

Potential environmental gains from service models (product-service systems)



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Cover design: EEA
Cover image © Deposit photo
Layout: ETC CE

Publication Date January 2025

EEA activity Circular Economy and Resource Use

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Preparation of this report has been co-funded by the European Environment Agency as part of a grant with the European Topic Centre on Circular economy and resource use (ETC CE) and expresses the views of the authors. The contents of this publication do not necessarily reflect the position or opinion of the European Commission or other institutions of the European Union. Neither the European Environment Agency nor the European Topic Centre on Circular economy and resource use is liable for any consequence stemming from the reuse of the information contained in this publication.

ETC CE coordinator: Vlaamse Instelling voor Technologisch Onderzoek (VITO)

ETC CE partners: Banson Editorial and Communications Ltd, česká informační agentura životního prostředí (CENIA), Collaborating Centre on Sustainable Consumption and Production (CSCP), Istituto Di Ricerca Sulla la Crescita Economica Sostenibile, Istituto Superiore per la Protezione e Ricerca Ambientale, IVL Swedish Environmental Research Institute, Norion Consult, Università Degli Studi Di Ferrara (SEEDS), German Environment Agency (UBA), Teknologian Tutkimuskeskus VTT oy, Wuppertal Institut für Klima, Umwelt, Energie gGmbH, World Resources Forum Association.

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Executive summary

This report presents the findings of research into Product-Service Systems (PSS), exploring their environmental impacts, unintended consequences, and scalability within the European market. The study focuses on five distinct product categories: 1) children's products, 2) textiles, 3) home appliances, 4) information and communications technology (ICT), and 5) furniture.

Drawing on a combination of desk research and qualitative interviews across 13 European PSS cases, the report analyses the strengths and challenges of this innovative business model. A shared feature among the five product groups is the potential for PSS solutions to extend product lifespans, enhance usage efficiency, and optimise the post-use phase. However, the approaches to achieving these outcomes vary significantly by product category and PSS model.

The research identifies key challenges for PSS companies in Europe, including legal and financial barriers, the need for standardised maintenance protocols, the importance of strong partnerships, and the influence of sociocultural factors on consumer behaviour. These challenges underscore the need for tailored strategies to ensure the successful implementation, sustainability, and scalability of PSS models. The report additionally underlines the importance of environmental monitoring and reporting on PSS models, not only as a tool for companies to assess and communicate their environmental impact but also in line with the broader European aim of encouraging more sustainable and circular consumption.

Europe provides fertile ground for PSS adoption, driven by growing sustainability concerns, progressive circular economy policies, and increasing consumer eco-consciousness. However, for PSS models to scale successfully, they must appeal beyond sustainability alone by delivering significant value to consumers. Convenience plays a pivotal role, with services such as transport, maintenance, and repairs often integrated into PSS offerings to enhance user experience. Competitive pricing relative to traditional ownership models is equally crucial; consumers must perceive PSS as offering superior overall value. Companies must also address the total cost of ownership, ensuring it remains accessible while incentivising subscription-based models.

Expanding market awareness is another critical factor. Many consumers remain unfamiliar with the concept of PSS and the advantages it can offer. Companies should invest in targeted marketing and educational initiatives to bridge this gap and encourage broader adoption of PSS solutions.

Ultimately, the future growth of PSS depends on several interrelated factors: consumer adoption rates, regulatory support, economic conditions, innovation, and effective communication. Success is likely to vary across industries and geographic regions, with certain cultural contexts and product categories demonstrating greater potential than others. By addressing existing challenges and leveraging opportunities, PSS can play a transformative role in Europe's transition toward a more sustainable and circular economy.

1 Introduction

The circular economy concept has gained significant attention in recent years and is progressively emerging as a top-priority policy agenda within the European context (Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Closing the Loop - An EU Action Plan for the Circular Economy, 2015; European Commission (2020): Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions: A New Circular Economy Action Plan For a Cleaner and More Competitive Europe, 2020). The transition towards circularity is a key objective of the European Green Deal (European Commission, 2021) – an initiative striving to transform the continent into a climate-neutral entity while decoupling economic growth from resource consumption. Consequently, there has been growing interest in exploring how businesses can rethink and move away from the conventional sales model, where products are sold, used and then discarded.

Instead, innovative business models are envisioned to reduce the reliance on raw-material production by optimising the use of products (EEA, 2021). These business models encompass a variety of approaches, such as offering the same product to multiple users rather than it being owned by a single consumer. Another approach involves prolonging product lifespans through meticulous design, improved use, and dedicated maintenance and repair. At the heart of this transformation lies a crucial principle: shifting from a consumption pattern centred around product ownership to a service-oriented consumption model.

One example of these circular business models is product-service systems (PSS), which prioritise the use of products over owning them. PSS focuses on delivering value through services rather than product sales, aligning consumption with a service-based approach. While PSS implementation holds the potential to enhance sustainability, it does not, however, inherently guarantee environmental gains in all cases. This study aims to provide an in-depth and nuanced review of the potential environmental gains arising from PSS models across Europe. The focus on PSS stems from its alignment with a key principle of the circular economy: shifting businesses and households from a consumption model based on product ownership to one centred on accessing the service or function the product provides. Often referred to as ‘product-as-a-service’, this concept has garnered significant attention in policy discussions, seminars, and conferences. Despite this interest, it remains unclear to what extent this circular business model is being adopted in Europe and whether the increased policy focus on circularity is effectively fostering its growth.

PSS is a focal point in European strategies like the Circular Economy Action Plan (European Commission, 2020), where it is highlighted as a model to accelerate the transition towards a more sustainable and resource-efficient economy. By situating PSS within the broader context of circular economy principles, the study investigates its current market presence, evaluates the potential environmental benefits it offers, and examines its scalability across diverse sectors and countries. Furthermore, the report examines the practical aspects of implementation, including logistical challenges, cultural norms and legal barriers that can impact the success of PSS.

An aspect often overlooked is the potential for unintended consequences when introducing novel business models such as PSS. For example, rebound effects – where increased efficiency leads to greater overall consumption – or challenges in ensuring resource efficiency across the lifecycle of shared products can undermine intended sustainability goals. Drawing from literature and stakeholder insights, the report dissects these unintended outcomes and proposes strategies for mitigation.

Finally, the report outlines a roadmap for identifying sectors with high potential for implementing PSS, offering practical guidance for targeting areas where these models could achieve the greatest environmental and economic impact.

2 Why product-service systems

Among the diverse approaches to circular business models, Product-Service Systems (PSS) stand out as one innovative strategy that shifts the focus from product ownership to providing customers with the functionality, performance or outcome of a product (EEA, 2021). In a PSS model, customers do not purchase or own a product but instead access its benefits through service agreements or subscription models.

PSS is a key example within the wider spectrum of circular business models, which also include closed-loop supply chains that emphasise recycling and remanufacturing, industrial symbiosis where industries share resources to minimise waste, and product-life extension strategies that focus on repair, refurbishment, and upgrading. The different models offer unique pathways to sustainability, with PSS contributing by decoupling resource consumption from economic growth and promoting service-based consumption patterns.

According to an extensive body of literature on this subject, PSS exhibit significant potential for enhancing the environmental performance of a value chain (Kim, 2020; Reim et al., 2015; Tukker, 2004a). This potential is harnessed through the integration of services and the optimisation of energy consumption, reducing consumables and extending the lifecycle of products. It is important to note, however, that PSS does not inherently ensure decreased resource consumption, as several authors have emphasised (Kjaer et al., 2016; Pigosso et al., 2010; Tukker, 2004a; Tukker & Tischner, 2006b). As a result, a critical question arises: under what circumstances and through what mechanisms can PSS effectively yield environmental benefits?

The essence of PSS lies in endeavouring to limit the production of products and/or the extraction of raw materials. As such, the primary focus of this project should be directed towards systems, which constitute the business model's core objective.

2.1 Product-service systems, product-as-a-service or product-ownership models

When it comes to the business model of offering products as a service, several terms are used interchangeably, such as PSS, product-as-a-service (PaaS) and product-ownership-model (POM). In this report, the term PSS is used to describe the overarching concept.

All three, PaaS, POM and PSS, refer to different approaches and frameworks within the broader concept of shifting from traditional ownership-based consumption to more sustainable and circular models. While they share similar goals, there are distinctions in their emphasis and implications.

The term PaaS is complicated by its broad application in various contexts, including platforms as service – for example cloud computing and other service-oriented systems. In recent years, PaaS have frequently been used by businesses, possibly in connection to an understanding of PaaS as ‘servitisation’ – the process of providing services instead of selling physical products (Baines et al., 2007; Vandermerwe & Rada, 1988). Here, businesses are increasingly adding service components to their existing products and creating a notion of selling a product as a service. The term PaaS does not, however, encompass the comprehensive transformation process that a company has to go through to be able to offer a product-as-a-service model.

Under a POM, customers retain ownership of a product, but the company provides maintenance, repairs, upgrades and/or even disposal services. Although the focus is on extending the lifespan of products and optimising their use, the concept retains the traditional ownership structure and does not include all elements of PSS. Furthermore, in the broader waste management and regulatory context, POM refers to the concept of ‘placed on the market’ and its role in calculating waste electrical and electronic equipment (WEEE), especially within the framework of European regulations.

Product-service systems is a more comprehensive term that covers various business models beyond mere ownership and focusing on delivering value through integrated solutions. It emphasises a systemic change in how products are designed, produced, used and disposed of to create a more sustainable and circular economy, and characterises of the total transition needed to implement the business model successfully. The transition to a PSS is a complex process in which the whole business and its systems must change – from cash flow, product design and internal processes to supply chains and consumer relationships. This transition alters the entire value-creation system compared to traditional linear business models. Additionally, PSS is a well-established term in the academic and professional discourse surrounding sustainability, making it a recognised and suitable choice for discussions related to the circular economy, environmental impacts and consumer behaviour in the context of product-based services (Ellen MacArthur Foundation, 2013).

2.2 Defining product-service systems

One of the first definitions defines PSS as “*a marketable set of products and services capable of jointly fulfilling a user’s need*” (Goedkoop, 1999). While this definition adopts a business-oriented perspective centred around meeting customer requirements, PSS was still conceived as a method of reducing environmental impacts (O. K. Mont, 2002). Although this definition highlights the imperative for PSS to decrease environmental impacts compared to traditional business models (O. K. Mont, 2002; Tukker, 2015), some companies perceive PSS as a strategic approach to strengthen their market position and gain competitive advantages. This variance in perception is partly attributed to the evolving and fluctuating significance of sustainability over time (Kjaer et al., 2019).

Nevertheless, despite numerous definitions circulating, no universally adopted characterisation of PSS exists. Often, it is simply referred to as an alternative model where the focus is not on the physical product but on the desired experience or outcome (EEA, 2024). Among the most frequently referenced definitions in the literature is the one provided by Tukker (Tukker, 2004a), defining PSS as a blend of products and services intended to satisfy specific customer needs while generating value. Tukker also acknowledges, however, that PSS strategies and the extent of value integration can vary, leading him to create the following classification encompassing three primary categories of PSS.

- **Product-oriented services** focus mainly on selling products on the same terms as linear business models. This PSS business model, however, has additional services added, such as maintenance, repair or take-back solutions.
- **Use-oriented services** focus on selling the product function but does not include a change in the ownership of a traditional linear sales model. The ownership stays with the provider and not the consumer and the product is often shared between more than one user, with the aim of maximising the product’s life and use and expanding the life of the materials.
- **Result-oriented services** focus on selling the result of a function on which the provider and clients agree and then aim to achieved through a service, a product or without a predetermined product. This could be offering transport without leasing a car or offering a laundry service (Beuren & Miguel, 2012).

Various PSS models exhibit distinct economic and environmental characteristics within these three categories. Consequently, Tukker has developed a total of eight archetypical models for PSS. This nuanced approach allows for a finer distinction across the spectrum of complexities inherent in the three primary PSS categories. The three categories and eight sub-categories are illustrated in Figure 1.

Nonetheless, this commonly employed PSS definition also strives to offer the possibility of contributing to environmental, social and economic sustainability. Some PSS solutions exhibit significant potential for sustainability, others less so (Ceschin, 2013; Manzini & Vezzoli, 2002).

According to Tukker (Tukker, 2004b), the different PSS types result in environmental improvements of varied magnitude, with the *functional result* PSS model leading to the most significant environmental benefits since solutions can be offered based on approaches different from the existing product concept.

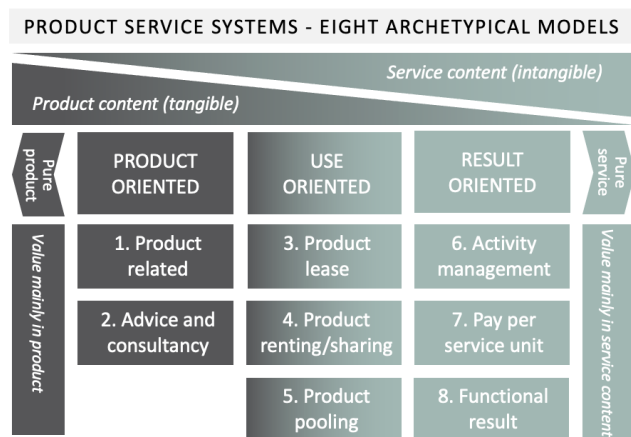


Figure 1: Eight archetypical models of product-service systems (Source: Tukker (2004))

Product-related service and Advice/Consultancy involves services, advice, and consultancy associated with a product, focusing on improving maintenance practices and extending product life. It often includes take-back agreements for efficient recycling and reuse processes. The benefits relate to better-organised maintenance or automatically generating information that will improve the product's or service's functionality by prolonging the length of the PSS offer. In addition, take-back agreements allow for more efficient recycling and reuse processes for the PSS provider (Evans et al., 2007; Tonelli et al., 2009; Tukker & Tischner, 2006b).

With **Product Lease**, the provider retains ownership, often handling maintenance and repairs. The lessee pays a regular fee for unlimited and individual access to the leased product. While the model can offer financial benefits, concerns arise if the lease encourages careless use or if manufacturers design products for frequent replacement (Agrawal et al., 2012; Madsen, 2015). Leasing contracts are often used simply as financial instruments to assist with financing. A leasing company buys a product from a producer and leases it to a customer, taking responsibility for some damage or malfunctions. To contribute to significant environmental improvement, the manufacturer of products should show an interest in increasing product longevity through maintenance and upgrading. At the end of the product's life, it should not be sold to the user but returned to the producer for remanufacturing and reuse.

Product Renting/Sharing and Product Pooling involve models where users rent, share, or pool products. In Renting or Sharing, different users sequentially use the product, while Pooling allows simultaneous use by multiple users. Similar to leasing, these models can offer significant environmental benefits, especially when the environmental burden is tied to manufacturing. If manufacturing is a key environmental concern, sharing and intensive use of the exact product can reduce the overall impact. However, the positive environmental outcome may be smaller if the use phase dominates and the PSS does not result in lower overall usage. Despite this, Pooling can still contribute to lower environmental impacts as more people utilise the product simultaneously. Car-sharing services like Zipcar exemplify product pooling. Multiple users can access and use the same vehicle concurrently, reducing the need for individual ownership and potentially lowering environmental impacts associated with manufacturing and resource use. However, there is a risk of inadvertently encouraging increased car use due to newfound affordability.

Activity Management involves outsourcing a part of a company's activity to a third party, often with performance indicators to control service quality. Examples include outsourcing catering and office cleaning. The activities can lower environmental impacts, particularly if efficiency gains are associated with material use rather than human time inputs.

Pay per Unit involves paying for the actual use or consumption of a product or service. Examples include pay-per-print formulas adopted by copier producers, covering all necessary activities to keep the service

available. Pay per unit overcomes the split incentive between the costs of manufacturing a product and the costs occurring in the use phase. Limited environmental gains can likely be realised, but radical improvements over time cannot be expected since the technological system does not fundamentally change.

Functional Result offers a specific result or service aligned with the end user's needs. This model has the highest potential for positive environmental impact as providers have the knowledge to design low-impact systems. Examples include companies promising a 'pleasant climate' rather than selling specific equipment or ensuring farmers a maximum harvest loss instead of selling pesticides.

Product-oriented services, which can in some ways resemble linear sales models but with additional services, are seen to have limited environmental potential and are omitted from the definition of PSS in the European Commission's latest sustainable finance taxonomy (European Commission, n.d.a). This can be understood as an expression of the Commission's recognition of the greater potential in use- and result-oriented PSS business models and a desire to focus on the development and advancement of these two models. It may be necessary to focus on innovative business models that demonstrate disruptive potential to radically transform the way of consuming and circulating products to achieve the greatest possible environmental benefit (Geissdoerfer et al., 2023). The exclusion of product-oriented services from the Commission's definition of PSS models might indicate an effort to address this issue.

2.3 Well-established product-service system business models

Product-service systems have been a part of economic landscapes for many years. Some have quietly become woven into everyday life, often seamlessly blending into the way in which people access and use products. Some PSS models may not even be identified as such; for instance, leasing a car, laundry services, subscribing to a streaming service or even using a shared workspace are all examples of PSS arrangements, although they might not be immediately associated with the term.

Furthermore, PSS have evolved beyond their initial focus solely on environmental benefits (Baines et al., 2007). While the core idea remains anchored in minimising environmental impacts through shared use and resource optimisation, they have also been harnessed by companies as potent business optimisation strategies. This shift is seen as a means of augmenting a company's market standing and competitive edge. By adopting PSS, companies can enhance customer engagement, loyalty, and retention. They can offer tailored solutions, ensuring that products remain relevant and efficient throughout their lifecycle. This adaptability not only fosters customer satisfaction but also positions these businesses as forward-looking, responsive entities in a rapidly changing marketplace (Kjaer et al., 2019).

A well-established PSS business model that has been present in the market for decades is the rental of workwear. As an example, the Finnish textile company Lindström (Lindström Group, n.d.), established in 1848, began offering rental solutions in the 1950s as a response to a shortage of textile products. Today, Lindström still offers workwear based on a rental model and brands itself as a sustainable and easy-to-use textile service. The rental of workwear mainly operates as a business-to-business (B2B) model and includes not just the supply of workwear but also washing, maintaining, repairing, renewing and storing the products.

