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# Product-Services for a Resource-Efficient and Circular Economy: An Updated Review

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**Abstract:** The development of product-service systems (PSSs) has become one of the most prominent ways in which to promote a circular and resource-efficient economy. These systems shift the focus from selling products as commodities to offering solutions that fulfil customers' needs and provide added value. PSSs have gained attention due to their potential to foster sustainability, particularly in the context of the circular economy and resource efficiency. This review article analyzes the literature on PSSs for the period of 2016–2022, aiming to explore the links between PSSs, sustainability, circular economy, and resource efficiency. Close to 160 relevant articles were identified and examined. The overall findings reinforce contributions from previous studies, which denote a tendency towards sector-specific studies, barriers, and stimuli to implementation and adoption, and PSS design methodologies in specific industries and sectors. The overall results show a steady growth of PSS literature, as well as consistency in its definition, despite variations according to the perspective from which the topic is analyzed. This study focuses on eight main trends in PSS research, along with eight challenges that arise in its design, implementation, and adoption, identifying avenues for future research.

**Keywords:** product-service system; sustainability; circular economy; resource efficiency; literature review



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## 1. Introduction

In recent years, the development of product-service systems (PSSs) has emerged as a prominent approach to fostering a circular and resource-efficient economy. Having emerged as a research topic in the 1990s, PSSs continue to register consistent growth in publications, mainly due to a growing interest in its links with information and communication technologies (ICTs) and its adoption by specific industrial sectors, as well as by scientific areas such as management, manufacturing, or design [1,2]. This has led to the rise of different research fields, with their own specific terminologies and definitions. In broad terms, PSS literature can be divided into eight general themes, which will be explored more thoroughly in the subsequent sections: (1) sustainable development; (2) circular economy (CE); (3) servitization; (4) digitalization and Industry 4.0; (5) collaboration and networks; (6) design methodologies; (7) business models and performance measurement; and (8) resource efficiency.

Despite the broadening of research fields and thematic areas, there are still several remaining controversies and research gaps that hinder PSS development. Several studies mention the difficulty of reconciling the industrial and environmental perspectives in PSSs. While the first sees the development and implementation of PSSs by companies and industries as a way to increase market share, as well as revenue and profits, the second mostly sees PSSs as a viable response to merge economic and sustainable development. By shifting the traditional focus from selling products as mere commodities to providing holistic solutions that

meet customers' needs and deliver added value, PSSs have garnered considerable attention due to their potential contribution to sustainability objectives within the context of the CE and resource efficiency [3–5]. Nevertheless, the contribution of PSSs towards circularity and sustainability is still a highly contested topic and mostly dependent upon the type of PSS (product-, service-, or use-oriented PSS) [6]. Concurrently, the benefits of adopting PSS models to companies and consumers are not as straightforward as they may seem.

This review refers to problems such as metrics and indicators, which often lack consistent and standardized measurement frameworks; debates surrounding business model viability; technological integration, its benefits and challenges; the policy and regulatory frameworks necessary for creating a favorable environment for PSS implementation; and the need for systemic approaches. While existing studies have made significant contributions in delineating the aforementioned aspects, this review addresses often overlooked factors: issues such as equity, social inclusion, and consumption dynamics are crucial in implementing PSSs. Recognizing that consumption patterns remain a primary hurdle to achieving a resource-efficient and circular economic system, this article aims to bring this aspect into sharper focus.

The article delves into the existing literature on PSSs, with a specific focus on the period from 2016 to 2022. The focus on this period is related to the publication of Tukker's 2015 literature review [6], from which the present one draws inspiration. It aims to explore the interconnections between PSSs, sustainability, circular economy, and resource efficiency. For this purpose, approximately 160 research papers were selected and used to shed light on the progress of PSS research over the past seven years. Through systematic examination, it was possible to synthesize and evaluate the prevailing body of knowledge on the topic (Section 2). This section also includes a reference to the methodology used in this research. In Section 3, a discussion of results is presented, where main trends, topics, and challenges are identified. Ultimately, this review contributes to the growing body of knowledge and fosters discussions that will drive the advancement of sustainable and circular practices within the realm of PSSs.

## 2. PSS Literature: State of the Art

### *2.1. Methodology*

The literature search was conducted through Scopus, which is acknowledged as one of the most complete journal databases available [6,7]. The search used a combination of the terms "product-service systems" AND "sustainability", with 365 results for the period between 2016 and 2022; "product-service systems" AND "resource efficiency", with 36 results for the same period; and "product-service systems" AND "circular economy", which yielded 2014 results for those same years.

From here, a manual revision of the total set of articles was conducted and exclusion criteria were applied, resulting in 267 articles. A subsequent analysis for eligibility was conducted as a means to understand which articles referred to the relationship between PSSs, resource efficiency, and circular economy in the intended sense, which yielded 227 papers. The final full-body reading and in-depth analysis were done for a set of 159 papers (Table 1).

**Table 1.** Methodology procedure for the literature review.

| Scopus Search | "Product-Service Systems" and "Sustainability" | "Product-Service Systems" and "Resource Efficiency" | Product-Service Systems" and "Circular Economy" | Total |
|---|---|---|---|---|
| Screening | $n$ = 365 | $n$ = 36<br>Application of exclusion criteria:<br>Only English language articles<br>Exclusion of gray literature<br>Exclusion of duplicate articles | $n$ = 2014 | $n$ = 2415<br>$n$ = 267 |
| Eligibility | Abstract reading (assertion of relevance for the review)<br>Key-word analysis | | | $n$ = 227 |
| Articles selected for analysis | Full body reading of the papers included for analysis. | | | $n$ = 159 |

### 2.2. Analysis of Results

The final 159 articles came from 55 different journals and reviews. Most articles were elicited from "Sustainability" (36 articles) and "Journal of Cleaner Production" (42 articles) (Figure 1). Despite the concentration of articles in these two particular journals, it is clear that the PSS concept is steadily gaining interest, as evidenced by the continuous growth of publications, which can be attributed to the integration of different sectors over the years [2].

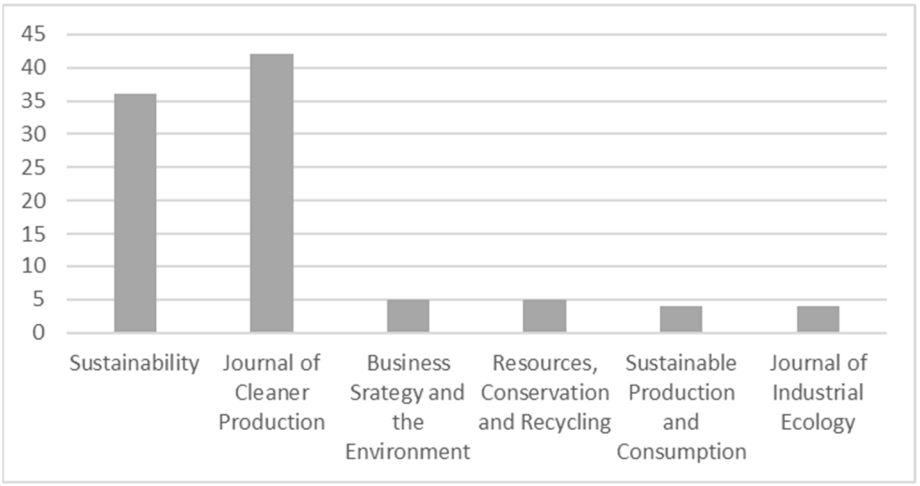


**Figure 1.** Graph depicting the journals with the most publications.

Co-occurrences between the three researched terms were registered (Figure 2). The graph shows that there are 26 articles pertaining both to sustainability and CE, 5 pertaining to sustainability and resource efficiency, and 9 referring to the three searched terms.

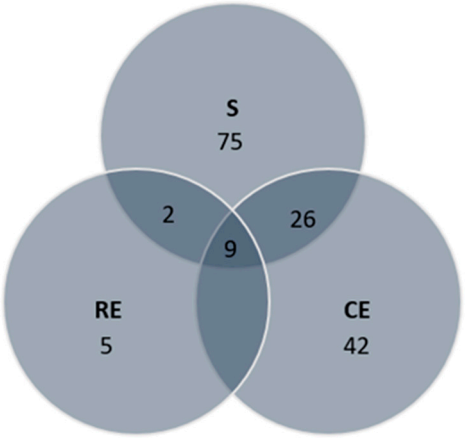


**Figure 2.** Graph representing the number of co-occurrences of sustainability (S), circular economy (CE), and resource efficiency (RE) themes in the literature.

## 3. Discussion of Results

Following this brief analysis of publication metrics, a content analysis is in order. A revision of the evolution of the PSS concept and its relation to other concepts, such as Smart PSS, Industrial PSS, and Sustainable PSS was conducted. Subsequently, the analysis focuses on a discussion of different thematic areas found in the selected literature. This analysis aims to accurately determine the actual contribution of PSS development and implementation to the transition towards a sustainable, resource-efficient and circular economy, as well as establish its major defining themes and challenges.

### *3.1. The PSS Concept*

Overall, the concept of PSS has remained relatively stable throughout the years. A PSS is most often defined in the literature as an integrated set of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling final customer needs [1,8–16]. Variations in this definition are mostly associated with the perspective from which it is analyzed. Authors writing from an environmental perspective often complement this definition by adding that this combination of products and services aims to satisfy individual customer needs sustainably and taking environmental factors into account [2,17–19].

Indeed, PSSs are seen as a way to incorporate sustainability into business models [15]. However, business model perspectives do not always consider sustainability as a main factor in motivating the transition to servitization. More often than not, companies see the shift from selling products to selling services as a way to increase their own competitive advantage [10] and augment their distinctive features [20]. Still, this interpretation does not eliminate or dismiss environmental concerns. In fact, one of the main distinctive features of PSS is that they present a way to address the triple bottom line and respond simultaneously to economic, social, and environmental issues [21,22]. Their promise to create significant positive or reduce negative impacts on the environment and society is what justifies its frequent framing as a strategy for CE [2].

