viewed as a primary advantage. However, concerns arise over the difficulty of comparing LaaS with traditional lighting purchases and assessing direct and indirect financial effects. For example, shifting costs from capital expenditures (CapEx) to operational expenditures (OpEx) may lower a building's perceived value, complicating discussions with stakeholders like asset managers. This

issue was highlighted during a workshop with a Danish pension fund and is supported by academic research that underscores the potential depreciation effects when a third party owns lighting fixtures (Rex & Kron, 2022). Conversely, operational leasing could create a rapidly growing asset for LaaS providers, which may negatively affect their financial stability. In our pilot project with Fischer Lighting, a Danish circular lighting company, we faced difficulties developing a LaaS pricing model that offered customers enough economic incentive to choose high-quality lighting over cheaper, low-quality alternatives while ensuring Fischer Lighting's financial stability.

> ”
>
> *Moving to service-based contracts and take-back schemes is the way forward – but nobody [...] is currently doing this for lighting*
>
> **– Danish pension fund**

A general lack of knowledge about LaaS further contributes to stakeholder uncertainty, as there is limited practical experience with the model in the Nordics. Potential customers are unsure about legal aspects, such as liability in case of damage or the fate of product ownership if a LaaS provider goes bankrupt. There are also concerns regarding the division of responsibilities between service providers, electricians, and facility managers. For lighting companies interested in providing LaaS, understanding market needs and developing a business model based on long-term commitments and revenue generation presents a significant challenge. Furthermore, these companies also depend on the provision of components by their suppliers, which might not be able to guarantee product longevity and availability of spare parts needed to fulfil the LaaS contract. These conditions make it difficult for small, innovative companies to lead the way in this emerging sector.

Legal uncertainties surrounding LaaS stem from the lack of regulatory support for contracts governing functional sales and product ownership. Research shows that elements incorporated into the building, such as facades, windows, etc., will be considered "fixtures" and, therefore, owned by the building owner, even if a contract specifies otherwise. While there is no specific legal assessment for Nordic countries, these principles of property law and ownership of buildings apply in most European civil law systems, where legal solutions to secure ownership over building elements can vary (Ploeger et al., 2019). However, recent research on circular economy principles in construction provides evidence that lighting is considered a non-fixture. This means LaaS is generally not problematic from a property law perspective (Ploeger et al., 2019). Nonetheless, investigating these legal issues of property ownership can still be complex and costly for companies interested in LaaS development and may be perceived as a barrier to transitioning.

13.3.2 Environmental potential

The primary environmental benefit of LaaS lies in its ability to reduce energy consumption by installing energy-efficient lighting – especially in cases where such upgrades would not have occurred due to high upfront costs. A comparative assessment of a Swedish municipal procurement case found that the long-term environmental impact of indoor lighting in school buildings was reduced by nearly half when using a LaaS solution (Jacobson et al., 2021). However, as with other PSS models, the environmental benefits can vary depending on the business model and specific implementation scenarios.

From a circular perspective, LaaS offers additional benefits by incentivising higher-quality products that can be upgraded, repaired, and maintained. By incorporating take-back schemes and the ability to transfer contracts between customers, LaaS has the potential to extend the lifespan of products further, which otherwise would often get thrown out. Since LaaS providers are responsible for product performance throughout the contract period, there is a strong motivation to design products with modularity and durability in mind. For example, the Swiss lighting producer ETAP adopted a LaaS model and, in this process, completely revamped its product designs to focus on modularity and compatibility between different product types (PAACT, 2024). This shift was crucial, as LaaS contracts often span 3 to 10 years, during which the provider must be able to offer repairs and replacements. Conversely, LaaS can also benefit suppliers already focused on circular design and longevity, such as the Danish lighting company Fischer Lighting, which already follows circular design principles in its product development.

13.3.3 Socioeconomic and other benefits

Beyond its environmental potential, LaaS can help overcome financial barriers to accessing high-quality lighting. Improved lighting quality is linked to improved mental and physical health and increased productivity. For example, the International Labour Organisation finds poor workplace lighting can lead to accidents, eye strain, stress and headaches. At the same time, too much light can equally lead to headaches and stress (International Labour Organisation, n.d.). Thus, high-quality lighting can increase workplace productivity and reduce accidents and errors. However, the hidden cost of poor lighting – such as negative health impacts at offices – is often overlooked in cost calculations for lighting. This was demonstrated in the case of Bollnäs municipality (Frisén, 2022).

LaaS can also benefit customers who need flexible and adjustable lighting solutions. For example, for retail spaces that frequently undergo refurbishment to attract customers, LaaS can easily accommodate these changing requirements (Frisén, 2022). According to a large Danish pension fund, shifting lighting needs in buildings often results in facility managers storing functional but old luminaires in basements or other storage areas. However, these stored luminaires are often forgotten and left unused. LaaS addresses this issue by ensuring that lighting is efficiently managed and updated, eliminating the need for redundant storage.

13.3.4 Conclusions

Lighting-as-a-service (LaaS) offers significant potential to reduce environmental impacts by promoting energy-efficient lighting and extending the lifecycle of lighting products through maintenance, upgrades, and reuse. By shifting from a traditional ownership model to a service-based one, LaaS encourages the use of high-quality, durable products, supporting circular economy principles. The environmental benefits are particularly clear in cases where LaaS enables lighting upgrades that might otherwise be delayed due to high upfront costs, as seen in the Swedish municipal case study.

While the primary benefits of LaaS lie in its ability to reduce energy consumption and waste, it also provides some additional value for businesses, particularly regarding flexibility and managing lighting needs over time. LaaS can help avoid the storage of redundant lighting fixtures, as the service ensures regular updates and management of lighting systems. Additional socioeconomic impacts of LaaS include improved health and productivity through better lighting quality.

Despite the environmental and operational advantages, the uptake of LaaS in the Nordics is still limited. Key barriers include a lack of knowledge, legal uncertainties, and challenges in comparing LaaS to traditional purchasing models. To realise its full potential, broader awareness and policy support will be necessary to overcome these obstacles and encourage more widespread adoption of LaaS in the region.

13.4 Temporary constructions

In the Nordics, there are an increasing number of policy targets that emphasise preservation and repurposing of existing building mass as well as selective demolition in addition to policy targets related to increasing CDW recycling rates and the environmental performance of new buildings (Nordic Council of Ministers, n.d.-b). This is an important development since the highest circularity potential lies in Refuse, Rethink and Reduce strategies, where waste and virgin resource use is avoided and reduced. In the current reality of the building sector, it is, however, hard to avoid (targeted) demolition and redevelopment of buildings, as well as new constructions and demolition of existing buildings to replace them with new ones that meet the requirements of owners and tenants. In this context, circular solutions for building elements become highly relevant since they may add the flexibility needed for tenants but allow for easier reuse and transformation of spaces with positive effects through reduced CDW – both now and in the future.

One major building element in most buildings today is gypsum plasterboard walls, commonly used as partition walls in all types of buildings. When needs change or when new tenants move into a building, or when entire buildings are demolished because the floor plans or other building elements do not suit the tenant's needs, these plaster walls are torn down. This waste is often disposed of in landfills, leading to the loss of valuable materials, carbon emissions, and further environmental degradation. The urgency of

transitioning to circular construction solutions is thus clear. Modular partition walls, which can be easily assembled, disassembled, and reused, represent a critical innovation in this context. These systems align with the principles of the circular economy by allowing for easier reuse and retention of the value of materials within the economy for as long as possible, thereby reducing the demand for new resources and lowering carbon emissions associated with material production and waste management.

13.4.1 Circular walls as a concept and the relevance of PSS models

Modular or circular walls have existed in various forms for several years, but the growing focus on circularity and sustainability in the buildings sector has spurred new initiatives to innovate the product group and provide new products that do not have the limitations of existing models, which has confined modular walls to being a niche construction element.

In Denmark, the two largest municipalities, Copenhagen and Aarhus, have initiated two separate initiatives to develop prototypes for circular wall solutions together with architects and engineering companies. These are, respectively, a gypsum-based solution that resembles existing plaster walls but with a design that allows them to be reused (Københavns Kommune, n.d.) and a new, fully modular and biobased inner wall design (AART, n.d.). A startup company, Mellow Designs, is also working on scaling up a design that combines universal scaffolding systems and biobased materials for the outer panels to create a flexible and adaptable wall solution (Mellow Designs, n.d.). The modular partition systems can be easily reconfigured to meet changing needs, thus extending the lifecycle of materials and reducing the need for new construction. These are all different from most existing partition walls, including modular variations, because they are designed for disassembly and reuse rather than recycling only. In Denmark, the two largest municipalities, Copenhagen and Aarhus, have initiated two separate initiatives to develop prototypes for circular wall solutions together with architects and engineering companies. These are, respectively, a gypsum-based solution that resembles existing plaster walls but with a design that allows them to be reused.

Walls are generally considered part of the fixed building layout and floor design rather than a standalone product. Therefore, a substantial cultural shift is needed for stakeholders involved in the planning of renovations and new builds to consider walls as temporary elements despite having both an interest and a need for the advantages they provide. A company renting a large office space will likely not want to deal with the hassle of owning the walls, while the building owner does not want to handle the logistics of storing spare parts and surplus walls that may or may not be needed by future tenants. PSS models may offer a solution to this challenge by shifting the ownership of walls to a third-party provider responsible for handling and maintaining the walls while providing a flexible solution to tenants and building owners.

13.4.2 The building sector's desire for more circular solutions

The building sector is under increasing pressure to adopt more sustainable practices, driven by a combination of regulatory, economic, and social factors. Customer expectations are evolving, with an increasing demand for buildings that not only meet functional requirements but also minimise environmental impact. Institutional investors, such as pension funds and large corporations, face increasing requirements for sustainability reporting and seeking carbon emission reductions across their operations, including office buildings and properties under management. This trend in customer preferences drives the market towards greater awareness of buildings' resource footprints and the need for more circular solutions (Grainer, 2024).

Certifications such as LEED, BREEAM and DGNB have become important benchmarks and a competitive parameter for construction and redevelopment projects for public and private sector clients, encouraging developers to seek out and adopt circular and sustainable solutions (Nordic Council of Ministers, n.d.-b). Some companies are taking further steps to encourage the reduction of carbon emissions by, for example, applying internal CO_2e emission pricing and a threshold for emissions by new buildings to encourage the use of more sustainable materials and building practices (Wihlborgs, 2022).

Barriers to implementing and growing the solution

While the potential benefits of circular walls are significant, their implementation and contribution to emission reduction goals are not without challenges. Technical barriers remain a critical concern, particularly in areas such as sound attenuation, fire safety, and expectations for the adaptability of modular systems. The need for flexibility and circularity of the systems and the use of innovative biobased materials that are yet to undergo rigorous testing may be at odds with the regulatory and technical requirements for sound attenuation and fire safety. To allow for compliance while ensuring adaptability of these systems to different needs, careful consideration and ongoing innovation and testing is needed, which requires significant investment and industry support.

Scalability is another critical issue. While circular walls may work well in specific contexts, such as office spaces, scaling these solutions to broader applications, including residential buildings and public institutions, requires overcoming new technical, logistical and cultural challenges. Addressing these barriers is crucial to ensuring that circular walls can achieve widespread adoption and contribute meaningfully to the sector's sustainability goals. Another key barrier is the industry's ingrained preference for ownership and the associated economic models. Similar to the challenges faced in other industries, changing the culture of ownership will require a fundamental shift in how companies manage assets. Developing a robust market for circular walls, potentially provided through PSS models, involves establishing new logistical frameworks for modular wall assembly, disassembly, and resale. This includes creating a network of resellers, buyers, and service providers who can support the lifecycle of these products.

Moreover, market maturity and the sector's risk appetite play a significant role in adopting circular walls. According to stakeholders, cost considerations still dominate customer decisions, though sustainability certifications play an increasing role in tenders for developers. As the solutions mature and awareness of their environmental and economic benefits grows, there is potential for these markets to evolve, especially with the support of targeted policies and incentives.

13.4.3 Environmental potential

Due to the early stage of development, there is a lack of comprehensive analysis and practical examples to document the environmental benefits of circular walls. Prototype examples, including those by Aarhus and Copenhagen municipalities, show that resource use and CO_2e emission reductions are possible during the lifetime of circular walls (AART et al., 2022; Københavns Kommune, n.d.), compared to traditional solutions. Unlike other circular economy initiatives that might inadvertently lead to increased consumption elsewhere, using circular walls is unlikely to result in additional resource use and rebound effects. However, quantifying these benefits requires further scale of their implementation and documentation.

The absence of robust data makes it difficult for policymakers and industry stakeholders to fully assess the potential impact of circular walls and develop targeted strategies for their adoption. Nevertheless, the negative environmental effects of existing practices are well documented, including substantial amounts of construction and demolition waste from plaster walls and other building elements across the Nordic countries (Nordic Council of Ministers, 2024b), underscoring the need for new solutions.

13.4.4 Conclusion

While challenges remain, adopting circular partition walls, including the potential of PSS models to overcome market barriers, presents a promising pathway for the construction industry to reduce its environmental footprint and move towards more sustainable practices. By addressing both the technical and market barriers and building a stronger evidence base, the industry can unlock the full potential of these innovative solutions. Actors across the building sector, including owners, developers, and policymakers, can play an important role by increasing their support for developing and scaling up circular walls.

14. OTHER PSS PRODUCT GROUPS

This report has focused on key product groups where PSS models are well-established. However, while not as prominent in the Nordic region, some categories still show potential for Product-Service Systems. These product types have not been given their own category due to the limited number of existing examples. However, they still offer opportunities for increasing product utilisation, reducing waste, and leveraging smart technology.

This section highlights emerging PSS solutions in the Nordic region across less established categories such as agriculture, infrastructure, animal care, plants, and dinner subscriptions and catering. While these areas are not yet as developed as the major product groups, they represent promising avenues for future growth in PSS adoption.

14.1 Agriculture and nature preservation

The Nordic agricultural sector provides products in various categories, such as food, animal fodder, fibres, construction materials, and energy generation. While PSS services in this sector are still limited, there is potential for growth. Existing PSS services mainly focus on B2B and B2G, such as contractors offering haying or other tasks across multiple farms. However, the sector holds opportunities for expanding leasing, renting, and pooling models, particularly for agricultural machinery, which comes with high acquisition costs.

PSS solutions in agriculture could improve the utilisation of expensive machinery by facilitating shared access to state-of-the-art technologies, such as precision-based drone distribution of fertilisers and pesticides. Such technologies could help lower emissions and pollution from the agriculture sector. These models also encourage more efficient land use and resource management by offering access to machinery that may otherwise be financially out of reach.

An example of a PSS model in agriculture is Nielsen's Service, an SME offering agricultural services such as ploughing, potato planting and harvesting, pruning of protective forest belts, and nature conservation. Nielsen's Service uses the latest technologies for efficient planting and harvesting, particularly in soft soils (Nielsen's Service, n.d.). While the company's services are described as sustainable, the actual impacts on biodiversity depend on the specific agricultural methods used, offering both benefits and potential challenges for ecosystems.

Another interesting aspect of this category is the inclusion of animals within PSS models, particularly those focused on ecosystem services provided by animals. For instance, some providers lease grazing animals for nature preservation, contributing to local biodiversity and offering potential benefits to animal welfare. These animals can replace machinery

for tasks like mowing, improving soil health by reducing compaction and fostering better soil conservation. However, the overall environmental impact of PSS solutions involving animals remains undocumented and highly variable, depending on factors like production intensity, waste management, and transport. Although grazing can positively affect biodiversity and soil quality, animals emit greenhouse gases. Thus, the environmental benefits of such models need further investigation.

14.2 Plants

In the Nordic Region, plants are a popular element of interior design, known for enhancing the aesthetic appeal of spaces while improving physical health and emotional well-being (Lohr & Pearson-Mims, 2000). Although PSS solutions for plants are widely available in the B2B and B2G sectors, they are yet to gain traction in the B2C market. Common offerings include potted plants, plant walls, and comprehensive maintenance services. Some providers offer functional result models, ensuring consistent greenery in office environments, but use-oriented models – such as plant rentals with maintenance – remain the most common.

The environmental impact of PSS solutions for plants largely depends on how the plants are produced. Plants grown in heated greenhouses, for example, can result in higher emissions. Additionally, the production process often involves using fertilisers and pesticides, which can contribute to nutrient pollution in water bodies. However, when well-managed, PSS models for plants have the potential to extend the lifespan of plants, providing psychological benefits and contributing to CO_2 capture. Depending on factors such as transportation, plant type, and maintenance practices, PSS models may offer environmental advantages compared to traditional ownership models.

One example of a PSS for plant is the Swedish Ambius providing plant furnishings for businesses through both sales and a rental-based PSS model. Their subscription service includes design, installation, and regular maintenance, ensuring plants remain healthy and vibrant. Ambius retains ownership of the plants, and clients receive reimbursement when the plants lose their ornamental value, provided the maintenance contract continues. Ambius's approach extends plant lifespans and ensures optimal plant health through regular care. While no detailed environmental impact data is available, the model has potential benefits, including improved employee well-being, reduced plant replacement needs, and lower demand for new plant production.

Overall, the environmental impact of PSS solutions for plants depends largely on production practices. Plants grown in heated greenhouses can result in significant emissions, and the use of fertilisers and pesticides can contribute to water pollution. Thus, the production method and type of plants offered play a role in the environmental impact assessment. However, the most critical factor in assessing the environmental benefits of such PSS models (as well as many other product groups) is whether the service effectively replaces the need for product sales. For example, if the PSS model leads to the rental and maintenance of plants that would otherwise be bought and

quickly die, it can reduce the demand for new production. Well-managed PSS models that prolong plant life, enhance CO_2 capture, and reduce product turnover offer a clear advantage over traditional ownership models – in particular, if the sourcing of plants is based on environmental and biodiversity considerations.

15. SUSTAINABILITY POTENTIAL OF NORDIC PSS MODELS

Over the past two decades, the sustainability potential of PSS has been at the forefront of business model development and scholarly debate. In fact, for some researchers, these sustainability benefits are now considered fundamental to the very definition of PSS (Sarasini et al., 2024). Originally, PSS was hypothesised to have the potential to reduce environmental impacts by up to 90% (Tukker, 2004b). However, the literature still lacks comprehensive evidence on the actual environmental impact reductions achieved through PSS implementation (ETC, n.d.). While recent studies affirm that PSS offers substantial potential for minimising overall environmental impact (Sarasini et al., 2024), they also highlight the complexities involved, including the risk of induced impacts and rebound effects, where unintended consequences may offset initial environmental gains (Kjaer et al., 2017).