Another well-established and widespread PSS business model is car sharing which has existed since the late 1940s. One of the earliest European experiences with carsharing can be traced to a cooperative, known as "Sefage", initiated in Zurich, Switzerland, in 1948. This cooperative emerged as a response to economic challenges, presenting an alternative to car ownership by facilitating shared usage among those facing financial constraints (Li et al., 2021).

In recent decades, the concept of car-sharing has gained popularity as a flexible and cost-effective mobility solution, allowing individuals to enjoy private car usage without the burdens of ownership and associated responsibilities. This rise in popularity is attributed to the convenience it offers and its flexibility compared to public transport (Li et al., 2021). The future outlook for car-sharing is optimistic, with the number of European users projected to reach 20.74 million by 2027 (Statista, 2024d). While sustainability may not be the primary driver for car sharing, it holds the potential to bring environmental benefits to the mobility industry. Car sharing can contribute to the reduction of traffic, pollution, and oil dependence, especially with the ongoing innovations in electric cars impacting the industry (Li et al., 2021).

These well-established PSS business models are examples of how PSS can work well and have become embedded in society for many years. However, their integration has come about because of a lack of materials, economic pressures, and consumer convenience rather than solely from concerns about sustainability.

2.4 Emerging product-service system models

With a focus within the literature on PSS business models previously revolving around the economic optimisation of a business, recent literature has emphasised the sustainability aspects of PSS, renewing the original focus on sustainability (Kristensen & Remmen, 2019). Sustainability has started to become a motivating factor for companies to implementing PSS and a driver of business improvements.

A field in which sustainability has been a motivational factor behind establishing different PSS models is mobility. Here, mobility as a service (MaaS) is a new business model that is rapidly gaining traction in European capital cities. The model integrates various public and private transport options, such as metros, buses, taxis, cycling, and car-, bicycle-, and e-scooter-sharing schemes accessed through a real-time apps (Jittrapirom et al., 2017). The model thus leverages existing infrastructure and public transport solutions, offering a on-demand mobility solution.

Mobility as a service stands out as an innovative approach that not only enhances consumer convenience but also holds the potential to limit reliance on fossil fuel-based transport. While MaaS platforms encourage ease of access to transportation, they also run the risk of promoting private vehicle use over walking or more sustainable forms of transport. To mitigate this risk, opting for eco-friendly options, such as public buses instead of taxis or personal vehicles, can significantly minimise the environmental impact of journeys, aligning with the overarching sustainability goals these PSS models aim to achieve (Jang et al., 2021).

Sustainability-driven initiatives are gaining traction in the packaging industry, where the excessive use and disposal of single-use plastic packaging have sparked interest in reusable systems (Ellen MacArthur Foundation, 2019). Packaging companies are shifting towards circular principles, challenging the traditional linear business models centred on disposable materials. The application of PSS in the packaging sector, exemplified by European cases like Re-Zip, Swapp, Re-pack, and Looping, holds promise in addressing the packaging waste issue. Companies such as Re-Zip and Re-pack have developed PSS models for reusable packaging in e-commerce (RE-ZIP, n.d.), Looping provides reusable transport packaging services for containers (Looping, n.d.) , and Swapp offers a system for reusable product packaging in beverages, cosmetics, and cleaning products (Swapp, n.d.). Despite these positive developments, there is still limited knowledge on adopting PSS approaches to tackle the packaging crisis.

Despite positive developments, there's limited knowledge on adopting PSS approaches to tackle the packaging crisis. Emerging PSS models aim to reduce material consumption and disrupt established norms.

However, it's essential not to assume that reusable packaging is universally more sustainable. Factors such as energy demand in recirculation processes, material inputs, and shifts in consumption behaviour must

be considered. Pioneering PSS models in the packaging industry have transformative potential, extending beyond the sector. As these models gain traction, they can serve as blueprints inspiring change in other industries, offering a pathway to economic growth decoupled from resource consumption (Kjaer et al., 2019).

2.5 Potential environmental gains of product-service systems

Driven by the need for more effective and sustainable ways of using the planet's resources, research suggests high potential for environmental gains from PSS business models. More than 20 years of research on PSS have produced significant scientific literature on the topic. The literature, however, analyses the PSS concept from a plurality of points of view and research on PSS is becoming increasingly fine-grained while some fundamental aspects of PSS remain dispersed (Barravecchia et al., 2021). A wide range of literature reviews has been published in the last 10 years trying to map the potential of PSS. Each of these, however, analyses the PSS from its specific point of view, sometimes losing the overall view of the phenomenon and resulting in a lack of updated reviews of the whole PSS literature corpus (Moro et al., 2020). Literature documenting the environmental benefits of PSS is sparse since the field to investigate is widespread, and the gains are hard to document. As shown in several studies (Kjaer et al., 2019; O. Mont et al., 2006; Roman et al., 2023; Tukker, 2004a), Moro et al. (Moro et al., 2020) state that there is a lack of emphasis on the factors that can foster the acceptance of opportunities to explore the sustainability of the PSS as many publications that highlight the benefits of PSS primarily consider the inside of organisations, especially economic ones.

While PSS are good candidates as sustainable business models, the demonstration of their sustainability and their contribution to transformative economic practices remain to be made (Roman et al., 2023). Through an extensive PSS literature review, Moro et al. (Moro et al., 2020) have identified 36 benefits of PSS, of which nine are environmental ones, including the reduction of environmental impacts and the greater use of products. The environmental benefits can favour both producers and society in general. Annarelli et al. (Annarelli et al., 2016) point out that the most recognised benefit, by 62 % of the publications they analysed, is the reduction of environmental impacts. How and when the environmental benefit occurs is not, however, precisely defined.

Many articles describe the potential benefits of PSS models. Ceschin (Ceschin, 2013), for example, focuses on how economic drivers can lead to benefits of PSS that reduce material and energy consumption, increase reuse and prolong the active lifetime of products and materials, while Kuo et al. (Kuo et al., 2010) explain how PSS can support and improve service efficiency, and reduce resource consumption and waste through repeated use and remanufacturing of products, components and raw materials.

According to Moro et al. (Moro et al., 2020), literature reviews of PSS publications usually focuses on:

- PSS typologies, including the comparison among them, and examples analysed by the recent literature;
- PSS benefits to customers, including how organisations could develop their PSS value propositions;
- PSS barriers and opportunities to address them, aiming to help organisations implement their PSS business models more effectively;
- cross-country analyses of PSS benefits and barriers to identify patterns and differences in PSS implementation;
- recent trends and new topics related to PSS, for example digitalised PSS, digital services, and smart PSS.

There are, however, few life cycle assessments of PSS and their results are mixed (Moreau et al., 2020; Roman et al., 2023). Literature documenting environmental performance against non-circular businesses mostly focuses on specific case studies. Examples are the SystemIQ report (SystemIQ, 2021) targeting

everything-as-a-service (XaaS) models to improve resource productivity and decrease environmental impacts compared to ordinary business models. The envisaged benefits are related to the assumption that producers take responsibility for their products when applying PSS principles. The report states that cars-as-a-service PSS models can annually save 70.9 million tonnes of carbon dioxide equivalent (CO₂e) emissions and achieve a 39 % reduction in the total cost of ownership (TCO) compared to individual car ownerships. It also argues that equipment-as-a-service models potentially prevent 1–2 million tonnes of ferrous scrap globally which can lead to a reduction of 37–65 % savings in annual carbon dioxide (CO₂) emissions in 2030, and that white-goods-as-a-service models can contribute to a reduction of 1.3 million tonnes of CO₂e yearly.

(Estrada et al., 2017) focus on bike-sharing to obtain sustainability gains in five areas, based on experience from Bergamo, Italy: reduced traffic congestion; improved air quality; increased accessibility; reduced last-mile problems by filling the gap between stations or stops and final destinations; and improved health of the residents. These conclusions are mirrored in a study of a Chinese bike-sharing scheme, which suggests that PSS (as a broad term) decouple economic success from material consumption and hence reduce the environmental impact of economic activity (Wu & Zhu, 2017).

Kristensen and Remmen (2019) investigated the environmental gains for PSS for furniture with a specific Danish example through which the procurement of school furniture was substituted by the provision of the five-year service of *'innovative learning environments encompassing students' different learning styles and needs'*. The environmental gains were achieved through resource optimisation and efficiency in the manufacturing of products, extending product life, modular designs that can ease refurbishment and reuse of modules and materials, and the actual reuse of old furniture.

A recent Finnish lifecycle study of jeans revealed that PSS rental or sharing models were not necessarily environmentally preferable to ordinary linear sales models (Levänen et al., 2021). It all comes down to the way the jeans are used, with extended use showing the greatest environmental gains, followed by re-selling scenarios. The industrial processing of discarded jeans into new raw materials is the most critical process in environmental terms, as the replaced emissions from cotton production are relatively low.

According to (Reim et al., 2015) sustainability tactics can ensure that the PSS business models are implemented successfully, achieving economic and environmental benefits. This study argues that the best way to obtain environmental gains is through the increased use of resources or innovation that improves production or delivery. The study argues that environmental gains can be obtained if the company strives to optimise the use of resources and designs the business model with the specific objective of being more sustainable while avoiding rebound effects. The study presents a critical connection between the business models and tactics and links strategic-level decisions to operational-level action.

(Kjaer et al., 2019) state that *"even though PSS originate from a strong sustainability perspective, a shift in focus from environmental benefits to economic benefits has occurred during the last decade"* and (Roman et al., 2023) question the assumption, sometimes made implicitly, that specific business models are sustainable *per se*. They argue that knowledge about PSS sustainability is scattered since so many factors must be taken into account, for example, different methodologies – traditional and non-traditional lifecycle analyses (LCAs), non-traditional LCAs, multi-criteria assessments etc.; different types of PSS – product, use, result oriented, in different sectors and different places; different assumptions – type of energy used in production, use and transport, reference scenarios compared to PSS scenarios, perimeters of the study, the diversity of environmental effects considered, etc.

(Roman et al., 2023) raise two primary concerns regarding PSS and whether their business models can be inherently sustainable. Firstly, there is a concern that the lack of clear specifications regarding what constitutes a sustainable PSS could hinder research and the accumulation of knowledge in this area. Without a clear understanding of the sustainable aspects of PSS, it becomes challenging to advance research effectively. Secondly, there is a growing worry that an increasing number of companies might adopt PSS-like models to diversify their offerings and boost profits, presenting themselves as

environmentally friendly or seeking to green their business model. Without careful consideration of potential impacts and actual environmental gains, however, these initiatives may fall short. It is important to note that there are various non-environmental motives for businesses to adopt PSS, such as increasing customer loyalty, generating regular payments or charging higher amounts for products with more extended payment schedules. It is, therefore, essential to determine whether firms embrace PSS as part of a significant sustainability-driven transformation or merely pursue opportunistic PSS-like offers.

While it is necessary to consider the case-specific nature and complexities associated with evaluating environmental gains, the core principles behind PSS remain rooted in the potential for additional benefits for producers, customers and the environment. By focusing on delivering services and outcomes rather than selling products, PSS models have the potential to promote resource efficiency, waste reduction and a transition to a circular economy, including the following.

1. **Resource efficiency:** PSS encourage the efficient use of resources by shifting the focus from selling products to providing services. Instead of buying and owning a product, customers access the functionality they need through a service. This can reduce the overall demand for raw materials and decrease the environmental impact of extraction, manufacturing and disposal.
2. **Extended product lifespans:** with PSS, manufacturers have a vested interest in ensuring the longevity and durability of their products because they retain ownership. This leads to better product design, the use of higher-quality materials, and improved maintenance and repair services. By extending the lifespan of products, PSS can reduce the frequency of replacements and lower the associated environmental impacts.
3. **Improved product design:** PSS encourages manufacturers to shift their focus from producing and selling individual products to providing sustainable and innovative solutions. This often leads to more efficient, eco-friendly and modular product designs that are easier to maintain, upgrade and repair. Enhanced product design reduces energy consumption, material waste and environmental pollution throughout the product's lifecycle.
4. **Reduced waste generation:** PSS models promote resource recovery and recycling. Manufacturers are incentivised to take back and refurbish products at the end of their service life, ensuring proper disposal or the recycling of components and materials. This approach can help reduce waste generation, landfill usage and the need for raw-material extraction.
5. **Behavioural change and sustainable consumption:** PSS can also influence consumer behaviour by fostering a shift from a culture of ownership to one of access and sharing. This change in mindset promotes a more sustainable approach to consumption, through which individuals prioritise the use and enjoyment of products over their ownership. Consequently, the demand for new products decreases, resulting in lower environmental impacts associated with production and disposal.
6. **Collaboration and shared infrastructure:** PSS models often involve collaboration between multiple stakeholders, including manufacturers, service providers and consumers. This collaboration can lead to shared infrastructure, such as car-sharing services or tool libraries, which reduces the number of products needed, optimises resource utilisation, and decreases environmental burdens.

Overall, PSS have the potential to significantly contribute to a more sustainable and circular economy by promoting resource efficiency, extending product lifespans, reducing waste generation, fostering better product design, encouraging sustainable consumption patterns and facilitating collaborative approaches. However, the literature also emphasises the importance of considering the cultural and subjective aspects of ownership and the appropriate use of products when their ownership remains with the provider. These circumstances can arise, for example, in PSS, which implies leasing products. When users act less responsibly around the leased products, this can lead to shorter product lifespans, frequent replacements, and, ultimately, adverse environmental impacts.

2.6 Potential disadvantages and unintended consequences of product-service systems

While PSS offer a pathway towards environmental progress, it is imperative to recognise that merely adopting one of these business models does not inherently ensure sustainability. The literature review shows that the environmental gains differ between the types of PSS business models applied; a PSS business model is not always more environmentally beneficial than the linear solution it replaces. It is impossible to assess a PSS model's environmental performance without digging down into the details, where the answer is typically embedded. For example, even though a PSS model appears to be environmentally beneficial in one specific country, it cannot be said to have universal environmental value without a proper analysis covering different geographies, consumer patterns, logistics, etc.

Although PSS have the potential to lead to resource reduction and improved sustainability, such outcomes are contingent upon careful consideration and strategic design. One crucial factor to remember is that optimising one stage of a product's lifecycle might inadvertently lead to increased resource consumption in others. This dynamic introduces the concept of a burden shift, where positive gains achieved in one area might be offset by negative repercussions elsewhere. Despite this possibility, no effective evaluation method for PSS has been devised (Sai et al., 2023). By using LCA approaches combined with consumer surveys, however, some research has been conducted into the potential disadvantages and unintended consequences of PSS. A recent study focusing on digital camera rental services in Japan, for example, revealed that while PSS has potential benefits, some scenarios could lead to increased greenhouse gas emissions compared to traditional purchase-only systems, mainly caused by delivery processes. Additionally, the study identified distinct consumer segments and projected countrywide environmental impacts, highlighting the need for proactive service design to mitigate unintended consequences of PSS implementation (Sai et al., 2023).

Moreover, PSS strategies warrant careful consideration due to potential complications concerning consumer acceptance and broader business implications (Tukker & Tischner, 2006a). One notable challenge associated with PSS implementation is the occurrence of rebound effects or unintended consequences, which are often tied to changes in consumer behaviour (Kjaer et al., 2019; Tukker, 2004b). Predicting and managing such effects can be problematic since these depend on how consumers respond to new PSS offerings (Goedkoop, 1999).

Rebound effects can occur when a product is offered for a lower price through sharing and reusing systems, and in this way, contribute to an unsustainable increase in user consumption. One example is a well-known car-sharing service that provides vehicles at significantly lower costs than traditional car ownership (Ceschin & Vezzoli, 2010; Kuntzky et al., 2013; Teles et al., 2018; Williams, 2007). While this encourages sharing and reduces individual car ownership, it could inadvertently lead to a surge in car use due to the newfound affordability. Any uptick in use could offset the intended benefits, resulting in increased traffic pressure, resource consumption and environmental impacts. The central question here is whether this newfound access to cars would primarily limit the acquisition and subsequent production of new vehicles or whether it would instead primarily reduce the usage of public transport or bicycles.

In essence, PSS's potential benefits must be navigated with prudence, understanding that their success hinges on intricate factors, including resource optimisation, shifts in user behaviour and market dynamics. Strategic design and thorough analysis are essential to ensure that PSS models yield their desired environmental gains while minimising the risk of unintended consequences.

A SystemIQ report (SystemIQ, 2021) argues that addressing the potential rebound effects is essential when designing PSS. Reducing the total cost of ownership and increasing consumers' access can stimulate demand for more convenient and cheaper services. Service-based usage models can, however, potentially lead to carefree consumption patterns and encourage greater transport demand or ever-faster innovation cycles that create challenges for manufacturers, while examples such as Internet of Things (IoT) applications can require additional material inputs or energy consumption. These unexpected

consequences and rebound effects of a PSS and the behaviour it creates affect the service's environmental impact either *directly* or *indirectly*.

The direct rebound effect occurs when the increased efficiency and reduced resource consumption resulting from PSS lead to lower consumer costs, but, as a result, consumers increase their overall consumption or demand for the PSS, partially or fully offsetting the initial resource savings (Li et al., 2021). As the above-mentioned example where the cost of using a car-sharing service decreases, resulting in individuals becoming more inclined to use the service more frequently or for longer distances, potentially increasing overall transport-related impacts. Other examples of direct rebound effects could include:

- More comfortable and cheaper services could replace less competitive services that are better for the environment.
- Service-based usage models, such as for electric scooters, leading to carefree and extensive consumption patterns.
- Increased transport demands for new PSS models, such as more frequent transport related to service performance and the transportation of goods.
- Extended innovation cycles in technology, potentially leading to the continued use of outdated or less energy-efficient technology, which may not be environmentally beneficial in the long term.

Indirect rebound effects are related to broader system-level impacts resulting from the adoption of a PSS. For instance, when PSS models lead to cost savings for businesses, they may reinvest these in expanding their operations or introducing new products and services. This can lead to increased production and overall consumption, potentially offsetting the resource efficiency gains achieved through the PSS. Rebound effects can undermine the environmental benefits of a PSS and highlight the importance of considering broader system dynamics and consumer behaviour when implementing them. To mitigate rebound effects, it is crucial to design PSS systems that encourage sustainable consumption patterns, raise consumer awareness about the environmental impacts of their choices, and ensure that efficiency gains are not solely directed towards increased consumption. When PSS help save money, one must ensure this money is not spent on other impactful products or services. It is worth noting that the magnitude and significance of rebound effects can vary depending on factors such as consumer behaviour, market conditions, pricing strategies, and the specific characteristics of the PSS model being implemented (Roman et al., 2023). This also requires a thorough understanding of the multiple and complex interactions between actors in business ecosystems, which vary in their support for the sustainable development of PSS (Roman et al., 2023).