The combination of products and services that function as a system to generate value and meet customer requirements remains consistent across all definitions. In contrast to conventional business models, the primary distinction is the emphasis on PSSs' potential positive environmental impacts [23]. Regardless of the perspective from which it is analyzed, it is clear that the PSS concept has become more stable in the literature, as can be seen in Table 2.

**Table 2.** Examples of PSS definitions found in the literature.

| Author | Definition |
| --- | --- |
| [24] | "PSS can separate value creation from material and energy consumption and thus significantly reduce life-cycle environmental impact compared to traditional product-only systems." |
| [25] | "(. . .) bundles of physical products, services, and information, seamlessly combined to provide more value than the parts alone." |
| [26] | "(. . .) business models that can potentially decouple the satisfaction of consumer needs from environmental impacts." |
| [27] | "Product-service system (PSS) is defined as a system composed by four components: product, service, supporting network and infrastructures. PSS has become a rich and diverse research field, with related concepts such as integrated solutions, service transition, service infusion, total care product, and integrated product and service offering." |
| [28] | "A PSS is a resource efficient system of products and services supported by networks and infrastructure." |
| [29] | "The Product–Service System (PSS) model is a business model that integrates products and services to fulfil customer needs through pay-per-use, short-term rental or long-term lease models." |
| [30] | "Business models such as Product-Service Systems (PSS) represent an opportunity to establish a synergic relationship between the environment and economic growth." |
| [10] | "(. . .) tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customer needs." |
| [31] | "Product Service System (. . .) is a market proposition that extends the traditional functionality of a product by incorporating additional services." |
| [5] | "(. . .) services such as take-back, repair, and repurpose are often provided effectively with products by manufacturers, where such an offering is often called a product/service system (PSS)." |
| [32] | "(. . .) transition of gathering products and services into one offer." |
| [22] | "(. . .) a mix of tangible products and intangible services designed and combined to increase the value for customers (. . .)". |
| [33] | "(. . .) a business strategy towards dematerialisation which is able to meet both economic and environmental objectives at the same time (. . .)". |
| [34] | "(. . .) PSS presents the potential for generating win-win solutions that promote profit, environmental, and social benefits (. . .)". |

This paper uses [6]'s definition, which remains current and offers an integrative definition of PSS: a mix of tangible products and intangible services designed and combined to respond to consumer needs in a way that contributes to the development of a circular and sustainable economy. However, the practices that will promote a shift towards a PSS business model remain an open topic [30], and PSS implementation does not guarantee the dematerialization of the economy nor the decoupling of economic growth from excessive resource consumption and waste generation [24,26,35,36]. On this matter, Ref. [37] proposes a distinction between productivity-oriented services and environmentally oriented services, referred to by the authors as "green servitization". Green servitization can be thought of as a business strategy that reconciles economic and sustainability goals through the provision of green services, which are offerings supported by digital technologies that assist the transition to and compliance with a broader sustainability agenda [37]. However, green servitization business models may not always include principles associated with the CE, such as the reintegration of waste into the production flow, potentially hindering its contribution to sustainable development. According to [38], PSSs' contribution to resource efficiency and sustainable development varies according to the different PSS types earlier defined by [6]: product-, use-, or result-oriented PSS. In product-oriented PSSs, the business model is still very much guided by the sale of products, to which some services are added. In use-oriented PSSs, the traditional product is still central, but the business model is not geared towards its sale. The provider retains possession of the product and provides temporary access to it along with additional services. In result-oriented PSSs, the user and provider agree upon a particular outcome without a product being involved. The offering is predicated on the notion that the consumer pays for an end result [38]. In a different perspective, Ref. [39] see the contribution of PSSs to a healthy environment as not being dependent upon product, use, or outcome orientation, but rather on how the company manages residual material flows. Reference [40] also concluded that servitization had no effect on firms' environmental policies, and that there is a need for a deeper understanding of PSSs' effect on the environment.

In practical terms, the shift from exclusively selling products to providing services associated with the products involves not only a shift in the business model of companies, but also a wide range of practices that are dependent upon stakeholder and consumer engagement. The implementation of PSSs rests on the adoption of consumption practices usually associated with a CE, such as leasing, renting, repairing, or reusing. From an industrial standpoint, this usually means a necessary restructuring of the business model of a company, which must now implement reverse logistics and take-back programs, allowing them to extend product lifetime through repair, remanufacture, updates, and substituting goods with services [11]. This transition emphasizes function over product, and the increase in efficiency, whether factual or supposed, results in an increased value perception from customers and reduces negative environmental impacts [41]. In this sense, it is critical to think of PSSs from a systemic point of view, being composed of not only products and the services that come with them, but above all as a system of network players and supporting infrastructure [42].

More recently, other PSS definitions can be found. The proliferation of research fields has led to the emergence of field- or industry-specific terms and definitions. This had already been noted in [6]'s review and is framed as a double-edged sword: while ultimately enriching PSS research, it can also give way to imprecisions. In this review, a set of reoccurring terms was identified, such as Smart PSS, Sustainable PSS, and Industrial PSS (Figure 3).

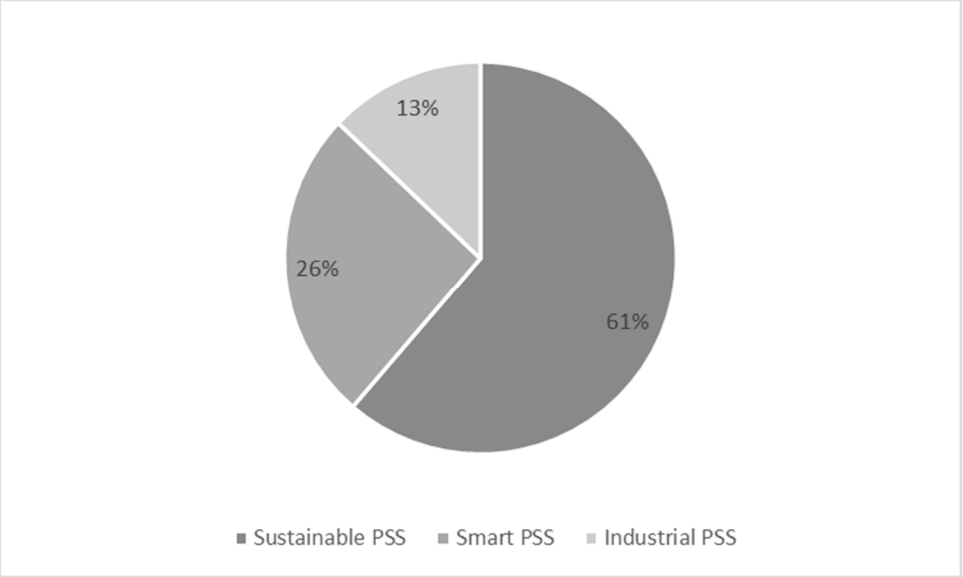


**Figure 3.** Graph representing the presence of different definitions of PSS variations found in the literature.

Sustainable PSSs are a means to achieve benefits in the three dimensions of sustainability: economic, environmental, and social [42]. In this sense, Sustainable PSSs not only offer sustainable services that improve marketability and provide satisfactory responses to customers' needs, but also deliver sustainability benefits [43]. Despite its apparent redundancy, the emergence of the term refers to the intentional integration of sustainability into PSSs. Although PSSs are often seen as more sustainable than traditional product offerings when it comes to the use of resources and consumption patterns, their contribution to sustainability is a frequent debate point. Reference [14] calls attention to some issues related to PSSs' lack of ability to address sustainability matters due to a lack of consideration of barriers along the complete lifecycle of the PSS. Still, according to the authors, Sustainable PSSs can be accomplished through the evaluation of implementation obstacles that impede the widespread adoption of PSSs and the incorporation of these obstacles during the design phase.

According to [19], it is evident that the distinction between product and service no longer exists in the industrial sector and that new, unified approaches to design, development, and execution are required. Industrial PSSs refer to a business model that integrates products and services into a unified offering, often in the context of industrial manufacturing and operations. Similar to the definition of a PSS, the goal is to shift the emphasis from solely selling products to offering integrated solutions composed of physical products, related services, and digital solutions as a way to meet consumers' needs. Industrial PSSs typically involve close collaboration between manufacturers, service providers, and consumers and are based on the establishment of long-term relationships between a network of stakeholders [44]. Offerings vary according to industry and context, but often include elements such as product design, manufacturing, maintenance, repair, end-of-life management, and even human resource training. Services provided can also include technical and non-technical support for the product, processes and information during the lifecycle of the product, and can adapt to market dynamics [44].

Regarding Smart PSSs, this category broadly refers to the integration of smart products and services into innovative solutions that respond to customer needs. References [45,46] describe this category as a transdisciplinary sociotechnical system consisting of various stakeholders, intelligent systems, and digital servitization. Reference [47] refers to it as a digitally enabled business solution delivered within an ecosystem that yields economic and sustainable value to the customer by integrating products and services into a single intelli-

gent offer. Among others, offerings may include smart systems that integrate connected devices, security services, remote monitoring, and subscription-based software that provides updates and customer support. Because these offerings combine physical products with value-added services enabled by digital technologies, they are able to provide enhanced value, functionality, and customer experiences. By leveraging digital technologies, companies can optimize product use, improve efficiency, increase customer satisfaction, and foster long-term relationships with consumers and stakeholders [48].

### *3.2. Key Emergent Themes in the Literature*

From the analysis of the selected articles, it was possible to identify and define eight key themes emerging from the literature regarding PSSs. By looking at Figure 4, it is possible to conclude that the most common subjects are sustainable development, circular economy, and business models and performance measurement. To a lesser extent, matters such as servitization, collaboration and networks, digitalization and Industry 4.0, design methodologies, and resource efficiency are also amongst the main topics found in the literature.