The question is how we can ensure that PSS fulfils the overall sustainability potential and how we measure the actual impact of PSS, both positive and negative. Even though the concept of PSS has evolved over the past two decades, it doesn't remain easy to demonstrate and quantify the actual benefits of the business models. The most used method for assessing a product's environmental impact is Life Cycle Assessment (LCA). However, this method is primarily developed to assess "linear" products, i.e. from cradle to grave, making it challenging to calculate the benefits and unintended consequences of circular products and services, particularly PSS, as the core of these business models is the service and function of the product and not the product itself. It is necessary to consider which important assumptions and system boundaries should be included to make the calculation truly reflect the PSS model. Parameters such as capital goods, return rates, system losses, transport distances, and consumer behaviour are critical factors that might significantly impact the business model's actual environmental impact.

In this analysis of PSS's sustainability potential, we will first review the theoretical advantages, possible disadvantages, important parameters when evaluating PSS's environmental impact, and existing studies on the sustainability potential of the selected product categories. Secondly, findings regarding sustainability assessments from this project and the pilots will be presented. All of this will contribute to describing the archetype for a 'sustainable PSS solution'.

15.1 Theoretical potentials of PSS

Circular business models aim to decouple economic growth from resource use, which is also the case with PSS (Kjaer et al., 2018). The core of PSS is to focus on selling services instead of products, which is expected to reduce the need for new products. The PSS concept embraces different business models, including renting and leasing, allowing multiple users to share a single product. This approach is believed to generate several incentives that support more sustainable consumption systems, such as encouraging the design of longer-lasting products (as companies benefit financially from increased durability), reducing the number of products needed to fulfil consumers' needs, which reduces resource consumption and waste, and promoting sustainable consumer behaviour (Mont, 2002).

In recent years, research on PSS has largely focused on the business and economic drivers that support the shift to a service economy. However, most studies investigating the environmental potential of PSS are case-specific, offering valuable insights into the barriers and opportunities within certain product categories. Yet, this focus leaves gaps in understanding the broader, overarching environmental benefits that PSS could offer across industries and markets. More comprehensive research is needed to assess the full potential of PSS in driving sustainable consumption and production systems.

Although PSS is promising as a sustainable business model, its sustainability impact and contribution to transformative economic practices have yet to be demonstrated. Moro et al. (2020) identified 36 benefits of PSS through an extensive literature review, including nine environmental ones, such as reducing environmental impact and promoting greater product use. These environmental benefits can positively impact both providers and society. Annarelli et al. (2016) note that the most widely recognised advantage (reported in 62% of analysed publications) is the reduction of environmental impact. However, the specifics of how and when this occurs are poorly described. Ceschin (2013b) examines how economic factors can reduce material and energy consumption, encourage product reuse, and extend the active lifespan of products and materials. Similarly, Kuo et al. highlight how PSS can enhance service efficiency while minimising resource consumption and waste through repeated use and remanufacturing of products, materials, or components.

The primary environmental potential of PSS lies in meeting consumer needs with fewer new products. By implementing strategies such as repair, reuse, sharing, and product take-back programs, PSS providers can reduce the demand for virgin materials, decrease energy consumption, and generate less waste. These practices improve resource efficiency, reduce pollution, and lower greenhouse gas emissions, contributing to a more sustainable consumption model (Kjaer et al., 2018; Korhonen et al., 2018).

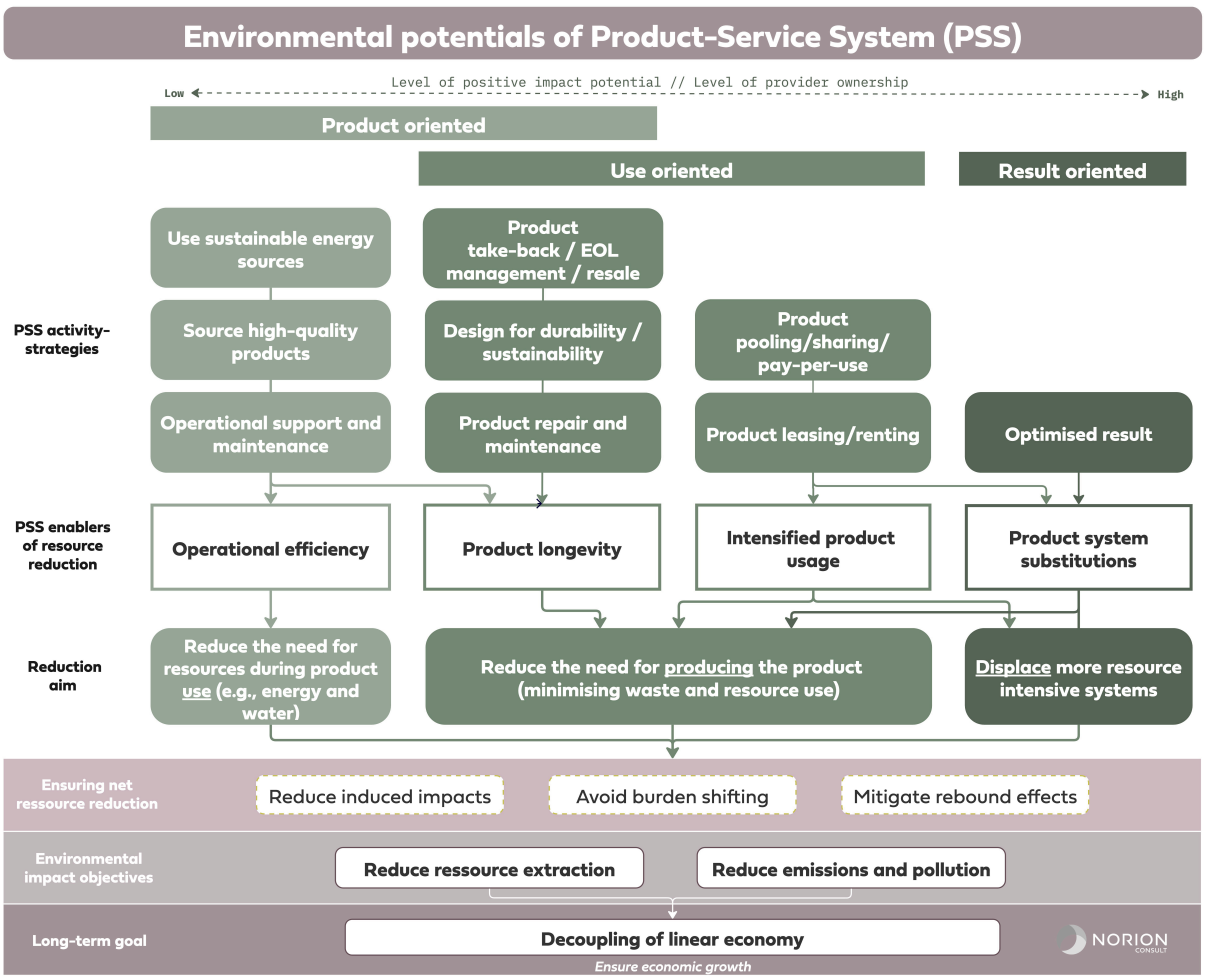

Figure 17: The overall environmental aim of PSS, the CE activities and enablers.
The model is developed by Norion; inspired by Kjaer et al., (2018), Tukker (2004a) and Korhonen et al. (2018) and adjusted with pilot findings.

The model in figure 17 presents the environmental perspectives of PSS, illustrating how different PSS models – **product-oriented, use-oriented, and result-oriented** – contribute to resource reduction and broader sustainability goals. Depending on the PSS model employed, specific PSS activity strategies are applied, directly influencing company and customer resource use and waste production, while also indirectly supporting wider environmental objectives such as mitigating climate change and reducing pollution.

Product-oriented models typically involve a lower degree of producer ownership and generally offer a more modest potential for environmental impact reduction. Their primary focus is on improving operational efficiency and, to some extent, extending product longevity. Key activities include using sustainable energy sources, sourcing high-quality products, and providing operational support and maintenance (represented by the lighter green boxes). While these strategies are effective, they are less impactful compared to more advanced approaches.

Some product-oriented models incorporate elements traditionally found in use-oriented models, such as product take-back management, design for durability, and product repair. When these strategies are adopted, product-oriented models move closer to enabling product longevity and can achieve more significant sustainability benefits.

As we move towards **use-oriented models**, the strategies become more advanced, incorporating both the elements of product-oriented models and additional approaches to achieve product longevity and intensified product usage. These models often involve product sharing, leasing, or renting, reducing the need for manufacturing new products, thereby minimising waste and resource use. **Result-oriented models** take this even further by substituting entire product systems with services, offering the greatest potential for dematerialisation and resource savings.

Overall, these strategies directly contribute to the reduction aims of decreasing resource use, waste, and new product production while indirectly supporting broader environmental goals such as reducing resource extraction, emissions, and pollution. However, to achieve the long-term goal of decoupling economic growth from the linear economy, it is crucial to ensure net resource reduction by reducing induced impacts, such as energy consumption, avoiding burden shifting, where environmental costs are transferred to another area, and mitigating rebound effects, which can occur when efficiency gains lead to increased consumption.

Each PSS model offers different levels of sustainability potential, and these potentials are maximised through the careful design and use of products, alongside effective management to avoid unintended consequences like rebound effects. The model demonstrates how PSS can be a powerful driver of sustainability and a key enabler of the circular economy when optimised for environmental and economic performance.

15.2 Ensuring the environmental benefits of PSS

While PSS holds potential for environmental progress, adopting these business models does not automatically guarantee significant environmental gains. A thorough evaluation of a PSS model's environmental impact must consider not only the potential for avoided emissions but also any negative effects arising from the service's operation, including rebound effects (Kjaer et al., 2018)

15.2.1 Induced impact directly related to PSS

PSS models provide systems where services can be purchased without affecting the quality of the desired function. Figure 18 illustrates a circular system example within a PSS, showing the process of product production, delivery, storage, distribution, return, preparation for the next use, and waste management. Compared to linear business models, PSS involves additional environmental considerations, particularly in terms of transportation, customer interaction, product return processes, and extending product lifespan.

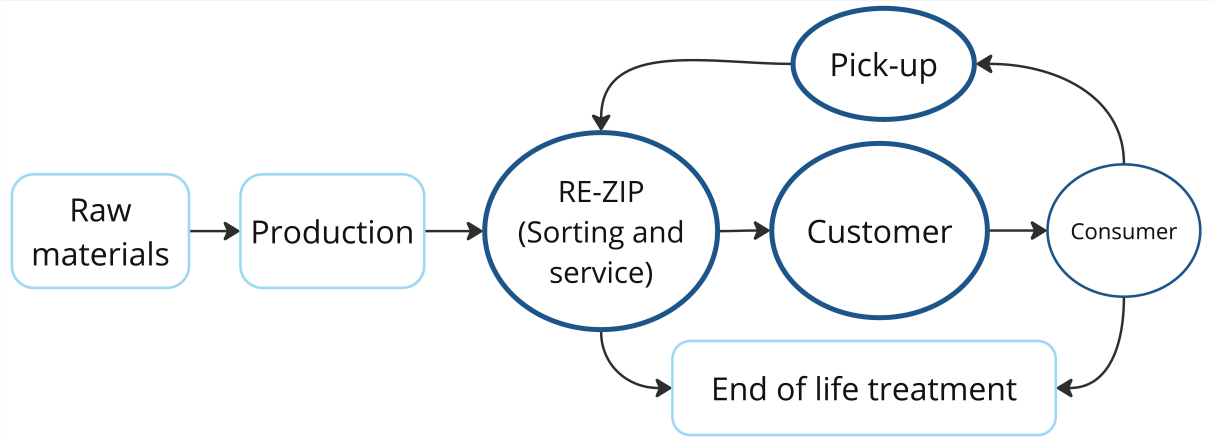

Figure 18: Example of PSS business model.

Several factors influence the overall environmental performance of PSS models. Below are key considerations that can either enhance or hinder the environmental benefits of PSS:

- **Transportation:** Transportation is often one of the largest contributors to CO_2e emissions in studies evaluating PSS models. This is particularly significant during the use phase, where products are delivered to consumers and later returned to the PSS provider. Additionally, emissions increase if users must travel to access the service. In some instances, transportation emissions alone can determine whether a PSS model has a lower environmental impact compared to traditional alternatives (Martin et al., 2021). Transportation emissions frequently surpass those associated with product repair and maintenance, including emissions from spare parts and product cleaning. This is also seen in the project pilots in section 6 and 8.
- **Return rate:** The return rate of products in circular systems is critical to the model's environmental performance, especially in low-value product-oriented PSS models, such as reusable to-go cups or e-commerce packaging services. Reusable products typically have higher environmental impacts during production than single-use products, meaning that any loss of products has significant environmental consequences, as it drives the need for additional production to maintain the system's function. Findings from pilots in the packaging product category in section 6.

- **Capital goods/operation of the system:** Capital goods (e.g., machinery, vehicles, tools) and the overall system operation in PSS models can result in higher environmental impacts compared to traditional business models (Kjaer et al., 2017). This is due to the systems needing additional services and products, such as machinery for washing, energy for IT-systems to operate the system. Eg., when having a system where the PSS provider rent out cups for to-go drink, the provider needs an IT-system to keep track on the cups and when and if these are returned. This might include having an IT-system or additional electronic equipment. Furthermore, the provider also needs to wash the products, and therefore also need washing equipment. All of these products and systems can induce the impact on the overall system. This includes not only the traditional definition of capital goods but also the additional products and services required to operate the system, such as electronic devices and IT infrastructure.
- **Utility and substitution rate:** Utility and substitution rates are crucial factors when comparing PSS to other business models, as they indicate the extent to which the service reduces the need for traditional products. A higher utility rate means more effective product use, while a higher substitution rate shows how well the service replaces the need for new products.
- **Production:** PSS models often rely on high-quality products designed for longevity, which can reduce the need for frequent replacements (Sarasini et al., 2024). However, this may result in increased environmental impact during production due to the use of more refined raw materials and complex manufacturing processes compared to traditional products.
- **Product longevity:** In theory, PSS products are designed for longer lifespans through durability, repair, and reuse. However, the actual lifespan depends on how consumers interact with the service (Sarasini et al., 2024). Consumer indifference, loss of responsibility for products, and various types of obsolescence (e.g., technological or psychological) can reduce product longevity. Although intensified use may lead to better product utilisation, it could also result in shorter lifespans due to wear and tear (Sierra-Fontalvo et al., 2024).

Rebound effects

The rebound effects of PSS models – both direct and indirect – are not widely examined (Alfarisi et al., 2022) and are difficult to investigate due to their strong dependence on consumer behaviour and perception of value. Rebound effects occur when behavioural or systemic responses reduce the positive environmental gains of PSS (Font Vivanco et al., 2016).

For instance, when products are offered at lower prices through sharing or reuse systems, this affordability can lead to an increase in user consumption that outweighs the intended environmental benefits. A key example is car-sharing. While it reduces the need for individual car ownership, it may unintentionally result in increased car usage as

more people gain affordable access to cars. The critical question is whether this expanded access primarily reduces the demand for new vehicle production or, instead, displaces the use of public transport, cycling, or walking (ETC, n.d.).

Rebound effects in PSS are influenced by triggers, which mediate changes in consumption, and drivers, which moderate the extent and conditions of those changes. Table 7 illustrates categories of rebound effects and examples of specific triggers.

Table 7: Examples of triggers and drivers for rebound effects.
Inspiration from Guzzo & Pigosso (2024), Andrew et al. (2024), and Kjaer et al. (2024).

Category	Example of trigger and drivers	Example of Rebound Effects (RE) and Secondary Benefits (SB)
Economic/financial	Price, profit, income	Reduced use costs can lead to extended use or new investments (RE)
Consumer choices	Preferences, motivation	Convenience in service can lead to the need of additional products and service (RE)
Company choices	Productivity, re-investment	Increase in revenue can lead to reinvestment in more efficient PSS solutions (SB)
Socio-cultural	Cultural acceptance, status	Moral licensing from sustainable activity can lead to consumers indulging in other consumption (RE) Consumers may feel less responsibility toward the products leading to a shorter product lifetime. (RE)
Physical constraints	Time, space, access	Time saved can lead to extended use of service (RE) Space saved by using more efficient or compact products and services might free up room for additional consumption.
Goods and services	Substitution, utility	Monitoring of use leading to enhanced performance and management of service (SB)
Other	Information, skills	

When examining rebound effects, it is important to distinguish between direct and indirect impacts.

- **Direct rebound effects** arise as an immediate response to the introduction of a PSS model, such as when a car-sharing platform makes driving more affordable and accessible, leading to more frequent use of cars (Font Vivanco et al., 2016).
- **Indirect rebound effects**, on the other hand, are related to broader systemic impacts. For example, if a PSS model results in cost savings for businesses, those savings could be reinvested in additional products, potentially increasing resource use. Similarly, if consumers save money by using a PSS service, they may redirect those savings toward increased consumption of other goods, counteracting the intended environmental benefits (Guzzo & Pigosso, 2024).

The successful implementation of PSS can drive more sustainable behaviours or trigger rebound effects and other induced impacts that significantly reduce the overall sustainability potential. Understanding the scale and impact of these potential consequences is crucial. By identifying the triggers and drivers of rebound effects, businesses can mitigate negative impacts and prevent unnecessary rebound responses.

15.2.1 Reducing unintended consequences

Induced impacts and rebound effects are difficult to predict, but Life Cycle Assessments (LCAs) can help evaluate the potential negative consequences and identify ways to mitigate them (Kjaer et al., 2018). Originally designed for linear products, LCAs must be adapted to capture the possible benefits and unintended consequences of PSS models. Key questions to address include the study's purpose, reference systems, functional units, processes and subsystems included in the system boundaries, and key assumptions related to the use phase, where much of PSS's environmental impact occurs:

Substitution of traditional systems

Does the PSS's sustainability potential depend on its ability to substitute another specific product system? For example, a car-sharing system could substitute individual car ownership, or a reuse system could substitute new products.

Support systems and processes

Does the PSS depend on support systems and additional processes that could influence the environmental outcomes? For instance, extra transport for returns, maintenance services, or extra processes (e.g. cleaning or servicing of products for leasing/renting/sharing)

Increased demand

Is there a risk that the PSS will increase the demand for the service by making it more convenient, accessible, or socially appealing, leading to higher consumption? (e.g. if the PSS increases convenience, access, social status and/or helps the user save time and money)

Spillover effects

Could cost savings from the PSS lead to increased demand for other products or services, offsetting environmental benefits? (e.g. if the PSS help the provider and/or customer save money)

LCA is conducted through four iterative phases: a) goal and scope, b) inventory assessment, c) impact assessment, d) interpretation) (ISO, 2006a, 2006b). In the context of PSS, the first phase – defining the goal and scope – is especially important for accurately assessing the system's environmental impacts.

During this phase, decisions are made regarding system boundaries, reference scenarios, functional units, and key assumptions, all of which are crucial for evaluating the specific characteristics of PSS models (Kjaer et al., 2017). Important steps and considerations include:

Scope and reference system

The first step is to clearly define the purpose and desired outcomes of the study. This helps determine whether the goal is to optimise a PSS, compare it with other alternatives, or evaluate the consequences of its implementation. Once the scope is defined, the reference system is established. The reference system represents the modelled scenario that meets the functional unit's requirements and is essential for making meaningful comparisons.