3 Introduction to case studies

The overall objective of the project is to deepen the understanding of the environmental gains of consumption models that focus on the service required rather than ownership of the product that provides that service. Based on a review of the existing literature on PSS, the environmental gains of these types of business models are case-specific and cannot be determined on a more general level. Comparative assessments are complex; apparent minor changes in the business model can significantly influence the overall environmental performance of the PSS in question, and rebound effects also alter the picture.

Since there is limited literature regarding PSS and which specific environmental benefits can be identified, the analysis is based on the available evidence in combination with qualitative data obtained from interviews carried out for the project.

3.1 Case selection

The selection of cases for inclusion was guided by three fundamental criteria that ensure a comprehensive and insightful exploration of PSS models.

- **Transparency of the PSS model:** The cases chosen must offer a clear and transparent PSS model that allows for the assessment of environmental benefits. This transparency is essential for accurate evaluation and comparison.
- **Distinct PSS Identity:** The cases must represent recognisable PSS models, distinct from general green businesses. These models should align with Tukker's (Tukker, 2004b) eight subcategories of PSS, providing a solid foundation for classification and analysis.
- **Disruptive potential and innovation:** Chosen cases should demonstrate a disruptive potential by causing radical changes to existing industries or markets through innovative approaches. This criterion emphasises the transformative power of PSS models.

The project aims to include a diverse range of cases to provide a comprehensive perspective on the challenges, potentials and experiences associated with PSS models. These include recent commercial-scale operations that provide examples of successful rollouts that are transferable across European countries. A common thread among all cases is their significant environmental potential.

The study's focus on the selected product areas is guided by a thorough literature review of emerging PSS models across Europe. To ensure a robust analysis, the project investigated 12 cases within five specific product groups (Figure 2)



Figure 2: Case studies within five product groups investigated

The comparative analysis within these product groups allows for a comprehensive exploration of different business models, with the added benefit of representing a diverse range of countries. The project is dedicated to selecting cases that exhibit environmental potential through four main avenues (Figure 3)

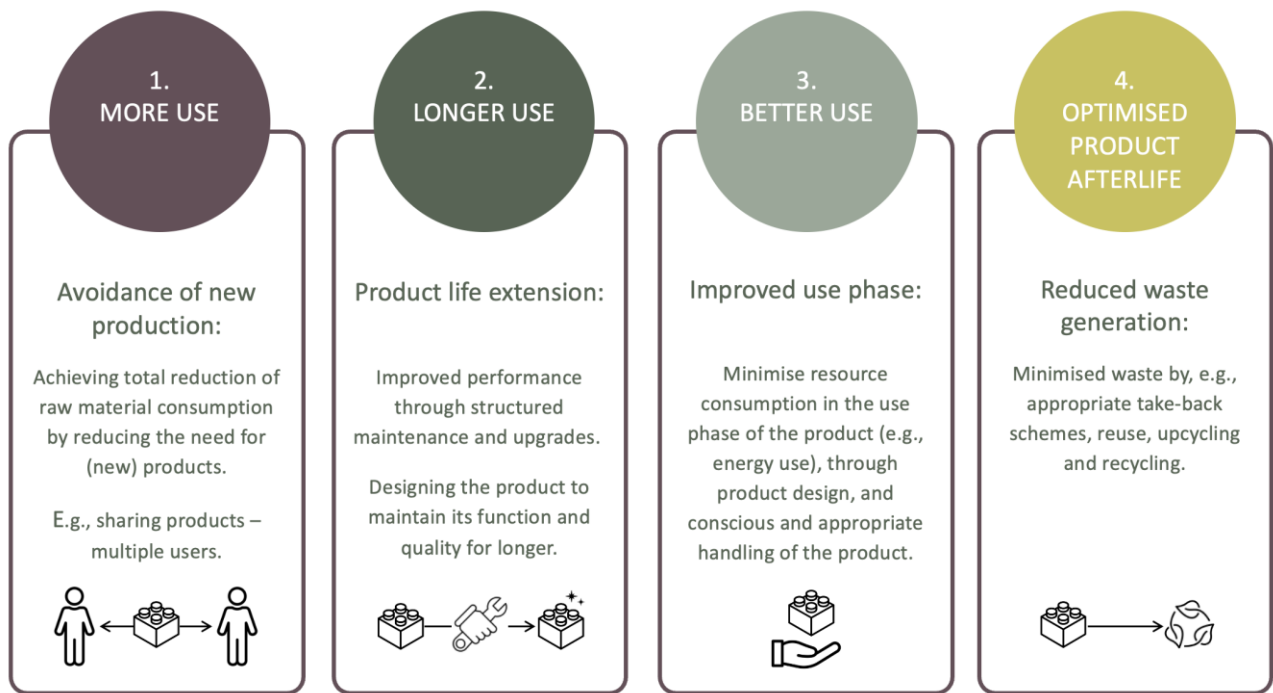


Figure 3: The selected cases exhibited environmental potential through four main avenues

In essence, the project's case selection process aimed to create a well-rounded, representative sample that illustrates the potential of PSS models across various industries and countries while highlighting their environmental benefits.

4 Children's products

As an overall product group, PSS solutions for children's products include products ranging from toys and strollers to sunhats and rain boots. The common denominator for these products is their very short utilisation spans. Children (or parents) constitute a unique target group in relation to material products because such products as baby carriers, highchairs, jumpsuits and breast pumps are only needed for a short period as children grow and develop rapidly. As they mature, the need for products shifts quickly, with their changing requirements, dimensions, abilities and developmental stages.

Consequently, these segments underscore an imperative to address the short-lived nature of children's product utility in alignment with the core principles of PSS. The challenge lies in designing innovative approaches that optimise product usage and minimise wastage while keeping transport emissions at a minimum, thereby creating more sustainable and resource-efficient consumption patterns for children's products.

4.1 European market trends

Each day witnesses the arrival of newborns in Europe: in the year 2021 alone, 4.09 million babies were born in the EU (Eurostat, 2023c), demonstrating the size of the market for children's products. The rapid development of young children during their first year's results in a high replacement rate for children's products. The short use phase means that many products have a very limited utility value, which does not resonate well with the fact that many children's products are made from high-impact materials.

In 2006, a Swedish study identified prams as an interesting and unexplored product group for which a PSS could potentially be developed (O. Mont et al., 2006). At the time, not many, if any, examples of PSS could be found for baby products. The study focused on prams as they are designed to be very durable, and yet, most families use their first prams for an average of just 6–8 months and a conventional sitting stroller for 6–12 months. The study argues that prams are typically discarded because the textile is worn out or becomes old-fashioned, while the chassis and basket usually last for years. Further, it highlights the discrepancy in the lifetime of different pram modules and a significant inefficiency in the use period of children's mobility products, which leads to the wasteful use of resources. The study concludes that implementing different PSS models for children's products could offer a new way of counteracting this inefficiency. By sharing the same products among multiple users and increasing the lifespan of products through PSS frameworks, with careful design and maintenance activities, the potential to minimise the demand for new raw material production becomes substantial.

The global market value for children's products is estimated to be EUR 154 billion and is expected to grow strongly (Statista, 2024b, 2024c). The informal sharing economy, in which parents share used children's products among their family and friends and the formalised secondhand market offering customers the chance to acquire used, but often high-quality, items, continues to thrive. In Sweden in 2006, for instance, 65–75 % of the demand for prams in 2006 was met by secondhand products (O. Mont et al., 2006), and it is likely that this is even greater today (Jaye, 2022; O. Mont et al., 2006; Schelde, 2019; Valor et al., 2022). This means that manufacturers only profit from the initial sale, while private actors are responsible for the remaining ones until the product can no longer fulfil its purpose. The large secondhand market for children's products and its growth shows that younger parents have a positive attitude towards used products and underlines the opportunity for manufacturers to profit from more circular business solutions.

4.2 Introduction to cases on children's products

The identified companies in this product group are mainly within the use-oriented PSS spectrum, offering different rental solutions for varying age groups. The companies are spread across Denmark, France,

Germany, Iceland, the Netherlands, Norway and Sweden and are predominately transparent about their circular motivations and visions. Rental options for children’s toys – either individually picked or packed in mixed boxes – can be found through the German company **Tribu**, **Lib&Lou** in France, **Barnalán** in Iceland and **LalaToys**, **Dear Baby** and **Lejetøjs Klubben** in Denmark. A variety of equipment, from strollers to beds and gravity blankets, can be rented through **Baby BoogieWoogie** in Denmark, **Tiny Library** in the Netherlands, **Parently** in Sweden and **Nomadi** and **StrollMe** in Germany. **Circos**, a Dutch company, and **Hyber**, a Swedish one, offer subscriptions to children’s clothing by age, and the Norwegian company **Bergans** rents out snowsuits for children as an add-on to their regular sales model. Other companies, for example, **BabySam** in Denmark and **Móðurást** in Iceland, offer rentals of breast pumps and baby scales, although these companies are still built around regular sales models.

For this report’s review and analysis, three cases were chosen, all offering children’s products through a rental model. The cases were chosen according to the prioritised selection criteria and their common willingness to share their experience in establishing and operating their individual PSS models.

Table 4.1 Presentation of children’s products cases

Case	Description
Parently Sweden Est. 2019	<ul style="list-style-type: none"> - Based on a subscription model, the Swedish offers baby gear as a service, including insurance, swaps, delivery, returns and needed maintenance. The rental duration is flexible, catering to diverse customer requirements, with longer subscriptions correlating to reduced costs. - Products are maintained, repaired, or refurbished (if needed) by a local business partner after each use phase. Products that no longer meet quality standards are either taken apart and used as spare parts to other products, recycled or sold through an external partner, such as the producers themselves. - Revenue share model: most items remain owned by their respective manufacturers, while Parently gets 50 % of the rental yields. - The customer base is concentrated in Stockholm, Sweden (50 %), followed by the wider Swedish market (49 %) and Copenhagen, Denmark (1 %).
Nomadi Germany Est. 2020	<ul style="list-style-type: none"> - Nomadi provides a rental service for children's equipment and toys, with customers subscribing on a monthly basis or paying rent while actively using the rented products. - Products are maintained, repaired or refurbished (if needed) after each use. When a product no longer meets quality standards, it is sold through the company's website. - Retailer/revenue share: operates through a combined retailer and revenue-sharing model, maintaining ownership of most products while collaborating with producers on select items. - The primary customer demographic is mothers (75 %) and fathers (25 %), aged 25–44, living in Germany and Austria.
Tribu Germany Est. 2020	<ul style="list-style-type: none"> - Rents out boxes of toys for children through a subscription model. The toys are selected by experts and tailored to specific age groups and developmental stages. - Products are maintained, repaired (if possible) or refurbished (if needed) after each use. Products that no longer meet quality standards are sold through the company's website. Products beyond repair or refurbishment are recycled. - Retailer: products are solely owned by Tribu. - Targets parents with young children as the primary customer base, mainly located in Germany and Austria.

Parently, **Nomadi** and **Tribu** share a common business model centred around children's product rental as their core offering. Each company carefully selects their products, emphasising durable materials that ensure prolonged product lifespans. The three selected cases are all relatively new, having been in business for less than five years, and each has 5–10 employees. The shared motivation for establishing these businesses stems from a desire to provide a sustainable, circular alternative to the prevalent use-

and-dispose culture, a perspective shaped by their experience as parents themselves. With their business models, they want to help parents choose the right products at the right time. In addition, Parently is additionally motivated by its explicit goal of guiding producers of children's products towards transitioning from linear to circular design practices.

Sustainability is a focal point in all three cases, and each company aims to convey this commitment to its customers and business partners. Therefore, they also have high expectations and requirements for their partnerships. While functioning as retailers, Parently and Nomadi additionally adopt a revenue-sharing model, where the manufacturers still own certain products. Thus, Parently and Nomadi act as links between the brands and their consumers.

A noteworthy distinction between these three cases and traditional sales models lies in their circular approach. The products complete a cycle by returning to the companies for cleaning, maintenance and repairs before being circulated to new customers. While Nomadi and Tribu manage this process in-house, Parently partners with an external service provider. Furthermore, all three companies maintain close ties with logistics partners, a critical component given the substantial transport involved. The various partnerships, whether for maintenance, logistics or manufacturing, are a central aspect of the business model and of great value, as the collaborations mutually strengthen both parties.

4.3 Environmental gains and climate benefits

Existing literature on PSS business models for children's products highlights significant environmental and climate benefits achievable through circular practices. A study conducted in Singapore over five years focused on prams, comparing various consumption scenarios to identify the most environmentally beneficial option (Kerdlap et al., 2021). The study revealed that renting prams resulted in 29–46 % lower lifecycle environmental impacts, depending on the impact category, compared to purchasing and disposing of them after initial use. 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 carefully manage and limit heavy cleaning cycles. This precaution is necessary to ensure that the overall lifecycle environmental impacts remain within the boundaries of traditional ownership scenarios.

A similar conclusion was drawn in a Master's thesis examining Thule bicycle trailers for children (Sen, 2022). This LCA, performed on three consumption scenarios of bicycle trailers in Sweden, shows that a 12-year leasing scenario (S1) spread between four users performed 28–33 % better (depending on the focus of the LCA impact category) than an ordinary ownership scenario (S2), in which the trailer was disposed of after six years of use. The study also shows that if a second owner uses the bike trailer for six more years, this scenario (S3) will perform 25–32 % better than the leasing scenario (S1).

4.3.1 Production, maintenance, and transportation factors

The two studies described above conducted comprehensive assessments across various impact categories, covering factors such as climate change, fossil depletion, freshwater ecotoxicity, ionising radiation, marine ecotoxicity, ozone depletion and photochemical oxidant formation. Within these categories, the leasing scenarios showed significant disparities when compared to conventional ownership ones. The research indicates that the production phase of prams and bike trailers is the primary contributor to their lifetime environmental impacts, while maintenance plays a pivotal role in the impact categories. Ensuring that the products involved can provide a service for as many years as possible without heavy maintenance can significantly decrease environmental impacts compared to ownership. Thus, products should be durable

and designed in such a way as to allow easy and resource-efficient maintenance – durable products reduce the need for maintenance, while modular designs make it simple to disassemble and repair them (Kerdlap et al., 2021). Consequently, the design and choice of materials used in these products assume critical importance.

Another influential factor was transport within the leasing scenarios. Negative impacts were observed in both the transport between customers and the company and between the company and maintenance partners. Furthermore, the transport of spare parts for product refurbishment, especially when these were sourced from distant suppliers, negatively affected the environmental gains of the business model. The study on Thule bike trailers suggests that a decentralisation of distribution centres, incorporating multiple locations for maintenance and administration, can play a positive role in reducing transport emissions.

Maintenance as life extension or appearance improvement?

Maintenance plays a crucial role within PSS models for children's products, with both environmental and functional implications. In the context of PSS models, maintenance and refurbishment are integral components that influence the environmental impact of the leasing service when compared to alternative scenarios such as product resale or passing to a second user. In academia, maintaining products is recognised as *“an important product quality attribute that has a significant influence on operational effectiveness and lifecycle cost”* (Liu et al., 2016). Maintenance is seen as a way of extending product life and reducing environmental impacts compared to an early product replacement (Lee et al., 2023). It is, however, important to acknowledge that different products have different environmental impact profiles across their lifecycles (Lee et al., 2023). In the **case** of prams, for example, the heavy cleaning required to bring one back to being as good as new affects the leasing model's total environmental impact (Kerdlap et al., 2021). The impact of the cleaning procedure is not included in scenarios of passing on the product to second and subsequent users. Indeed, it is expected that the product will fulfil its purpose for three more years without this cleaning.

It is important to distinguish between maintaining a product to optimise its appearance and its potential role in prolonging the product's lifespan. In the case of bike trailers, the refurbishment process within a leasing model might have observable environmental consequences. When analysing the scenario of passing the product on to additional users for six years without extensive refurbishment, a key question arises: Is maintenance primarily focused on cosmetic aspects and customer perception, or does it significantly prolong the product's life and ensure environmental benefits when compared to alternative scenarios?

This distinction highlights the nuanced role of maintenance within the circular economy. While some aspects of maintenance might address aesthetic concerns and consumer expectations, others could actively contribute to extending a product's functional life, thereby aligning with the circular economy's principles of resource efficiency and waste reduction. An evaluation of maintenance's environmental impacts needs to consider both immediate effects and the long-term benefits of prolonging a product's useful life. This assessment can provide valuable insights into the broader environmental and sustainability implications of PSS models, informing decisions on maintenance strategies, product design and consumer engagement.

An opportunity could lie in communicating distinct maintenance strategies to consumers, potentially extending a product's useful life beyond the assumed period of use. Implementing predictive maintenance strategies would require an in-depth study of product functionality and deterioration, consumer behaviour and maintenance habits during the leasing period. Such an approach could potentially strengthen the PSS model by offering extended use periods. Furthermore, it could shape consumer perceptions regarding the condition of leased products compared to new ones, fostering more sustainable consumption behaviour.

4.3.2 Improvements in the use phase

Another significant factor impacting environmental outcomes is highlighted in a Danish study focusing on the children's clothing rental company, Vigga (Kjaer et al., 2019). This illustrates how PSS models contribute to decoupling economic growth from resource consumption and underlines that substantial environmental potential lies within the consumer's use phase of the products. The study emphasises that handling rented children's clothing appropriately can significantly extend the products' lifespans. Notably, the cleaning process of clothing plays an important role – both for the product itself, extending its lifespan, and for minimising the environmental impacts in the use phase. A detailed customer care guide provided by the company helps customers follow the recommended cleaning processes. This proactive approach ultimately leads to the extension of the product's lifespan. By fostering responsible use, the study suggests that a product's longevity can be significantly increased, leading to improved environmental outcomes.

4.3.3 Empirical insights: Environmental considerations from case studies

This study's empirical findings reveal that rental companies encounter challenges quantifying and documenting their environmental impacts and climate benefits. Conducting LCAs is a resource-intensive task that demands a significant level of professional expertise, making them relatively costly to implement, particularly for small and medium-sized enterprises (SMEs). Therefore, the three cases presented—Parently, Nomadi, and Tribu—currently do not have comprehensive documentation of their environmental impacts. Nonetheless, all three companies share a common aspiration to gain such documentation.