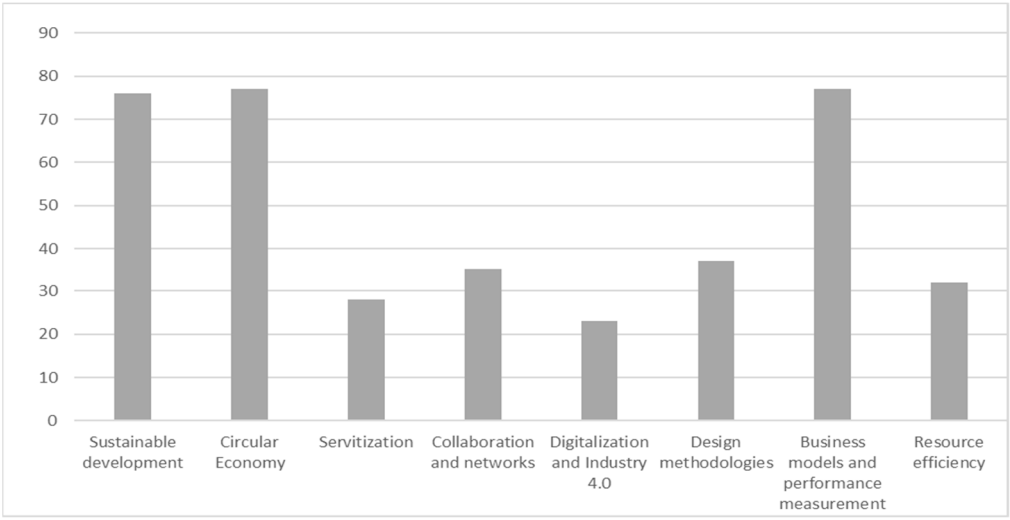


**Figure 4.** Graph representing the presence of main topics found in the PSS literature.

Overall, themes found in the literature show that PSS development and implementation in production and consumption practices can be linked to grand challenges research. These can be defined as having a supra-national nature and are made up of urgent global issues, such as climate change, resource depletion, and social inequalities [49]. In parallel with these challenges, PSSs propose novel approaches to decouple economic growth from resource consumption and environmental degradation. The CE, which emphasizes the closing of material cycles and the promotion of circular value chains, provides a framework for implementing PSSs in a variety of industrial settings, provided that the appropriate innovation environment and policy framework are adequate [49].

#### 3.2.1. Sustainable Development

Sustainable development remains a significant aspect of PSS literature, which may be attributed to the fact that sustainability has become a determining factor in businesses' long-term success [20]. Increased competition, growing environmental pressures, and the diversification of consumer needs demand integrated solutions to generate value. However, the potential contribution of PSSs towards sustainable development depends upon the successful integration of all components of the system [20]. Despite the undeniable link and co-occurrence of terms in the literature, recent studies have highlighted that PSS offerings are neither always nor necessarily sustainable. Indeed, PSS business models may

be adopted by industries and manufacturers based on their own economic interests, rather than on an internalization of environmental and social concerns [16].

Several researchers have explored how PSSs can contribute to sustainable development goals by minimizing resource consumption, improving energy efficiency, and reducing environmental impacts [18]. However, not a lot has been written on the aspect of social sustainability [50]. Because of its conceptual complexity [42], social sustainability has been neglected in sustainability research, which has mainly focused on environmental aspects [35]. Ref. [50] defines social sustainability as being linked to human wellbeing and to the flourishing of present and future societies. These factors are related, but not limited, to health, employment, safety, competence, community, and social meaning [51]. Sustainability must then be considered from a more holistic approach, instead of being made equivalent to only environmental concerns, such as energy, materials, and waste.

#### 3.2.2. Circular Economy

By overcoming the limitations of linear patterns of production, consumption, and waste, the CE is one of the most promising strategies for sustainable development. Various industrial sectors may have significant mitigation benefits from applying CE principles, especially through energy efficiency [11]. As a result, the CE concept has influenced PSS research, as a growing academic literature has explored how PSSs can facilitate the transition towards a circular economic system by incorporating product life extension, motivating the implementation of sharing platforms, and contributing to waste reduction strategies [8,24,52]. On the one hand, as a governing paradigm for business processes, CE allows companies to simultaneously concentrate on economic value creation and environmental considerations, garnering interest due to its potential to integrate business and societal goals [53]. On the other hand, according to [54], PSS-based business models have the potential to accomplish CE principles by fostering the transition from a tangible to an intangible goods-dominant logic. Consumption practices associated with the CE, such as sharing, renting, repairing, reusing, or recycling, also lead to an increase in product use, supporting the idea that PSS design has a great potential to facilitate the CE transition [8].

Despite the fact that PSSs can be instrumental in realizing a CE and in decoupling economic growth from resource consumption, they do not offer that implicit guarantee [55]. For instance, product leasing is not necessarily more environmentally friendly, but may actually encourage more frequent product replacements. Takeback services may involve the redistribution and remanufacturing of products. Used products do not always substitute new products, particularly when sold at a discount, resulting in an increase in general consumption. Although this scenario has its advantages in terms of preventing cannibalization, it does not result in an overall reduction of resource consumption [39,56]. In order to avoid these types of rebound effects and realize the transition from a linear to a circular economy, PSSs must be intentionally designed [8], as well as consider the outer and inner circles of industrial practices [57]. Its purported contribution to this transition has also become an increasingly large debate subject. Authors such as [53] refer to the fact that circular value proposition design research using PSSs is still in its initial stages. Nevertheless, literature finds that PSSs play a crucial role in circular economies, aiming to add value to the product's use at lower lifecycle costs [58].

#### 3.2.3. Servitization

The concept of servitization is closely related to that of PSSs, since both refer to the integration of products and services within business models [1]. Servitization implies a shift from a transactional product-selling model to customer satisfaction through the delivery of the product's inherent service and value. Although servitization is a promising field for academics and practitioners, its uptake is hindered by a number of obstacles, including a dearth of shared understanding [59].

While as a business strategy, PSSs emphasize the creation and delivery of value through the integration of products, services, and even information and data in order

to provide a comprehensive solution to the consumer, servitization refers to a broader strategic transformation process that involves shifting from a product-centric business model to one focused on delivering services alongside or instead of physical products [15]. It encompasses and requires organizational changes, capabilities, and mindsets to transition from a product-oriented company to one that provides value through services. Servitization covers a continuum spanning from fundamental product-focused services to customized and process-focused services and, ultimately, to the delivery of comprehensive solutions [60]. Thus, PSSs can be seen as a specific business model that focuses on providing comprehensive solutions, while servitization represents a broader transformation towards a service-centric business model. Servitization encompasses changes in organizational strategy, capabilities, and the delivery of value through services, while PSSs are one example of how servitization can be implemented [15]. Servitization has the potential to enhance a company's capacity to provide a superior customer experience. By reducing reliance on sales, servitization increases both earned income and budget stability, and by increasing customer loyalty, it improves the quality of the customer relationship model [24].

There is a growing body of literature on the relationship between servitization business models and the CE, but only a few articles connect these two concepts to PSSs [53]. Still, PSS-based circular business models are widely acknowledged in scientific and industrial research as the most suitable for achieving circularity [15]. Reference [45] points to the fact that the merging of digitalization and servitization provides the occasion to satisfy the demands of a new reality and consumer market, leading to a greater integration of PSSs in industry. This integration has great potential for fostering a sustainable manufacturing industry and sustaining competitiveness and innovation. This potential can only be realized through a deeper comprehension of these business models' nuances [53]. According to [35], the impact of digitalization on the economic and environmental dimensions of sustainability is enhanced by both fundamental and advanced services, whereas the results are limited for social sustainability. In order to be successful, the implementation of servitization calls for companies to reconfigure their capabilities, strategies, and culture [61]. Practical and academic understanding of servitization should determine its capacity to propose and implement PSSs and offer support for the incorporation of socio-technical systems theory to systematically define these capacities [19].

#### 3.2.4. Digitalization and Industry 4.0

The rise of digital technologies has had a significant impact on several industrial sectors at the process level (e.g., new tools), the organizational level (e.g., new services), the business level (e.g., changes in roles along the value chain, changes in customer relations), and the society level (e.g., types of work, decision-making) [62]. It has also had a significant impact on PSS research. In the era of Industry 4.0, digital technologies are transforming the daily lives of citizens and accelerating the offer of integrated products and services to generate new value and strengthen customer relationships. In the context of Smart PSSs, digital servitization has also emerged as a fruitful research area. Reference [47] identifies three main trends of digital servitization: company interaction, data sharing management capabilities, and platforms to support digital transformation towards Smart PSS.

Studies have explored the integration of digital technologies such as Internet of Things (IoT), big data analytics, artificial intelligence, and cloud computing into PSSs to enhance customer experience, optimize resource use, and enable new business models. However, there are important challenges regarding digitalization, such as intellectual property rights and the most effective ways to collaborate in data management, storage, and analysis. For manufacturers, digital offers also rely heavily on a PSS approach, as they must be founded on fundamental product and customer knowledge, as well as the scalability of services [61].