Functional unit (FU)

The functional unit (FU) defines the function of the system being assessed and quantifies the services provided. It serves as the basis for comparison between different systems. While the FU for traditional products can be narrowly defined, the FU for PSS must encompass all system elements, including consumer behaviour and alternative ways of providing the service. At a minimum, the FU should describe the measurable function, including *quantity* (how much?), *duration* (for how long?), and, if relevant, *location* (where?).

Calculating the reference flow in circular flows

When calculating the reference flow of products in a circular system (as PSS), one must consider the Number of Uses (NU) of the products (the number of times a product can or will be used before it is discarded as waste) and the Loss Rate (LR) (meaning the percentage of products that are not returned to the system) and relate these to the number of usages expressed by the functional unit (FU). If NU and LR are known, the reference flow can be calculated by using the following formula:

$$RF=(FU/NU) + (FU/NU)*LR*(NU-1)$$[2]

2. FU = the number of usages needed to fulfil the functional unit, LR = the loss rate per usage, NU = total number of uses before discard, this can include different reasons for discharging the products, e.g., the technical lifespan or if products are only used for a specific amount of time, regardless of technical lifespan. Developed by Louise Laumann Kjær, 2024.

The formula assumes that the products lost in the system (either by not being returned, because of breakage, or not being used anymore because of other factors) are sent to waste management and are substituted by new products to retain the function of the system.

Consider a circular system of reusable cups. The functional unit includes a quantity of 1000 servings (FU=1000), e.g. corresponding to 50 servings over 20 occasions. The cups are thus to be used 20 times (NU=20) before they are discarded. Without any losses in the system, the reference flow for the cups would be 50 cups (1000/20). However, only 90% is returned for every use, resulting in a loss rate (LR) of 0.1 (10%) per recirculation. Since the 50 cups are recirculated 19 times (NU-1), the number of extra cups that must be added to the reference flow is (FU/NU)*LR*(NU-1) = 50*0.1*(20-1) = 95 cups. The reference flow is the total number of cups needed to be produced, and waste managed is 50+95=145 cups.

System boundaries

Setting the system boundaries involves identifying and including all relevant processes affected by the PSS. This ensures that the analysis captures the full environmental impact. Special attention should be paid to the use phase, as well as potential rebound effects, to provide a comprehensive assessment.

Data collection

PSS models often involve complex systems with multiple products, making access to primary data challenging. Unlike LCAs for traditional linear products, primary data from production processes may be less critical. Instead, collecting primary data for the use phase is vital, as rebound effects and other impacts typically occur during this period. Both quantitative and qualitative user data are important to build accurate assumptions.

Important use parameters

Various factors in the use phase can significantly influence the PSS's environmental performance. Assumptions regarding product usage, user behaviour, and other parameters must be carefully quantified through surveys, field studies, focus groups, or literature reviews. As the assessment progresses and new insights emerge, the reference flows and system boundaries may need to be revisited to ensure the most accurate representation of the system's environmental impact.

15.2.2 Sustainability potential within the different industries

The investigation of the ten product categories in this project shows significant variation in the actual emissions and reduction potential of PSS models. Assumptions and system boundaries significantly impact the overall results of the studies. Table 8. provides an overview of the different studies, results, and potential consequences for each category.

Table 8: Overview of different studies, results, and potential consequences for each product category.

Product group	Description of PSS examples	Environmental impact	Overall examples of possible negative impacts
Transportation	Cars and ride sharing system	30% increase – 50% reduction in $kgCO_2e$ per person using the system (Zheng et al., 2019)	Customers often do not take proper care of shared products, which can lead to a significantly reduced lifespan—particularly evident with items like e-scooters. In shared transport systems, such as car-sharing platforms, additional environmental impacts may arise if users have to drive extra distances to pick up passengers, leading to increased overall transport usage.
	Smart bike system	30–62% reduction in $kgCO_2e$ per year (Bonilla-Alicea et al., 2020)	
	Shared dockless standing e-scooter system	20% increase in gCO_2e per passenger km (Moreau et al., 2020)	
	Bicycle sharing systems	25–50% reduction in $kgCO_2e$ per user per year (Zheng et al., 2019)	
Packaging	Reusable food container	24–64% reduction in $kgCO_2e$ if reused 1–100 times	When customers do not return the packaging, the PSS provider must buy more products
Machinery and Tools	Tool rental of electric chainsaw (B2C)	25% increase in $kgCO_2e$ (Martin et al., 2021)	Additional user transportation is the main reason for increased emissions.
Appliances and Furniture	Laundromat in residential building	1.8% reduction in kgCO2 per year (Amasawa et al., 2018)	Pay-per-wash models may encourage customers to overload washing machines to maximize value, potentially leading to technical issues and reduced equipment lifespan. In the case of furniture, offering it as a service does not necessarily result in customers owning fewer pieces or keeping them for a longer period. Moreover, the furniture market already has a well-established second-hand segment, making it challenging to sell furniture as a service.
	Shared laundromats	26% reduction in CO_2 per kg of laundry (Klint & Peters, 2021)	
	Pay per use washing machine	16.4% reduction in $kgCO_2e$ per year (Bressanelli et al., 2022)	

Products for Children	Rental of prams	25% reduction in tons CO2e/number prams/children year (Kerdlap et al., 2021b)	Inappropriate costumer behaviour such as overusing the system, additional consumption of other products, and improper handling of products. Emotional attachment and desire to retain the products. Costumers' perception of hygiene concern can cause over cleaning and therefore more use of water and chemicals
	Cloth diapers as a service	30–70% reduction in kgCO2e (Hoffmann et al., 2020)	
Textiles	Library for clothing (T-shirts)	40% reduction – 10% increase in $kgCO_2e$ per use (Zamani et al., 2017)	Recent experience and studies find that companies providing PSS for textiles face unexpected financial consequences and slow return on their investments. Additionally, inappropriate costumer behaviour is also identified as a possible negative impact for textiles.
	Library for clothing (Jeans)	50% reduction – 1% increase in $kgCO_2e$ per use (Zamani et al., 2017)	
	Apparel as a service (Formal dress)	43% reduction in $kgCO_2e$ (Monticelli & Costamagna, 2023)	
Seasonal and Special Occasions	Peer-to-peer shared access of boats	63% reduction in $kgCO_2e$ (Warmington-Lundström & Laurenti, 2020)	Availability and affordance of products may lead to extended product need and use.
Electrical equipment and IT solutions	Rental service of digital cameras	150% increase in CO_2e through consequential LCA (Sai et al., 2023)	Difficult to rent out used electronics, as it is difficult to estimate the device life span. Increased energy use and transportation. Users might not take good care of the device.
Buildings	PSS on an office building	27% reduced environmental score than conventional building (Smidt Dreijer et al., 2013)	

15.3 Environmental performance of the pilot projects

During the project, 16 pilot projects were conducted to analyse various elements of PSS models. In six of these pilots, the focus was on assessing the environmental performance of the models. As part of this analysis, three Life Cycle Assessments (LCAs)[3] were conducted and three climate calculation tools were developed to evaluate the environmental impacts. The key difference between these approaches lies in the scope of the environmental impact categories considered. The LCAs included a broad range of impact categories, whereas the climate calculation tools focused exclusively on greenhouse gas (GHG) emissions.

In the three LCAs, all relevant environmental impact categories were assessed, but two of the cases prioritised GHG emissions as the main metric for comparison. On the other hand, the climate calculation tools were focused solely on GHG emissions, primarily using Product Carbon Footprint (PCF) as the foundation for their analysis. Although GHG emissions are the most common metric for comparing products, focusing solely on GHG emissions may overlook significant impacts in other areas, such as land use and resource depletion, which are also relevant in both PSS and traditional product models.

The PSS models evaluated in these pilots spanned multiple sectors, including **tools** (section 7.4), **reusable packaging for e-commerce** (Section 6.2), **takeaway cups** (Section 6.1), **freight packaging** (Section 6.3), and **furniture** (Section 8.2). Each product group's environmental performance is discussed in detail within its respective chapter, providing insights into the performance of PSS models in those sectors and the potential for further resource efficiency and sustainability gains

Table 9 summarises the results, showing both best-case and worst-case scenarios across various parameters, which contributed to the overall climate impact. Detailed assumptions for these scenarios can be found in annex 2.

3. The LCAs have been modelled in SimaPro using the Ecoinvent 3.0 database and the ReCiPe 2016 Midtpoint (H) or Environmental Footprint (3.0) impact assessment method. Two assessments followed the consequential approach, and three followed the attributional approach.

Table 9: Overview of impact reductions from different pilot companies.

Pilot	Climate impact (CO2e)	Description
Rolling scaffolding	Same emissions – 45% reduction	The baseline for the calculations was set at 15 years of rolling scaffolding usage with a utility rate twice as high as in the traditional ownership model. To explore both the best- and worst-case scenarios for tool sharing, different utility rates and transportation distances were assessed. The findings indicate that increasing the utility of the scaffolding significantly enhances its potential for emission reduction. However, this is only achievable if transport emissions are also minimised. Additionally, higher usage rates could potentially reduce the product's lifespan, so this trade-off needs to be managed carefully.
Reusable to-go cup	12% increase – 92% reduction	The assessment was based on 13,036 servings of hot beverages in to-go cups, equivalent to 36 servings per day over the course of one year (365 days). Both the return rate and the number of uses were evaluated in best- and worst-case scenarios, revealing that while both factors significantly affect the system's overall environmental impact, the return rate is the most critical variable. The analysis showed that if only 60% of the cups are returned, emissions would increase by 12%. However, if 98% of the cups are returned, emissions would decrease by 92%, highlighting the importance of optimising return rates to maximise environmental benefits.
Reusable packaging for e-commerce	60% increase – 50% reduction	The assessment focused on 1 m² of packaging used to contain and protect dry goods during transportation and storage for a single delivery. Both soft and hard case packaging types were evaluated. The results showed that cardboard boxes require fewer reuse cycles compared to reusable bags for e-commerce packaging. In this scenario, introducing 100 new products and reusing 200 demonstrated that cardboard boxes could reduce emissions by 50%, whereas reusable bags increased emissions by 60%. This increase is primarily due to the heavier and more durable materials used in reusable bags compared to single-use paper bags, which contribute to higher initial production emissions.
Reusable freight packaging for construction modules	6% increase – 46% reduction	The assessment focused on covers for 4,000 modules for storage or transportation twice a year over a period of one to two years in Sweden and Norway, amounting to 16,000 total uses. The results showed that when reusable materials are introduced, they are typically made from stronger and heavier materials, resulting in higher production emissions compared to single-use alternatives. As a result, these reusable materials must be used a certain number of times before their overall CO_2e emissions are lower than those of single-use materials. The key takeaway is that the environmental benefit of reusable materials depends heavily on achieving a sufficient number of reuse cycles.
Reuse of furniture	12–64% reduction	The assessment focused on a bundle of clean, functional, neutral-looking furniture – comprising sleeping, seating, and dining elements – designed to serve 100 people over a six-month period in Malmö and Lund. The reference flow was based on meeting the functional needs of 100 individuals (primarily students). Three scenarios were selected as reference points, informed by on-site interviews with Swedish exchange students. This assessment highlights the critical role of user surveys in evaluating the environmental performance of PSS models, as they provide valuable insights into how well the PSS solutions actually substitute for traditional alternatives. These user insights are essential for accurately determining the environmental impact and the effectiveness of the PSS.

16. PAVING THE WAY TO SUSTAINABLE PSS MODELS

Nordic businesses looking to adopt or expand PSS models face various challenges depending on the industry, market maturity, target segment (B2B, B2G, B2C), and specific business models. This section explores challenges and enablers common across sectors and product groups, drawing from insights from literature reviews and extensive engagement with PSS providers through interviews, workshops, and pilot projects.

Four key categories of barriers and enablers have been analysed: cultural, technical, economic, and regulatory.

- **Cultural barriers** include deep-rooted consumer behaviours, such as preferences for product ownership, gendered norms influencing alternative business models, and preconceived notions about PSS. They also include aspects related to company culture, such as companies' hesitance to change long-term practices and embark on a new way of working.
- **Technical barriers** embrace the absence of standardised solutions, administrative complexities, and difficulties documenting circular and sustainable models.
- **Economic barriers** encompass access to financing, competition with traditional product sales, high labour costs, internal capacity constraints, and public procurement challenges.
- **Regulatory barriers** encompass a lack of supporting regulations, a regulatory landscape geared towards linear business models, and an absence of legislative and financial guidance to assist PSS providers in navigating complex legal frameworks..

Table 10 provides a comprehensive view of the challenges and opportunities for advancing PSS in the Nordic Region.

Table 10: Overview of challenges and opportunities for advancing PSS in the Nordic Region.

CULTURAL
Challenges
• **Resistance to change**: Long-standing practices around product ownership and acquisition are hard to shift, both for businesses and consumers. • **Emotional attachment to products**: Customers may prefer owning products due to sentimental value or a sense of personal control. • **Negative perceptions of second-hand or shared goods:** Some customers associate rented or reused products with lower quality or status. • **The attitude-behaviour gap**: Although customers express interest in and support for sustainable solutions, their actual purchasing behaviour often does not align with these values. • **Insufficient communication materials:** It can be difficult to craft clear and compelling messaging that *resonates* with customers and effectively communicates the benefits of PSS, requiring adjusted marketing strategies. • **Customer concerns:** Issues surrounding product availability, potentially higher costs compared to linear models and concerns about hygiene in reused or rented products can deter adaptation. • **Hesitation on product tracking:** Customers may be uncomfortable with tracking technology, fearing privacy concerns or over-surveillance. • **Limited understanding of sustainability**: Customers can be very focused on e.g. recycled content, which can unintentionally reduce product durability, and thus hinder the high reuse rates.
Enablers
• **User-friendly systems:** Simple, intuitive platforms making PSS models easily accessible. • **High flexibility:** Adaptable services that can meet diverse customer needs. • **Personal customer service:** A personalised approach helps build trust and foster long-term customer relationships. • **High mutual trust:** Cultivation of trust between providers and customers. • **Experience-based value offers:** Additional value through experiences, such as educational resources or community engagement. • **Sustainability-driven consumer demand:** An increased focus on circular solutions amongst younger consumers. • **Demonstrating safety and hygiene:** Cleanliness and safety in reused products. • **Detailed FAQs on PSS solutions:** Clear and thorough information about PSS terms and conditions. • **Consumer-centric value offers:** Tailored offerings to meet specific customer needs and preferences. • **Demonstrating social, economic, and environmental benefits:** Clear and persuading presentation of the broader benefits of PSS models. • **Peer influence and social proof:** Demonstration of successful PSS adoption by other companies or customers. • **Larger networks**: Being part of a broader, standardised network with streamlined communication and enhanced operational efficiency.

TECHNICAL

Challenges

- **Resource-intensive operational documentation:** Documenting and managing the operational aspects of PSS models, such as inventory, usage, and return-rates, requires significant time and resources.
- **Inadequate infrastructure:** The existing infrastructure does not fully support the requirements of PSS models, especially in areas like logistics, reverse supply chains, and product returns (e.g. options for return points).
- **Analogue systems:** Many providers use non-digital (analogue) registration, monitoring, and documentation systems increasing costs and complicating efforts to streamline operations, securing financing, and building partnerships.
- **Low availability of IT solutions**: Standard IT systems for e.g. collection, cleaning, and tracking are lacking, hindering the ability to scale PSS models effectively.
- **Branding**: The reuse of products in PSS solutions often limit the ability to personalise or brand offerings, reducing appeal for B2B customers who seek more customisation.
- **Unclear terms**: Both customers and providers often face uncertainties about ownership terms, reverse logistics processes, and the overall management of products within PSS models, creating confusion and delays.

Enablers

- **Shorter distances between return points:** Increasing the number of convenient return locations for customers can facilitate easier product returns.
- **Master databases for product tracking**: The availability of centralised databases for tracking products can enhance operational efficiency and enable more accurate monitoring of product usage, condition, and lifecycle.
- **Alignment with existing sustainability strategies:** Well documented PSS solutions, that easily integrate into a cooperate customers' sustainability goals, are more likely to be adopted.
- **Digital Product Passports (DPPs)**: Introducing DPPs can improve data availability across the lifecycle of a product, making it easier to track, manage, reuse, and recycle products within the PSS model.
- **IT systems for subscription management**: Advanced IT systems that streamline the management of subscription-based models can improve operational efficiency and enhance customer experience.
- **Efficient digital operation systems:** Digital tools can streamline operations so that leasing systems can be run efficiently.

ECONOMIC

Challenges

- **Competition from low-cost linear products:** Easily accessible, cheap linear products create strong competition for PSS solutions, making it difficult to develop economically attractive alternatives to product ownership.
- **Labour-intensive business models:** PSS solutions often rely on more labour-based activities than product-sales models, which challenge the economic viability in the Nordics due to high salaries of workers.
- **Economic viability challenges:** PSS models face difficulties in reaching financial sustainability due to high upfront costs for acquiring diverse products and long payback periods, making it harder to secure funding and investment.
- **Customers retention**: It can be challenging to keep customers loyal to PSS models, particularly when faced with competing ownership models.
- **Public procurement bias:** A focus on low prices over quality in public procurement creates barriers for PSS providers.
- **Challenges in pricing flexibility:** Long-term contracts in PSS models often restrict dynamic pricing, affecting profitability and adaptability to market changes.
- **Resource-intensive loan applications:** Securing financing is a challenging and time-consuming process for PSS providers, particularly SMEs.
- **Weaker financial structures in SMEs:** SME-sized PSS providers often struggle with lower liquidity and fewer financing options.
- **Lack of financial guidance:** Business guidance networks rarely offer support tailored to the needs of PSS providers.
- **Hesitation from financiers:** Investors are often reluctant to back PSS models due to perceived risks and uncertainties.
- **Difficulty accessing scalable financing:** PSS providers, especially SMEs, struggle to secure financing that grows with their business, limiting expansion opportunities.

Enablers

- **Lower total cost of ownership:** Shifting the focus on TCO can help PSS demonstrating the lower long-term costs, for example through extended product lifespan.
- **Tailored pricing solutions: :** Tailored pricing models and flexible payment systems that suit different customer types and increase customer satisfaction.
- **Combining active and passive revenue streams**: PSS models can generate both active income from services and passive income from product leasing.
- **Strong relationships with suppliers**: PSS providers benefit from strong relationship with suppliers to ensure the availability of spare parts and the high quality of their products, crucial for the long-term economic viability of their services.
- **Public funding opportunities**: Public funds and government grants can help PSS solutions to overcome financial barriers and support the scaling and innovation of their business models.
- **Provider-based insurance**: Offering insurance solutions directly through the provider can mitigate risks for both customers and providers, making PSS more attractive.
- **Public procurement**: Public procurement can facilitate PSS development if suppliers are engaged early in the public procurement process.