Despite the absence of formal documentation, the cases are united by their overarching aim of extending product usability and maximising the value derived from the resources invested in their creation. Parently has taken a proactive approach, collaborating with Vinnova, the IVL Swedish Environmental Research Institute, the Impact Business Modelling System, and Lund University. Together, they have developed an impact plan outlining Parently's sustainability agenda and vision.

The impact plan underscores a compelling argument: if all European parents opted for using existing products, for example, through rentals, instead of purchasing new ones, a remarkable reduction of 1.5 million tonnes of CO₂ emissions per year could be achieved (Parently, n.d.). To put this in perspective, this level of saving is equivalent to the energy consumption of 150,000 households. The aspiration to realise such significant environmental gains underlines the central mission of these companies as they strive to contribute to a more sustainable future.

Logistics and packaging

Parently, Nomadi and Tribu are aware of the significant environmental impact of logistics when renting products, particularly the transport between rental periods. This observation aligns closely with findings in the existing literature. All three cases use a logistics partner to handle products between customers, the company and maintenance partners. This partnership is deemed essential, even though it has negative environmental implications.

To address transport-related environmental impacts, local hubs have been considered to minimise total travel distances. However, company resource limitations currently hinder the implementation of this approach. Closely connected to the logistics procedure is the companies' packaging procedure. All three have established policies for material usage and have actively engaged in collaboration to mitigate their packaging environmental footprint.

A shared practice among the three companies is reusing products' original cardboard packaging whenever feasible. When this solution is no longer possible, Nomadi uses refurbished cardboard boxes from

sendmepack (sendmepack, n.d.). These boxes circulate between Nomadi and new customers, creating a sustainable packaging cycle. Similarly, Tribu utilises recyclable cardboard boxes sourced from Ocean Package (The Ocean Package, 2024), which can be easily reused by their customers.

Parently highlights a potential challenge associated with the repeated use of a product's original packaging. Over time, worn and tape-covered cardboard boxes could create a negative customer experience, potentially influencing the perception of the enclosed products. This consideration underlines the difficult task of balancing sustainability issues and customer satisfaction throughout their operations. To address this, Parently has been actively involved in a reuse project for packaging with Stora Enso, Bring Logistics and Lund University, in which two trials have been carried out and evaluated involving return logistics and a new type of box from Stora Enso.

Maintenance

Another central focal point for all three cases is their approach to handling and maintaining products and the associated environmental implications. Parently considers maintenance to be the "*heart of the business*", setting them apart from traditional sales models. As previously mentioned, maintenance is, on the one hand, a practice that extends the lifespan of products but, on the other hand, carries a potentially negative environmental impact, particularly if performed frequently and extensively. Each of the three companies studied has established a comprehensive maintenance procedure covering cleaning, repairs and refurbishment. This approach ensures that their products consistently meet high standards, effectively optimising their useful lives. All three cases emphasise using non-toxic cleaning methods to ensure the safety of the children using their products. Parently articulates the possibilities of freezing products as an innovative cleaning procedure, which is both effective and gentle from an environmental perspective. This approach involves relatively new and costly technology, however, so Parently has not yet adapted it to their everyday procedures. If products get minor scratches, these are repaired; if parts are damaged, they are replaced to the extent possible. Notably, the companies observe a trend in modern product design favouring a modular approach, through which spare parts can be acquired to extend the functionality and use of items. This shift in design philosophy holds significant potential for reducing products' environmental impacts as it contributes to extending their useful lives.

The use and end-of-life phases

The use phase, during which customers can access the products, is a focal point for all three cases. Nomadi and Tribu provide clear guidelines to assist their customers in handling the products appropriately, thereby prolonging their usefulness. These include details of gentle cleaning methods for items such as strollers, cribs and carriers. This is fully aligned with the recommendations from literature which underline the positive environmental impact of comprehensive care guides during the use phase. When the products no longer meet the requirements for rental, all three companies have established end-of-life procedures through which products that no longer meet the rental requirements are either refurbished and sold on their respective websites or disposed of in rare instances. Given that Parently, Nomadi, and Tribu are relatively new ventures, their experience of products exiting the use cycle is still limited.

Furthermore, Tribu is actively exploring partnerships with toy manufacturers who can use their discarded products to create new toys, contributing to a more sustainable and circular economy. This example underlines how PSS providers, such as Tribu, can play a pivotal role in enhancing environmental sustainability when compared to traditional ownership models. Product-service system models can stand out by not only ensuring the proper maintenance and extended use of products throughout their functional lifespan but also by assuming responsibility for their end-of-life phase. This comprehensive approach can yield substantial positive impacts compared to conventional ownership models, making PSS a preferred choice in terms of environmental benefits.

Increased product utility

A fundamental difference between traditional business and PSS models lies in their revenue generation and incentive structures. In a traditional ownership-based business model, companies generate revenue only through the initial sale of their products. Once sold, the company's financial interest in the product diminishes, as it will not directly benefit from its subsequent use, maintenance or resale within the consumer-to-consumer (C2C) market. As a result, there is often less incentive for companies to design products with long extended lifespans or to actively support the products' reuse or resale.

In contrast, PSS models introduce a shift in the revenue generation mechanism. Companies that operate PSS earn revenue through continued service provision, such as renting or leasing the product to consumers. This creates a direct financial incentive for these companies to maximise the product's use and lifespan, as each additional use or rental cycle translates to increased revenue. In this scenario, the longer the product remains in circulation and is used by multiple customers, the more profitable it becomes for the company.

This financial alignment drives PSS providers to design products that are durable, easy to repair and adaptable to changing user needs. By focusing on extending product lifespans, PSS models can encourage resource efficiency and waste reduction. Additionally, PSS providers are usually motivated to ensure that their products are maintained and refurbished to maintain their functionality and desirability.

In essence, the companies studied emphasise optimising their products' use phase through maintenance, supplying user guidelines and end-of-life procedures, underlining their commitment to sustainability and circularity. While the focus on maintenance plays a pivotal role in the cases' business models, it also underscores the delicate balance they strive to achieve between enhancing product longevity and minimising environmental footprints.

4.4 Unintended consequences and rebound effects

The potential for unintended consequences in the shift from traditional ownership to rental or leasing models must include considerations of how consumer behaviour might be influenced. While renting products can offer economic benefits, such as increased disposable income, it could also lead to heightened consumption of other goods. This phenomenon, known as a rebound effect, could counteract the environmental gains achieved through the rental model by driving higher demand for other new products and increased production.

4.4.1 Inappropriate consumer behaviour

The 2019 study focusing on Vigga, a Danish children's clothing rental company, sheds light on important considerations regarding the potential rebound effects of subscription-based models (Kjaer et al., 2019). These factors can introduce complexities and potential negative environmental impacts that must be carefully evaluated. The study highlights the possibility that changes in customer behaviour due to subscribing to a service can lead to unintended environmental consequences. When customers save space by renting children's clothing, for example, they may use the saved space to accommodate other products, potentially offsetting the environmental gains achieved through renting. This phenomenon is observed in various studies of children's products, where an increase in disposable money as a result of rental schemes can stimulate additional purchases. This can be attributed to the notion that customers may view their rental choices as a form of sustainable action, justifying additional consumption in other areas (O. Mont et al., 2006).

All three cases analysed for this report mentioned the potential stimulation of inappropriate customer behaviour in relation to their business models. Aligned with literature findings, the increased disposable income resulting from subscribing to or renting products can lead to additional purchases of other products, the improper handling of products and overusing the system. This risk is acknowledged by all three companies and they have observed varying degrees of such behaviour among their customers.

Parently, for instance, encountered a customer who rented 14 prams and strollers from the Bugaboo brand over a relatively short period "*just because she could*". This behaviour generated significant transport, effectively reversing the environmental benefits of product sharing. Likewise, Nomadi and Tribu are aware of the potential for customers to overuse the system and actively address this behaviour in their communication efforts, emphasising the principle of less being better.

4.4.2 Emotional attachment

Another aspect of human behaviour that can influence the environmental impact of PSS models is the emotional attachment that customers may develop toward rented products. In the case of Viggas children's clothing rental service, parents reported forming sentimental connections to the clothing as it reminded them of their children's growth and development. This emotional bond can lead to a desire to retain the clothing, potentially prompting additional purchases once the rental period ends (Petersen & Riisberg, 2017).

Both Nomadi and Tribu offer customers the option of purchasing products after the rental period. Tribu occasionally receives inquiries from customers who want to purchase one or more of the toys they have rented after the end of the rental period due to their child's strong attachment to particular items. Parently also receives significant interest from customers wanting to purchase products after the rental period, but their focus remains on promoting product circularity. Nomadi encourages product circulation, but if customers express a desire to buy, they advise choosing high-quality items that will last longer. This phenomenon aligns with the literature's findings that emotional attachment to products can hinder circular behaviour and can be seen as an unintended consequence of the business model.

4.4.3 Hygiene concerns

Additionally, attitudes to hygiene plays a crucial role in the adoption and success of rental products. In a study discussing the environmental aspects of rental solutions for prams, the negative environmental impacts of heavy, frequent cleaning of rental prams are discussed (Kerdlap et al., 2021). To handle this, light or heavy cleaning processes are recommended depending on the need after each rental period. The light cleaning procedures, using water, gentle cleaning agents and open-air drying, are suggested for prams that are returned in good condition after short rental periods. Heavy cleaning procedures, using larger amounts of water, chemical cleaning agents and electrical, warm drying procedures are recommended only when products are returned stained or damaged. This solution is ideal from an environmental standpoint. Still, it may be impractical from a customer-service standpoint and could ultimately affect customer trust and the rental company's reputation due to concerns about cleanliness.

Managing both the potential stimulation of inappropriate consumer behaviour and addressing hygiene concerns are critical to the successful implementation of rental and leasing models – particularly for children's products. Striking a balance between environmental considerations and customer expectations is essential in ensuring such business models' overall sustainability and effectiveness.

4.5 Implementation factors

Two critical implementation factors emerged consistently across all three cases: finance and culture. The challenge of financing was a common obstacle faced by the cases studied during their start-up and early stages. The initial procurement of products and the process of building up a suitable inventory were highlighted as significant hurdles. To overcome this, a gradual approach was adopted, relying on cash flow to fuel growth. Nomadi, for instance, encountered difficulties in keeping up with product demand due to these financial constraints. In the initial stages, Parently struggled to secure funding due to limited liquidity, even though they had contracts worth SEK 2.5 million (approximately EUR 220,000). Additionally, Parently faced the dilemma of finding insurance coverage for its revenue-sharing model, as it did not own its products. The solution was a Swedish insurance company (Omocom, n.d.) specialising in PSS business models.

The second common factor is the cultural understanding of product ownership and the PSS business model. The companies have invested considerable effort in conveying and explaining their business models, emphasising the value of subscribing to or renting children's products. Parently, for example, emphasises that leasing a pram for several years may not yield substantial financial savings compared to a traditional purchase – the true value of renting lies in the comprehensive subscription services provided – repairs, maintenance and insurance. Consumers, however, often associate the concept of subscription services with digital services and magazines, making it challenging to communicate the benefits of this model. To bridge this gap, continuous communication efforts are undertaken to educate consumers about the business model, the services included and its environmental advantages.

Despite the companies' awareness of the environmental concerns surrounding logistics, the transport of products is practically unavoidable in their business models. An unintended consequence experienced by Parently is that while customers are flexible about collecting their parcels from local collection points, they are less willing to use them when returning products. This results in increased logistics, as each product has to be individually picked up rather than collected from a collection point.

Overall, the empirical data gathered from the cases underlines the complex interplay between consumer behaviour and the circular economy in the context of PSS models – particularly for children's products where emotional attachment can play a significant role.

4.6 Sub-conclusion

As children grow and develop rapidly, the use of children's products is typically short-lived. This brief product lifecycle, along with the inherent durability and easy maintenance often linked to these items, makes them well suited for a circular-economy approach. Rental services offer an added convenience, allowing parents to test products before committing to permanent purchases. This reduces the chances of making misguided buying decisions and provides the flexibility to adapt to the evolving needs and preferences of growing children.

In Northern Europe, particularly in Scandinavia Germany and the Netherlands, PSS models have a significant presence for offering a range of solutions for children's items.

The environmental benefits of renting or leasing children's products stem from product sharing and extending a product's lifespan, thus decreasing the overall demand for new products. Additionally, PPS can provide added options for improved recycling systems at the end of each product's life.

There are, however, negative aspects associated with increased logistics and maintenance procedures tied to product rental or leasing, which can outweigh the environmental benefits of multiple consumers sharing the same product. Maintenance activities are particularly relevant when dealing with children's products.

Furthermore, PSS models for children's products can encourage undesirable consumer behaviour, such as excessive usage, additional purchases or the improper handling of products.

Cultural factors and finance issues pose significant barriers to growth in this product category. Establishing inventory and ensuring products in revenue-sharing business models can be challenging for PSS start-ups.

To foster growth opportunities within the children's product sector, companies must communicate PSS as a business model effectively and outline their product handling and maintenance practices. Developing distinct maintenance strategies and communicating them to customers can optimise and extend product lifespans while positively influencing customer perceptions around hygiene. This, in turn, can encourage more people to embrace this sustainable business model.

5 Textiles

Textile consumption can be broadly categorised into clothes, footwear (which also includes leather shoes), and household textiles such as blankets, pillows and curtains (EEA, 2022)¹. This report focuses on clothing, given its predominant role in the textile industry and the high relevance of fashion trends for this segment.

The rise of fast fashion and the proliferation of low-price, low-quality clothing has led to a significant increase in textile production and subsequent disposal after just short periods of use. Presently, most clothes and business models within this sector are designed and optimised to fit the linear economic model. Consequently, most of the clothes that are discarded are not reused or recycled but end up in landfills or incineration facilities (ETC CE, 2024).

In the textile industry, access-based models hold the potential to promote more sustainable textile consumption. They are one of the four main business model types to support the shift towards a circular textile system since they can increase the use rate of the products, and hence lower resource use (ETC/WMGE, 2021). PSS can be referred to as clothing as a service (CaaS) or fashion as a service (FaaS). They encompass models in which clothes and fashion accessories are temporarily provided to customers through various schemes, including rentals, leasing or subscription models (Hibi, 2022).

5.1 European market trends

Within the EU alone, the average consumption of clothing per person amounted to more than 6kg of clothing per year in 2020, excluding other textile products (EEA, 2022). This important clothing consumption has far-reaching implications for sustainability and waste management. Due to the significant environmental consequences of the textile industry, there is a pressing need to explore and develop alternative consumption models. Product-service systems, or products as a service, are considered among the best-known alternatives.

At the European level, numerous companies offer PSS models for textiles, mainly through rental schemes. The European rental clothing market was estimated at USD 1.2 billion in 2019 – and is expected to double by 2025. With these numbers in mind, Europe is projected to become the second largest region in the world for clothing rental, trailing only behind the United States of America (Akseli, 2022).

In line with global patterns, the growth of the clothing rental market in Europe can be explained by the following different factors.

- **Sustainability perceptions:** a growing perception among consumers, especially younger generations, that renting clothing is more sustainable than traditional purchasing.
- **Supply-chain disruptions** causing shortages, inflation, longer delivery times and other challenges that can benefit the rental sector.
- **Economic factors** such as inflation can significantly impact consumers' purchasing power. Rental services can offer a cost-effective option, making them an attractive choice in times of economic uncertainty.
- **Technological advancement:** the rise of online platforms has made it easier for businesses to enter the clothing rental market. Additionally, these platforms facilitate effective marketing and promotion through social media, further driving the adoption of clothing rental services (Akseli, 2022).

¹ A more detailed categorisation includes carpets and other textiles such as robes and industrial textiles, but these categories only account for a relatively small share of overall EU textile consumption.

There are, however, big disparities between different European countries, including non-EU states, and some countries such as Germany and the United Kingdom are leading the market of those models (Market Data Forecast Ltd, 2023). Even though the market is still small, Europe is home to different types of PSS model targeting different types of customers. **Montreet** (Austria) and **Houdini** (Sweden), for example, specialise in outdoor apparel, producing high-quality outdoor clothes and accessories and offer both sales and rentals. Montreet additionally offers a repair service to extend the lifespans of its products. **Fjong** (Nordics) and **Le ClosetB** (France) have developed rental models for women’s clothes and **Menone** (France) has a similar model targeting men’s fashion. None of those three companies produce their clothes but offer existing brands for rental. **Mud Jeans** (Netherlands) specialises in producing highly durable jeans made of 40 % recycled material that can be bought or rented. Companies like **Drexcodes** (Italy) or **Studio Paillette** (France) focus on renting expensive designer clothes and dresses. Finally, companies such as **Hejco** (Sweden) specialise in renting workwear, targeting a specific customer base. In addition to those examples of CaaS and FaaS, other companies decided to also participate in developing alternative models for the textile industry by providing a platform for rentals, known as software as a service (SaaS), such as **Wedress** (Austria).

5.2 Introduction to cases

For this report, three companies operating within the PSS business model scheme have been selected for in-depth analysis.

- **Menone** stands out as a company specialising in men's everyday clothing, which is generally less represented within PSS compared to women's clothing. Additionally, the company's unfortunate closure due to financial difficulties makes it an intriguing case study.
- **Studio Paillette** was selected due to its specialisation in designer products, offering a particular perspective within the PSS landscape.
- **Wedress** was chosen because of its use of SaaS, showcasing the diversity of PSS models.

Additionally, the companies were prioritised because of their willingness to share their experiences and business insights.

Table 5.1 Presentation of textile cases

Case	Description
Menone France Est. 2022	<ul style="list-style-type: none"> - A French online shop offering rental of men’s clothes. The business started by renting boxes of clothes for a fixed price per box. Over time, Menone diversified and offered different rental agreements for the clothes. Clothes are displayed on a website and can be rented for a minimum of 30 days or purchased second-hand. - Initially, the founder was passionate about fashion and wanted to allow all to have access to good quality clothes and be able to dress well. The initial motivation was not environmental. - Due to numerous financial issues, Menone closed down in 2023.
Studio Paillette France Est. 2020	<ul style="list-style-type: none"> - A French online shop specialising in the rental of designer clothes. The company exclusively offers monthly rentals using a membership model. The main idea of Studio Paillette is to make expensive designer clothes accessible to a wider audience by offering cheap rental options. The company mainly offers women’s clothes but has also developed an offering of non-gendered ones. - The driving force behind this initiative was the founder's previous experience working with renowned designer labels and became disheartened witnessing the significant wastage of perfectly wearable clothing. Additionally, the idea was to bring expensive brands within everyone’s reach.