In the context of Smart PSSs, digital servitization has also emerged as a fruitful research area. Various ecosystem-integrated success factors can influence the implementation of digital servitization strategies. Three main trends can be found on this topic: interaction among companies, data sharing management abilities, and platforms to support digital transfor-

mation towards Smart PSSs. Interaction between firms is not an entirely novel requirement, but it is reinforced by digitally oriented business models. Overall, research finds that digitalization represents a chief driving force in the development of sustainable circular products, and a shift towards PSSs has been repeatedly suggested in the literature as a means to accelerate the transformation towards CE and digitalization [63]. Industry 4.0 facilitates the development of new business models and opportunities for manufacturers, enabling the enhancement of business performance in a sustainable way. Regarding its relationship with the CE, digitalization has the capacity to build visibility and intelligence into assets and products [63]. The CE emphasizes transforming business processes into sustainable resource systems. The IoT, robotics, and predictive analytics are transforming industries by accelerating production, profitability, productivity enhancement, error reduction, and process optimization. By utilizing digital technologies to enhance sustainable business performance, organizations are also improving their business performance [63]. However, it is important to note that investments in digitalization are not made homogeneously across industries. In a study by [61], it was determined that company size matters in terms of the different possibilities to develop and implement digitalization processes. Larger companies had clear strategies and made investments to adapt to digitalization by offering solutions with added value to customers and stakeholders. Medium-sized companies were also found to be agile, aware, and proactive in terms of implementing digitalization. Finally, in smaller companies, there were no systematic or formal plans or processes to adapt to the trends of digitalization, servitization, and sustainability. In the same study, Ref. [61] found that digitalization is seen by manufacturers as an opportunity to find new solutions to meet customer demand in a more efficient, competitive, and future-oriented manner. Sustainability, on the other hand, is a requirement fulfilled primarily due to legislation and regulations, even though a number of manufacturers are beginning to recognize market forces as a sustainability driver replacing legislation.

#### 3.2.5. Collaboration Networks

Collaborative approaches have been highlighted as crucial factors in developing successful PSSs, and can take the form of partnerships, alliances, and ecosystems to create and deliver value, which is provided via a broad business network involving multiple stakeholders. Companies have a simultaneous need to establish and oversee external value-producing networks, as well as use their internal resources to profit from them [16]. A value network is a collection of internal and external resources available to a PSS provider, who may integrate vertically or maintain co-optive connections with organizations to consume resources to create and deliver customer or end-user value [44]. Value propositions are crucial in various contexts. Reference [64], for instance, found that innovativeness, firm-level visions for CE, lifecycle thinking, stakeholder engagement, and customer functional need focus are focal points for value proposition. Reference [65] also discovered that the integration of maker, owner, and user increases the sustainability of the PSS, minimizing the environmental impact via the longer product life, increased reuse, recycling, and remanufacturing, material and energy efficiency, increased product usage, dematerialization, differentiation, and value-added services.

Ref. [66] argue that stakeholder interactions influence the provision and delivery of PSS value, particularly in the process of value creation through collaboration and partnership among consumers, suppliers, and other stakeholders. Approaching this matter from a systems perspective, reference [67] argues for the need for a broader recognition of value from multiple stakeholders, and that the type of interaction between them gradually changes from a transactional nature to a partnership one while shifting from a product to a system focus.

According to authors such as [68] or [16], to maximize sustainability upsides, stakeholder integration must reach beyond the value chain and incorporate governments, communities, and society on a large scale. The incorporation of numerous stakeholders would enable the PSS implementation to achieve a vast array of environmental and social out-

comes. As theorized by [69], multiple stakeholder engagement is crucial for sustainable business models. The authors present a number of propositions to support the sustainability of business models, such as the incorporation of triple bottom line benefits, sustainable value flows between multiple stakeholders, a value network with a revised purpose, design, and governance, and a comprehensive consideration of stakeholders' priorities and duties for shared value creation [69]. Knowledge and mapping of all relevant stakeholders would also be an important step in creating future product-service strategies, as it would allow one to visualize at what point within a product's lifecycle a certain stakeholder would be able to intervene and explore future circular PSSs [70]. Stakeholder networks and engagement are also important when it comes to consumption. According to [71], sustainable production and consumption are essential elements of PSSs. The author calls attention to forms of collaborative consumption and sharing, which typically happen via networks, as a way to reduce the production of goods, achieve environmental benefits, and enhance social capability. At the same time, close integration of all relevant actors can lead to better system management: by integrating customers in a collaborative network, support for these types of business models may be guaranteed through improved consumer acceptance, reduced risk perception, and growing confidence in decentralized approaches [72]. Multiple stakeholders can exert pressure on manufacturers to employ a service-based business model in an effort to improve their sustainability performance [73].

Collaboration networks and stakeholder engagement also have important implications at the territorial level. Sustainable PSS providers establish territorial networks that include a range of agents from the civil, industrial, and public sectors in order to mobilize assets to support value creation at the organizational, network, and territorial levels [16]. In turn, the development of territorial networks has the potential to strengthen social relations between actors and facilitate the PSS concept's adjustment to locally defined principles and priorities. Ideally, the incorporation of diverse territorial actors into PSS development will contribute to the sustainability and resiliency of particular areas [74]. Given that sustainability in the field of PSSs is primarily associated with resource efficiency and lifecycle assessment, territorial sustainability is assumed to be inextricable from PSS sustainability. As [74] put it, "[t]erritories are not only 'neutral' locations where economic activities are developed; they are considered as PSS co-constructors and resource providers" [74] (p. 1298). In fact, as part of a larger socio-spatial process, the territorial underpinning of a PSS approach explores the partnerships between stakeholders involved in the project's design and implementation.

#### 3.2.6. Design Methodologies

Understanding and integrating user needs and preferences remains important in PSS research. Literature has emphasized user involvement, co-creation, and user-centric design approaches to developing PSSs that meet customer requirements and enhance user experience. One of the main strands in the theme of PSS design is the role of digital technologies and the IoT in enabling CE strategies through design, as they allow learning from product-in-use data to improve the design of a new or renewed product or service [15,75]. However, according to [74], in order to contribute to the sustainability transition, PSSs need to be carefully designed, developed, and delivered for this very purpose, taking into full account lifecycle impacts [76].

The transition from selling products to providing services requires changes to product design, to the service bundles that either complement or replace the product, and, most importantly, to the value proposition of the business in question. The majority of companies face a significant challenge when redesigning a service or product because they must take into account operational risks, customization, and scalability. Nevertheless, redesigning a service or product can be viewed as an opportunity for the organization and a catalyst for the transition to a function-based business model [59]. Ref. [21] describes a number of success factors in the design of PSSs, such as the deployment of a service within a manufacturer that already intervened and managed similar activities, the creation of synergies between resources and activities, and the reduction of costs.

There are plenty of research studies referring to "Design for X" (DfX) [77]. This is a general term that refers to a set of design methodologies and principles focused on optimizing a product or system for specific objectives or considerations and has been proposed as a means of bridging the knowledge divide between product designers and service managers regarding product lifecycle stages [77]. Some examples are design for durability, design for disassembly, design for accessibility, design for sustainability, among others [78–81]. DfX approaches have already been utilized to support the PSS design process, but, according to [77], they must be better integrated into a circular design framework. Due to a higher awareness and sensibility towards environmental issues on the part of stakeholders and consumers, manufacturers are expected to deliver products with increasing levels of complexity, sustainability, and innovation. However, when it comes to design methodologies found in the literature, most contributions are theoretical.

Furthermore, in order to address issues such as skill development and job creation, a broader understanding of consumer issues that go beyond product use must accompany the conceptual design of Sustainable PSSs. At the same time, community and stakeholder engagement can be a way to foster open innovation in the CE. Services, unlike products, are characterized by their interactivity. Services rely on human behavior, cognition, emotions, and needs, and therefore place a greater emphasis on organizational and human capital factors than on physical assets. Consequently, PSSs require increased customer and business partner involvement in both design and delivery, as well as an understanding of the customer's needs and conditions. As a result, PSSs are characterized by greater complexity and risk than conventional products [19]. A comprehensive approach to design enables better preparation for resource integration in the early stages of PSS design [82].

#### 3.2.7. Business Models and Performance Measurement

The business sector is attempting to address the several transitions of the last few decades, resulting in the creation of new business models that merge competitiveness and sustainability [24,47]. The literature shows a focus on the development and analysis of business models that support PSS implementation. As a business model, PSS represents an innovation in the corporate field by associating products and services into a single value proposition. This value proposition proves profitable for the company and the consumer, while decoupling economic value from resource consumption and reducing the environmental impact along the product's lifecycle.

Companies are exploring CE-based value propositions and developing circular business models (CBMs) as the concept of corporate sustainability gains prominence within business organizations. The business model of a company describes the rationale for its existence or how it generates and captures value in economic, cultural, and social contexts. Companies design their products and services in accordance with their business models, which are interdependent and regarded as a blueprint for their operations. According to [83], a CBM comprises a company's value proposition and integrates it with the creation, delivery, and capture of value. It distinguishes itself from conventional, linear business models by emphasizing high-value and high-quality material cycles. The concept of CBM is based on the research field of business models, as well as other fields such as closed loop value chains and industrial ecology [84]. The most common business model archetypes found in the literature are 3Rs-based business models (recycling, reusing, remanufacturing) and PSSs [83,85]. Within these categories, upgradable PSS business models have the potential to generate greater profits for upgrade service providers, reduce product lifecycle costs for consumers, and lower environmental impacts [86]. This concept is closely linked to product lifecycle management, which allows manufacturers to create and capture value that is dispersed throughout the PSS lifecycle via services such as remote monitoring and diagnosis, predictive and preventive maintenance, and product optimization [86]. In today's market environment, manufacturing businesses face significant challenges, such as a reduction in product development periods and product lifecycles, an increase in the demand for customization, and a decrease in production quantities due to the expansion of product

varieties. To overcome these obstacles, it is necessary to have a thorough understanding of the product range and features produced and/or assembled in the system [87]. To improve manufacturers' strategic awareness and preparedness for upgrade service provision, it is essential to comprehend why specific suppliers offer equipment upgrade services and what steps they take to ensure the success of their upgrade service offerings. The absence of strategic understanding can be remedied by identifying the primary motivations that continue to motivate manufacturers to offer equipment upgrade services. Market drivers are primarily concerned with responding to market demands, and upgrade services may enable the equipment to be adapted to imposed government regulations or shifting consumer demands. This contributes to the enhancement of the consumer value proposition. Financial drivers, on the other hand, refer to improved profit margins compared to new equipment sales and relatively stable revenue during economic downturns [86].