REGULATORY

Challenges

- **Lack of regulatory incentives for circular production:** Existing regulations do not sufficiently encourage businesses to adopt circular consumption practices, limiting the push for PSS adoption.
- **Legal uncertainties for PSS providers:** Many PSS providers face ambiguity in areas such taxation, accounting, and legal processes, as regulations are more aligned with traditional linear business models.
- **Lack of clear regulations for product ownership and liability in PSS:** A lack of clarity in legal frameworks about product ownership and liability in PSS models can be a significant barrier for both providers and customers, and it is often expensive for PSS providers to get legal support in the implementation process.
- **Customer uncertainty about rights:** Potential customers are often unclear about their rights when using PSS solutions, which can hinder adoption.
- **Lack of supportive taxation policies**: The Nordics lack tax incentives that facilitate increased reuse of products (such as VAT exemptions) through PSS solutions and high labour taxes contribute to making PSS models less competitive.
- **GDPR-related hesitations**: In countries like Sweden, concerns over compliance with GDPR (data privacy) regulations make PSS providers hesitant to adopt digital solutions for operational tracking, slowing down the digitalisation of PSS.
- **Compliance with sustainability reporting**: It is often difficult for PSS – especially SMEs – to measure and document the environmental benefits of their models, making it challenging for them to comply with reporting standards.
- **Slow implementation of regulations:** Delays in implementing EU directives, such as the recent EPR for packaging create uncertainty and may hinder adaptation to PSS models.

Enablers

- **New circular business legislation:** New legislation supporting circular business practices typically results in an initial surge in market interest and adoption.
- **Sector-specific strategies and action plans:** More concrete and actionable policies that support PSS development within a specific sector can support the transition towards a wider adoption.
- **Guidance on compliance:** Public guidance for PSS providers on how to comply with regulation and environmental reporting standards can help them ensure compliance.
- **Mandatory sustainability reporting**: Regulations requiring sustainability reporting and green claims will help level the playing field for larger, well-established PSS companies, as many already document their circular business practices effectively.
- **Green tax shift**: Shifting taxes from labour to natural resources could improve PSS competitiveness by promoting labour-intensive practices such as repair and maintenance.
- **EPR implementation**: Extended Producer Responsibility (EPR) regulations, such as for packaging and textiles, encourage sustainable practices like reuse and recycling, and help to create a more level playing field between PSS providers and linear business models.

The barriers and enablers are closely interlinked, reflecting PSS providers' complexity in navigating the market and the regulatory and economic landscapes. This is particularly evident in the case of public procurement, which is often perceived as a barrier for PSS providers due to its ties to cultural, economic, and regulatory factors. Yet, it also holds the potential to act as an enabler and exemplary case for PSS adoption. Many challenges, such as high product acquisition costs or difficulties in securing financing, are compounded by slow regulatory adaptation and an overall market structure favouring linear business models. For instance, regulatory gaps create uncertainty that intensifies financial hurdles like profitability and scalability, especially for smaller PSS providers.

Enablers – such as supportive regulations, technological innovations, and shifting consumer perceptions – can directly counterbalance the barriers. Policies like EPR can incentivise circular practices, offering opportunities for PSS providers to scale more effectively. Digital innovations can streamline operations, helping to reduce costs and improve business efficiency.

In general, far more challenges than enablers have been identified through consultations with PSS providers and pilot projects, reflecting PSS providers' desire to voice the specific challenges and concerns they face in a system still geared toward linear practices. The businesses are operating in a transitional period, where consumers are still adjusting to sustainable consumption, and market conditions and regulations continue favouring traditional ownership models. The identified challenges often centre around overcoming these structural disadvantages to make their business models economically and environmentally viable.

Conversely, the enablers share a common theme of making circular consumption more convenient, accessible, and beneficial for customers. While the current market may favour linear models, these enablers signal a shift toward a more sustainable future, where regulatory support, consumer behaviour, and market dynamics increasingly align with the principles of circularity and sustainability. Ultimately, the success of PSS models depends on leveraging these enablers while addressing the barriers, creating a business ecosystem that can support both profitability and sustainability.

Looking Ahead

The following section will dive deeper into three critical areas that have surfaced as essential for the growth of PSS models:

1. Shifting the culture of ownership and enhancing the value proposition: Changing deeply ingrained consumer behaviours and clarifying PSS's benefits will be vital in driving adoption.
2. Financing PSS models: Overcoming financial hurdles, including securing scalable funding, is key to ensuring the long-term viability of PSS businesses.
3. Leveraging public procurement as a driver for PSS adoption: Public procurement presents a powerful opportunity to mainstream PSS models, especially if regulatory frameworks and purchasing policies begin to prioritise circular solutions.

These deep dives will explore how to unlock the potential of PSS models and turn barriers into opportunities for sustainable business development.

16.1 Culture of ownership and value proposition of PSS

PSS models differ from traditional ownership models by emphasising performance, product use, and functionality over ownership. However, a major challenge for PSS providers is developing and communicating the value proposition of these systems, especially given the deeply ingrained culture of ownership across the B2C, B2B, and B2G sectors. Customers are accustomed to owning the products they acquire, a behaviour long embedded in the traditional linear economy. To succeed, PSS providers must find effective ways to demonstrate the value of their services to target groups and overcome these entrenched ownership habits.

16.1.1 The culture of ownership

One of the most pervasive challenges for PSS providers is addressing the deep-rooted culture of ownership. Consumers across all market segments have developed long-standing attachments to products within the linear economic system, where ownership equates to control and familiarity. PSS models challenge these ingrained habits, whether based on product rental, leasing, or shared access (Cherry & Pidgeon, 2018). The culture of ownership has been evident in all the pilot projects conducted across various product groups. Some companies have made strides in market maturation, helping customers decrease the desire for ownership (section 7.4), but many others are still at the beginning of this transition journey (sections 5.4 and 10.2).

The culture of ownership is particularly apparent with products that carry personal or emotional value and items that may contain sensitive user information. For example, there is a well-established B2B segment for workwear in the clothing rental market, but there is still only a niche market for occasional wear within B2C, with even fewer examples in casual wear. This disparity may partly stem from the emotional attachment to personal clothing, in contrast to workwear, but it should be noted that even in B2B markets, emotional connections can arise. For instance, Nethire's experience shows that in sectors like construction, workers may feel personally connected to the tools they use daily, making them hesitant to adopt rental.

PSS solutions can bring customers potential drawbacks and risks that discourage them from exploring alternatives to ownership models. These concerns often revolve around guaranteed product access and the convenience of acquiring and returning items, fuelling fear of losing control (Cherry & Pidgeon, 2018). For instance, in membership-based PSS models for clothing, tools, or bicycle rentals, customers may worry that the products they need won't be available in the right size, condition, or brand. PSS providers must balance offering a wide product assortment to meet these demands without encountering financial or storage challenges, all while maintaining a high product use rate to remain

environmentally sustainable. These issues are particularly prominent in B2C markets, where PSS often struggle to create sufficient customer value.

Ownership gives customers a sense of control over usage and availability since external factors don't influence their access to the product. As a result, PSS providers must demonstrate the advantages of PSS models over what customers perceive as the limitations. While PSS models offer benefits like flexibility, maintenance, and repair services, customers may still perceive inconveniences, such as ongoing payments, product wear and tear, and potential inaccessibility. The value proposition is often clearest in cases where the products are expensive, have short-term usage needs, or require complex maintenance – like large infrastructure machinery, specialised equipment, or high-cost cargo bicycles.

Successfully shifting the culture of ownership will require PSS providers to consistently convey their models' convenience, cost savings, and environmental benefits, making clear the long-term advantages over traditional ownership.

16.1.2 Demonstrating value in a culture of ownership

In this project, we encountered numerous Nordic PSS providers with clear visions – such as reducing plastic waste or increasing product use rates – who struggle to demonstrate their services' value to potential customers effectively. One significant challenge is that customers seek value not only in functional terms but across multiple dimensions, including economic, emotional, and symbolic value (Catulli et al., n.d.).

Communicating cost-savings and long-term value

One of the key challenges PSS providers face is demonstrating their services' monetary value and long-term cost savings – and making customers understand, that convenience also comes at a cost. This is especially prevalent in the B2C segment, where consumers often focus on visible, immediate costs without considering the operational costs during the product's lifetime. Studies show that customers frequently underestimate the ongoing costs of product use, maintenance, and depreciation – as seen in car ownership (Gössling et al., 2022), where car-sharing users often directly compare rental and fuel expenses, overlooking the Total Cost of Ownership (TCO).

Similarly, clothing rental customers may view rental fees as high compared to purchasing, even though they often buy clothing that is rarely worn. Clothing rental studies show consumers are more inclined to rent expensive, occasional wear, knowing they would otherwise face high cost-per-wear (Gustafsson & Spitzbart, 2020). However, customer perceptions of acceptable rental prices vary significantly, with some expecting to pay less than 10% of the product's acquisition price, while others see that as excessive. Most B2C customers agree that PSS pricing should be modular – long-term rentals should result in a lower per-day price than short-term rentals as seen in section 11.2.

Part of the explanation is that calculating TCO requires a deep understanding of all operational costs, which can be difficult to predict, especially for variables like future maintenance and repairs. Some benefits, such as repair coverage or spare part availability, may only become apparent to customers after prolonged use, further complicating the calculation and the value communication.

By helping customers understand TCO, providers can make clear comparisons to traditional ownership costs, making long-term savings more tangible and highlighting the economic value PSS offers. However, it is important to note that cost savings are not always guaranteed, as the convenience and flexibility of a service-based model can come at a higher price – but then, transparency on costs can help understand the value of these additional services better. For example, in the case of lighting-as-a-service, TCO calculations can help customers better understand the potential savings related to energy efficiency, reduced upfront installation costs, and fewer repair and maintenance costs compared with the ongoing subscription fees, as seen in section 13.3.

The personal touch vs. scalability

PSS models are often service-centric, making them more complex to communicate and analyse than traditional product offerings (Marek, 2020). High-quality service is integral to PSS value but can also be resource-intensive and costly, as seen in pilot projects like Vaatepuu (Section 10.2), Rent a Bike (Section 5.4) and Nethire (Section 7.4). For instance, Vaatepuu members greatly valued personalised styling advice and problem-solving assistance with damaged or late-returned items. However, providing such individualised attention is labour-intensive and often heavily reliant on one person, such as the founder, making it difficult to scale or sustain.

Common misconceptions about PSS models, such as concerns over hygiene, legal liabilities, and product availability, require additional information efforts and an obligation to constantly deliver a high quality of service. For example, in reusable cup systems, successful implementation depends on behavioural changes from both B2B staff, who must introduce the service to customers, and end-consumers, who must change their consumption habits and return the cup after usage. This complexity necessitates extra communication and education, particularly when dealing with user behavioural changes.

Many PSS services appeal to customers through a 'personal touch,' fostered by strong trust, personalised customer service, and flexibility from the provider. Maintaining the 'personal touch' while scaling can be challenging. Focusing on personalised customer service can divert attention from scaling efforts, while scaling up can dilute personal connections with customers as operations grow and become more impersonal (Mohamad et al., 2014). The pilot findings show that many customers see close relationships as a key driver for engaging with PSS solutions. Some even describe the personal connection as the most significant factor influencing their choice to adopt PSS.

As such, PSS providers must find ways to maintain this personal touch as they scale – for example, by developing a business model that can be replicated in other locations or markets. This way, businesses can ensure consistency in delivering services while achieving the same level of quality and satisfaction for their customers, building on the experiences from their initial venture. Alternatively, companies can focus on building a sustainable business model that does not depend on further market expansion and growth but is rooted in a local community or a specific market segment.

Environmental benefits are difficult to quantify and communicate

Quantifying environmental benefits remains a challenge for many PSS providers, especially SMEs. The environmental advantages of PSS are often assumed rather than rigorously demonstrated, making it hard for companies to articulate these benefits clearly. Moreover, the actual environmental impact depends significantly on user behaviour and interaction with the service. For example, in the reusable cup pilot project with Kleen Hub, the true environmental benefit depends on product usage, return rates, and the logistics of the operational system, as seen in section 6.1. Comprehensive environmental assessments, such as life cycle assessments (LCA), are complex and resource-intensive but necessary to fully communicate PSS's environmental value in line with marketing regulations.

Social benefits for customers and local communities

Many PSS models offer social benefits in addition to economic and environmental benefits. For example, in membership-based clothing rental services, customers might initially be interested in supplementing their wardrobe by renting specific pieces to "spice up" their collection; over time, however, they may feel part of a broader community with similar fashion interests or sustainability values as seen in section 10.2.

Many PSS providers in the Nordics incorporate socio-economic business models, offering local employment opportunities through labour-intensive services such as the repair and maintenance of bikes, electronics, and other products. In some cases, like the Danish circular lighting company Fischer Lighting, this includes integrating individuals who struggle to find employment as seen in section 13.3, supporting local job creation and skill development and enhancing the PSS model's sustainability. Emphasising the PSS models' social and economic contributions can appeal to customers and stakeholders who value corporate social responsibility and the positive impact on local communities.

16.1.3 Conclusions, recommendations and further resources

PSS providers often struggle to develop a clear value proposition in competition with traditional product sales. Customers are used to owning products rather than renting or leasing them. PSS models promote use-oriented consumption, which requires a cultural shift in household and business sectors. It is crucially important for PSS providers to define the factors that differentiate their offerings from traditional products and communicate what customers can expect from their service regarding personalisation, support, and problem-solving.

Understanding and mapping customer journeys can help identify key points where value is generated. However, this requires a deep dive into how customer segments experience and benefit from the service. Moreover, the complex nature of PSS services – such as dealing with questions related to insurance, damages, or loss – demands more extensive communication with customers than selling a simple product. Thus, PSS providers must develop detailed FAQs and other resources to address customer concerns and highlight the customer support structures offered. Given customers' general interest but hesitance to fully commit to PSS models, personal recommendations and testimonials can further help attract new users.

Another solution may be to collaborate with other PSS companies. Creating networks with 'competing' providers can foster collaboration and knowledge sharing (Terziovski, 2003). By exchanging ideas and experiences, PSS companies can overcome challenges in maintaining high-quality customer service while scaling and unlocking new funding opportunities (Schoonjans et al., 2013). Our pilot projects showed that SMEs working within PSS models are generally open to helping each other navigate these shared challenges related to the value proposition.

LIST OF RESOURCES FOR VALUE PROPOSITION DEVELOPMENT:

- Ellen Mc Arthur Foundation (n.d.) – Product Journey Mapping
- DTU Proteus (2014) – TCO Chart
- Circulator (n.d.) – Circular Business Models Mixer
- Nordic Innovation (2021): Nordic Circular Economy Playbook
- Nordic Green Growth Research and Innovation programme (2021): CIRCit Norden

16.2 Financing PSS Models

Realising the potential of PSS business models depends strongly on the provider's ability to address questions related to financial factors and business configurations. Implementing a PSS model can be a promising business opportunity because it can secure long-term recurring revenue with higher returns on the investment. Still, the provider may face significant challenges in ensuring stable cash flows, managing value chain risks, and aligning investments with repayment periods. Moreover, finance providers are often reluctant to grant loans to new circular business models due to lack of knowledge and the new types of risks that are associated with them. Still, access to capital is at the heart of the challenges for PSS.

16.2.1 The challenge of providing *more* than a good business case

While all businesses must present a good case to attract investments, non-linear business models face additional barriers because it can be difficult to align them to perform well on traditional financial evaluation measures, such as key economic indicators and asset structure. Interviews with Nordic financial institutions reveal several challenges that non-linear business models, such as PSS, face when seeking financing.

Traditional financial metrics and PSS models

Firms, especially SMEs and start-ups, often rely on external sources of finance to fund innovation. Those external sources are often banks, which are legally obligated to follow stringent due diligence procedures and require business customers to live up to certain financial metrics to access capital. Banks and financial institutions often mandate co-payment arrangements and expect the business to contribute equity – usually at least 20% of the loan or total financing amount. Banks also expect a detailed budget and a thorough business development plan that addresses potential challenges and outlines growth strategies. Documentation reflecting an in-depth understanding of the business' assets, risks related to financing, development visions and security of payment, with the latter being highlighted as the most important aspect for evaluating prospecting firms. Bookkeeping data for at least one year is essential, as well as proof of successful maintenance of previous loans or financing sources and a comprehensive overview of historical financial accounts highlighting profits and positive repayment history of interest and loans.

For start-ups, fulfilling these requirements is difficult, not least for PSS models, which typically require substantial upfront loans or investment to create a sufficient scale for generating ongoing revenue while paying interest rates and investment costs 5.3. This long-term revenue focus differs from traditional models, where every sale provides the full return immediately, allowing businesses to scale their production and/or procurement organically according to demand.

Key financial indicators

Key economic metrics, most commonly *return on assets*, are typically suited to linear business models and will be inadequate for evaluating the efficiency of use-oriented PSS providers, requiring significant capital investment, as the assets remain on the provider's balance sheet, increasing their financial exposure. Traditional accounting practices exacerbate this by considering owning and maintaining assets a financial risk (Cf. section 5.4).

Linear models are driven by direct sales and profitability linked to asset disposal, while PSS models generate recurring revenue through incremental payments (Acsinte & Verbeek, 2017; Kirchherr et al., 2018). The lower returns on assets and the circular economy principles inherent in PSS models add complexity, as they require a shift in financial evaluation away from short-term profitability towards long-term value

creation. The business's asset-heavy nature limits operational agility, making it challenging to adapt to market fluctuations or technological advancements swiftly (Kirchherr et al., 2018; Reim et al., 2021)

The mismatch between the timing of revenue generation and capital outlays can lead to cash flow challenges, making it difficult to maintain an adequate liquidity level (Cf. Section 5.4 and 6.3). If access to risk capital is present, the issue can be partially addressed through financing arrangements that offer longer payback periods. However, this may result in higher total investment costs due to increased interest rates over the extended period.

Net income measures, which compare gross income to expenses, may appear lower for PSS models because income is distributed over time, while costs, such as labour and interest payments, tend to rise in the short to mid-term (Linder et al., 2022). Solvency ratios, which gauge a firm's ability to meet long-term debt obligations, pose a challenge, as the interest coverage ratio may be lower for PSS firms due to the combination of high upfront investment and the gradual accumulation of revenue. These factors can lead to an inaccurate financial evaluation of PSS businesses when using traditional financial ratios (Linder et al., 2022). PSS providers must develop new financial metrics aligned with their business model, emphasising sustainability, recurring revenue streams, steady growth, and long-term financial health to exhibit a good business case and attract investors (Fallahi et al., 2023; Toxopeus et al., 2021; Vinnova, 2017).

Banks generally accept a wide range of forms of collateral but traditionally prefer tangible, reusable assets. PSS providers who deal with consumer goods of low capital value, such as clothing, provide little security for loans due to their low resell value (Berger & Udell, 2006) – a challenge recognised in the project's pilots.