Wedress
Austria
Est. 2020

- The company operates as a rental platform providing a SaaS solution. They describe themselves as the Airbnb of fashion, providing a platform on which brands and individuals can offer clothing rentals through the Wedress platform. Furthermore, the company offers an application programming interface (API) that allows brands to integrate their websites with the platform. The platform primarily focuses on high-quality clothing and accessories.
- The founder of Wedress is an early advocate of sustainability and had been increasingly troubled by the environmental impact of clothing purchases. The inception of Wedress coincided with a time when environmental concerns related to textiles were on the rise, but consumers were still reluctant to give up fashion.

Menone is typically seen as an everyday fashion rental choice, unlike Studio Paillette, which specialises in a rentals for special occasions. Both, however, share the common objective of making high-end, branded clothing, often with premium price tags, accessible to middle-class consumers at an affordable rate. Wedress, on the other hand, combines elements of both everyday and special-occasion fashion rentals, even though a majority of the clothing available on the platform is suitable for special occasions.

5.3 Environmental gains and climate benefits

Today's fashion industry is one of the most wasteful and polluting industries, contributing to a global concern. According to the European Environment Agency, EU consumption of textiles had on average the fourth highest impact on the environment and climate change from a global life cycle perspective. It was the consumption area with the third highest impact on water and land use, and the fifth highest in terms of raw material use and greenhouse gas emissions (EEA, 2022). The European Parliament's Research Service (EPRS) estimates that in 2015 the global industry consumed 79 billion cubic meters of water, emitted 1.7 billion tonnes of CO₂ and generated 92 million tonnes of waste in growing crops and producing textile and clothes and these numbers are expected to increase by 50 % by 2030 if current production and consumption trends continue (EPRS, 2019).

Additionally, the growing of natural fibres contributes to deforestation and biodiversity loss. By 2030, the textile industry may demand 35 % more land, potentially displacing millions of hectares of natural habitats (Environmental Audit Committee, 2019). Synthetic fibres, on the other hand, largely derived from petroleum, are energy-intensive and generate microplastics during manufacturing processes, use and disposal (ETC CE, 2023). Since the textile value chain is one of the most complex supply chains and environmental effects arise at all product-life stages, it is however very complex to compare and assess all these environmental impacts, and more research and data on these impacts is needed (ETC CE, 2023).

At the same time, the potential for resource savings in this sector is substantial, since, on average, one in three garments is never worn or is worn less than once in three months (Bodenheimer et al., 2022). A transition from a linear to a circular approach is needed and PSS models for clothing, such as rentals, are among the alternative business models that aim to reduce the production and disposal of clothes by increasing their use and extending their lifetimes.

The environmental gains of PSS in the textile industry have been researched in different LCA studies that compared rental services with standard ownership models (Levänen et al., 2021). The studies generally agree that PSS models for clothing offer great potential to reduce the environmental footprint of this sector. However, this potential depends highly on the business model and policy of the companies operating the models. In some cases, PSS can have an equal or higher environmental impact than ownership models.

Although some studies claim that the rental of everyday clothing would likely have a larger impact from a sustainability perspective, most studies conducted are focused on rental models offering primarily high-end, luxury or special-occasion wear (Adam et al., 2018; Arrigo, 2021; Gyde & McNeill, 2021; Lang et al., 2019).

A recent study by Levänen et al. (2021) compares the CO₂ emissions impact of jeans in ownership with rental or reuse models. It focuses solely on global warming potential (GWP), excluding other environmental factors such as water and toxic chemical use, and waste generation. The literature reveals two critical factors to consider when assessing a rental model's environmental benefits: increased product lifespans and transport emissions.

5.3.1 Extended product lifespan

Extending the use of clothing can substantially reduce its GWP. In essence, the longer clothes are worn, the less environmental impact they have by avoiding the need for additional production. The degree of environmental benefit varies, however, depending on the type of garment and its use (Levänen et al., 2021). Indeed, the bigger the impacts of the garment on the environment, the more important it is to extend its lifespan. The impacts vary greatly depending on the type of material used as well as the quantity. For example, a pair of jeans will require more material to produce than an underwear.

Another study, also considering additional environmental factors including water usage pollution, found that for infrequently used clothing, such as special-occasion wear, the adoption of a rental or leasing model can have significantly more positive environmental outcomes compared to conventional ownership. In contrast, for everyday items, t-shirts for example, the environmental advantage of a PSS model has limited potential of reducing the environmental impacts. In cases where the clothing lifespan is not necessarily extended, the PSS model can even have a greater environmental impact than the traditional ownership model (Piontek et al., 2020).

5.3.2 Transportation emissions

Because of increased transport between different customers, rental services have a higher potential of emitting CO₂ during the use phase than traditional ownership models, including first- and second-hand purchases. Therefore, the mode of transport chosen by the company will significantly impact the overall environmental benefit of such a model (Levänen et al., 2021). This was confirmed by one of the case studies. Indeed, Menone's business model was based on a minimum rental period of 30 days, explicitly chosen to avoid an increase in transport needs. Based in the French city of Marseille, Menone also decided to deliver to local customers on foot, when possible, to reduce the potential impact. For customers in other cities in France, Menone outsourced the delivery to Colissimo, a parcel delivery service affiliated to the French postal service.

5.3.3 Waste avoidance

The case studies also highlighted additional environmental considerations. Clothing as a service has a high potential to avoid waste. Menone claims that none of the clothes initially purchased had gone to waste because they paid a lot of attention to buying high-quality clothing, which lasts well compared to low-quality fast fashion. Clothes that eventually run out of fashion are sold as second-hand products, extending their lifetime. Studio Paillette also achieve increased product lifetimes by repairing, mending and maintaining the clothes – it keeps its clothes for two years. after which the clothes are sold if they are still wearable or sent to Weturn for recycling into new textiles. Even though it is unclear if the general amount of textile waste is reduced by rental services, it appears clear from the case studies that they tend to increase the lifetime of the clothes by choosing high-quality fabrics and selling them on after repeated use.

As much as the lifetime of the clothes depends significantly on the quality of the fabric, the maintenance and way they are used are also decisive. The case studies have also shown additional aspects which can considerably impact the level of benefit to the environment of such a model. For instance, packaging is

considered by the companies interviewed as one aspect for which effort is needed. Menone, for example, decided to partner with Hipli, a French company which produces reusable packaging. Hipli also works as a PSS for packaging with Menone renting its packaging. This further decreases the environmental burden of deliveries by reducing the amount of packaging waste.

Waste avoidance is also a result of fewer purchases from customers who use a CaaS model. According to data from Studio Paillette, as a result of their offering, 16,700 fewer clothing items were bought in 2023. This also suggests that many clothes will not have been thrown away at their end of life. In addition, renting clothes can help minimize waste of unsold goods, as some researchers argue that renting requires less stock of goods compared to traditional retail (Bodenheimer et al., 2022).

The waste avoidance can also be dependent on the national legislation of the EU members states. In 2020, France voted a new law (law on the fight against waste and the circular economy), which obliges all producers, importers and distributors of textile products to reuse, in particular by donating essential products to associations working to combat precariousness and to social economy structures, or to reuse or recycle their unsold goods. This will inevitably have a positive impact for the unsold clothes of the whole textile industry.

5.4 Unintended consequences

There is a perception that rental services might face the rapid degradation of their clothes because of inappropriate behaviour by consumers (Bodenheimer et al., 2022). On the contrary, the interviewed companies had not experienced poor customer behaviour and were somewhat surprised how few of clothes that came back damaged or degraded. Overconsumption of clothes – over rental by customers – was also not experienced, and there was evidence of increased consumption of clothes through the rental model.

The companies, however, faced unexpected financial consequences – they did not expect the return on their investment in the models to be so slow.

5.5 Implementation factors

Demand for these consumption models is growing as customers find them more convenient. They give people access to fashion brands otherwise unreachable for most and have a reputation for having a lower environmental footprint. Nonetheless, establishing a successful and long-lasting business using the CaaS model comes with significant challenges.

5.5.1 Financial implications

Firstly, financial challenges represent the most significant barrier to running a CaaS business. This can be illustrated by Menone, which was forced to close after 1.5 years for financial reasons. This type of model requires a large initial investment to buy the clothes. This investment is then repeated each season as the collection needs to respond to fashion trends, especially when the company's primary aim is to offer fashionable clothes. With rentals and leasing, the margins are lower than with sales and it takes longer to achieve a return on investment, which can create a situation in which the income does not cover the large initial and regular investments, thereby causing financial difficulties. This was confirmed by Studio Paillette, which also pinpointed initial investment as being one of the biggest barriers to overcome. Wedress also mentioned the need of more financial support for these business models. Such start-ups have to develop in a society that encourages consumers to purchase rather than rent and in which it is

hard compete as a rental service. To overcome this barrier, new start-ups offering CaaS could receive financial support, especially during the first years, to give them a chance to develop a viable long-term.

5.5.2 Cultural infrastructure

The third barrier identified and very much highlighted by Wedress is the lack of adequate infrastructure and logistics to truly develop CaaS models. As highlighted above, a rental system for clothing involves more transport of goods. To avoid having a worse impact on the environment than an ownership model, it is crucial for CaaS companies to develop a sustainable delivery process. This could also involve developing decentralised warehouses for the clothes, reducing to a minimum the impact of transportation. It is recommended that governments, municipalities and urban planners take account of the development of rental services in their planning.

5.6 Sub-conclusions

In Europe, PSS in the clothing sector are currently still in their infancy. There is, however, true potential for those systems to grow and develop across Europe. Although the first motivation for customers to adopt such systems is not lessening environmental impacts but rather the access they give to expensive brands; there is a growing demand for these types of models. The environmental benefits of such models, however, depend largely on the duration of rental agreements, transport methods and the fate of the clothes once they reach their end of life for the company.

When properly designed, PSS models for textiles can offer clothes with a very much reduced environmental footprints, especially for special-occasion clothes that are not worn often. Marketing the true environmental gains of the companies operating a PSS model can help reach new customers across Europe, in a context in which an increasing numbers of sectors are trying to become more circular.

Misconceptions remain among the public especially on the cleanliness and practicality of such a model in the clothing sector. Clients using CaaS models are, however, usually convinced once they adopt them. There is, therefore, a great opportunity to dispel misconception and prejudices by raising awareness about the use of such a model and campaigns through which people can try out the rental of clothes with no long-term engagement.

The initial investment for start-ups remains the biggest identified barrier. There is a need for unified support across Europe to encourage new companies. This goes hand-in-hand with support for developing circular infrastructure to enable the easier spread of the PSS business models.

6 Home appliances

The household appliances market covers appliances typically used in private households to perform various tasks, such as cleaning, washing, cooking and refrigeration. The market is divided into two main segments: (1) major appliances, such as refrigerators, dishwashers, washing machines and air conditioners; and (2) small appliances, such as vacuum cleaners, toasters, coffee machines and irons. Household appliances are a core area of consumption in developed and developing countries and projections related to increases in population and average income forecast that consumption in this sector will grow. Due to the resources required for the manufacturing of appliances and the resource consumption during their use, this product category is considered important for the uptake of sustainable production and consumption models.

The environmental impact of the household appliance sector is one of the highest. A recent LCA found that the use phase of appliances is responsible for the highest share of its environmental impacts, followed by the materials used for production (Hischier et al., 2020). The same study found that, on average, one-third of appliances are more than a decade old. Combining these two empirical observations, it is clear how old, energy- and water-inefficient appliances may be a key hotspot for environmental impacts today.

The market has also highly relevant social implications regarding access to basic needs, for instance in relation to the growing issue of energy poverty. The share of household budgets spent on domestic energy services grew from 6 % in 2000 to 9 % in 2014 for low-income families, compared to an average increase from 5 % to 6 % for the entire population (Pye et al., 2015). In 2018, the European poorest households spent 8.3% of their total expenditure on energy, and up to 15%-22% in some Central and Eastern European countries (Cambridge Econometrics et al., 2020).

The COVID-19 crisis, followed by the surge in energy prices and the Russian invasion of Ukraine in 2022, have worsened an already difficult situation. After heating and the provision of hot water, energy-intensive appliances are a substantial reason for high energy bills, but low-income families can often not afford more efficient appliances due to their higher price, giving rise to a vicious cycle of relevant environmental and social implications.

6.1 European market trends

The household appliances market is defined by a competitive landscape with several major manufacturers with wide international distribution networks. Both business-to-consumer (B2C) and B2B business models are part of the market. Business-to-consumer business models focus on individual consumers, while B2B models deal with other companies and landlords, including residential ones and owners of student accommodation. Global revenues of the household appliance sector amounted to USD 1 trillion in 2023 and the market is expected to grow at a compound annual growth rate (CAGR) of 4.75 % between 2023 and 2028) (Statista, 2024a). In terms of volumes, the market is expected to reach 5.0 billion items by 2028.

Europe is a major market for household appliances, generating sales revenues of more than USD 100 billion every year of which Major appliances account for roughly 60 %. The European market is expected to grow at a CAGR of 2.33 % in 2023–2028. One of the major trends in the European market is the growing adoption of smart appliances. Currently, around 15 million people in Europe use these, and their number is expected to increase ten-fold in the next ten years (Modor Intelligence, 2023), a trend which should increase the water and energy efficiency of household appliances. The demand for multi-functional household appliances is also increasing among consumers in Europe. The household appliances market in Europe is fragmented with the presence of several vendors, with some of the key players being Electrolux AB, Bosch, Hitachi, Miele and Whirlpool.

6.2 Introduction to cases of household appliances-as-a-service

The PSS business model in the household appliances sector involves the transfer of the right to use the appliance to the end consumer, without a transfer of ownership. Both the manufacturers of appliances and the distributors/vendors can have the role of service providers.

Broadly, two main PSS models in the household appliances sector are the following.

1. **Leasing model:** each month the end consumers pays a fee and in return the service of using the appliance is provided. In most cases, this model is independent of the actual usage of the appliance, for example, the number of washes in a month for a washing machine. This model is applied both for B2C or B2B business models. With B2C ones, a single household typically benefits from the service, while under B2B models, the appliance can be shared by a group of households through the role of a common landlord or individuals in an office.
2. **Pay-per-use model:** a service model in which payment to the owner of the appliance is based on actual use, rather than a standard monthly fee. Thanks to digital technologies applied on the machine, service providers have information about the current use of machines and can monitor it. With this model, service providers can apply a differentiated service-price structure, where more energy and water-intensive uses attract higher fees.

In both models, it is most common that the fee not only includes the use of the service, but also the delivery of the appliance, its installation, maintenance and repair when needed. While both models can work with single households as customers, it should be noted that a significant share of this market is taken by sharing models, for example, when appliances are available to an entire apartment block or student house. The sharing model presents its own specific advantages in terms of environmental performance, which is highlighted in the analysis below. Only a few household appliances, however, such as washing machines and tumble dryers, are suitable for sharing.

The emergence and adoption of PSS in the household appliance sector is very different across different countries and cultures, and represents a small share of the total market. This business model is currently offered both by large manufacturers, who are well-established players in the household appliances market and for whom the major share of revenues still comes from traditional sales channels, and by small and medium-sized enterprises (SMEs). The SMEs who enter this market tend to be motivated by innovation in the distribution/use of the appliances and tend to focus exclusively on the PSS offering. The first category includes such companies as Bosch, Electrolux AB and Miele, while the second one startups and SMEs as Homie and Bundles.

For this report's review and the analysis, three cases are chosen: two large corporates operating both traditional sales and leasing – **Electrolux AB** and **Bosch** – and one only using a PSS model – **Homie**.

Table 6.1 Presentation of home appliances cases

Case	Description
Electrolux AB Sweden Est. 1919	<ul style="list-style-type: none"> - Electrolux AB is a multinational household appliance manufacturer based in Sweden. - In 2019, it launched a subscription-based home appliance-as-a-service pilot in Sweden and China. In Sweden, the pilot included Electrolux's Pure i9 robotic vacuum cleaner, while in China it also included an air purifier. In both cases, the subscription also included an appliance usage tracking app and other supporting maintenance services. - In 2022, Electrolux began to offer the Levande all-in-one subscription-service platform in Singapore, which includes setup, delivery, repair, recycling and a 48-hour guaranteed like-for-like replacement policy. It applies to a wide range of appliances, such as washing machines, dryers, refrigerators, and vacuum cleaners.

	<ul style="list-style-type: none"> - In 2022, Electrolux also launched a new appliance-as-a-service programme for landlords and signed a customer agreement with one of Sweden’s largest landlords, SKB. The concept involves leasing major appliances such as washing machines to landlords with furnished apartments, with the service including maintenance, repairs and replacement if necessary. - In their latest 2022 Sustainability Report, Electrolux mentions that one of the challenges to the roadmap to 2030 is to “optimize product lifespans in a way that benefits the consumer, Electrolux and the environment”.
<p>Bosch Germany Est. 1886</p>	<ul style="list-style-type: none"> - The Bosch Group is a leading multinational global supplier of technology and services, with headquarters in Germany. Bosch offers different models of appliances-as-a-service. - Blue Movement: fee-based leasing model, currently operating in Germany and the Netherlands, offering a wide range of appliances from major one such as refrigerators, freezers, washing machines, dryers and dishwashers, to small ones, including coffee machines and vacuum cleaners. Different fees are applicable depending on the appliance category and efficiency class. They claim that they refurbish 97 % of the devices they get back after the end of the subscription before leasing them again. If refurbishment is not possible, all appliances are recycled. - WeWash: an innovative spin-off from BSH Hausgeräte Europe’s largest manufacturer of household appliances, which offers a sharing pay-per-use model in several countries across the EU, with a focus on washing machines and tumble dryers. WeWash is a hardware device that can be installed on existing washing machines and acts as a digital billing system. It is typically installed in residencies in which a number of households live together and in hostels or student houses. If no washing machines are present, WeWash equips the washroom with energy-efficiency Bosch appliances through the all-inclusive WeWash care package. - The Papillon project is an appliance-as-a-service joint initiative of Bosch and Samenlevingsopbouw West-Vlaanderen, a Belgian social enterprise. The initiative was conceptualised to address the ongoing energy-poverty crisis that affects low-income households in Europe. Through it, customers can access energy-efficient household appliances at an affordable monthly rental cost. Customers have access to a selection of appliances from Bosch, including refrigerators, freezers, washing machines, dryers and dishwashers. For a monthly cost, the appliances can be rented for ten years. Services such as delivery, installation, repair and return are included in the fee.
<p>Homie Netherlands Est. 2018</p>	<ul style="list-style-type: none"> - Homie is a Dutch SME, which started as a demonstrator of academic research on the potential of PSS for products with strong use-phase impact. Currently, they claim to have more than 4 700 users with subscriptions for household appliances. - Since 2018, they have been offering appliances on a pay-per-use basis. Today, HOMIE offers a hybrid pay-per-use business model for washing and drying with a monthly usage minimum. With pay-per-use subscriptions, Homie encourages and rewards energy-efficient washing behaviour among users by making energy-efficient programmes cheaper than less efficient ones. - HOMIE also offers other appliances and products as-a-service, including microwave ovens, touch bins, irons and vacuum cleaners, for an all-inclusive monthly fee. Included fee are free repairs, transport and recycling of old appliances. The fixed monthly fee also allows unlimited use.