Scholars have also explored performance measurement frameworks and metrics specific to PSSs to assess economic, environmental, and social impacts. These consistently involve methodologies such as Lifecycle Assessment (LCA) and Lifecycle Costing (LCC) [55,88,89]. These methods can be used to quantify changes in environmental and economic outcomes, which makes them financially attractive for companies to implement in their business models and thus contribute to a CE [88]. However, particular challenges must be addressed when using LCA to evaluate the environmental performance of PSS business models, including the identification and definition of the reference system, the definition of the functional unit, and the setting of system boundaries [55]. However, as pointed out by [89], the majority of literature concerning the environmental impacts of business models in the CE is concerned with traditional products within traditional sales models that are remanufactured and compares the remanufacturing process with the traditional manufacturing process. In the majority of LCA studies, CE product design strategies and PSS or other circular business models are not addressed. There is an urgent need for more LCAs that convey the prospective benefits and disadvantages of circular economies more accurately.

#### 3.2.8. Resource Efficiency

There is a recognized relationship between PSSs and resource efficiency. PSSs are often considered a potential solution to improve resource efficiency and sustainability in various industries.

According to [22], a better integration of resource efficiency into PSS design can follow approaches such as multi-level analysis, which can be used to define the main PSS functions; Business Use Case analysis, which defines interactions between external actors and the system under consideration; Serious Games, which can help elicit PSS requirements and investigate their lifecycle; and Quality Functional Deployment, which allows the mapping of customer needs.

Ref. [90] argues that the increase in resource efficiency is directly linked to the duration of use, the time a consumer obtains access to a specific product, and the type of product that is accessed. Change at the product-service system levels has the potential to influence business models to generate more meaning and dematerialization in an organization's output, contributing to the diffusion of the preventive business strategy and the transition from material efficiency to resource sufficiency [26].

### *3.3. Challenges Found in PSS Literature*

While the fields of PSSs, circular economy, and resource efficiency have seen significant advancements, there are still several controversies and research gaps that remain. Some of the main areas of contention and knowledge limitations pertain to metrics and indicators, business model viability, behavioral and cultural change, systemic approaches, policy and regulatory frameworks, social equity and inclusion, technological integration, and long-term impacts and transitions.

#### 3.3.1. Metrics and Indicators

One ongoing challenge in the field of PSS research is the development of comprehensive metrics and indicators to assess the environmental, economic, and social performance of PSSs and circular economy initiatives. Because PSSs are multidimensional systems with a variety of actors and product-service combinations, their evaluation is a difficult endeavor [91]. There is a need for the development and application of standardized and consistent measurement frameworks that can capture the multifaceted impacts of these approaches [92].

As previously mentioned in Section 3.2.7, one of the most often used methods for assessing PSS success in implementation is Lifecycle Assessment (LCA). Ref. [93] presents a methodology for the integrated sustainability assessment of a PSS lifecycle that considers the triple bottom line using the service unit. Ref. [94] also proposed an evaluation scheme for PSS models that consists of a set of 94 evaluation criteria that can be used both from a provider and a user perspective and allows the comparison of different PSS models or the evaluation of one single model.

However, the literature body on sustainability assessment also takes a systemic approach as opposed to a singular emphasis on individual sustainability effects and presents a small proportion of quantitative evaluation [92]. An increase in the number of quantitative studies would be useful for a more objective analysis of sustainability assessment results. Ref. [92] also notes a "positive bias" in the literature: in their study, the authors mentioned that the number of statements on the negative sustainability effects of PSSs was almost 10 times lower than the results for the positive effects. Negative effects were most frequently described in the social dimension (45%), followed by the economic (40%) and ecological dimensions (20%).

There is also a need to consider the relationship between drivers and indicators. Economic sustainability is usually measured through cost reductions, economic growth, and profit margins. Community benefit and customer satisfaction were the primary indicators of positive effects in the social sustainability dimension. In terms of economic sustainability, the PSS business model's elevated risks were evaluated as negative effect drivers. In the environmental aspect, increased operational complexity was frequently viewed as an inhibitor [92].

Authors such as [31,61] have identified several risks in a partial analysis of sustainability performance. There is also the need to understand that PSS evaluation requires multiple perspectives on a case-specific basis, as they are complex combinations of components and attributes [94]. Overall, the literature is consistent in acknowledging that there is a dearth of integrated tools to aid conventional manufacturing industries in implementing PSSs and assist designers in the development process. Additionally, PSS assessment usually takes place after the product design stage and is not directly associated with the service design and knowledge stages. Another common issue is the absence of information sharing and management of product-service relationships. On this topic, the literature demonstrates the need to create a closed loop between the design and evaluation of the PSS lifecycle through the design and development of novel methodologies [22].

#### 3.3.2. Business Model Viability

While the PSS and CE concepts hold promise, there are ongoing debates regarding their financial viability. Some argue that transitioning from traditional product-based models to service-oriented approaches can be costly and may face resistance from customers. Research is needed to explore sustainable business models that are economically feasible and attractive for both providers and users.

Circular supply chains are often used in PSS offerings. These are defined as forward and reverse supply chains that are coordinated through strategic business ecosystem integration to create value from product or service, byproduct, and useful waste flows over long lifecycles [95]. The implementation of a circular business model and supply chain represents challenges, which vary according to offering, market, and company size, among

other variables. Circular business models pose significant obstacles to the entrepreneur's preemptive uncertainty reduction. In addition, PSS variants that facilitate return flow control in circular business models increase the possibility of adverse effects from ineffective uncertainty reduction resulting from increased capital commitments. In the PSS literature, it is widely acknowledged that efficient product retrieval is a challenging but essential aspect of remanufacturing. The predictability and dependability of the return flow are particular hardships. This complicates capacity planning by requiring technical expertise, return flow obstacles, customer type restrictions, product category limitations, cannibalization risk, fashion vulnerability, capital commitment, and operational risk [96]. Reference [97] has a different perspective, asserting that PSS adoption enables remanufacturers to reduce uncertainties regarding the schedule, quantity, and quality of returned items, resulting in increased profitability and greener products. The potential for reducing uncertainties lies mostly in the upgradability of services: performance-based service contracts that include periodic enhancements of a product's performance can pave the way for new disruptive PSSs that are able to transform consumption patterns and business models [86].

Overall, the research literature found that the maturation and linkage of CBMs and the role of product design in achieving CE are limited [83]. Product design plays a crucial role in the development of new CBMs, as it must change if the fundamental logics of value creation and capture are to be modified for CBM innovation to be viable. It appears that waste reduction, recycling, and energy efficiency are dominating the academic discourse.

#### 3.3.3. Behavioral and Cultural Change

Implementing PSS and CE principles often requires significant behavioral and cultural shifts. PSSs can encourage circularity, enable circular strategies by extending the life of products, and encourage dematerialization through access-based consumption, increased product use intensity, and better corporate control over the lifecycles of products [98]. Motivated by industry shifts and rising consumer demand for more ethically produced products and services, businesses are looking for alternative means of creating and delivering value [29]. However, encouraging consumers to adopt sharing or renting models, embrace repair and remanufacturing, and change consumption patterns can be challenging. Understanding the barriers and drivers of behavioral change is a crucial research gap. Indeed, in order for a PSS to thrive and contribute to a CE, it is not only necessary to introduce circularity measures into business models, but to also take into account the behavioral aspects that determine consumption choices and habits. Concurringly, there are also difficulties in implementing these types of business models in companies, as they may result in reduced profits and competitiveness, especially in smaller companies that face higher risks and uncertainties [29].

To address negative environmental impacts, a growing global endeavor to reduce current consumption patterns is underway. Those impacts can be mitigated by concurrent changes to business models and consumer behavior, where one can interchangeably influence the other [86]. Providing products as services can alter consumption patterns and lead to the optimization of supply chains and product design in order to enhance the value proposition for the consumer and the business.

Consumer motivations for participating in PSSs have been studied, and it has been determined that most consumers predominantly value economic and practical benefits. One of the most essential aspects of PSS uptake is trust between PSS providers and consumers. PSSs' approach to business is not solely transactional; rather, it relies on inter-party trust to ensure the system's long-term viability. The timely return of products by customers, the dependability of distribution services, and the prompt completion of outsourced washing or repairs are crucial for businesses. The human element poses the greatest systemic challenge and an effort to expand consumer access to products is not always aligned with consumption and waste reduction goals [29].

Ref. [99] proposed an analysis of consumption patterns based on different types of capital. They place particular importance on forms of social capital, consisting of character-

istics of social organizations such as norms, trust, beliefs, and networks, whose members collaborate to increase social efficiency. Within social capital, the authors found that peer influence plays a noteworthy role in consumer behavior. Peer influence moderates the relationship between environmental concern, perceived worsening of environmental problems, perceived environmental responsibility, and green product purchasing behavior. This is particularly relevant given the dominance of ICTs: virtual communities are an essential means of disseminating information, and product reviews and information will serve as references for other community members. The authors concluded that the greater the social media influence and social capital, the more willing consumers are to purchase a PSS. It is also important to note that, despite the facilitating role of information and communication technologies in expanding the adoption of PSS, some of its categories may be conditioned by external factors, such as location. For instance, reference [100] found that a rental service is heavily influenced by the location of the rental depot, which conditions its uptake by consumers. Nevertheless, the impacts of the product and accessories, infrastructure, waste management, and use are reduced compared to the alternative.

Another factor affecting consumer behavior noted in the literature is its symbolic nature. Goods and services are often consumed for their sign value, which sometimes surpasses their functional performance [101]. In this sense, the potential of customization is one of PSSs' greatest strengths [28,102–104]. Although it can be seen as a barrier to the implementation of circular measures in industry [102], the customization of accessed products can simultaneously increase market acceptance and individual customer satisfaction. The results of a study by [104] show that consumer acceptance rises if a product simultaneously satisfies intangible and functional needs, and that customization can infuse those intangible meanings and values into accessed products. In order to effectively infuse meaning into PSSs, it is necessary to identify the favorable social conventions at play in a given context [103]. Because consumption is defined by sociocultural aspects, customization can lead to a sense of appropriation and identification with a specific consumer community [105]. In this sense, the incorporation of a socio-cultural lens into user research and design practices could eventually lead to greater PSS acceptance [103].