16.2.2 Opportunities

The challenge of ensuring sufficient capital is especially evident for smaller businesses and start-ups. Mature businesses wanting to venture into PSS business models do not rely on external capital to the same extent as small businesses. Successful PSS solutions are often supplementary business avenues by companies with successful sales through traditional models, providing the required financial robustness.

CASE: 3STEPIT AND BNP

The joint venture between the Finnish IT company 3 Step IT and the multinational bank and financial service provider BNP Paribas combines expertise in IT lifecycle management with access to financial resources. The joint-venture offers businesses a comprehensive full-service circular PSS solution for IT devices, which has allowed the business to scale to 11 countries across Europe (4 in the Nordics) where they +3 mio. devices under management.

The joint venture between 3 Step IT and BNP Paribas offers substantial strategic advantages for 3 Step IT, particularly by enhancing its financial strength and operational capacity. Through this long-term partnership, 3 Step IT gains access to the extensive capital resources of BNP Paribas, a key factor in supporting large-scale leasing agreements and expanding their product-as-a-service offerings across Northern and Western Europe.

PSS providers can adopt efficient asset management strategies to mitigate financial challenges. This involves refining processes around asset operation, monitoring, maintenance, upgrading, and disposal – all to minimise costs.

Lease-and-lease-on and sale-and-leaseback arrangements can ease financial pressure by reducing direct ownership, improving liquidity, and introducing flexibility essential for navigating a dynamic market.

Figure 19: Example of lease-and-lease-on. Based on Fallahi et al. (2023).

The **lease-and-lease-on** model allows PSS providers to lease products from a third-party lessor and sublease them to customers, acting as an intermediary. In this model, the provider avoids significant upfront capital investment and the risks associated with asset ownership and obsolescence (Fallahi et al., 2023).

In a **sale-and-leaseback** model, a PSS provider sells ownership of assets to a third party while continuing to use the assets under a lease agreement. This approach releases

capital immobilised in the assets, enhancing liquidity and allowing for reinvestment in strategic initiatives (Fallahi et al., 2023) Lease payments and the loss of ownership necessitate a thorough evaluation of long-term financial implications to ensure profitability.

Figure 20: Example of sale-and-leaseback. Based on Fallahi et al. (2023).

16.2.3 Conclusions

Traditional banks are often hesitant to lend to PSS providers, especially SMEs, and governments should investigate solutions to provide financial instruments that reduce the risk of investing in promising circular business models. Financial institutions would be more willing to finance PSS ventures in co-payment structures where the government guarantees part of the loan.

Nordic countries have established a green financing institution, the **Nordic Green Bank** (Nefco), which provides financing for the global scaling of promising green business solutions (Nefco, n.d.). Nefco does not, however, consider the financing challenges of circular business models in its investment criteria and will consequently prioritise linear business models. Nefco does not support businesses that aim to develop their business in a national or cross-Nordic market (only an international market). The Nordic policymakers, therefore, do not need to look far to find an opportunity to help reduce the financing barriers of promising PSS businesses.

Sale-and-leaseback and lease-and-lease-on arrangements can improve liquidity for PSS providers. However, this might lead to an increase in overall costs and should thus be carefully evaluated by public institutions. Governments can support this by providing tax incentives and encouraging financial institutions to offer favourable terms to PSS providers adopting asset-based financing. Such strategies would reduce the capital constraints faced by PSS businesses, allowing them to grow and innovate without being burdened by large upfront investments.

Governments should use existing platforms to invest in upskilling initiatives and knowledge-sharing platforms to improve access to finance that helps PSS

providers navigate financial challenges. This could be done by enabling and encouraging regional business hubs, business clusters, and other similar public institutions to emphasise circular business models. These initiatives would ensure that SMEs and start-ups in the PSS sector have the skills and knowledge to structure their business cases effectively, access both formal and informal financing sources, and successfully manage their capital.

LIST OF RESOURCES FOR FURTHER INSIGHTS INTO FINANCIAL SOLUTIONS

- Research Institutes of Sweden (RISE) (2022). 13 solutions to financing PSS
- Circle Economy (2019). Product-as-a-Service Question Kit
- Stena Recycling (n.d.). As-a-Service – Unlocking business value
- OVAM (n.d.): CEvaluator – First aid in financing circular projects

16.3 Public procurement as an enabler for PSS

Due to its vast scale and purchasing power, public procurement holds significant potential to drive systemic changes towards sustainability. Moreover, it can signal the willingness of public institutions to drive social change, and help introduce more sustainable products and services to the wider society. Already, many assets for the public sector are procured through a PSS agreement, including vehicles, fixtures, coffee machines, printers, ICT equipment, and textiles for the healthcare and criminal justice sectors.

While no specific legal barriers prevent public institutions from procuring PSS solutions, PSS providers targeting the public sector still face significant challenges. Few municipalities actively include PSS solutions in their procurement strategies, with the exceptions primarily in areas like ICT, mobility (such as cars and bikes), and textiles.

Public procurement rules, which focus on the procedures for purchasing rather than the specifics of what is being purchased, are often criticised for being overly complex and restrictive, potentially limiting the flexibility needed for green procurement. However, the true challenge lies not in the rules but in the lack of knowledge and experience in identifying the most effective strategies and organisational setup for achieving green transitions (UNEP, 2021). Instead of adding more stringent requirements, there is a growing recognition that increasing knowledge and providing practical tools to incorporate climate and resource considerations into public procurement is essential. This issue has received public attention, underscoring the need for a more informed and practical approach to green procurement (Hamer, 2024; United Nations Environmental Programme, n.d.).

> *If there are no suppliers, you must cancel the competition due to lack of offers. Starting early allows you to prepare the market for PSS, but it can be risky for suppliers to adapt. It's beneficial if more public sector providers request the same thing*
>
> – Procurement consultant in a Nordic municipality

The Tender Process

Interviews with six Nordic municipalities identify the tender process as the main barrier to public procurement of PSS. For PSS to be considered, the demand must be explicitly stated in the procurement requirements within the tender document. Directive 2014/24/EU on public procurement mandates transparency and equal treatment in inviting tenders for goods or services. To ensure that PSS or "X-as-a-Service" providers can respond to municipal tenders, the tender must clearly state that rental, leasing, subscription, or pay-as-you-go solutions are considered. Alternatively, TCOs should be added as one of the evaluation criteria.

In the interviews, municipal procurers highlighted the necessity of competition when procuring goods or services. For larger contracts, a municipality must achieve three offers from the market, which can be challenging if there are few suppliers. At the same time, municipalities face significant challenges in preparing the market to deliver PSS solutions. If suppliers are not ready or willing to offer a PSS solution, procurement competitions may be cancelled due to a lack of bids, which will be costly for the municipality and delay the procurement of the needed services and goods. This situation highlights the importance of early market engagement, where municipalities must start the procurement process well in advance to prepare and educate the market.

Traditional suppliers may hesitate to adapt to the PSS model unless there is clear and consistent demand from the public sector. The public procurement entities can engage in transparent, pre-commercial dialogue with potential suppliers. Still, they often lack the resources and expertise to effectively guide this market transformation, further complicating the transition to PSS procurement.

CASE: LIGHTNING-AS-A-SERVICE IN BOLLNÄS MUNICIPALITY

Bollnäs Municipality, driven by its environmental policy to minimise its environmental impact, embarked on a five-year procurement project for indoor lighting in a 1,200 square meters school facility. The municipality aimed for energy efficiency and products made from reused and recycled materials whenever possible. The procurement specifications included requirements for lux levels (brightness), colour temperature, and flicker rates, with bids evaluated based on price per square meter of illuminated space.

The process attracted significant interest from the market, with the municipality actively engaging in multiple stages of dialogue with potential suppliers. This resulted in strong participation, with 14 representatives from nine different lighting companies attending the initial meetings, and three companies ultimately submitted competitive bids.

The contract was awarded to Två punkt ett, an innovative company and the smallest of the bidders in terms of size. "I would say that Bollnäs municipality is the bravest municipality in Sweden to invest in this type of service," says Joel Smedberg, founder and owner of Två punkt ett (Inköpsrådet, 2018).

16.3.1 Framework agreements and PSS

Many framework agreements pose a significant barrier to PSS adoption due to their extensive and rigid requirements.

Like single procurements, these agreements require that quantities and amounts be specified in the tender documents, offering limited flexibility (Bauer et al., 2016).

Typically, a framework agreement can last up to four years, with a competitive award procedure required if the contract's total value exceeds the established threshold (Konkurrenseverket, n.d.). In fact, the European Court of Justice has ruled that a framework agreement expires once the total value or quantity of predefined purchases reaches the scope specified by the contracting authority (Dalgaard Pedersen et al., 2019). This adds rigidity, making it difficult for municipalities to manage their needs over the agreement's duration, particularly when those needs are uncertain or evolving. Municipalities expressed concerns about estimating the quantity and type of products or services required over the four years, especially for PSS solutions where asset life often exceeds the duration of the framework agreement. This creates a challenging environment for PSS providers.

This lack of flexibility is particularly problematic for use-oriented PSS models, where procuring entities are concerned about returning assets with long lifespans, such as furniture and fixtures, every four years. For product-oriented PSS models, uncertainties

arise around whether and how a municipality can sell back products, as government institutions typically do not operate like corporations. Some municipalities find this feasible for certain product categories like ICT, while others lack the knowledge and experience to navigate these procurements effectively.

One interviewed municipality expressed specific concerns about the risks associated with take-back agreements, particularly the uncertainty surrounding the long-term viability of PSS providers. There is a reluctance to commit to such agreements if there is a possibility that the provider may no longer be operational by the end of the contract. This risk is compounded by potential conflicts of being tied to a voucher for new products while simultaneously being in a different framework agreement, limiting options and flexibility.

> ”
>
> *We are not sure if [a take-back or buy-back agreement] would conflict with future framework agreements*
>
> **– Head of business partnerships in a Nordic municipality**

The above risks, paired with the rigid nature of framework agreements, requiring all procurement aspects to be predefined, leave little room to adapt to changing circumstances or innovate with new PSS models. This inflexibility is particularly problematic because the supplier community in public procurement is dominated by large, established firms that operate primarily within linear business models, incorporating only select elements of circular practices. There is little room for startups or SMEs with more innovative or comprehensive PSS offerings.

ADDA, a procurement agency under Sveriges Kommuner och Regioner (SKR), offers guidelines for integrating “As-a-Service” elements in public procurement – a good step forward. However, centralised procurement entities like ADDA and the Danish equivalent SKI, which benefit from strong bargaining power due to their large volumes, tend to favour larger providers who can offer lower prices. This often results in smaller providers being priced out of the market. Additionally, smaller suppliers may face difficulties with pre-qualification procedures and other bureaucratic hurdles, putting them at a disadvantage compared to larger, more established companies. This dynamic reinforces the barriers, making it challenging for newer or smaller innovative companies to compete effectively in the public procurement arena.

A lack of early and meaningful pre-commercial engagement between suppliers and procurement bodies often results in missed opportunities to co-develop innovative solutions. This makes it difficult for municipalities to explore and adopt more flexible and innovative PSS options, ultimately hindering the potential for transformation in public procurement practices. Rigid and overly detailed specifications can also prevent suppliers from proposing innovative solutions that might more efficiently achieve the desired outcomes.

”

[PSS procurement] includes some relatively complex aspects, the municipality is not quite there yet, but we need to look at IT and how they have solved it

– Procurement consultant in a Danish municipality

Lifespan and logistics

PSS arrangements challenge conventional asset management practices. Assets acquired under PSS agreements often do not fit neatly into existing inventory and procurement systems, complicating the maintenance of accurate asset records. These assets are typically tied to service agreements rather than outright ownership, making tracking their condition, location, and lifecycle difficult and resource-intensive. Additionally, coordinating maintenance activities across multiple service providers and contracts can strain municipal resources, leading to potential inefficiencies and disruptions.

CASE: FROM PSS TO EXTENDED LIFETIME: HERNING MUNICIPALITY, DENMARK, 2013–2015

When we initially developed the guidelines, we engaged in technical dialogue with the market regarding the washing/renting of clothing for home care services. At first glance, the market seemed generally positive about the idea, but they immediately highlighted challenges and obstacles, such as the issue of handling clothing that had been treated and washed by their worst competitor for four years, recalls Anne-Merete Gier, a procurement consultant at Herning Municipality.

Since suppliers were not interested in handling competitors' clothing, the environmental cost-benefit analysis did not hold up. As a result, the procurement department opted for a traditional model where the municipality owns the work clothing. Instead of a circular model, the project has opened up opportunities for other sustainable initiatives. The procurement department is now focusing more on total cost of ownership (TCO) and ensuring that work clothing is passed down from one employee to another, rather than being personal, so that the clothing is only discarded when it is worn out (Alhola et al., 2017; Den Ansvarlige Indkøber, n.d.).

Uncertainty regarding Total Cost of Ownership (TCO)

PSS solutions are often perceived as more expensive than direct purchases due to the complexities involved in service agreements. Half of the municipalities interviewed cited cost as their primary concern, showing a preference for outright purchases over renting or leasing, except for short-term needs. Municipalities can prioritise Total Cost of Ownership (TCO) and sustainability requirements in their procurement decisions. Still, it can be challenging to address these priorities effectively as PSS maintenance agreement terms can be hard to estimate in terms of scope, frequency, and price throughout the useful life of the procured product.

Municipalities are required by accounting regulations to carefully consider the useful life of their assets when calculating the Total Cost of Ownership (TCO), involving cost assessment of maintaining and repairing these assets throughout their expected lifespan. ICT equipment and office machines are considered to have a maximum useful life of five years, while items like fixtures, furniture, vehicles, tools, and machinery are expected to last up to ten years. Therefore, when municipalities plan their budgets and procurement strategies, they must account for the full cost of ownership over these periods, including expected maintenance and repair expenses. Estimating the maintenance and repair needs can be challenging. Often, assets purchased through framework agreements are covered by warranties only for the duration of the agreement. Once these warranties expire, the responsibility – and cost – of maintaining the asset falls to the municipality. This underscores the importance of accurately estimating TCO to avoid unexpected expenses.

Organisations like the Danish SKI have developed specific guidelines and tools for TCO calculations to assist public procurers in integrating environmental criteria into their procurement decisions (Alhola et al., 2017). These tools help municipalities evaluate their procurement choices' long-term financial and environmental impacts.

Municipalities are generally restricted from take-back or buy-back solutions due to concerns about distorting market competition. One interviewed municipality suggested that take-back or buy-back options could be incorporated within the initial purchase agreement, with the terms reflected in the contract price. This approach would allow municipalities to recoup some costs at the end of an asset's life while remaining compliant with regulations.

16.4 Municipalities taking on PSS in innovative ways

Public institutions can achieve significant cost savings and environmental and social benefits by adopting PSS models themselves or applying these principles in innovative ways. The following two case studies illustrate how municipalities can lead by thinking beyond traditional frameworks and leveraging PSS to deliver more efficient, cost-effective, and sustainable services.

16.4.1 The municipality as a PSS facilitator

Municipalities can also facilitate a wider implementation of PSS solutions at a city level, as shown in the case of Aarhus municipality.

In January 2024, the City of Aarhus launched a three-year pilot project to implement a city-wide reusable cup system and address the growing challenge of takeaway packaging in municipal waste. The project is in collaboration with Rotake by TOMRA, a Norwegian manufacturer of reverse vending machines.

While the initial focus is on replacing single-use cups, the ambition is to expand the system to include other packaging types, such as meal boxes, as the project progresses. Thus, while the ambition is to develop the world's most attractive and effective circular system for takeaway packaging in order to minimise municipal waste, it also aims to create a knowledge base to support the implementation of EPR schemes on packaging, proposed EU legislation on packaging waste (PPWR) and the implementation of the Danish "Climate plan for a green waste sector and a circular economy" (Teknik og Miljø, Aarhus Kommune, 2023).

The reusable cup system in Aarhus already has 66 participating cafés and restaurants and 27 deposit machines across the city. So far, the system has reached a return rate of around 87 % for the cups, and 581,000 returns have been registered (Oct. 2024). It has been estimated that cups must circulate six times to be more environmentally friendly than single-use cups. Some cups, especially cold cups, have been circulated up to 32 times. End of life for most cups is just that they have not been returned. Very few are discarded for recycling due to wear or tear.

The system in Aarhus is designed as an open system, which means that reusable cups can be returned at all times to automated collection points in the city. Customers can get their takeaway drink in a reusable cup in one of the over 60 participating cafés and restaurants and return it at one of the 27 reverse vending machines (RVM) across the city. Consumers pay a 5 DKK deposit for the reusable cup, which is refunded directly to the consumer's bank account by tapping any debit-/credit card or device at the RVM when the cup is returned. The cups are then collected, transported to a sanitation facility in Aarhus for the washing, and redistributed to the participating cafés and restaurants.

Rethinking costs: municipal investment in reusable cup systems

Acknowledging that reusable packaging is more costly due to the externalised social and environmental impacts of single-use alternatives, the City of Aarhus launched an open tender process to test a reusable cup system. To support this initiative and help offset the higher costs, the municipality committed to covering a portion of the expenses for three years. In the future, single-use costs are expected to increase due to the implementation of upcoming legislation, making reuse alternatives more financially attractive. The operator of the reusable cup system must pay for the development, testing, and daily operations. This includes the infrastructure needed to collect, clean,

and distribute the cups. The goal is to create a system that can eventually run without relying on city funds. This financial support was provided under specific conditions, including achieving targets for the frequency of reusable cup use, so-called "rotations". The following table provides an overview of the requirements and the budget:

Table 11: Overview budget and rotations defined in tender proposal by Aarhus municipality.

Period	Expected rotations	Budget
Year 1	Min. 500,000	875,000 kr.
Year 2	Min. 1,500,000	1,875,000 kr.
Year 3	Over 1,500,000	750,000 kr.

The broader costs associated with single-use packaging are complex and far-reaching. Some of these costs are direct, like those related to municipal waste management and litter collection. Since much of the disposable packaging ends up in public trash bins, the municipality must manage the cleanup. However, other significant costs extend beyond waste collection. These include the negative social impacts of GHG emissions and the negative effects on urban living conditions, such as reduced quality of life for residents due to litter in public spaces. Such impacts can lower property values, harm mental well-being, and make city centres less appealing for both residents and visitors.

Before the pilot project, waste composition analysis in Aarhus revealed that 27% of inner-city waste is related to takeaway packaging (Grant et al., 2024). This figure rises to 46% when including all food and beverage packaging. First, findings on the effects of the reusable cup system suggest that it could help reduce the volume of single-use waste in Aarhus. During a weekend analysis, only seven reusable cups were found in city litter bins, while nearly 1,300 reusable cups were returned through reverse vending machines (Grant et al., 2024). This shift suggests a potential reduction in the city's waste management burden, though the exact financial savings remain uncertain. It is important to note that waste collection costs are shared among various types of waste, so removing single-use packaging might not directly translate into proportional cost savings for the municipality. In the case of Aarhus, cost savings are not expected to occur as long as the market share remains low. This outlook is anticipated to shift only if the system transitions away from a model of voluntary adherence.