Electrolux AB, Bosch and Homie present clear differences across their appliance-as-a-service offerings. While all three companies have fixed subscription models, through which appliances are leased/rented for a monthly fee, Homie also uses pay-per-use business model, which encourages more sustainable washing behaviour through lower service unit fees. This is a relevant difference in relation to the assessment of the environmental implications of home appliances-as-a-service compared to traditional sales models.

The three companies’ motives in introducing PSS offerings also differ. While Electrolux AB and Bosch have developed their offering alongside traditional sales options, Homie was established exclusively as a service

provider. For the established players, this new offering is seen as an opportunity to experiment and develop new relationships with their customers, including the possibility of attracting the interest of sustainability-conscious ones, seen as a market segment that will grow in the future. For Homie the main driver has been backing up the sustainability promise of PSS with a real business case.

6.2.1 Enabling factors

In the case of Electrolux AB, three main factors at the company level have been identified:

- increased focus on digital design, which has enabled new customer relationships and increased the quality of the app and interface with clients;
- influence on product design, with pilot projects in this area pushing the product design team to improve reparability and the possibility of refurbishing appliances;
- the existence for many years of an established repair and refurbishment department, facilitating the acquisition of the knowledge and skills necessary to operate in this market.

Bosch has also identified the PSS offering as an opportunity to stimulate research and development (R&D) in rethinking product design to lower costs and increase value over entire lifecycles. This translates into research for components that last longer, how to make repairs easier and what other materials can be used to increase the value of recycling. For established players, PSS is seen as an area in which a new customer value proposition, environmental benefits and economic gains can be complementary.

6.2.2 Target customers

Depending on the actual offering, target customers may differ widely. In the case of Bosch's Papillon project, for example, the target customers are families living in energy poverty, selected as eligible for the programme by a social cooperative. Despite differences among the various models, several common elements emerged in the information-gathering about customers who might be interested in this type of service.

- **Convenience:** with appliances as a service, customers do not need to go through the hassles associated with purchase and owning the appliance, such as maintenance and repairs. This is particularly relevant for customers who are aware they will be living in a specific location for a limited time, for example those with temporary rental contracts.
- **Sustainability:** customers may be interested in sustainability and care that appliances offered through the service are refurbished and will certainly be recycled. In the case of sharing appliances, they might also appreciate the optimal use of an appliance. With pay-per-use models, customers may be interested in the combination of more sustainable behaviour and lower costs.
- **Quality standard:** as the company retains ownership of the appliances, customers expect high-quality items which will last long. This model gives customers access to energy and water-efficient appliances. Furthermore, when the machine needs to be replaced, there is no extra cost for the customers.
- **Experimentation:** in the case of more innovative products, such as cleaning robots, the subscription model provides customers with the opportunity to test a product before choosing whether or not to purchase it.

This market is considered to be evolving, with future growth potential through the attraction of new types of customers. It is important to note that customers in this segment might not have sustainability as the only, or even leading, motive when choosing an appliance as a service. Convenience and quality play a big part, too.

6.3 Environmental gains and climate benefits

The environmental gains and climate benefits of household appliances as a service depend on several factors. One concerns whether the appliances are used exclusively by one household or shared across different ones living in the same building. That is, whether PSS are deployed using a sharing-economy model. Another factor relates to the difference between leasing models with fixed subscriptions and pay-per-use models with the monthly fee dependent on the actual use of the appliance.

Despite differences, however, it is possible to highlight some key environmental gains from household-appliance PSS.

- **Resource efficiency:** PSS models push manufacturers to produce durable and long-lasting appliances. This shift at the R&D and design level results in a reduced need for frequent replacements – slowing resource loops – and minimises the overall demand for raw materials and energy required for production. This is also achieved through preventive maintenance, due to the use of digitally connected devices. As the appliance remains owned by the company, additional efforts could be made to ensure that the value of the appliance is maximised throughout its lifecycle.
- **Reduced waste:** as products remain the property of the service provider, they can easily be refurbished, repaired and recycled. This allows closing resource loops and reduces the amount of electronic waste and discarded items in landfill.
- **Energy and water efficiency:** PSS models often provide energy- and water-efficiency appliances to customers, who might otherwise not have access to them. Improvements in the water and energy efficiency of appliances can have a significant effect in terms of emissions reduction from the operation of the appliances.

To fully grasp the magnitude of the actual environmental gains and climate benefits of appliances as a service, it is important to remember that lifecycle studies highlight the use phase of appliances as the one having the greatest environmental impacts, followed by the materials and energy used for their production. This implies that benefits stemming from product longevity, reducing production volumes, and reduced waste certainly have an important role to play, but measures to lower impacts during the use remain paramount.

In this regard, pay-per-use may have a unique potential in terms of environmental gains. With this model, in fact, customers may become more conscious of their resource consumption as they directly pay for the service unit they use. In turn, this may lead to a more responsible use of the product and a reduction in energy and water consumption. Homie has been testing this model for several years and the company found that on average users with a pay-per-use subscription consume around 26 % less water and energy. Homie performed some empirical studies on the environmental gains and found that their users wash 12 times per month as opposed to the European average of 13–14 times, and wash at 38° C, rather than the 43 ° C European average (Bocken et al., 2018) – a significant difference that could be ascribed to the pay-per-use model. As this effect is due to behavioural change, it might also lead to the spill-over effect of individuals becoming more aware of ways of making their daily lives more sustainable across other, unrelated product categories.

Another case of lowered environmental impact during the use phase was noted in Bosch's Papillon project. As low-income households living in energy poverty tend to have older, less water- and energy efficient appliances, the provision of energy efficient ones through the subscription service has a high potential to have a positive effect, from both an environmental and social point of view. The fact that energy efficient machines are provided through an accessible monthly fee enables families to use such appliances, to which they would otherwise not have access.

Finally, the reduced environmental impact of sharing models – such as the one enabled by Bosch’s WeWash – comes from the fact that several people sharing the appliance, therefore reducing production volumes. This again has an effect on the consumption of virgin raw materials. When, however, it comes to the potential for PSS models to be coupled with sharing models in the context of household appliances, it should be stressed that the type of appliances that can be shared appears to be quite limited. While having shared washing machines and tumble dryers is quite common nowadays in a variety of contexts, even in a traditional sales model, this seems to be much less relevant in the case of other household appliances such as refrigerators and freezers.

6.4 Unintended consequences

Some unintended negative consequences are related to the consumer behaviour and handling of the appliances. As the appliance remains property of the company and repair/replacement are included in the monthly fee, some consumers may abuse this contractual relationship by neither take proper care of the appliance nor make the right use of it. In Homie’s pay-per-use model, for instance, the company noticed that as people pay per wash, they have an incentive to fit as many items as possible in a single wash, potentially creating technical problems.

Lack of care and improper handling by users should not, however, be understood as the most common problem. Indeed, all the companies reported such cases to be rare, thanks in part to a closer company-customer relationship which enables better and continuous communication. Bosch, for instance, stated that users involved in the Papillon project take very good care of their appliances because they appreciate the project and the opportunities it provides them.

Another potential unintended consequence arises from the early termination of contracts. If customers do this, more logistics would be involved, which would increase the environmental footprint of the whole model. Furthermore, it would create secondhand appliances which are more difficult to include in this model, leading to a further need for the production of new appliances.

When it comes to potential consumption rebound effects, the risk appears to be rather low for household appliances. As the category covers task-oriented appliances, washing clothes, storing food, etc., if the appliance satisfies the need, there is no risk of over consumption.

6.5 Implementation factors

Several factors would be required for a large-scale implementation of PSS for household appliances. The main issues identified by the companies interviewed are: market, financial, cultural and logistical factors. It should be noted that these factors are not unique to this product category and can be found across several others.

6.5.1 Market factors

In terms of business model potential, this is generally seen as a growing market, which may attract customers due to convenience and improved environmental performance. It is, however, expected that the traditional sales model will remain dominant with PSS offerings only covering a marginal share of the market. From a business perspective, companies see a great opportunity in creating new, longer and closer relationships with customers thanks to this model. The mass scalability of the model is currently unclear, due to logistical, financial and cultural aspects.

6.5.2 Financial factors

This business model is economically viable, but it entails substantial variations in a company's cashflow. While investments are required at the beginning, income is spread over time through the payment of monthly fees. This may impact working capital in the future. By taking this into account in the monthly fee, however, it is possible to find a solution through which income is spread over time, hence delayed in the future, yet more substantial than with a simple sales model. Economic viability may be achieved by postponing the cashflow but increasing income per unit of product. Financial factors are strictly linked with legal factors: in Belgium, for instance, Bosch has adopted a rental rather than a leasing model, which would involve more legal barriers to overcome.

6.5.3 Cultural factors

The adoption of such a model is deemed more or less likely depending on the geographical location and the cultural norms in a specific market, specifically in relation to the notion of ownership. The cases presented in the analysis above tend to focus only on a limited number of European countries, such as Belgium, Germany, the Netherlands and Sweden. Across European markets, customers might still prefer to own their appliances rather than leasing or sharing them. This is a factor which is applicable to many PSS.

On the cultural side, Electrolux has also identified some challenges when it comes to communicating the benefit of an appliance as a service. Customers often look at the monthly fee as an exchange for the appliance, overlooking the fact that maintenance and repairs are included in the monthly fee. These additional services should be better communicated and understood by customers for them to be able to make a proper comparison between buying and leasing household appliances.

6.5.4 Logistical factors

Logistics is another key component to enable household appliances as a service. With this model, the logistics and reverse logistics requirements differ greatly from a traditional sales model. If a manufacturer is used to operating with distributors, for instance, it only needs big trucks to deliver to the distributors' network. When delivering to end consumers, however, this is not efficient if even possible, and it therefore requires different partners in the supply chain.

The information technology (IT) infrastructure to manage this system also needs to be taken into account. On the one hand, customer relations require a new IT system; on the other, there are additional requirements to monitor, gather and analyse data from the appliances in order to have an overview on when maintenance and repairs should be carried out.

6.6 Sub-conclusion

Product-service systems currently represent a marginal share of the household appliances market in Europe. Both large, established companies and emerging SMEs are experimenting with the model, attracting customers, especially thanks to its convenience, quality and sustainability claims. The most common model is a fixed monthly subscription for the use of an appliance, while pay-per-use models are still rare, especially when not coupled with a sharing-economy model.

The highest potential for environmental gains and climate benefits lies in improving the performance of the appliances during their use phase. When PSS models provide more efficient appliances to customers than they would otherwise own, energy and water consumption savings can be substantial, significantly

reducing CO₂ emissions. Pay-per-use models, in which the unit price is tied to sustainability criteria, as operated by Homie, offer additional opportunities for behavioural change by users. Furthermore, PSS offerings can become drivers of sustainable innovation at the product-design level and have positive spillover effects on all a company's offerings, including through traditional sales channels.

Several barriers to the wider adoption of household appliances as a service have been identified, including market, financial, logistical and cultural issues. Although overcoming these barriers seems feasible, the main impediment remains the willingness of customers to lease a household appliance rather than buying one, especially when it is needed beyond a short period.

7 Information and communication technology

Information and communication technology (ICT) is an extended term for information technology (IT), focusing more on interpersonal communication and education (Indika, 2011). It is an umbrella term that refers to merging audio-visual and telephone networks with computers, including mobile phone devices and services, radio and television, video-conferencing applications and educational services (Wikipedia, 2023).

7.1 European market

The ICT industry is huge and growing rapidly. Ranking as one of the largest industries in the world, the ICT market is estimated at USD 5.5 trillion in 2022, rising to and almost USD 6 trillion in 2023 (Statista Research Department, 2023). The United States has a 36 % share of the global industry and the EU about 11 %. In 2020, the value added by the EU's ICT sector was equivalent to 5.2 % of its GDP (Eurostat, 2023b). Spending on ICT in Europe is expected to grow by 2.8 % year-on-year in 2023 in constant currency terms, reaching USD 1 184.5 billion. Electrical and electronic equipment waste (WEEE) is the fastest growing waste stream in the EU (EU Reporter Correspondent, 2020). In 2022, 11.2 kg of WEEE were collected per inhabitant in the EU, corresponding to about 40 % of the annual average of electrical and electronic equipment placed on the market in the preceding three years. Out of the collected WEEE, 80 % is recycled (Eurostat, 2024). Europe also still exports hazardous waste – about 10 % of the ICT waste from the investigated countries is exported. The waste from Western Europe is mainly sent to Eastern Europe, West Africa and Asia (Liebmann, 2015).

The ICT industry has different subsectors for example: manufacturing, wholesale, publishing, programming, telecommunications, processing, and repair (Eurostat, 2023a). The two PSS cases highlighted here are both concerned the telecommunications and repair subsectors: **Everphone** in Germany is a device-as-a-service (DaaS) business, renting out new mobile phones and tablets; **Inrego** in Sweden sells used and repaired ICT devices with DaaS as a sub offer.

7.2 Introduction to cases

Other examples of PSS providers in the ICT industry include the following.

Grover (Germany) that serves both private customers and businesses, offering subscription rentals of ICT and other tech products. They use both new and reused devices.

Printer4you (Germany) main business is printers but they also rent out an array of other technical devices, for example, tablets, personal computers (PCs), televisions (TVs) and mobile phones. They offer contracts of 12, 24 or 36 months with customers having the option to of buying their devices at the end of the rental period.

Repeat (Netherlands) offering a product oriented PSS model by manufacturing headphones with replaceable individual parts. Their unique approach extends to providing free lifetime repairs, showcasing a commitment to sustainability and longevity in their products.

Table 7.1 Presentation of information and communication technology cases

Case	Description
Everphone Germany	- Device-as-a-service (DaaS), with rental models for B2B clients. More than 1 000 businesses as clients. DaaS for smartphones + tablets + accessories (keyboards and headphones). Everphone offers integration, setup and replacement of devices if they

<p>Est. 2016</p>	<p>break (Eversetup, Evermanage, Evercare). The company provides rental cycles of 2–3 years with an option of extension. The customers have a portal from which to run their subscription and, if wanted, can upgrade or exchange their devices.</p> <ul style="list-style-type: none"> - Everphone mainly supplies companies with 200 employees or more. - Everphone refurbishes almost all their devices, 98 % in 2022, largely for the secondhand market, and recycles the rest. - Everphone collaborate with big refurbishing companies in Europe for the B2C market. Their main customers are larger companies, since their minimum requirement is to supply at least 200 devices. - Everphone has designed software that enables a safe separation of work and private modes on the phone, encouraging the use of one device rather than two. - Everphone aims to decrease raw material consumption as the use of the phones is maximised. It further aims to decrease WEEE, mainly by renovating and then releasing the product to the secondhand market once it is no longer fit for the PSS. - Additionally, it have incorporated incentives, such as planting trees, to encourage longer rental periods
<p>Inrego Sweden Est. 1995</p>	<ul style="list-style-type: none"> - Inrego purchases used devices from companies, repairs and updates them and resells B2B and B2C. Products categories includes computers, mobiles, tablets, docking stations, TV's and spare parts. It only sells online. It also rents their products on demand; this makes up around 15–20 % of their revenues Rental contracts are for 24 or 36 months. - Inrego's typical customer has 0–200 employees – larger companies tend to buy, according to Inrego. - Inrego claims to offer the only ICT PSS providing residual value on the devices they sell, making it possible for the customer to return the device after 24 months for 20 % of the purchase price or 10 % after 36 months. - The company aims to reduce raw material consumption, mainly by selling/renting used products. It further aims to reduce WEEE and extend product lifetimes by renovating, maintaining and selling/renting used products.

7.3 Environmental gains and climate benefits

As already stated, the ICT market is huge and growing rapidly. When looking to the environmental effects from ICT, aspects such as high impacts from production, short lifespans and a lack of waste handling are essential. Product-service-systems could potentially be one way to lower these environmental effects.

Devices generally have a short service life. A survey in Germany in 2023, for example, revealed that 23 % of the correspondents had used their smartphone for less than 6 months, 32 % for 7–12 months, 19 % for 1-2 years, 12 % for 2-3 years and only 11 % had used them longer than three years (Tenzer, 2023). Furthermore, the recycling rate of devices is low, a study estimated the recycling rate to be under 15 % in Europe (Rizos et al., 2019). Many devices moreover are estimated to be part of unused stock, Rizos et al. (2019) estimate there to be up to 700 million such devices in Europe alone. Materials that today either go into other waste flows rather than recycling or are still lying around in households could be recovered, including significant amounts of valuable resources such as cobalt, copper, gold, lithium, palladium and silver. As an example of the potential, the same study estimates that recycling all devices could recover up to 14.9 tonnes of these valuable resources.