Nevertheless, some business models may not reduce consumption, despite their sustainability potential, and the sustainability outcomes of PSS are neither certain nor transparent [98]. External factors (such as changes in style and product obsolescence) abbreviate product lifetimes regardless of material durability, thereby compromising strategies to increase their longevity. The value of a PSS offering depends on the degree to which production and ownership are supplanted by rental, which can be understood as the replacement rate. This scenario enables the occurrence of rebound effects, in which the positive impacts on the environment are less than what was predicted, mainly due to changes in behavior, such as an increase in consumption or substitutional effects.

It is important to note that a cultural shift is necessary, but not only on the part of the consumer. Firms must also abandon the traditional means by which they set their development trajectories in favor of a method that is better aligned with current requirements [106]. This cultural paradigm shift encompasses the transition from divisions to interdepartmental collaboration, the modification of traditional business practices, and the transition from transactional to service-oriented behavior, taking into account factors such as a change in product ownership or minimal order quantity [59].

#### 3.3.4. Systemic Approaches

Many studies in the field have focused on individual PSS initiatives or specific sectors, but there is a need for more systemic approaches. Research should address the systemic implications of scaling up PSS and CE practices across multiple sectors and value chains, considering interactions, feedback loops, and potential unintended consequences.

One of the most challenging aspects in this regard is the collaboration among various stakeholders, including manufacturers, service providers, suppliers, and customers. Aligning their efforts, interests, and needs can indeed be challenging, due to differences

in priorities, business models, and organizational cultures [59]. Another aspect has to do with business model innovation: integrating products and services requires new revenue streams, pricing models, and customer engagement strategies. This can be challenging, as it involves transforming established practices, realigning organizational structures, and overcoming internal resistance to change [16,66,76].

#### 3.3.5. Policy and Regulatory Frameworks

The role of policies and regulations in promoting PSSs, CE, and resource efficiency needs further exploration. There is a need to investigate the effectiveness of existing policies, identify barriers, and propose new policy frameworks that incentivize sustainable practices and provide a supportive environment for their adoption.

Ref. [34] approaches the topic of policy from a social practice perspective. Social practice theory provides insights into how consumption-focused approaches may be advantageous for PSS development. Sustainability cannot be accomplished solely through innovations on the supply side; additional research is required to consider the demand side of sustainable consumption. In fact, inadequate acceptance, adoption, and diffusion have impeded the mainstream adoption of alternative PSS consumption models. It could be proposed that new ways of using PSS options will only have significance in sustainability transitions if they assist in reconfiguring and modifying collective practice so that these emergent ways of taking part in the practice become stable and recognizable. Therefore, policymakers play an essential role in the substitution of unsustainable practices. Ref. [101] also calls attention to the importance of environmental policy instruments as potential modelers of behavior. The phasing out of environmentally harmful subsidies, the internalization of external costs, resource-efficient electricity production and distribution, resource-efficient mobility, the minimization of food losses and waste, and the achievement of resource efficiency and industrial symbiosis through PSSs are some relevant domains in which policy can play an important role [107].

#### 3.3.6. Social Equity and Inclusion

PSS models have been praised for their contribution to the social aspects of sustainability. One of them is related to the possibility of extending access to products and services to low- and middle-income families, as the reduction of costs allows goods to be more accessible, improving sentiments of social equity and cohesion [108]. This is also applicable to lower-income investors and entrepreneurs, as the PSS option for industries eliminates the need for high upfront investments and prevents interruption of use [108]. At the same time, because PSSs have the potential to create new markets and opportunities, they could also empower local economies and enhance overall quality of life through the strengthening of long-term relations among different stakeholders [109]. There is a need to investigate the ways in which PSS and CE initiatives promote social equity and inclusion. Research should address how these models can be designed to benefit all members of society, including marginalized communities, and avoid exacerbating existing inequalities.

In designing and implementing PSSs, attention must be paid to issues such as access and affordability. Pricing and payment structures should be made inclusive and affordable, enabling a wide range of users to benefit from the system. This includes considering pricing tiers, subsidies, or alternative payment models to accommodate different income levels [59]. At the same time, digitalization, a staple of PSSs, poses its own problems. Not everyone has equal access to technology, Internet connectivity, or digital literacy skills. This gap can be addressed through education, training programs, and affordable access to devices [61].

There is also the matter of location and cultural sensitivity. Economic inequalities brought forth by environmental issues can indirectly make way for a range of undesirable consequences, which vary according to time (short-, medium-, or long-term) and space (local, regional, or global) [101]. Implementation of PSSs in different countries and regions means that there will likely be differences in the acceptance level of consumers due to the impact of socio-cultural factors [106]. Other crucial questions require consideration,

such as the forms and processes of governance that could enable an effective and equitable transition towards a CE [110].

#### 3.3.7. Technological Integration

The integration of emerging technologies, such as artificial intelligence, blockchain, and the IoT, into PSS and CE systems is an area that requires further investigation. Issues such as compatibility between different components, interoperability, scalability, data security and privacy, and user acceptance are among the main challenges. Recent exploratory studies indicate low adoption of these strategies and business models in industry due to manufacturing firms' limited strategic awareness and preparedness [86]. Ref. [60] also argues that the digital transformation allows the development of adequate infrastructures for the deployment of servitization in business, and digital tools are an important factor in the application of "front-end" and "back-end" features to increase and enhance the extent of servitization and raise consumer value. However, digital transformations that favor servitization have significant organizational implications and frequently necessitate the adoption of new organizational forms. For example, supply-chain integration requires more networked and matrix-type organizational structures [35]. Additionally, digitalization brings with it the need to explore large quantities of data and, in some cases, to provide real-time feedback, which is especially challenging for companies that rely on centralized business models and must now rely on distributed ones [91]. Digital capabilities vary depending on the business model and become increasingly significant during the transition to a service-centric business model [29], as well as depending on company size [111]. An essential issue has to do with industries' and companies' readiness for change, which is more of a social than a technical aspect, including dimensions such as strategy, leadership, and organizational structure [91]. A greater understanding of the potential benefits, risks, and challenges associated with technological integration is essential to the effective and responsible implementation of PSSs.

#### 3.3.8. Long-Term Impacts and Transitions

There is limited research on the long-term impacts and transitions associated with PSS and CE approaches. Longitudinal studies are needed to assess the durability, scalability, and transformative potential of these models over time.

To date, the environmental consequences of innovation and efficiency improvements have received little consideration. It could be argued that innovations and efficiency improvements have been counterproductive in the sense that they have so far encouraged an increase in consumption by lowering prices. As a result, increased consumption stimulates economic expansion, resetting the cycle through incremental innovation [101].

In terms of economic implications, PSSs can have both positive and negative ones. Despite the fact that they can generate new business opportunities, revenue streams, and employment opportunities, they may also disrupt existing industries and business models. For instance, PSSs can result in a decline in the sales of traditional products, affecting the manufacturing industry. Understanding the economic ramifications and facilitating transitions for all stakeholders are essential for long-term sustainability. This also has implications for the job market. The transition to service-oriented models could result in changes to job functions, talent requirements, and employment patterns. It is essential that the transition be accompanied by adequate training programs, reskilling initiatives, and social safety nets for affected employees [61]. Moreover, PSSs should prioritize ethical working conditions, labor rights, and equitable benefit distribution among service providers and other stakeholders.

## 4. Conclusions

The development of PSSs has gained special attention as a key strategy for promoting sustainability and resource efficiency within the context of the CE. This review article has provided an overview of the literature on PSS from 2016 to 2022, focusing on its

interconnections with sustainability, resource efficiency, and the CE. Through a systematic examination of approximately 160 research papers, it was possible to synthesize and evaluate the prevailing knowledge in this field. Regarding this study's main limitations, a lack of specific case studies must be admitted to, which would potentially help establish a more concrete link between PSSs, sustainability and the CE. However, such a study would fall outside the scope of this review, and a direct correlation between PSSs and sustainable, circular development remains, as most of the analyzed literature suggests, a contested matter. The evaluation of this correlation and of the potential benefits of PSSs to sustainable and circular systems requires continuous and consistent empirical research. Despite this limitation, this review highlights the growing importance of PSS as a fundamental strategy for promoting sustainability and resource efficiency within the context of the CE, attesting to its potential for reshaping industrial systems. It provides a conceptual foundation for understanding how PSSs can contribute to achieving sustainable and circular development, as well as the potential challenges and gaps in the existing research. Identifying these gaps and contested matters helps to direct future research efforts towards resolving these uncertainties. The main theoretical implications highlight the significance of PSS as a strategy for sustainability and circularity, the interconnectedness of PSSs with sustainability and the CE, the multidisciplinary nature of PSS research, and the importance of empirical studies, social considerations, and practical assessments. These implications provide valuable directions and a framework for further research and policy formulation to foster sustainable and circular development through the integration of PSSs.

Findings from previous studies allow for the identification of several trends and challenges in PSS research. Eight main trends were identified, including sector-specific studies, barriers and stimuli to implementation and adoption, PSS design methodologies, and the exploration of topics such as the CE, servitization, digitalization and Industry 4.0, collaboration and networks, design methodologies, and business models and performance measurement. These trends demonstrate the diverse and multidisciplinary nature of PSS research. It was found that, despite variations in perspectives and terminology, the definition of PSS remains consistent throughout the literature. However, there are still controversies and research gaps that need to be addressed. The reconciliation of industrial and environmental perspectives, the contribution of PSSs to circularity and sustainability, and the benefits and challenges for both companies and consumers are areas that require further investigation. This scenario implies that the PSS concept and its link to the CE are still somewhat unfamiliar and underdeveloped for enterprises. Inadequate strategic knowledge and readiness could hinder the effective implementation of these strategies, thereby impeding the achievement of their economic, environmental, and social worth. Other areas in need of deeper examination include the link between territorial aspects and the establishment of PSS networks. In terms of assessment methodologies, it is argued that future work needs to address practical aspects of CE, focusing on a better development of use case-based assessment of the sustainability effects of PSSs, assisted by data technologies.