Additionally, transitioning to reusable packaging has implications for environmental costs. An LCA conducted on the system in Aarhus shows that the system can reduce GHG emissions compared to single-use cups as long as each is reused at least six times, if a return rate of 83% is achieved (Bradbury et al., 2023). Reducing waste also benefits

the urban environment, leading to a cleaner city. Potentially, this can contribute to improved well-being for residents.

Overall, the case of Aarhus illustrates an innovative approach to addressing specific challenges by adopting PSS models and reducing waste while promoting sustainable consumer behaviour. By supporting the initial phases of the reusable cup system, Aarhus is not only addressing some of the immediate costs but also working toward a cleaner, more sustainable urban environment. Though immediate savings are not guaranteed, the potential for future benefits offers a promising path for managing the environmental and social impacts of takeaway packaging.

16.4.2 The municipality as a PSS actor

An alternative to purchasing PSS solutions is for municipalities to become PSS providers themselves, which is already happening in relation to schools, healthcare institutions, and administrative units. Several municipalities are exploring ways to extend the lifecycle of furniture and interior products in the Nordic region by offering municipal institutions varying access levels rather than ownership.

One of the more advantageous approaches is for municipalities to establish a warehouse for internal reuse instead of relying on a private company to manage the collection, storage, and redistribution of furniture through a PSS model. By providing this service internally, municipalities gain greater control and oversight of furniture inventories across all departments, leading to more efficient resource management and reduced waste. Unlike private companies prioritising profitability, municipalities can focus on long-term sustainability by allocating more resources toward refurbishing and preparing items for reuse. This strategy not only extends the lifespan of the products but also creates inclusive employment opportunities – social benefits that profit-driven companies might overlook.

Redistribution for reuse through a municipal warehouse

Several Nordic municipalities have either established or are in the process of setting up municipal warehouses to redistribute furniture and interior products discarded by the public sector. Often, these items are not discarded because they are broken beyond repair but because they are no longer in need or because storing or relocating is more expensive than buying new ones. While the pilot study with Oslo Municipality revealed that many individual sectors (e.g., universities, public schools, and hospitals) already have internal systems for redistributing these items, a centralised municipal warehouse increases the scale and effectiveness of such efforts. By pooling a larger supply of items and offering extended storage capabilities, municipalities can better match surplus items with the needs of other public entities. The municipalities interviewed during the pilot study implementing these systems provide a digital platform to showcase available items and expand visibility and potential demand. This approach plays a crucial role in promoting continued use of the items. Individual entities often lack the communication tools to advertise what they have available effectively. Moreover, there is often a demand

for multiple identical items (e.g., a full set of chairs for a school), which smaller entities may be unable to supply. As a result, single items can become difficult to repurpose or reuse.

SURVEY METHODOLOGY

The survey was shared in Oslo Municipality's internal Facebook group and personally sent out to relevant contacts and stakeholders in the various public services. The survey inquired about the estimation of amounts of items discarded in the last month, frequency and pattern of discarding items, the condition of the items, reasons for them being discarded, and the respondents' view on the potential benefits of a warehouse for reuse. 89 services in Oslo Municipality answered the survey. Overall, there was an even distribution between the services sector and size (defined as the number of users).

Redistributing furniture and interior products through a warehouse can increase their lifetime, significantly reduce the spending on new furniture in the overall municipality budget, avoid municipal CO_2 emissions and resource consumption, and provide inclusive jobs for people outside the labour market.

In Oslo municipality's pilot case, a conservative estimate based on the extrapolation of a survey among municipal entities suggests that 67,000 items are discarded yearly (excluding one-time discards due to renovations or relocations) – including chairs, tables, storage units, lighting, home appliances (washing machines, stoves, fridges), beds, office supplies, toys, decorations, and kitchen appliances. Respondents said 17% were in good condition and 13% in medium condition, indicating that up to 30% could be reused after refurbishment.

Table 12 provides an overview of the yearly distribution per category, including the estimated average amount per public entity.

Table 12: Overview of yearly distribution per product category.

	Chairs	Tables	Storage	Lighting	Home appliences	Beds	Office supply	Toys	Decoration	Kitchen appliances	Other	SUM
Total	9,145	5,724	5,720	4,070	4,099	3,632	10,042	1,702	3,232	4,804	4,908	**57,079**
Average per entity	7	4	4	3	3	3	7	1	2	4	4	**42**

Redistributing these massive amounts of discarded items could result in substantial economic and environmental savings. By avoiding procuring new furniture, Oslo could save approximately 122 million NOK annually, or 90,000 NOK per public entity. The most significant economic potential lies in reusing high-cost items like beds, chairs, and tables. Additionally, this reuse could prevent the production of new items, avoiding an estimated 2,723 tons of CO_2 emissions, with home appliances offering the highest potential for environmental impact.

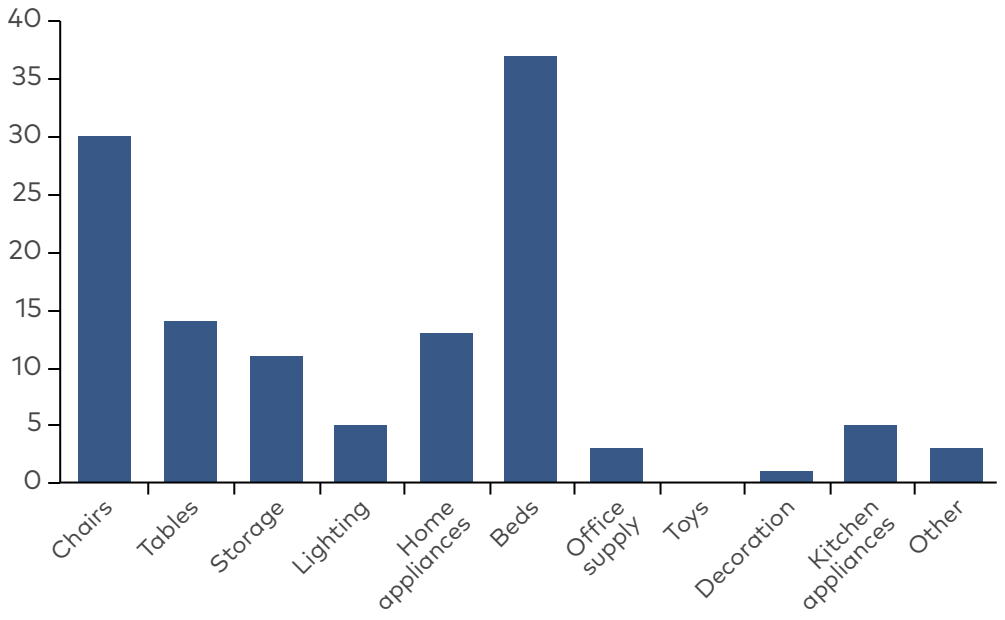

Figure 20: Overview of value of avoidable purchases of new items in millions NOK.

Reusing these items would reduce the need to produce new ones. Assuming an 80% replacement rate, where items are restored to good condition, reusing all 57,000 items can potentially avoid 2,723 tons of CO_2e. This estimate is based on a combination of the CO_2e per new item and the amount discarded for each category. Among the categories, home appliances offer the greatest potential for reducing emissions, given their higher environmental impact during production.

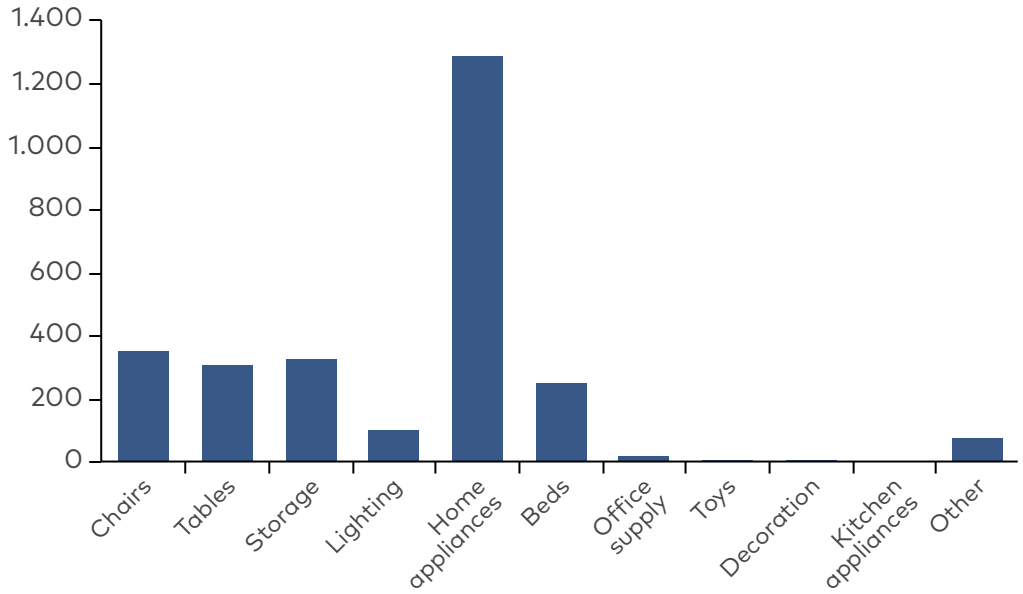

Figure 21: Overview of CO_2e avoided per product category in tonne.

Preparing all items for reuse requires both human resources and materials to some extent. Given the high salaries in the Nordics, labour costs represent a significant expense, likely exceeding the costs of establishing and renting the warehouse. Since the latter two expenses can vary significantly depending on the location, they are excluded from the current calculation. The required labour hours have been estimated based on the varying degrees of work needed to refurbish items, depending on their condition. It is projected that approximately 71 full-time positions would be necessary to prepare all items for reuse. However, this estimate is indicative, as more accurate figures would depend on a detailed understanding of the specific repairs required for each item category.

Based on all these calculations, the reuse of discarded items is projected to result in total savings of 79.7 million NOK, in addition to the environmental benefits and the social impact of creating jobs. The economic savings are primarily driven by reduced procurement costs for new items, offset by labour costs for refurbishing the discarded goods. The estimated requirement of 71 full-time positions to prepare the items accounts for most labour expenses. If these roles are filled through inclusive employment programs, salary costs could be reduced, improving the financial outcome. This would make the overall economic balance more favourable, reinforcing the financial viability of the initiative while maximising its social benefits.

Table 13: Balance sheet.

Balance sheet	
Saved costs from procurement of new items	122 mill. NOK
Salary costs	- 42.3 mill. NOK
Financial result	**+ 79.7 mill. NOK**
Avoided CO_2e	2,723 ton
Number of inclusive jobs	71 jobs

Key recommendations for municipal warehouse operations:

1. Prioritise temporary storage for items displaced during renovations or relocations.
2. Centralise warehouse operations in one large facility rather than multiple smaller ones.
3. Create space for a showroom to display available items.
4. Offer items for free to simplify the process and increase uptake.
5. Provide free transport to and from the warehouse to encourage participation, especially for entities without transportation.
6. Focus on high-demand, high-impact items such as chairs, home appliances, tables, and office supplies.
7. Utilise the warehouse as a source of inclusive jobs to reduce costs and increase social benefits.

Municipal leasing

Municipalities can take another step toward becoming full-fledged PSS providers through leasing programs. One example is the municipality of Gothenburg, where each public entity leases furniture, interior products, ICT equipment, vehicles, and even unique items like a chocolate fountain.

This system was established in 1992 to improve oversight and management of the various leasing agreements municipal entities were entering into. Since 2007, Gothenburg has mandated that all municipal entities lease furniture and fixtures valued above 50% of the 'base amount' (approximately SEK 28,000) with a repayment term of more than three years. These leasing agreements are managed through Gothenburg City Leasing, and municipal entities pay a monthly fee for each item. Once the item has been fully paid for, the entity gains the right to use it indefinitely, though ownership remains with Gothenburg City Leasing.

The system is highly efficient, thanks to a well-functioning IT platform that enables just six employees to manage approximately 100,000 leasing agreements. This approach enhances operational control, reduces the need for large upfront purchases, and aligns with sustainable practices by encouraging longer product lifecycles and resource management across municipal sectors.

16.4 Possibilities for public procurement to enhance PSS adoption

Organisational inadequacy and limited familiarity with PSS solutions are significant barriers for municipalities considering alternative procurement methods. PSS involves complex arrangements, such as long-term service agreements or shared ownership, which the procurers are unfamiliar with and perceive as risky. Even though public agencies, in principle, promote "as-a-service" models, the confidence to pursue these options remains low. The knowledge gap makes it difficult for procurement teams to draft suitable contracts, evaluate PSS proposals, or manage the logistics of these agreements.

Innovation in public procurement: Countries like Norway and Finland are exploring innovative public procurement methods that could help overcome some of the barriers discussed. Years back, this approach was widely applied in Sweden and was very successful (Bauer et al., 2014). Today, Norway seems to take the lead, as the National Programme for Supplier Development (Leverandørutviklingsprogrammet / LUP) is designed to accelerate innovation and the development of new solutions through strategic public procurement. This program not only fosters innovation but also creates new market opportunities by encouraging suppliers to develop solutions tailored to municipal needs.

In innovative procurement processes, municipalities avoid specifying pre-defined solutions. Instead, they communicate their needs and desired functions to the market, inviting businesses to propose the best possible solutions through a marked dialogue (Innovative Anskaffelse, 2022). This approach allows municipalities to harness the creativity and expertise of suppliers, encouraging tailored solutions that may not have emerged from more traditional procurement processes. EU procurement regulations allow for flexibility as long as certain principles are followed. For example, Malmö has successfully required service and repair options for prams, demonstrating that the market can adapt to the demands of significant customers like municipalities. By addressing these barriers and capitalising on these possibilities, municipalities can unlock the full potential of PSS solutions, driving more sustainable and cost-effective procurement practices in the public sector.

Offering direct awards in public procurement: This offers a streamlined approach to acquiring goods and services, particularly for smaller contracts or specialised needs. Still, the method is only applicable for procurements under the regulatory thresholds. Direct awards are particularly beneficial in encouraging small and medium-sized enterprises (SMEs) to participate in public procurement by reducing the barriers encountered in

larger tenders. Through direct awards, councils can pilot new PSS models, allowing for the testing of their effectiveness on a smaller scale before wider adoption is considered. This strategy fosters innovation and supports the transition to more sustainable practices by enabling tailored solutions that meet specific public needs. Ultimately, within the confines of procurement regulations, direct awards can be crucial in advancing efficiency, sustainability, and innovation in public services.

CASE: FURNITURE AS A SERVICE IN AALBORG MUNICIPALITY

While interviews have repeatedly highlighted the challenges of procuring PSS solutions, Aalborg Municipality has made a notable advancement in public procurement by incorporating circular economy principles into the refurbishment of school environments. In this procurement initiative, the municipality issued a tender that focused on reusing, repairing, and repurposing old school furniture to create sustainable and innovative learning spaces.

Aalborg Municipality recognises that the success of this project was heavily dependent on extensive collaboration with various stakeholders, including Aalborg University, local schools, and sustainability networks. This collaborative effort ensured that resources from outdated learning environments were effectively utilised without compromising on quality. The Danish furniture manufacturer Højer Møbler was selected to implement the project, offering a solution that combined furniture reuse with pedagogical design, aiming to enhance student well-being and improve the learning environment.

By viewing old school furniture as a resource rather than waste, the municipality is setting an example in applying circular economy practices within public procurement, demonstrating potential for broader application in the non-traditional PSS-procurements across other sectors. (Netværk For Bæredygtig Erhvervsudvikling Norddanmark, 2018)

Capacity building and organisational strengthening: Procurement entities should prepare ambitious circular visions and goals with operational strategies, conducive structures, capacitated procurers and effective systems. Expanding knowledge and providing tools will help public procurers identify and implement PSS opportunities more effectively. Clear guidelines on integrating PSS, such as structuring contracts and managing products and assets procured through PSS, might increase confidence in their use. These resources could gradually increase demand for PSS, encouraging suppliers to offer more tailored solutions. This, in turn, may improve sustainability and efficiency outcomes in public procurement over time.

Operating as a PSS provider: An alternative to purchasing PSS solutions is for municipalities to become PSS providers themselves. By taking on this role, they can explore innovative ways to extend the lifecycle of furniture, interior products, and other goods used in public institutions. In the Nordics, several municipalities have adopted this approach, offering access to products rather than transferring ownership. For example, public institutions may lease furniture, ICT equipment, and other goods directly from the municipality, which retains ownership and manages maintenance. Additionally, municipalities can play a key role in redistributing discarded items for reuse, ensuring that these products find a second life within other institutions or community spaces. These innovative approaches can lead to significant economic and environmental benefits by reducing the need for new purchases, cutting down on waste, and optimising the use of resources throughout the lifecycle of various products.

Facilitating PSS implementation at a city level: Municipalities can support the adoption of PSS solutions at the city level, as seen in Aarhus' Rotake reuse system. This initiative, funded in part by the municipality, was introduced in participating coffee shops and restaurants to help reduce waste from takeaway packaging. By encouraging the return of reusable cups, Aarhus aims to decrease waste while promoting more sustainable consumer habits. This example shows how municipalities can adopt new approaches to foster sustainability, moving beyond traditional methods of waste management.

LIST OF RESOURCES FOR FURTHER INSIGHTS INTO PUBLIC PROCUREMENT STRATEGIES FOR ENHANCING PSS ADAPTION

- City Loops (2023): Circular Procurement in Europe: Handbook for local and regional governments
- Interreg North Sea Region ProCirc (2022): Circular Procurement Transformation Guidance
- European Commission (2021). An analysis of SMEs needs in public procurement
- Procure Partnerships (2020). The Benefits of Direct Award

17. CONCLUSIONS

This project has explored the potential of Product-Service Systems (PSS) in advancing the transition toward a circular economy in the Nordic region. Three years of devoted efforts with literature studies, interviews, workshops, and 16 pilot projects have created a significant pool of knowledge on barriers and enablers of successful PSS models. The project has analysed PSS models' environmental potential and identifies the conditions under which these service-based solutions can contribute positively to environmental sustainability.

The findings draw attention to the important roles of policymakers, financial actors, public institutions, and businesses in creating more favourable conditions for the broader adoption and scaling of PSS solutions. Conclusions and recommendations for pursuing PSS in the Nordics have been prepared and discussed with numerous actors.