A study by IVL Swedish Environmental Research Institute, in cooperation with Inrego (Wranne, 2020) estimates the climate benefits of reusing different IT products. Their estimates include the avoided impact from production, transport and waste handling of new products as well as from the increased transport and renovation estimated for the reuse process. A renovated notebook, for example, gives an estimated

average climate saving of 280 kilograms of carbon dioxide equivalent (kg CO₂e); a renovated desktop, 470 kg CO₂e and renovated components, an average of 22 kg CO₂e. The avoided impact from new production is by far the largest of all the sub processes included in their equation. Rizos et al. (2019) estimate that approximately 80 % of the climate emissions comes from the production phase. This points strongly to the need for increased longevity and more efficient use of products to avoid new production. Indeed, Rizos et al. (2019) estimate that over a 10-year period between 20 million tonnes CO₂e emissions could be avoided by prolonging the lifespan of devices by one year.

The environmental gains from ICT as a service depend on the respective business model. For instance, the two cases included here have different models: Everphone mainly rents out new devices while Inrego mainly rents/sells used products. Everphone's main environmental gain can be assumed to be the increased efficiency of usage as well as avoided WEEE. Inrego's, however, can be assumed to be the avoided raw material consumption due to reusing existing products. A challenge already mentioned is that ICT products generally have a short lifespans. Both companies, however, aim to increase lifespans as much as possible within their respective models.

Everphone aims to avoid WEEE, and this is also one of their biggest environmental gains according to them. They refurbish used phones and give or sell them to the secondhand market, thereby extending the lifespans of devices. Another of their main environmental gains is the increase in use – they aim to have an impact on the inefficient handling of devices – today, for example, many devices end up in drawers, etc. when they are no longer in use. In this way an overall environmental aim of Everphone is to decrease the raw material consumption as phones are used more efficiently. One challenge that they raise, however is that data on, for example, how long phones are used today is uncertain and good data is lacking. This in turn makes for example climate savings from their model difficult to estimate.

Inrego's main environmental gains come from the fact that it sells and rents almost only used IT products. Consequently, it aims to avoid the consumption of raw materials and production of new products. As Inrego refurbishes products, it extends their lifespans up to the point at which it is no longer possible, for reasons such as demand, etc. When this point is reached, they hand the products over to markets in which there is a demand for them, such as schools in other countries, so that their use is maximized. One challenge Inrego raises is the fact that whilst production of new technology is to a large degree automated while renovation is a time-consuming process that mainly needs to be done manually.

7.4 Unintended consequences

One unintended consequence of a PSS model based on a renting phones could be that the user rents the device for a shorter time than they would use it if they were to buy it. This could be the case if it is convenient or economically beneficial to rent. According to one of the cases renting B2B, this should not be a common issue however as it would not be economically viable for a company to have a very short rental period. The gain from renting compared to buying a phone also depends, however, on how long a phone is used in other models compared to typical rental periods. That is hard to know as unfortunately statistics are lacking. A problem with products such as phones is that it is difficult to rent out used ones, effectively defining the product's lifespan as its first use cycle. However, a company with a rental model might have a better solution for what to do with the device when it is no longer wanted, for instance making sure it goes to the second hand market or is recycled.

An unintended consequence, similar to the other product cases, could be if the products are taken care of more poorly for example when renting instead of buying. This could be an effect of feeling that it is not as important to take good care of a product if it is not yours. This however is not seen as a substantial problem according to Everphone, as people generally know how to take care of smartphones.

Climate impacts from reuse such as transport and renovation could have a negative effect on the savings from reuse. The savings from avoiding new production are, however, often large enough to make that impact comparably small (Wranne, 2020).

Another possible negative impact could result if a used product results in an increase in energy use. This could be the case if the reused product is less energy efficient due to its older age. Inrego, however, claim that the increase in energy use is likely to be negligible, mainly due to the efficiency newer products. The difference between much older technology and new would be larger.

7.5 Implementation factors

7.5.1 Business models

Everphone and Inrego have very different business models, with Everphone using a straightforward DaaS, and Inrego focusing on reselling refurbished used devices. Everphone purchases new devices and rents them out to large companies, on an average of 2–3-year contracts, offering services to facilitate the companies' phone usage. Everphone then sells the used devices on through resellers to private customers. Everphone has also developed software enabling a secure division between work and private modes on their phones, encouraging the use of one device instead of two.

Inrego resells secondhand devices, mostly from companies, and offers rentals, which make up 15–20 % of their total revenue, only on demand. Inrego purchases used computers and, primarily, phones from businesses, repairs them and sells them online, B2B or B2C. They collaborate with the biggest resellers of ICT in Sweden and offer them residual value for the products after set number of months, so that the reseller can offer the customer a lower price per month than they otherwise could have. The reseller earns extra money, the customer pays less and Inrego secures a more reliable supply of devices.

The two companies target different markets with Inrego's main customer being businesses with fewer than 200 employees and Everphone primarily servicing companies with 200 or more employees. Everphone has a service-centred business model in which the development of new software is also essential in providing attractive and optimised services to their customers. Inrego's business is centred around a more traditional consumption pattern of purchasing devices.

Neither Everphone nor Inrego work, directly or indirectly, with what could be seen as the most effective PSS business model in terms of incentivising high-quality production, longevity of product and possibilities of reuse, which is manufacturer ownership. In such a model the manufacturer would be the owner of the product and would use another entity, such as Everphone, as the implementor of a PSS business model. The manufacturer would get a percentage of the leasing fee of every device and would therefore be incentivised to produce products that last longer and with parts that are reusable in the production of new devices. This could be seen as the most efficient model in terms of resource efficiency, minimising the use of virgin materials and minimising greenhouse gas emissions. Everphone recognises the difficulty in increasing the circularity of their product production as they are "in the hands the producers". Implementing revenue sharing models with manufacturers could address this and decrease the ICT sectors' high dependency on virgin resources.

7.5.2 Scalability

The use and need for ICT devices across Europe is big and still growing, so PSS solutions for this industry are highly desirable and could potentially have massive effects in terms of reducing product production and therefore the amount of virgin material used.

Everphone's model to provide DaaS to companies can be seen as quite scalable and universal since it outsources a lot of the "device hassle" to Everphone, making it potentially attractive to a high number of businesses. It also uses new devices, requiring no cultural challenges that can otherwise come with the implementation of secondhand devices in companies when employees are expecting brand new products. The challenge with Everphone's model is that it requires considerable focus on software development and implementation to enable a high level of automated service to customers. This offer of being a one-stop-shop for companies is what makes it be able to compete with a more linear and traditional model of purchasing new products.

Inrego's model is seen as being scalable for other reasons. According to research, 700 million devices lie around unused in European households (Rizos et al., 2019). This gives an amazing potential for refurbishing these products and giving them a second life by selling or renting them, something that can be assumed to be possible throughout the EU. The challenge with Inrego's business model is that the refurbishment requires skill sets that might be scarce and also the manual labour involved is more expensive than industrialized maintenance. The economic viability of the model could therefore be more volatile than Everphone's one. A challenge for Inrego is also that its model requires customers to purchase secondhand devices instead of new ones, which might appeal more to already environmentally conscious customers than others. While Inrego's model could be seen to work extra well in Sweden because there is a high turnover of devices, it might be less successful in countries in which people use their devices for longer, making them older at the point of refurbishment and possibly not as easy to modernise.

The two business models could be seen to quite complimentary and both can be assumed to be highly scalable within the EU, though with different economic and skillset challenges. Everphone's model requires greater service processes to be developed and implemented before a DaaS can be offered. Inrego's business model does not require the same amount of process work, rather it requires the acquiring of the secondhand devices and establishing collaborations with repair companies that can service them.

7.5.3 Challenges

The greatest challenges of the ICT industry, circularity wise, is the high dependency on planned obsolescence as central to the current business models. The second greatest challenge is cultural and consumption related, with the general societal resistance to purchasing or having used products instead of new ones. A general problem with products such as phones and other devices is that it is difficult to rent or sell used ones due to technical developments and societal norms. For instance, rather than being broken or dysfunctional, the most common reason for replacing devices is new and improved functions (Everphone, 2023). This in turn could define a product's lifespan as its first use cycle.

7.6 Sub-conclusions

The potential of environmental gains through a greater PSS implementation in the ICT sector in Europe can be assumed to be high because of the extensive use of devices and large quantities of WEEE currently produced. Both models reviewed in this chapter could be scalable across the EU, one model requiring greater process development to be implemented and the other one requiring specific skillsets and product stock. Both require cultural changes, one of renting instead of buying and the other one of buying a secondhand device instead of a new one.

To allow for easier implementation of Inrego's model focus has to be placed on meeting the needs for increased ICT repair skillsets in the work force and creating efficient systems of collection of used ICT devices to meet the need for material stock. Furthermore, emphasis should be placed on normalising the purchasing of refurbished goods rather than new ones.

To allow for easier implementation of the Everphone model focus should be placed mainly on normalising the renting products rather than buying new ones. It would also be advisable to look further into PSS models that support the manufacturer retaining the ownership of product to incentivise greater circularity and longevity of products.

Moving the industry towards business models that build on shared revenue with manufacturers can be seen as a key factor in supporting the important move away from the planned-obsolence centric model that is significant in the industry today. A revenue sharing model would incentivise product longevity and other circular factors fundamental to the mitigation of negative environmental impacts.

8 Furniture

The furniture market covers different segments, for example defined by one study as the following seven ones: dining room, living room, bedroom, kitchen, lamps and lighting, plastic, floor coverings and office furniture. This report will focus on the removable furniture and fittings, not fixed interior design elements, such as kitchen cabinets.

8.1 European market

The global furniture market is large, with a revenue of about USD 766 billion in 2023, and is expected to grow annually by 5 % in the coming years. The turnover of the EU furniture market was about EUR 96 billion in 2020, making it about 20 % of the total global market (Deign-Expo, 2021). In the EU, approximately 1 million people are employed in the furniture industry across 130 000 companies (European Commission, n.d.b). European production of office furniture, measured in current values, increased by 13 % in 2022, reaching a value of EUR 9.5 billion (World Furniture, 2022). In 2022 the five largest consumers by value in Europe were Germany, EUR 16.8 billion; UK, EUR 14.2 billion; Italy, EUR 10.2 billion; France, EUR 9.0 billion; and Spain, EUR 4.4 billion.

The furniture industry creates 10.5 million tonnes of waste in the EU every year, 82 % of that arising from the domestic sector and 18 % from businesses (Forrest et al., 2017). Of this total, 80–90 % is either incinerated or sent to landfill and only about 10 % is recycled (Forrest et al., 2017). The reuse of furniture in Europe is calculated to be 6 % of total furniture waste (Forrest et al., 2017).

Researching the prevalence of furniture as a service (FaaS) on the European furniture market indicates that renting furniture to offices (B2B) is the commonest model. That market is represented by actors such as Nornorm in Denmark, Martela in Finland, Ahrend in the Netherlands, and Beleco and Rekomo in Sweden. This section focuses on B2B office furniture, since it has been difficult to find other major FaaS areas, and the office furniture PSS market is also growing, making it a good candidate for further investigating the environmental gains because of the scaling possibilities of PSS models.

Regarding furniture waste, Germany tops that list in the EU, producing approximately 2,3 million tonnes of waste in 2018, with France, UK and Italy in second place producing between 1,2 to approximately 1,5 tonnes (Besch, 2005).

Nornorm, Beleco, Ahrend offer similar B2B services. Ahrend is a furniture producer that offers linear and circular services, stating that their FaaS production uses 40% less new materials than their linear production (Royal Ahrend, n.d.). Rekomo sells and rents office furniture B2B and B2C but does not offer any additional services as the other companies do (Rekomo, n.d.). Martela has more extended offers than the other providers, offering an educational environment as a service (Lärmiljö som tjänst) and a Workplace as a service (WaaS). It also offers additional services such as storage, inventory of existing stock and furniture care services (Martela, n.d.).

The furniture industry is more highly regulated in the EU than other industries, with several policy priorities such as the use of safe raw materials and ensuring sustainable and socially fair European and international value chains (European Economic and Social Committee, 2022).

Table 8.1 Presentation of furniture cases

Case	Description
Nornorm Denmark	- Nornorm offers a B2B FaaS – complete furniture rental service, including delivery, installation with options to redesign the space on a needs basis, and returns. Furniture

<p>Est. 2020</p>	<p>is installed on the first day of an active subscription. Nornorm’s main cutomers are large corporations, the real estate industry and growing companies.</p> <ul style="list-style-type: none"> - Nornorm offers three design lines of classic Nordic style furniture, from which the customer can choose. Nornorm proposes a plan for the office space, providing 3D visualisations which allow customers to switch furniture and see how that changes costs. - Nornorm recovers and refurbishes all the used furniture in their supply chain and rents it to new customers. This makes its revenue directly dependent on minimising the materials and products used. <ul style="list-style-type: none"> o Nornorm subscriptions are timeless, with 6 month notice clause, and it provide app for customers with details of their furniture’s status and care guides. - To lower its environmental impact Nornorm has established switching days when they optimise transport for furniture changes between clients. - Nornorm aims to decrease raw material consumption and waste as its furniture, as well as spare parts, are kept in a loop and reused for as long as possible. Product life extension is an important goal as the furniture is made from high quality material and refurbishments, repair and maintenance are made when needed.
<p>Beleco Sweden Est. 2016</p>	<ul style="list-style-type: none"> - Beleco offers B2B FaaS. Beleco rents out furniture to offices or events, taking care of delivery, assembly, disassembly and returns. Customers have the flexibility to alter their furniture rentals on a needs basis. Belecoc main customers are tech companies and co-working venues. - Beleco offers free design proposals after a customer specifies their needs. Beleco collaborates with 50 brands and has no pronounced overall design style. - Beleco offers four different subscriptions; per day, month, 6 months or 12 months. Except for per day, all have one month’s cancellation clauses. With the 12-month plan Beleco claims the customer can save 50 % of the rental fees. - To rent from Beleco customers are required to have insurance that covers costs if the furniture is damaged. - Customers run their subscriptions from Beleco’s workspace platform, through which they can change their subscription or scale their furniture rental package up or down. - Beleco works to facilitate the PSS industry, and focuses on platform, tool and software development, such as a supplier portal, a warehouse management system and a transport management system – eight storage facilities currently use Beleco’s warehouse management system. Beleco is also launching an asset management system soon. . - Beleco encourages producers to retain the ownership of their products, Beleco only renting them, to incentivise manuaftirers to improve quality. - Beleco aims to decrease raw material consumption and waste by keeping furniture as and spare parts in a loop for as long as possible. Extending product lifespans is an important goal, for instance by ensuring the furniture is made from high-quality material and is maintained, repaired and refurbished when needed.

8.2 Environmental gains and climate benefits

Previous studies point to extending the lifetime of furniture as well as reuse and remanufacturing in order to achieve circular flows (Witte, 2020). To achieve longevity Besch (Besch, 2005) highlights strategies of designing for durability, maintenance, repair, the reuse of parts and remanufacturing of used furniture, and leasing or renting.

The furniture industry is, as previously mentioned, far from circular today, generating large amounts of waste of which a small part is reused or recycled. Furniture production is responsible, for example, for

significant deforestation, cotton production and chemical use, all of which have climate impacts (Forrest et al., 2017).

The largest environmental impact from furniture comes from production and raw material extraction. To reduce the environmental impact, it is therefore imperative to avoid new production. Furniture can contain several different materials, ranging from textiles to metals, wood and plastics, many of which have heavy environmental burdens. According to Forrest et al (2017), (Andersson et al., 2022) furniture textiles have the highest climate impact of all the materials they studied, with 22 tonnes of CO₂e emitted per tonne of material produced, while just 10 tonnes of CO₂e per are emitted in the mining and processing of a tonne of aluminium and 3 tonnes of CO₂e per tonne of plastic. Although the climate impact of wood is lower, preserving wood sequesters carbon – an important reason for preserving wooden furniture.

Previous studies reveal several advantages in reusing and prolonging the life of furniture when it comes to avoiding climate impacts. Furniture is a product that has a rather high flow, as it is often exchanged more often than needed, especially in offices (Andersson et al., 2022); it is not an active product, meaning it has no energy use associated with it (Andersson et al., 2022); and it is a comparably easy product to repair and reuse (Andersson et al., 2022).

To exemplify the potential benefits of reusing furniture, one study estimates that 21,000 tonnes of CO₂e emissions could be avoided each year in Sweden if furniture products were reused when offices were renovated offices (Andersson et al., 2018). Another study that only considered the Gothenburg region showed that 3 300 tonnes of CO₂e emissions could be avoided yearly (Andersson et al., 2021).

The potentially avoided climate impact from circular models is larger than those generated by maintenance or transport (IVL, 2022). This implies that there are generally significant environmental benefits of, for example, reuse, even if this involves more transport or renovation. Furthermore, it is presumably better to reuse furniture than material recycle it, as producing materials often has higher environmental impacts than material recycling the components (Forrest et al., 2017).

As with all potential benefits from reuse or other similar models, the potential environmental benefits depend on avoiding the production of new items. If FaaS are successful in avoiding raw material extraction and production, then there are substantial environmental gains to be made.

Nornorm focuses on achieving as closed a loop as possible. The company does not sell furniture, so Nornorm benefit from prolonging the lifespan of the products for as long as possible. They only source high-quality classic design furniture characterised by robust materials, such as leather and wood, that can age gracefully and undergo easy repairs. Their biggest environmental focus is on lowering overconsumption and embedding values of resource savings and waste prevention, which, according to them, is a substantial environmental benefits. The company takes care of spare parts as much as possible, and reuses parts as well as fabrics to make new parts. It is not obvious how to measure the climate benefits, as they will include many assumptions. According to Nornorm, their costumers save up to 70 % of climate-affecting emissions by using their FaaS rather than buying furniture. This calculation includes assumptions such as the lifespan of Nornorm furniture being four times longer that which customers buying as NORNORM furniture is regularly refurbished. Nornorm calculations include allowances for storage and transport over the furniture's lifetime. The company's ambition is o to have zero waste when their furniture eventually reaches the end of its life through reuse or material recycling.

Beleco encourages manufacturers to retain the ownership of their products, which can be assumed to have significant environmental benefit if this incentivises them to make their products last as long as possible rather than producing as many new products as possible. Beleco further only rents out furniture and does not sell any and thereby incentivise themselves to make the products last as long as possible. They work with sustainable and high-quality materials that are long lasting and designs that are timeless, with the aim of reducing raw material consumption due to the increased longevity of their products. They

claim they will save at least 2 million tonnes CO₂e by 2030 and that they will engender systemic change, such as a reduction in furniture production leading to fewer factories being needed.