The review also sheds light on important considerations often overlooked in PSS research. Issues such as equity, social inclusion, and consumption dynamics play a crucial role in PSS implementation. Understanding consumer behavior and addressing consumption patterns are vital for achieving a resource-efficient and circular economic system. Metrics and indicators, business model viability, technological integration, policy and regulatory frameworks, and systemic approaches are additional factors that need to be examined to advance the field.

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## References

1. Kurpiela, S.; Teuteberg, F. Strategic planning of product-service systems: A systematic literature review. *J. Clean. Prod.* **2022**, *338*, 130528. [CrossRef]
2. Moro, S.R.; Cauchick-Miguel, P.A.; de Sousa Mendes, G.H. Literature analysis on product-service systems business model: A promising research field. *Braz. J. Oper. Prod. Manag.* **2022**, *19*, 1–18. [CrossRef]
3. Bressanelli, G.; Adrodegari, F.; Perona, M.; Saccani, N. Exploring how usage-focused business models enable circular economy through digital technologies. *Sustainability* **2018**, *10*, 639. [CrossRef]
4. Erkoyuncu, J.A.; Roy, R.; Shehab, E.; Durugbo, C.; Khan, S.; Datta, P. An effective uncertainty based framework for sustainable industrial product-service system transformation. *J. Clean. Prod.* **2019**, *208*, 160–177. [CrossRef]
5. Sakao, T.; Liu, Y.; Gustafsson, R.; Thörnblad, G. A Method for Lifecycle Design of Product/Service Systems Using PLM Software. In *Product Lifecycle Management and the Industry of the Future, Proceedings of the 14th IFIP WG 5.1 International Conference, PLM 2017, Seville, Spain, 10–12 July 2017*; Springer: New York, NY, USA, 2017; pp. 710–718. [CrossRef]
6. Tukker, A. Product services for a resource-efficient and circular economy—A review. *J. Clean. Prod.* **2015**, *97*, 76–91. [CrossRef]
7. Falagas, M.E.; Pitsouni, E.I.; Malietzis, G.A.; Pappas, G. Comparison of PubMed, Scopus, Web of Science, and Google Scholar: Strengths and weaknesses. *FASEB J.* **2008**, *22*, 338–342. [CrossRef]
8. Åkesson, J.; Sundström, A.; Chirumalla, K.; Johansson, G. Exploring Challenges to Design Product-Service Systems in SMEs-A Case Study. In *Advances in Transdisciplinary Engineering*; IOS Press BV: Amsterdam, The Netherlands, 2022; pp. 63–74. [CrossRef]
9. Sakao, T. Increasing Value Capture by Enhancing Manufacturer Commitment—Designing a Value Cocreation System. *IEEE Eng. Manag. Rev.* **2022**, *50*, 79–87. [CrossRef]
10. Kühl, C.; Bourlakis, M.; Aktas, E.; Skipworth, H. Product-service systems and circular supply chain practices in UK SMEs: The moderating effect of internal environmental orientation. *J. Bus. Res.* **2022**, *146*, 155–165. [CrossRef]
11. Koide, R.; Murakami, S.; Nansai, K. Prioritising low-risk and high-potential circular economy strategies for decarbonisation: A meta-analysis on consumer-oriented product-service systems. *Renew. Sustain. Energy Rev.* **2022**, *155*, 111858. [CrossRef]
12. Li, D.; Huang, Y.; Sun, H.; Zhi, B. Achieving sustainability in sharing-based product service system: A contingency perspective. *J. Clean. Prod.* **2022**, *332*, 129997. [CrossRef]
13. Peura, P.; Voutilainen, O.; Kantola, J. From garbage to product and service systems: A longitudinal Finnish case study of waste management evolution. *Waste Manag.* **2022**, *140*, 143–153. [CrossRef] [PubMed]
14. Inagaki, Y.; Mitake, Y.; Tsuji, S.; Alfarisi, S.; Wang, H.; Shimomura, Y. Extracting the relationship between product-service system features and their implementation barriers based on a literature review. *Procedia CIRP* **2022**, *109*, 197–202. [CrossRef]
15. Vargas, J.P.; Lagos, A.P.M.; Torres, J.G.F.; Kinney, I.S.; Cortés, S.P.; Hurtado, J.P. Achieving Circularity through Novel Product-Service Systems in the Mining Industry: An Opportunity for Circularity. *Sustainability* **2022**, *14*, 3614. [CrossRef]
16. Delgadillo, E.; Reyes, T.; Baumgartner, R.J. Towards territorial product-service systems: A framework linking resources, networks and value creation. *Sustain. Prod. Consum.* **2021**, *28*, 1297–1313. [CrossRef]
17. Kolling, C.; de Medeiros, J.F.; Ribeiro, J.L.D.; Morea, D. A conceptual model to support sustainable Product-Service System implementation in the Brazilian agricultural machinery industry. *J. Clean. Prod.* **2022**, *355*, 131733. [CrossRef]
18. Lanzilotti, C.O.; Pinto, L.F.R.; Facchini, F.; Digiesi, S. Embedding Product-Service System of Cutting Tools into the Machining Process: An Eco-Efficiency Approach toward Sustainable Development. *Sustainability* **2022**, *14*, 1100. [CrossRef]
19. Münch, C.; Marx, E.; Benz, L.; Hartmann, E.; Matzner, M. Capabilities of digital servitization: Evidence from the socio-technical systems theory. *Technol. Forecast. Soc. Chang.* **2022**, *176*, 121361. [CrossRef]

20. Alfarisi, S.; Mitake, Y.; Tsutsui, Y.; Wang, H.; Shimomura, Y. A study of the rebound effect on the product-service system: Why should it be a top priority? *Procedia CIRP* **2022**, *109*, 257–262. [CrossRef]
21. Agher, J.R.; Dubois, P.; Aoussat, A. A bibliometric analysis of product-service systems' design methodologies: Potential root-cause identification of pss' failures. *Sustainability* **2022**, *13*, 6237. [CrossRef]
22. Marilungo, E.; Peruzzini, M.; Germani, M. Review of product-service system design methods. In *IFIP Advances in Information and Communication Technology*; Springer: New York, NY, USA, 2016; pp. 271–279. [CrossRef]
23. Radic, M.; Liebtrau, R.M.; Radic, D. From Product Manufacturer to System Provider: Revenue Models for Product Service Systems. In *Rediscovering the Essentiality of Marketing*; Springer: Cham, Switzerland, 2016; pp. 565–578. [CrossRef]
24. Batlles-delaFuente, A.; Belmonte-Ureña, L.J.; Plaza-úbeda, J.A.; Abad-Segura, E. Sustainable business model in the product-service system: Analysis of global research and associated eu legislation. *Int. J. Environ. Res. Public Health* **2021**, *18*, 10123. [CrossRef]
25. Gamba, D.; Malakhatka, E. Product-Service Systems Delivered by SMEs During Building Use Stage: Sustainability Criteria Framework. In *Smart and Sustainable Collaborative Networks 4.0, Proceedings of the 22nd IFIP WG 5.5 Working Conference on Virtual Enterprises, PRO-VE 2021, Saint-Étienne, France, 22–24 November 2021*; Springer Science and Business Media Deutschland GmbH: Cham, Switzerland, 2021; pp. 65–77. [CrossRef]
26. Valusyte, R. Circular Design Strategies in Manufacturing SME's: From Material to the Meaning and Dematerialization. In Proceedings of the 2021 IEEE International Conference on Technology and Entrepreneurship, ICTE 2021, Kaunas, Lithuania, 24–27 August 2021; Institute of Electrical and Electronics Engineers Inc.: Piscataway, NJ, USA, 2021. [CrossRef]
27. Zhou, C.; Song, W. Digitalization as a way forward: A bibliometric analysis of 20 Years of servitization research. *J. Clean. Prod.* **2021**, *300*, 126943. [CrossRef]
28. Catulli, M.; Sopjani, L.; Reed, N.; Tzilivakis, J.; Green, A. A socio-technical experiment with a resource efficient product service system. *Resour. Conserv. Recycl.* **2021**, *166*, 105364. [CrossRef]
29. Gyde, C.; McNeill, L.S. Fashion rental: Smart business or ethical folly? *Sustainability* **2022**, *13*, 8888. [CrossRef]
30. Tokarz, B.; Kohlbeck, E.; Beuren, F.H.; Fagundes, A.B.; Pereira, D. Systematic literature review: Opportunities and trends to the post-outbreak period of COVID-19. *Braz. J. Oper. Prod. Manag.* **2021**, *18*, 1–16. [CrossRef]
31. Annarelli, A.; Battistella, C.; Nonino, F. *The Road to Servitization How Product Service Systems Can Disrupt Companies' Business Models*; Springer: Cham, Switzerland, 2019.
32. Mahut, F.; Daaboul, J.; Bricogne, M.; Eynard, B. Product-Service Systems for servitization of the automotive industry: A literature review. *Int. J. Prod. Res.* **2017**, *55*, 2102–2120. [CrossRef]
33. Pereira, Á.; Carballo-Penela, A.; González-López, M.; Vence, X. A case study of servicizing in the farming-livestock sector: Organisational change and potential environmental improvement. *J. Clean. Prod.* **2016**, *124*, 84–93. [CrossRef]
34. Sousa-Zomer, T.T.; Miguel, P.A.C. Exploring the consumption side of sustainable product-service systems (PSS): An empirical study and insights for PSS sustainable design. *CIRP J. Manuf. Sci. Technol.* **2016**, *15*, 74–81. [CrossRef]
35. De La Calle, A.; Freije, I.; Oyarbide, A. Digital product-service innovation and sustainability: A multiple-case study in the capital goods industry. *Sustainability* **2022**, *13*, 6342. [CrossRef]
36. López, N.M.; Sáenz, J.L.S.; Biedermann, A.; Tierz, A.S. Sustainability assessment of product-service systems using flows between systems approach. *Sustainability* **2020**, *12*, 3415. [CrossRef]
37. Opazo-Basáez, M.; Vendrell-Herrero, F.; Bustinza, O.F. Uncovering productivity gains of digital and green servitization: Implications from the automotive industry. *Sustainability* **2018**, *10*, 1524. [CrossRef]
38. Borg, D.; Mont, O.; Schoonover, H. Consumer acceptance and value in use-oriented product-service systems: Lessons from Swedish consumer goods companies. *Sustainability* **2020**, *12*, 8079. [CrossRef]
39. Corvellec, H.; Stål, H.I. Evidencing the waste effect of Product-Service Systems (PSSs). *J. Clean. Prod.* **2017**, *145*, 14–24. [CrossRef]
40. Doni, F.; Corvino, A.; Martini, S.B. Servitization and sustainability actions. Evidence from European manufacturing companies. *J. Environ. Manag.* **2019**, *234*, 367–378. [CrossRef] [PubMed]
41. Fani, V.; Pirola, F.; Bindi, B.; Bandinelli, R.; Pezzotta, G. Design Product-Service Systems by Using a Hybrid Approach: The Fashion Renting Business Model. *Sustainability* **2022**, *14*, 5207. [CrossRef]
42. de Jesus Pacheco, D.A.; Caten, C.S.T.; Jung, C.F.; Pergher, I.; Hunt, J.D. Triple Bottom Line impacts of traditional Product-Service Systems models: Myth or truth? A Natural Language Understanding approach. *Environ. Impact Assess. Rev.* **2022**, *96*, 106819. [CrossRef]
43. Hahn, T.; Pinkse, J. A paradox approach to sustainable product-service systems. *Ind. Mark. Manag.* **2022**, *105*, 182–189. [CrossRef]
44. Nag, U.; Sharma, S.K.; Padhi, S.S. Evaluating value requirement for Industrial Product-Service System in circular economy for wind power-based renewable energy firms. *J. Clean. Prod.* **2022**, *340*, 130689. [CrossRef]
45. Junior, R.F.; Scur, G.; Nunes, B. Preparing for smart product-service system (PSS) implementation: An investigation into the Daimler group. *Prod. Plan. Control* **2022**, *33*, 56–70. [CrossRef]
46. Zheng, P.; Wang, Z.; Chen, C.H. Smart product-service systems: A novel transdisciplinary sociotechnical paradigm. In *Advances in Transdisciplinary Engineering*; IOS Press BV: Amsterdam, The Netherlands, 2019; pp. 234–241. [CrossRef]
47. Pirola, F.; Boucher, X.; Wiesner, S.; Pezzotta, G. Digital technologies in product-service systems: A literature review and a research agenda. *Comput. Ind.* **2020**, *123*, 103301. [CrossRef]
48. Li, X.; Chen, C.H.; Zheng, P.; Wang, Z.; Jiang, Z.; Jiang, Z. A knowledge graph-Aided concept–Knowledge approach for evolutionary smart product–Service system development. *J. Mech. Des. Trans. ASME* **2020**, *142*, 101403. [CrossRef]