State of PSS adoption in the Nordics

The project has identified more than 300 PSS business cases in the Nordics. The most financially sustainable solutions are found in the B2B segment, where economic viability appears more easily established than in the B2G and B2C markets. Total Cost of Ownership calculations are more common in B2B settings, allowing businesses to understand better the long-term economic benefits of renting or leasing products. Contract durations in the B2B segment also tend to be longer, offering PSS providers greater financial stability and planning security. However, PSS providers in the B2B market must be aware that their solutions often require extra work from end-users and must adjust their business models accordingly

PSS adoption in the B2C market has been less disruptive, with providers facing challenges translating the apparent consumer interest into long-term service subscriptions. Consumers in B2C markets tend to value personalised services and flexibility, which require significant internal resources from PSS providers and complicate scaling efforts.

The B2G market is enormous and characterised by the procurement of large volumes, often guided by national and local government sustainability visions. However, these positive factors have not led to a significant uptake of PSS solutions in the public sector due to organisational and bureaucratic constraints.

Environmental Potential of PSS

The project's life cycle assessments (LCAs) show that many PSS models hold significant environmental potential compared to traditional ownership models. In theory, PSS enables a decoupling from the linear economy by offering services rather than products, thus creating incentives to increase product lifetime expectancy and reducing resource consumption while maintaining economic growth. However, this potential is contingent on mitigating unintended negative consequences such as rebound effects and induced

impacts related to system operation. LCAs should be applied to assess potential environmental risks and ensure that PSS solutions achieve their sustainability goals. PSS providers can reduce induced impacts and maximise environmental benefits by identifying hotspots and unintended risks before implementation.

17.1 Recommendations

The recommendations below are tailored to enable four main stakeholder groups to contribute to strengthening the implementation of PSS models in the Nordics.

17.1.1 Recommendations for businesses

Nordic businesses looking to adopt or scale PSS models encounter challenges created or influenced by industry dynamics, market maturity, market segment (B2B, B2G, B2C), financial backup, and their specific business model. Several common obstacles emerge across sectors, product groups and market segments. The following recommendations offer general strategies for overcoming these challenges, applicable to a wide range of PSS providers, regardless of company size or industry:

Clearly define and communicate the added value of PSS offerings

One of the key challenges for PSS providers is demonstrating the unique value of their offerings compared to traditional product sales. Businesses should emphasise the long-term economic advantages of PSS through tools like Total Cost of Ownership (TCO) calculations and environmental/climate advantages documented through LCA. Also, other benefits, such as convenience, better product performance, enhanced maintenance services or social benefits should be more clearly communicated to the potential market. For both B2B and B2C segments, addressing perceived inconveniences and illustrating how PSS models improve the customer experience is essential. Real-life case studies and customer testimonials can build trust and drive interest.

Maintain personalisation while scaling

Many PSS customers highly value personalised customer service and strong support. Providers in the B2B sector need to consider not only their business clients but also the end users when designing and communicating their services. As SMEs scale their PSS offerings, maintaining the personalised approach that contributed to their initial success can become challenging. To address this, companies must balance implementing more standardised and efficient processes while preserving the personal relationships that keep customers engaged and satisfied. Digital tools can help achieve this by automating routine tasks while enabling tailored interactions where needed. Mapping customer journeys can also assist in identifying key touchpoints where personalised service adds the greatest value, allowing providers to tailor their offerings to enhance customer satisfaction and loyalty effectively.

Minimise unintended consequences and maximise environmental potential

PSS providers should proactively conduct risk and hotspot assessments before and during implementation to enhance environmental outcomes. Tools like Life Cycle Assessment (LCA) can help companies identify key environmental hotspots and improvement areas to optimise overall system efficiency. To maximise environmental benefits, providers should prioritise designing products for durability, ensuring high usage rates, substituting resource-intensive systems, and reducing emissions throughout operations. Additionally, consider how customer behaviour may impact environmental performance, as rebound effects or other unintended consequences can undermine the positive impact of the PSS model.

Foster strong relationships with suppliers

In circular value chains, building and maintaining strong, long-term relationships with suppliers is critical, as it ensures a reliable supply of spare parts and service-related components—key to maintaining product functionality and lifecycle performance. PSS companies that develop their products have greater potential to design for PSS, enabling better durability and repairability. Power dynamics within the value chain can pose challenges for companies relying on external suppliers. For instance, suppliers of products developed by large, powerful companies may struggle to provide essential guarantees, such as extended product lifespan warranties. This can create barriers for smaller PSS providers, limiting their ability to offer comprehensive service guarantees or circular solutions. Diversifying supplier relationships can increase resilience and flexibility.

Align financial metrics with long-term goals

To thrive in today's evolving business landscape, PSS providers must rethink traditional financial metrics and embrace those that better align with service-based models. Prioritising metrics focusing on sustainability, recurring revenue, and long-term financial resilience is key to demonstrating value to investors and supporting steady growth. By moving away from conventional sales-driven metrics, companies can showcase the stability of their business models over time. When traditional financing options fall short, PSS providers should consider alternative asset management strategies, such as lease-and-lease-on or sale-and-leaseback models. These strategies can provide much-needed liquidity, relieve the financial burden of asset ownership, and offer flexibility in navigating market uncertainties. By integrating these approaches, PSS companies can optimise cash flow, lower risk, and create a more sustainable growth path, ultimately making their business more attractive to investors and better equipped to weather financial challenges.

Utilise existing tools and foster collaboration

PSS providers should leverage existing tools and templates to enhance and streamline their business models. These ready-made resources can support businesses in efficiently implementing best practices, optimising operational processes, and reducing development costs. The most relevant tools, guides, and templates for Nordic PSS companies are outlined in the comprehensive guide developed as part of this project. By

utilising these tools, companies can focus on refining their unique offerings and delivering greater value to customers while accelerating the integration of PSS into their existing frameworks. Additionally, fostering collaboration between PSS providers within the same product category or across sectors facing similar challenges can unlock valuable synergies. Sharing knowledge, exchanging best practices, and working together can help businesses overcome common barriers, such as scaling operations and improving customer engagement strategies.

17.1.2 Recommendations for (Nordic) Policymakers

Nordic policymakers must focus on creating a level playing field to support the development of PSS models and help them compete with traditional linear models. This involves internalising linear business models' environmental and social costs to ensure that companies presenting circular approaches, like PSS, are not disadvantaged by higher operational costs.

Implement Extended Producer Responsibility (EPR) schemes

EPR schemes can be an effective tool in driving circular practices by making producers financially responsible for the end-of-life management of products. This encourages innovation in circular design, product reuse, and waste prevention. Integrating these schemes with other policy instruments across the Nordic region can promote a more comprehensive shift to circular practices. Eco-modulated fees within EPR schemes are important to promote sustainable product design. However, they must still provide sufficient incentives to reduce the number of new products introduced to the market, ensuring that models like PSS, which are not based on continuous product sales, remain competitive.

Introduce a tax shift from labour to natural resources

A tax shift from labour to natural resources would strongly support PSS development, especially in Nordic countries where high labour costs make repair and maintenance services expensive. Reducing taxes on labour and increasing taxes on virgin resources would lower the cost of labour-intensive services essential to PSS models. Additionally, tax incentives, such as VAT reductions on repair and rental services, could make circular services more appealing and affordable for consumers.

Provide targeted public funding

Public funding targeting circular companies is essential to help PSS providers – particularly start-ups and SMEs – overcome challenges in securing traditional financing. Their innovative business models are often perceived as high-risk or incompatible with conventional financial evaluation methods. Offering targeted funding through grants, subsidies, and low-interest loans can enable these companies to invest in research and development, scale their operations, and deliver more sustainable solutions to the market. Many consulted PSS companies have successfully expanded and scaled their business models thanks to such green financing schemes, demonstrating the critical role that public funding plays in accelerating the growth of circular business models.

Offer guidance on environmental reporting standards

Policymakers should provide clear guidance to help PSS providers comply with environmental reporting standards, such as EU Directives and national anti-greenwashing legislation. Expanding initiatives like Denmark's Business Service Hubs ("Erhvervshuse") and Innovation Norway would further assist PSS providers in navigating complex regulatory frameworks and building capacity and consumer trust. Additionally, guiding policy frameworks specific to their business models is crucial, as many companies are hesitant to explore the regulatory landscape for fear of inadvertently violating the rules. Clear, accessible information will empower PSS companies to operate confidently within compliance guidelines while driving sustainable innovation.

Develop sector-specific strategies and action plans

To successfully bridge the gap between broad circular economy ambitions and on-the-ground implementation, sector-specific strategies are crucial. While overarching frameworks are valuable, they often fail to address different industries' unique challenges and opportunities. By working closely with industry stakeholders, policymakers can identify each sector's barriers – related to regulation, market dynamics, or technological readiness – and craft strategies that effectively address these issues. Targeted action plans should include incentives for circular practices, clear guidelines for compliance, and sector-specific resources to aid businesses in transitioning to circular models. By establishing this supportive ecosystem, Nordic governments can drive the shift from linear to circular economies, positioning PSS as a key driver of sustainable production and consumption across the region.

17.1.3 Recommendations for public institutions

Public institutions play a pivotal role in driving the adoption of PSS by integrating circular economy principles into procurement processes. However, it is important to recognise that not all products are best suited for PSS, and ownership models can also effectively support sustainability when based on circular design principles and sustainability criteria. Current procurement frameworks often favour traditional linear models, which can limit innovation and hinder the uptake of PSS. Public institutions have the power to lead by example, creating demand for circular products and solutions while fostering sustainable business models, including PSS.

Revise public procurement policies

To enable broader adoption of PSS, public procurement policies must move away from rigid, predefined specifications favouring traditional product ownership. Instead, procurement strategies should focus on functional requirements what a product or service needs to achieve and Total Cost of Ownership (TCO), allowing suppliers to propose innovative, service-based solutions. For example, by shifting from buying products to procuring services (such as renting or leasing), public institutions can reduce their environmental impact and encourage the market to develop more sustainable offerings. Initiatives such as Norway's National Programme for Supplier Development

(LUP) are effective models for this shift, encouraging market innovation by focusing on the institution's needs rather than predefined solutions.

Prioritise total cost of ownership (TCO) and sustainability

Public institutions should incorporate Total Cost of Ownership (TCO) calculations and sustainability criteria in their procurement decisions rather than focusing solely on upfront costs. PSS models may appear more expensive initially but often result in long-term savings through reduced maintenance and repair costs. Providing clear tools and guidelines for TCO calculations, similar to those developed by Denmark's SKI (Statens og Kommunernes Indkøbsservice), will help public entities better assess PSS's financial and environmental benefits throughout the product or service lifecycle. This approach aligns financial decisions with circular economy principles, encouraging long-term sustainable practices.

Enhance capacity-building initiatives

Public institutions should invest in training and capacity-building for procurement professionals to ensure they understand how to incorporate PSS and circular economy principles into procurement strategies. Knowledge-sharing platforms and practical tools should be provided to guide procurement professionals in making climate- and resource-conscious decisions. By fostering a deeper understanding of circular procurement, public institutions can reduce knowledge gaps and drive the successful integration of PSS in their operations.

Engage suppliers early in the procurement process

Public institutions should adopt a proactive approach by engaging suppliers early in the procurement cycle. Pre-commercial dialogues between public buyers and potential suppliers can raise awareness of PSS models, align offerings with the circular economy, and prepare suppliers to meet the requirements of these service-based models. This early engagement can reduce procurement delays and create a more responsive market, increasing the likelihood of receiving innovative PSS bids.

Encourage smaller contracts and pilot projects

Public institutions should leverage direct awards and smaller contracts to foster experimentation with PSS models, particularly through pilot projects. Direct awards for smaller-scale contracts can reduce barriers to entry for SMEs, enabling them to showcase innovative solutions without the heavy administrative burdens of large-scale procurements. By testing PSS models on a smaller scale, public bodies can tailor services to their specific needs while encouraging innovation within the market.

Think outside the box – facilitate the adoption of PSS models directly

Public institutions can achieve significant cost savings and environmental and social benefits by adopting PSS models themselves or applying these principles in innovative ways. For instance, the pilot case of Oslo municipality shows that by establishing a system, a digital platform and a centralised warehouse for redistributing unwanted furniture to other public services, the municipality has the potential to save CO_2e and

public spending on new furniture while creating inclusive jobs. This way, the municipality uses the same mechanisms as a PSS provider for its public service entities, providing access over ownership and obtaining similar benefits as a private PSS provider. Municipalities can also address specific challenges by adopting PSS models in unexpected settings. Aarhus' Rotake reuse system, which was implemented in coffee shops to tackle waste and littering, is a prime example of how PSS can be applied creatively to solve environmental issues. By incentivising the return of reusable takeaway cups, Aarhus is reducing waste while promoting sustainable consumer behaviour. These examples show how municipalities can lead by thinking beyond traditional frameworks and leveraging PSS to deliver more efficient, cost-effective, and sustainable services.

17.1.4 Recommendations for financial actors

While all businesses need a strong case to attract investments, non-linear business models like PSS face additional hurdles. Traditional financial evaluation methods, such as key economic indicators and asset structure, are often misaligned with the long-term value creation that PSS offers. To better support PSS and other circular business models, financial actors and investors must adapt their evaluation criteria to reflect the unique financial dynamics of these models. The following recommendations outline key measures to achieve this shift:

Develop expertise in PSS financial structures

Banks, investors, and financial institutions should ensure they possess the internal expertise to manage the complexities of PSS models. PSS relies on recurring revenue streams rather than traditional upfront sales, necessitating tailored financial solutions that align with the cash flow dynamics of these models. By offering products that reflect the unique needs of PSS – such as longer repayment periods or flexible terms – financial institutions can help PSS providers scale without the limitations of conventional loan structures.

Implement risk-sharing mechanisms

Financial institutions should explore risk-sharing mechanisms, such as government-backed loan guarantees, to lower the risk of investing in PSS solutions. Co-payment structures, where governments guarantee a portion of the loan, can encourage banks to finance circular businesses and alleviate the capital constraints that often hinder PSS providers. These mechanisms will enable greater investment in sustainable models and reduce perceived financial risks.

Expand green financing to include PSS

Institutions like the Nordic Green Bank (Nefco) should broaden their investment criteria to include circular business models like PSS, often overlooked in favour of linear models. By offering dedicated support to national and cross-Nordic PSS businesses, green financing institutions can help overcome significant financial barriers, fostering a robust circular economy in the region.

Collaborate on knowledge-sharing and upskilling initiatives

Financial actors should work closely with public institutions to promote knowledge-sharing platforms and upskilling initiatives. These efforts should equip PSS providers – particularly startups and SMEs – with the financial management skills they need to access formal and informal capital. Upskilling PSS companies in understanding investor expectations and managing their finances will help them scale successfully within the circular economy.

17.1.5 Final thoughts and path forward

In conclusion, this project underscores the potential of PSS in the Nordic region's transition to a circular economy. By implementing the key recommendations outlined in this report, stakeholders can collectively create the conditions for PSS to thrive. As the shift from a linear to a circular economy accelerates, PSS can play a pivotal role in reducing resource consumption, fostering sustainability, and driving economic innovation. Continued collaboration between businesses, policymakers, financial actors, and public institutions is essential to realise this potential fully. Only by working together can we harness the full potential of PSS and unlock a more sustainable, resilient future for the Nordic Region.

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19. ABBREVIATIONS AND GLOSSAY

Abbrevia	Term	Definition
B2B	Business-to-Business	A type of commerce where transactions are conducted between businesses rather than directly with consumers.
B2C	Business-to-Consumer	A type of commerce where businesses sell products or services directly to consumers.
B2G	Business-to-Government	A type of commerce where businesses provide goods, services, or information directly to government and public agencies and organisations.
B2B2C	Business-to-Business-to-Consumer	A type of commerce where businesses provide its product or service to another business, which then provides it to the end consumer.
BIM	Business Information Modelling	A collected digital model of a building, used to explain terms, definitions, and connections between objects in construction.
CapEx	Capital Expenditure	The capital used by an organisation or company to procure, maintain, and improve assets and activities.
CBAM	Carbon Border Adjustment Mechanism	A carbon charge on carbon-intensive products, introduced under European Parliament and the Council's ordinance 2023/956.
CE	Circular Economy	An economic system focused on reusing and regenerating materials and products.
CO_2-eq	Carbon Dioxide Equivalent	A metric to compare the emissions from various greenhouse gases based on their global warming potential.
	Culture of Ownership	A cultural tendency for consumers to prefer owning the products they acquire.
	Direct Rebound Effect	Direct impacts in response to the introduction of a PSS model, affecting environmental outcomes.
	E-commerce	The buying and selling of goods and services, typically over the Internet.
EOL	End of Life	The final stage of a product's lifecycle, often involving disposal, recycling, or repurposing.

ETS	Emission Trading System	The European Union's system, established in 2025, to facilitate carbon emission trading and reduce greenhouse gas emissions.
FU	Functional Unit	A term for the amount of a product or system, based on its performance in its intended end-use.
GHG	Greenhouse Gas	Gases that trap heat in the Earth's atmosphere, contributing to global warming and climate change
ICT	Information and Communication Technology	A broad term for technologies facilitating communication, including wireless networks, the Internet, cell phones, software, and middleware.
	Indirect Rebound Effects	Indirect impacts related to broader systemic effects that occur when a PSS model is implemented.
	Lease-and-Lease-On	A model allowing an entity to lease products from a third-party lessor and then sublease them to others, acting as an intermediary.
LCA	Life-Cycle Assessment	The evaluation process of a product's environmental impact throughout its entire life cycle.
	Linear Economy	An economic model where products are purchased, used, and then disposed of.
LR	Loss Rate	Represents the ratio of losses, such as product loss, associated with a product-leasing model.
	Rebound Effects	Effects that occur when benefits from a PSS are diminished by changes in customer behaviour, impacting environmental goals.
PaaS	Product-as-a-Service	A specific application of the XaaS model for physical products, where customers access a product without owning it, and the provider manages maintenance and end-of-life processes
PCF	Product Carbon Footprint	Measures the greenhouse gas emissions generated across the lifecycle of a product or service.
POM	Product-Ownership Models	Business models that challenge traditional ownership transfer, common in linear economies, by keeping ownership with the provider.
	Product-Oriented Model	A model in which product ownership is transferred to the consumer, often with additional services like maintenance contracts.
	Product Pooling Model	A model where a product remains owned by the provider and is made simultaneously available to multiple users, who pay for its use.

PSS	Product-Service System	A business model that offers products, services, or outcomes to facilitate shared or collaborative consumption, often with pro-environmental goals.
	Result-Oriented Model	A model where the provider commits to delivering a specific result or outcome to the customer, with emphasis on service rather than the product itself.
	Sale-and-Leaseback	An agreement where the owner sells an asset to a purchaser and then leases it back, allowing the original owner to continue using the asset while freeing up capital.
TCO	Total Cost of Ownership	A financial estimate considering all costs associated with owning, operating, and maintaining a product over its entire life cycle, including initial purchase, maintenance, and disposal.
	Use-Oriented Model	A Product-Service System model where a provider retains product ownership but grants customers usage rights, often through rental or leasing
XaaS	X-as-a-Service	An umbrella term for business models where products, software, or services are delivered as a recurring service rather than a one-time purchase.