8.3 Unintended consequences

The environmental gains from FaaS models are dependent on avoiding the purchase of new furniture overall. This could be questionable if, for example, the FaaS model does not replace the need for more furniture but rather makes it easy either to have a larger number of items or make more frequent changes. This could be the case if, for example, rented furniture is used for shorter periods. This in itself does not mean that the renting model has a negative impact compared to ownership, as renting often entails several reuse cycles. It means, however, that the environmental gain is dependent on the longevity of the furniture and how many use cycles are realised. The two cases studied focus on keeping their furniture in closed loops for as long as possible, offering timeless designs together with maintenance and repairs. By having the furniture returned to Beleco or Nornorm at the end of the rental period, these companies are incentivised to extend the furniture's lifespan to the maximum possible extent.

Although FaaS and other circular business models should have many positive social effects, such as increased numbers of jobs, there is always the risk of unintended negative ones. Bimpizas and Genovese (Bimpizas & Genovese, 2020), for example, consider that there is a risk of large corporations taking over existing structures, such as small firms working in secondhand markets, the upstream supply chain, or carrying out refurbishments.

Another unintended consequence could involve greater impacts if short rental periods result in more logistics and other processes. Increased logistics between use/rental periods could mean more transport or storage taking place. Another factor could be greater energy usage during maintenance and repair. Both companies studied, however, claim that this element is small in comparison to the other climate savings made. This is borne out in a previous study from IVL (Andersson et al., 2022), which concluded that an office chair could be transported by lorry for approximately 14 700 kilometres before the climate impacts from transport equals the climate benefits from reuse.

Another unintended consequence could be that users do not take good care of the products. Neither of the studied companies thought this was a frequent problem. Beleco, however, charges for damage which probably provides their customers with enough of an incentive to be as careful with rented furniture as they would be with their own products.

8.4 Implementation factors

8.4.1 Business model

Nornorm and Beleco have very identical models at first glance, both renting office furniture B2B. They differ in terms of the amount of furniture they offer, the exact specifications of their different contracts and in that Nornorm is connected to a particular design style while Beleco is not. They offer similar additional services providing the possibility of changing the design and both include delivery and assembly in their rentals. The biggest difference is that Beleco collaborates with many more manufacturers and brands. Nornorm collaborates with eight brands and Beleco with more than 50. Beleco also collaborates closely with manufacturers to create a model under which manufacturers own their products and Beleco only rents from them, incentivising the production of high-quality, long-lasting furniture. Another difference is that Beleco is also working on platform development to facilitate the PSS industry in general.

8.4.2 Scalability

There is great potential in rental solutions for office furniture, as they have a huge turnover of furniture, which is said to be exchanged every 3–5 years, depending on the business. Nornorm has a concept that is currently simpler and for that reason, more easily copyable in other countries. They collaborate only with a few, reliable manufacturers and offer only a Nordic design style making it easier to scale, but possibly hindering expansion to non-Nordic European countries where different furniture styles are preferred. Beleco's model has greater potential in terms of environmental gains since its focus is on changing the whole business so that manufacturers are the actual owners of the products, incentivising repairability, longevity and quality. Beleco collaborates with a large number of manufacturers and brands, and also focuses seriously on software and digital tool development for related industries, such as logistics and transport. Therefore, while the model is in itself more difficult to copy, it could have a much greater effect on the furniture industry as a whole.

8.5 Sub-conclusions

The potential environmental benefits of extensive adoption of PSS in the furniture industry are substantial, particularly when high circularity is achieved. Both Beleco and Nornorm exemplify this by extending product lifespans. Nornorm achieves this through sourcing high-quality furniture of high-end materials and refurbishing it, while Beleco encourages manufacturers to retain ownership and engage with PSS providers such as Beleco, thereby promoting longer-lasting and more repairable products.

These models have potential for scalability across Europe. Nornorm's approach is relatively straightforward to implement as it relies on a limited number of partnerships rather than extensive sector-wide changes. In contrast, Beleco's model holds great promise for environmental gains but requires substantial planning and structural adjustments due to its dependence on manufacturers and brands willing to fundamentally transform their business models.

In summary, shared revenue business models in the furniture sector, through which manufacturers benefit from product rentals, subscriptions, longevity, and repairability, can play a crucial role in reducing climate-changing emissions and diminishing the use of virgin resources in the furniture sector.

9 Roadmap for application in high-potential sectors

The adoption of PSS business models in Europe holds great promise in driving the transition to a circular economy. This project has explored the environmental benefits of PSS across five product groups: children's products, textiles, home appliances, ICT, and furniture. Building on the information gathered in these cases, several common trends have emerged, highlighting the potential and challenges associated with implementing PSS.

The European PSS market includes both newly established businesses and long-standing enterprises. Newer companies often build their operations around rental or leasing arrangements, while older businesses frequently integrate PSS as a supplementary component rather than the central focus of their model.

In conjunction with existing scientific research, the analysis of the PSS cases included in this project has revealed that PSS can deliver environmental benefits by extending product lifespans, boosting product use, enhancing performance during product use and minimising waste generation. These aspects play a pivotal role in significantly reducing the overall environmental footprint. However, the full potential of PSS hinges on factors such as robust maintenance protocols, efficient logistics, and mitigation of rebound effects, which could undermine environmental gains if not addressed.

When examining the potential environmental gains of PSS models, it is possible to distinguish between four key aspects (Figure 4). PSS models can generally impact all four aspects or focus on specific ones. For a PSS model to be genuinely environmentally advantageous when compared to traditional sales models, the PSS case must prioritise at least one of these four aspects.

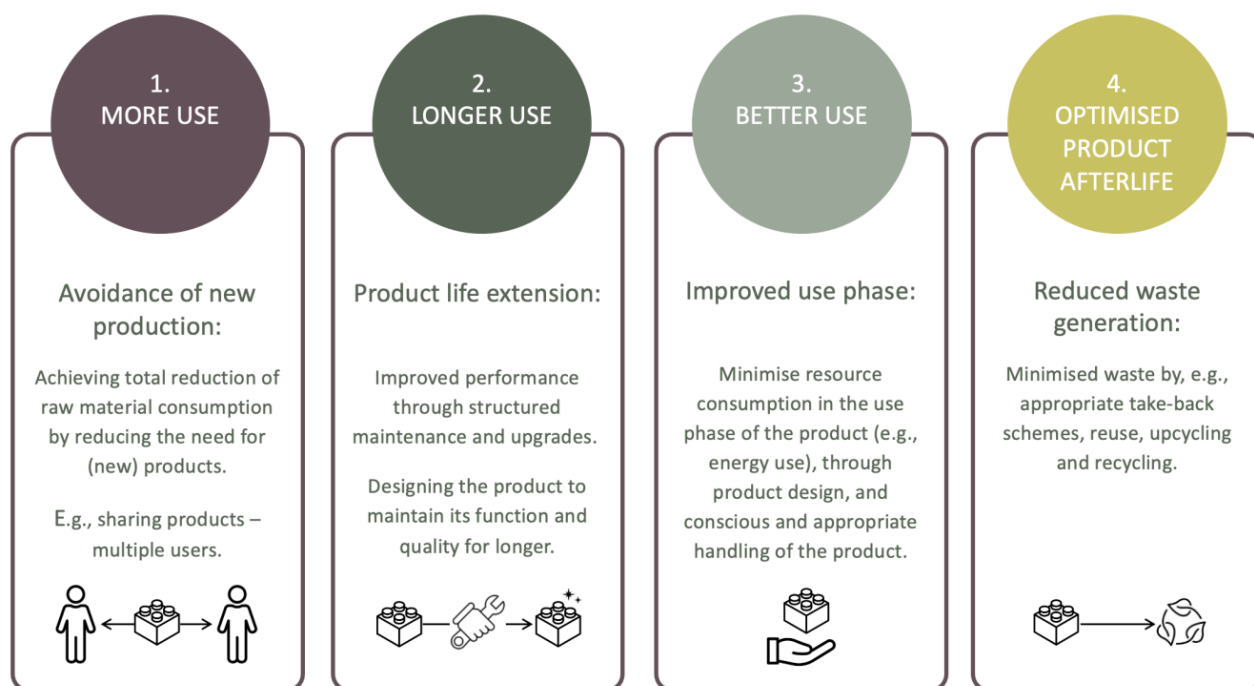


Figure 4: Four key aspects of product-service systems

The five product groups explored in this project all feature cases that address one or more of the four key environmental aspects identified in this study (Figure 4). Each group demonstrates principles of achieving **more use per product** and **longer use per product**. Products are distributed to multiple consumers through rental or leasing schemes, and the products are cleaned, maintained and/or repaired between each use period to extend their overall lifespan.

A common thread across nearly all the cases is the deliberate selection of products that meet specific criteria for durability and quality. These products are designed to endure extensive use and withstand the

test of time. For example, a furniture sector company has invested in high-quality furniture characterised by classic design and robust materials, such as leather and wood, that can age gracefully and undergo easy repairs.

Several cases prioritise products with a modular design, allowing for component replacement as needed. This approach necessitates that the product itself is designed with circularity in mind, enabling more efficient maintenance and repair. For example, clothing companies specialising in "special-occasion" designer clothes, such as Wedress, offer significant potential for their garments to be worn multiple times, in contrast to a traditional business model where they are sold but rarely worn. Another example is the development of ICT software, which enables a seamless and secure transition between private and work profiles on mobile phones, encourages extended product use, and reduces the need for two separate devices.

The concept of **better use per product** is also represented in several cases, particularly in the home appliance sector, in which items' energy and water usage are key environmental considerations. With pay-per-wash models, companies incentivise more resource-efficient use, such as lower-temperature washes, by providing economic benefits to consumers. In the children's products sector, companies have developed care guides to educate consumers on proper product handling, which not only promotes energy efficiency but also ensures optimal use and longevity of the products.

The theme of **optimised product afterlife** is prevalent across all five product groups studied. End-of-life procedures are integral to virtually every business model analysed, although the degree of integration varies. In the textile sector, for instance, Menone partnered with Hipli, a reusable packaging producer, to reduce waste during clothing shipping. Customers can reuse the packaging to return their worn items, allowing Menone to reuse it multiple times. In the home appliance sector, machines are reclaimed at the end of their leasing periods. If they can no longer be reintroduced into the product cycle, they are either refurbished or dismantled for reuse and recycling. In the furniture sector, one actor focuses on optimisation by reusing furniture components to repair other furniture still in use. Meanwhile, in the children's products category, companies resell refurbished items on their websites when these products no longer meet rental standards.

It is worth noting that while many companies adopt robust end-of-life measures, the extent of their efforts varies. In the children's product category, one company has partnered with a toy manufacturer to recycle damaged rental toys, transforming them into new products. This collaboration exemplifies a strong commitment to sustainability and circularity.

In summary, PSS solutions across a wide range of product demonstrate substantial potential for environmental benefits. These benefits include reducing the need for new production, extending product lifespans, optimising use phases, and minimising waste generation. The success of these models underscores the importance of thoughtful design, maintenance, and lifecycle strategies in achieving a circular economy.

9.1 Implementation factors

The potential for implementing and scaling PSS models within these five distinct market segments is substantial. These models offer adaptable solutions that broaden access to products and allow consumers to test them before committing to a purchase, thereby minimising the occurrence of misguided acquisitions.

In particular, PSS solutions show significant promise in sectors like children's products and ICT, where products often have short use phases and high turnover rates. By facilitating use by multiple consumers rather than a single owner, these models can maximise resource efficiency and minimise waste.

Across all five product groups, convenience emerges as a key value proposition for consumers and a primary motivator for choosing PSS over traditional ownership. However, for PSS solutions to succeed and scale effectively across Europe, several critical factors must be addressed.

9.1.1 Legal and financial aspects

Regulations must be adapted to accommodate PSS models, addressing issues such as liability, warranties, and consumer rights. Legal clarity will provide businesses with the confidence to invest in PSS. This study identified challenges faced by companies in securing loans, establishing inventory, and dealing with insurance for products not owned by them. These barriers are particularly acute during the start-up phase, which is often time-consuming and precarious.

Financing is a critical factor in supporting the growth of PSS companies. Private investors and banks should develop tailored loan products that cater to the unique needs of PSS businesses, particularly during their early stages, when capital investment is high, and returns may take longer compared to traditional models. For example, in the textiles sector, affordability is a major driver for consumers transitioning to PSS, as renting expensive clothing often proves more economical than purchasing it outright. This financial appeal frequently transcends environmental considerations.

Insurance providers also need to adapt their offerings to support PSS models. This includes developing more flexible and tailored policies that adjust the insurance coverage based on actual usage and leveraging data analytics to better assess risks and price products accurately. By offering competitive and realistic insurance solutions, insurers can foster a more supportive environment for PSS businesses.

9.1.2 Tax and value-added tax

The current taxation system presents challenges for PSS models, as it primarily focuses on purchase-based taxes. To align with the service-oriented nature of PSS, tax frameworks must evolve to a use-based taxation approach. This shift would ensure that taxation aligns with the value derived from the service rather than the product itself.

Implementing such a system would require increased reporting from PSS companies, such as tracking the number of uses and members. For smaller PSS companies, governments should simplify tax reporting requirements and provide exemptions from certain administrative obligations to reduce burdens and encourage participation.

Adapting taxation systems to accommodate PSS can ultimately benefit governments by increasing long-term revenue through recurring usage-based taxes rather than one-time purchase taxes. Regular reviews and adjustments to tax policies will be necessary to foster the continued growth of this sector.

9.1.3 Standardised maintenance procedure and collaborations

Developing standardised maintenance and repair procedures is essential to ensure the longevity and performance of products within the framework of PSS models. This requires collaboration between manufacturers, service providers and regulatory bodies.

Circularity must begin at the product design stage, with intentional efforts to craft products that are repairable, modular, and built for extended use. Traditional products can only have their lifespans extended to a limited degree; true circularity requires products designed for systemic reuse. This shift

necessitates collaboration between producers, who must adopt the role of “re-producers,” and retailers, who transition into service providers.

Partnerships can promote innovation and address technical and logistical challenges. As seen in the case of children's products, PSS companies have close ties with their partners, as external partners often provide essential services, such as logistics companies for product transport or repair and maintenance companies that handle cleaning, repairs and refurbishment.

9.1.4 Consumer awareness

Educating consumers about the advantages of PSS models is crucial for driving adoption. Awareness campaigns and product information should highlight the environmental and financial advantages of PSS while addressing common concerns about ownership, reliability, and costs.

Research shows that consumer behaviour plays a critical role in realising the benefits of PSS. For example, in the children's products sector, good customer practices, such as proper care and timely returns, enhance the effectiveness of PSS models. Education initiatives can help consumers understand how poor practices can undermine the sustainability of these systems.

The overall success of PSS hinges on the capacity to comprehend and cater to the evolving needs and preferences of the target market. Similarly, consumers must not only grasp the value proposition of PSS solutions but also trust that PSS companies will consistently deliver on their commitments. Customer satisfaction, loyalty, and retention are pivotal for success, requiring companies to maintain strong, ongoing relationships with their users and respond to feedback effectively.

9.1.5 Environmental monitoring and reporting

Continuous environmental monitoring and reporting play a vital role in evaluating the environmental impact of PSS models. Regular assessments can guide improvements, ensure sustainability goals are met, and foster transparency and accountability among stakeholders.

One way forward could be the establishment of international guidelines specifically tailored to the unique challenges faced by PSS companies, which differ significantly from those encountered by traditional sales-based businesses. Such guidelines could include standardised methodologies for measuring environmental contributions, enabling PSS companies to monitor their impact more effectively. Developing circularity indicators, for instance, would allow businesses to assess and report on the extent to which their operations align with circular economy principles.

Another pressing concern is the reliance on virgin resources, which are becoming scarce, expensive, and subject to regulatory restrictions. Measuring a company's dependency on virgin resources and assessing the associated risks is likely to become an essential practice in the near future. Emerging frameworks, such as the Taskforce for Nature-Related Financial Disclosures (TNFD) launched in 2023, are paving the way for businesses to evaluate these risks systematically. Integrating such tools into PSS models would enhance their sustainability and resilience.

By integrating environmental monitoring into their operations, PSS companies can better align their practices with sustainability goals and demonstrate accountability to consumers and regulators.

9.2 Growth potential

This report highlights the growing presence of PSS in various European product categories, such as ICT, children's products, furniture, textiles, and home appliances. While PSS models are gaining traction, their market share remains relatively small compared to traditional sales models. This raises critical questions: *what is the future potential of PSS, and could these models eventually play a central, or even dominant, role in the European market?*

Europe appears to be a fertile ground for PSS adoption due to several factors. Sustainability and environmental responsibility are becoming increasingly prominent, driven by policies that encourage a circular economy and aim to reduce waste and resource consumption. European consumers are becoming more conscious of the ecological impact of their purchasing decisions, which could lead to a growing preference for services over ownership.

To achieve scalability, however, PSS models must address motivations beyond sustainability. While environmental benefits appeal to certain consumer segments, the broader market requires PSS models to demonstrate tangible advantages over traditional ownership. Convenience is a critical factor in this regard. Many PSS models integrate value-added services, such as transportation, maintenance, and repairs, alongside product use. These features, if effectively marketed, can enhance the perceived convenience of PSS and drive broader adoption, making the shift from ownership to service-based models more appealing.

In particular, if the costs of PSS exceed those of traditional ownership, the perceived value must justify the additional expense. Companies must demonstrate how PSS can provide superior value, whether through flexibility, cost savings in other areas, or enhanced product performance.

A related factor for scalability is market awareness. Many consumers are still unfamiliar with the concept of PSS and the benefits it offers. Companies must invest in marketing and educational efforts to raise awareness, emphasising how PSS models align with consumer needs and sustainability goals.

Ultimately, the growth potential of PSS will depend on several factors, including consumer adoption rates, regulatory support, economic conditions, and the ability of companies to innovate and effectively communicate the advantages of PSS. Success is likely to vary across industries and regions, with some product categories and cultural settings presenting greater potential than others.

Scalability will be influenced by evolving consumer preferences. The perceived convenience of PSS, the role of sustainability in consumption choices, and the changing importance of product ownership will all shape the future market for PSS. As these factors converge, PSS models have the potential to play a transformative role in Europe's transition to a circular economy. By addressing current challenges and capitalising on opportunities, PSS can move from a niche market to a mainstream solution, driving both environmental and economic progress.

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