ANNEX 1: PRODUCT GROUPS AND PILOT PROJECTS

The 16 pilot projects conducted as part of the **PSS in the Nordics** initiative are outlined below, with product categories assessed in each pilot highlighted in **bold**. These pilots provided practical examples of PSS implementation across a variety of sectors, showcasing the potential of PSS models to improve sustainability and resource efficiency. Key activities undertaken during each pilot are summarised after the company name, giving an overview of the specific methods, challenges, and results from these real-world applications.

Product Group	Sub-Group	Pilot project
Trans-portation	Passenger cars	**Sirqel (NO):** Mapping Nordic financing opportunities, assessment on barriers to obtain financing for SME PSS companies and evaluating options to overcome the barriers. **Rent-a-Bike (FO):** Assessing increased appeal of PSS solutions, comparing the environmental impact of transportation modes, and developing strategies for waste reduction. **Liisabike (DK**): Expanding the business model to include product pooling to increase the utility of the cargo bikes and overcome current challenges with stock, capacity and scaling.
	Scooters	
	Boots	
	Bicycles	
Packaging	**Plastic & singly-use packaging**	**KleenHub (DK):** Conducting an environmental assessment of the PSS model for reusable plastic service compared to the linear model with disposable plastic and ceramic service. The purpose is to determine under what conditions the service is environmentally advantages to improve operations.
	E-Commerce	**REZIP (DK):** Developing an impact assessment tool, for continued evaluation and optimisation of PSS solution.
	Freight packaging	**Looping (NO):** Customer survey on perspectives on reuse and recycling, development of environmental calculation model, evaluations of options to establish new partnerships, and an assessment of Nordic regulatory frameworks for ethical marketing legislation and compliance as a PSS company within that framework.
Machinery & tools	**Heavy machinery**	**Nethire (DK):** Qualifying critical assumptions and conditions form the initial LCA (Life Cycle Assessment) study to strengthen the environmental impact documentation and highlight the potential environmental benefits of PSS compared to individual ownership. **Hjortkær Maskinfabrik (DK):** Piloting a more robust B2G business model, focusing on optimising existing PSS offerings, disseminating economic and environmental benefits, and identifying relevant financial leasing options for public entities to boost PSS adoption in public procurement.
	Processing equipment	
	Chemicals	
	Handheld tools	
Household appliances & furniture	White goods & Large appliances	**Furnlease (SE):** Investigating and analysing ways to reach potential customer groups and increase awareness of PSS for furniture and its environmental benefits. **CoHabit (SE):** Establishing B2B cooperation on supply and demand, increasing process efficiency in value distribution, developing roadmaps for scaling the business model, and assessing the sustainability impact of business activities. **Oslo Kommune (NO):** Implementing an effective PSS model to ensure increased reuse of furniture and other inventory in the Oslo municipality. Overview of product flow in furniture reuse, mapping potential partnerships, and developing a model.
	Furniture	

Products for children	Children's clothing	**Barnalán (IS):** Mapping and optimising the value chain, identifying new partnerships, and assessing awareness of customers on circularity potentials of the PSS model.
	Toys/ equipment	
Textiles	Workwear & household textiles	**Vaatepuu (FI):** Assessing behaviour-changing measures for sustainable consumer behaviour, evaluating opportunities for expansion into the Nordic market, identifying Nordic partnerships, and developing B2C and B2B strategies
	Clothing	
Seasonal & special occasions	Party & event equipment	**Iceland Camping Equipment (IS):** Assessment of local market development opportunities through surveys, assessing opportunities and barriers to market expansion in Sweden and Norway, mapping tourism hotspots, and value chains assessment and development of potential value chains with market expansions.
	Sports, camping & hiking gear	
Electronic equipment & solutions	Computers & Smartphones	
	Printers	
	Batteries	
	Cloud-Based Solutions	
Buildings	Buildings & space	**Fischer Lighting (DK):** Developing conceptual configuration of LaaS (Lighting as a Service), testing LaaS configurations with potential customers, implementing a new LaaS service in the Nordic region, including assessment of environmental and socio-economic benefits. **Mellow Design (DK):** Establishing new partnerships, assessing regulatory frameworks, conducting customer interviews and business model iterations, and developing a model covering a large geographical area without increased environmental impact
	Efficiency	
	Lighting	
	Temporary construction	
Other	Agriculture & nature preservation	
	Plants	

ANNEX 2: ASSUMPTIONS FOR ENVIRONMENTAL ASSESSMENT

Kleen Hub

The primary purpose of the Kleen Hub pilot was to assess the environmental impacts and potential savings of using reusable cups through PSS. To achieve this, a quantitative assessment of their system and environmental impacts, compared to a single-use scenario, and a qualitative analysis of customer interaction with the system were conducted. A functional unit was created to encompass the function that needed to be provided based on the consumption of reusable cups in a selected case café, which was then aggregated to reflect the annual cup usage.

The functional unit (FU) was 13,036 servings of hot beverages in to-go cups, corresponding to 36 servings a day for one year (365 days).

Based on data and assumptions from Kleen Hub, the cup has a technical lifespan of 200–300 uses and a return rate of 98%, corresponding to a loss rate of 2%. As these parameters are estimated to be relatively high for such a system, the assumptions have been tested through sensitivity analysis to investigate their overall impact on the results.

The reference flow to estimate the number of cups, service and operation needed to fulfil the functional unit, is estimated based on the formula for estimating reference flow in PSS (RF=(FU/NU) + (FU/NU) * LR * (NU-1)), the Kleen Hub reference flow was:

RF = (13,036/250) + (13,036/250) * (0.02) * (250-1) = **312 Kleen Hub cups.**

The included processes are:

1. 312 cups and lids produced (49g)
2. Washing per number of needed servings per year minus cups lost in the system = 13,036 servings – 261 lost cups = 12,775 washing
3. Operation per year
4. Waste management according to the cups returned and used 250 times, and cups disposed at the customer.
    a. Recycling: 51 cups
    b. Incinerated: 261 cups
5. All transportation is measured in kgkm

As the single-use cup cannot be reused, the total number of cups needed was the total number of servings to fulfil the FU: **13,036 single-use cups.** The included process are:

1. One cup and lid (24 g) multiplied by the number of cups needed in reference flow 2
2. Transportation in kgkm
3. Incineration for all cups in the reference flow

The system boundary for the Kleen Hub reference flow included all lifecycle phases, including operation, capital goods and washing, excluding important parameters regarding user behaviour. Parameters such as user transportation, whether users washed the cups before returning them, or any potential rebound effects were not included. However, these parameters were explored in a user survey, where users were questioned about their behaviour based on questionnaires and on-site interviews. Some critical assumptions and system boundaries were considered, and some of these were included in the results:

- **Transportation:** The cups are washed in the cafés as part of the existing facilities, meaning they are not transported to an external washing service. Furthermore, a key finding from the survey was that many users were first-time users, and the Kleen Hub service had not existed long enough to make general assumptions about user behaviour. Some users, however, expected to return the cups as part of their existing biking routes or by walking as they lived nearby. Therefore, added transportation during the use phase was not included, even though this is often considered a major negative impact of PSS. However, the system does not include additional transportation to and from cleaning and maintenance, as the cups are washed at the café. This is often seen as a major induced impact for PSS, but as Kleen Hub chose to use decentralised washing, their system does not include additional emissions from transportation.
- **Rebound effects (economy):** Rebound effects from the implementation of the PSS were not included. However, two important parameters, economy and substitution rate, could influence the possibility of rebound effects. As part of a campaign to raise awareness about the reusable cup system, the café offered a 10% discount on beverages when choosing a reusable cup. The potential rebound effects of this discount were not further investigated, even though the user survey showed that the discount was a great driver for choosing the reusable cup.
- **Rebound effect (substitution):** It was assumed that a reusable to-go cup would have a 1:1 replacement of another to-go cup, which, in this case, was considered a single-use cup. However, a possible consequence of the system is that the PPS might replace other reusable cups. This could either increase or reduce emissions: 1) if customers already own a cup but choose to use the Kleen Hub system, this will increase emissions, as the Kleen Hub cup would be an additional production of cups, or 2) reduce the need for producing other reusable cups, if the costumers would have bought a reusable cup, but now use the Kleen Hub system as an

alternative to owning their own. In the user survey, 30% said they would prefer to use their own cup (to avoid returning the cup). However, they did not specify whether this would replace another reusable cup.

- **Return rate:** The return rate was estimated based on Kleen Hub's previous system and aggregated data from four weeks of system piloting at a case café. However, asking the users to return the cup was a major barrier to using the system as they either were aware they wouldn't return it in time or already had multiple cups "stacking up" at home. A 98% return rate is considered high and might be unrealistic. Even though the rate is based on historical data, the importance of the return rate was still investigated during the pilot.
- **Technical lifespan/number of uses:** The technical lifespan/number of uses in this assessment is based on how many times the cups can technically be used before they are worn out and need to be replaced. However, it must be assumed that with such frequent use, some cups may be lost from the system, not only because they can no longer be used technically but also for other reasons. As the technical lifespan of the products are high, this assumption is also tested to investigate the importance of this parameter.
- **Operation and capital goods:** Operation of the system and the additional capital goods/equipment needed to operate the system is included in the assessment. This includes a tablet needed to use the system at the café and energy useage from the tablet and Kleen Hub server. As the investigation is done for one year, these emissions are added as a constant factor for one year, regardless of the number of cups.
- **Single use scenario:** The data for the single-use scenario is based on generic data, which may contribute to uncertain results. The lid was a significant contributor to the total emissions of the reference scenario, a sensitivity analysis of the lid's weight was conducted. This is done because the weight can vary and/or because customers sometimes choose not to have a lid on their cup. These results are not included in this report.

RE-ZIP

The primary purpose of the RE-ZIP pilot was to develop a calculation tool based on LCA, making it possible for RE-ZIP to calculate its actual environmental footprint for the metrics of kg CO_2e, m^3 water, and kg waste. The pilot wished to investigate the total amount of reusable e-commerce packaging produced and used at RE-ZIP and assess whether this is less impactful than single-use packaging. The tool was based on 'live data' from RE-ZIP, making investigating the amount of new and reclaimed packaging possible. The data provided by RE-ZIP distinguished whether the products were new or reused. However, the data could not indicate the number of reuses, only if the products had been scanned before.

The functional unit was *1 m^2 of packaging to contain and protect dry goods during transportation and storage for one delivery.*

As RE-ZIP rents out two different types of e-commerce packaging with different sizes, two functional units have been used in the assessment:

- *1 m^2 of **hard case** packaging to contain and protect dry goods during transportation and storage for one delivery*
- *1 m^2 of **soft case** packaging to contain and protect dry goods during transportation and storage for one delivery*

Different scenarios for assessing the functional unit were conducted to assess the impact of RE-ZIP packaging compared to single-use packaging. An average density (g/m^2) was applied for the single-use scenarios (cardboard, paper and plastic), and the g/m^2 for all RE-ZIP packaging was calculated. This was done to compare the different reference flows by multiplying the average g/m^2 with the total m^2 used for each packaging. For example, one RE-ZIP hard case's cardboard packaging has a surface area of 0.3 m^2 and weighs 181 g (603.3 g/m^2. Based on web scraping, to estimate the g/m^2 for the single-use reference flow, an average card box weighs 894 g/m^2. Therefore, a box with the same surface area as the RE-ZIP box weighs 256.8 g.

No customer or user surveys were made, making the use phase primarily based on assumptions.

- **Transportation:** As RE-ZIP packaging is used in multiple countries, the tool allows you to change the transport distance during the use phase, corrugating the distances based on actual transport data. Default distances are applied if no data is available. Transport during the packaging's use (at the end-user) is not included, even though this could be a possible rebound effect.
- **Return rate and allocation of emissions:** Input data is based on 'live' RE-ZIP data from the packaging scanning. The RE-ZIP scanner identifies whether the packaging is new or reclaimed. But not how many times the packaging are reclaim. It was

therefore not possible to estimate the return rate, and an allocation of production and end-of-life emissions was therefore made. As the registration of packaging only told if the packaging was reclaimed, emissions from production and end-oflife was therefore all allocated to new packaging. The allocation was therefore made based on the assumption that emissions from production and EOL was allocated to new products (products that have not been reused yet). Reused products, therefore, have no emissions regarding production and EOL but only the use phase (sorting, transportation, etc.).

- **Functional unit and reference flow:** To ensure a functional unit that could be aggregated to a large amount of packaging and still be comparable, this was based on the amount of packaging in m^2. Therefore, the reference flow for the single-use alternative became an average of multiple packaging to make it possible to aggregate and compare with various RE-ZIP packaging. Thus, this also impacted the accuracy of the specific packaging. An alternative method would be to define FU and reference flows for each RE-ZIP packaging, ensuring 1:1 comparability.

NetHire

The purpose of the first phase of the NetHire pilot was to assess the environmental impact of NetHire's rental of tools and machinery. To investigate potential environmental benefits and any hotspots associated with NetHire's tool rental services, the rental of rolling scaffolds was chosen as an example. This was done to examine the hypotheses regarding the environmental advantages of craft companies renting tools rather than owning them. The two fundamental hypotheses were that NetHire, through their sharing model and decentralised storage, 1) increases the utility and 2) reduces transportation distances for rolling scaffolds used on construction sites. The study aimed to identify the conditions and thresholds at which NetHire's business model becomes more environmentally sustainable than individual ownership.

This pilot examined the total float of rolling scaffoldings and total days of renting per year at NetHire, and the functional unit was therefore determined based on this, making it: Use of rolling scaffolds 8406 times per year, in 15 years in Denmark. The Nethire reference flow was the production and distribution of 50.2 rolling scaffolds for rental, utilised 66% of the time, each with an expected lifespan of 15 years. This was compared with individual ownership with the assumption that these scaffolding were used 20% of the time: Production and distribution of 100.4 rolling scaffolds for private use, utilised 20% of the time, each with an expected lifespan of 15 years. Both estimations a based on previous studies of NetHires costumers[4] and an investigation of the lifespan of rollings scaffoldings.

4. Internal investigation. Can be explained upon request.

This functional unit makes it difficult to include other alternatives and possible rebound effects, but the aim was to investigate the importance of the product utility of tools in B2B. Three important assumptions were made:

- **Transportation:** It was assumed that rental reduces transport distances as these can use decentralised storage. The distances were 80 km for NetHire, and 113.1 for individual ownership. The importance of this assumption was tested.
- **Utility:** Rental models are assumed to have a higher utility than individual ownership, as multiple users can use the products. The utility rate for individual ownership is assumed to be 20%, and for Nethire, 66%. The importance of this assumption was tested for Nethire but not for individual ownership, even though this is seen as a critical assumption.
- **Substitution:** It was assumed that renting a rolling scaffolding would substitute 1:1 owning a rolling scaffolding. Therefore, other products that the scaffolding could substitute, such as ladders or lifts or the substitution of other rental systems, are not included. The importance of this assumption was not tested, as the system is based on the use of a rolling scaffold in a professional context (B2B), and it is assumed that the customers would use a rolling scaffolding in both scenarios.

Looping

The Looping pilot aimed to develop a GHG calculation tool. The tool calculates the emissions from the whole lifecycle of Looping's system, including production, transportation, and maintenance. This allows Looping to estimate its system's impact and compare this with single-use packaging.

The functional unit of the calculation to be used in the calculation tool is one m^2 covered module for transportation or storage in Norway and Sweden for one year. This was aggregated for two years of use of packaging, corresponding to covering 16000 modules (846,800m^2) for storage or transportation for two years in Sweden and Norway. The Looping reference flow was calculated based on the formula ((RF=(FU/NU) + (FU/NU)*LR*(NU-1)):

- The Looping scenario involved 4240 reusable covers used twice yearly, including maintenance, repair, discharging, and lost covers. This was calculated based on a 2% loss rate per year and two uses of the covers per year. Using the formula for calculating the reference flow:

  16,000((0.02)+0.98*(1/20)) = 240 covers lost a year = total of 4240 covers*

The compared reference single-use reference scenario:

- 16,000 times, covering the modules in single-use packaging.

The development of the calculation tool is primarily based on EPDs from Looping and single-use materials. The calculations to assess the maintenance and repair of the covers are based on additional data collected onsite at Looping. The most critical assumptions are:

- **Production and end-of-life data:** Emission factors for the production and waste management of Looping and single-use covers are based on data from selected EPDs. Looping has an EPD for its material. The EPDs for single-use materials have been selected based on Looping's knowledge of which materials and quantities are used in the industry.
- **Average data for m^2:** The average m^2 per cover is calculated by calculating the average m^2 of all Looping covers. This is used to estimate the default values, the average maintenance emissions, and the number of covers lost in the system.
- **Maintenance data:** A weighted average emission factor has been determined to calculate the emissions associated with maintenance. This is based on historical data regarding the amount of cleaning and repairs performed. The calculation is based on the percentage share of each activity performed when a cover is returned. The maintenance data includes washing and different types of repair (small and large).
- **Transportation:** Transport is an adjustable factor, and Looping can choose between three different transport types. Transport is calculated in kgkm to calculate the proportion of total transport attributed to each product. This approach is used because Looping typically uses groupage transport (medium and large trucks) or assumes that more than one product is being transported (electric van). In this report, the distance is 200 km. Transportation from production to distribution is a part of the EPDs.
- **Single-use scenario:** The EPDs utilised in the single-use scenario are based on assumptions of the materials used in a realistic module covering. An average of several EPDs was calculated to represent a plausible scenario to address this limitation. The average values for the single-use scenario are calculated based on Looping's customer's previous solution. Here, the average amount of each material per m^2 is determined by dividing the total material used for each cover type by the total m^2 of the covering.

CoHabit

CoHabit's environmental assessment aimed to investigate the number of cycles needed for their furniture and the impact of longer transport distances. The assessment is based on quantitative primary and secondary data to evaluate the CoHabit system and three pieces of furniture. Qualitative data through an on-site user survey was also collected to investigate different reference flows and user behaviour. This resulted in three different reference scenarios to show the different behaviour scenarios.

The functional unit was a bundle of clean, fully functional, neutral-looking furniture consisting of a place to sleep, sit and eat for 100 people during six months in Malmø and Lund. The reference flows needed to fulfil 100 people's need for the functional unit were calculated for three scenarios based on findings from on-site interviews with Swedish exchange students:

1. Worst case scenario: To buy new furniture and throw these out after use. Reference flow: production and disposal of 100 bundles
2. Baseline scenario: Based on on-site interviews, a baseline scenario representing the 'real' use of furniture was created and divided into the number of students who buy reused furniture and reuse them afterwards (83%), buy new furniture but reuse them afterwards (7%), or buy new furniture and throw it out (10%).
3. CoHabit scenario: CoHabit buy reused furniture and reuses it at least seven times.

ABOUT THIS PUBLICATION

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