49. Liu, Y.; Xing, Y.; Vendrell-Herrero, F.; Bustinza, O.F. Setting contextual conditions to resolve grand challenges through responsible innovation: A comparative patent analysis in the circular economy. *J. Prod. Innov. Manag.* **2023**, 1–24. [CrossRef]
50. Corsini, L.; Moultrie, J. What is design for social sustainability? A systematic literature review for designers of product-service systems. *Sustainability* **2022**, *13*, 5963. [CrossRef]
51. Missimer, M.; Robèrt, K.H.; Broman, G. A strategic approach to social sustainability—Part 2: A principle-based definition. *J. Clean. Prod.* **2017**, *140*, 42–52. [CrossRef]
52. Neligan, A.; Baumgartner, R.J.; Geissdoerfer, M.; Schöggl, J.P. Circular disruption: Digitalisation as a driver of circular economy business models. *Bus. Strategy Environ.* **2023**, *32*, 1175–1188. [CrossRef]
53. Langley, D.J. Digital Product-Service Systems: The Role of Data in the Transition to Servitization Business Models. *Sustainability* **2022**, *14*, 1303. [CrossRef]
54. Nyvall, M.; Zobel, T.; Mark-Herbert, C. Use-oriented business model. *Corp. Soc. Responsib. Environ. Manag.* **2023**, *30*, 1314–1324. [CrossRef]
55. Kjaer, L.L.; Pagoropoulos, A.; Schmidt, J.H.; McAloone, T.C. Challenges when evaluating Product/Service-Systems through Life Cycle Assessment. *J. Clean. Prod.* **2016**, *120*, 95–104. [CrossRef]
56. Kjaer, L.L.; Pigosso, D.C.A.; Niero, M.; Bech, N.M.; McAloone, T.C. Product/Service-Systems for a Circular Economy: The Route to Decoupling Economic Growth from Resource Consumption? *J. Ind. Ecol.* **2019**, *23*, 22–35. [CrossRef]
57. Lahcen, B.; Eyckmans, J.; Rousseau, S.; Dams, Y.; Brusselaers, J. Modelling the circular economy: Introducing a supply chain equilibrium approach. *Ecol. Econ.* **2022**, *197*, 107451. [CrossRef]
58. Nishino, N.; Kimita, K.; Ito, T. Mechanism for matching circular products and customers with top trading cycles. *CIRP Ann.* **2022**, *71*, 5–8. [CrossRef]
59. Hidalgo-Carvajal, D.; Carrasco-Gallego, R.; Morales-Alonso, G. From goods to services and from linear to circular: The role of servitization's challenges and drivers in the shifting process. *Sustainability* **2022**, *13*, 4539. [CrossRef]
60. Galera-Zarco, C.; Campos, J.A. Exploring servitization in industrial construction: A sustainable approach. *Sustainability* **2022**, *13*, 8002. [CrossRef]
61. Hallstedt, S.I.; Isaksson, O.; Rönnbäck, A.A.Ö. The need for new product development capabilities from digitalization, sustainability, and servitization trends. *Sustainability* **2020**, *12*, 222. [CrossRef]
62. Lugnet, J.; Ericson, Å.; Larsson, T. Design of product–service systems: Toward an updated discourse. *Systems* **2020**, *8*, 45. [CrossRef]
63. Agrawal, R.; Wankhede, V.A.; Kumar, A.; Luthra, S.; Huisingh, D. Progress and trends in integrating Industry 4.0 within Circular Economy: A comprehensive literature review and future research propositions. *Bus. Strategy Environ.* **2022**, *31*, 559–579. [CrossRef]
64. da Costa, F.S.; Pigosso, D.C.A.; McAloone, T.C.; Rozenfeld, H. Towards product-service system oriented to circular economy: A systematic review of value proposition design approaches. *J. Clean. Prod.* **2020**, *257*, 120507. [CrossRef]
65. Yang, M.; Evans, S. Product-service system business model archetypes and sustainability. *J. Clean. Prod.* **2019**, *220*, 1156–1166. [CrossRef]
66. Negash, Y.T.; Sarmiento, L.S.C.; Tseng, M.L.; Jantarakolica, K.; Tan, K. Sustainable product-service system hierarchical framework under uncertainties: The pharmaceutical industry in Ecuador. *J. Clean. Prod.* **2021**, *294*, 126188. [CrossRef]
67. Kristensen, H.S.; Remmen, A. A framework for sustainable value propositions in product-service systems. *J. Clean. Prod.* **2019**, *223*, 25–35. [CrossRef]
68. Behnam, S.; Cagliano, R.; Grijalvo, M. How should firms reconcile their open innovation capabilities for incorporating external actors in innovations aimed at sustainable development? *J. Clean. Prod.* **2018**, *170*, 950–965. [CrossRef]
69. Evans, S.; Vladimirova, D.; Holgado, M.; Van Fossen, K.; Yang, M.; Silva, E.A.; Barlow, C.Y. Business Model Innovation for Sustainability: Towards a Unified Perspective for Creation of Sustainable Business Models. *Bus. Strategy Environ.* **2017**, *26*, 597–608. [CrossRef]
70. Sinclair, M.; Sheldrick, L.; Moreno, M.; Dewberry, E. Consumer intervention mapping-A tool for designing future product strategies within circular product service systems. *Sustainability* **2018**, *10*, 2088. [CrossRef]
71. Retamal, M. Product-service systems in Southeast Asia: Business practices and factors influencing environmental sustainability. *J. Clean. Prod.* **2017**, *143*, 894–903. [CrossRef]
72. Sousa-Zomer, T.T.; Miguel, P.A.C. The main challenges for social life cycle assessment (SLCA) to support the social impacts analysis of product-service systems. *Int. J. Life Cycle Assess.* **2018**, *23*, 607–616. [CrossRef]
73. Szász, L.; Seer, L. Towards an operations strategy model of servitization: The role of sustainability pressure. *Oper. Manag. Res.* **2018**, *11*, 51–66. [CrossRef]
74. Jaime, E.E.D.; Carrillo, T.R.; Baumgartner, R. Circular PSS strategies: An exploration of the integration of territorial resources. In Proceedings of the International Conference on Engineering Design, ICED, Delft, The Netherlands, 5–8 August 2019; Cambridge University Press: Cambridge, UK, 2019; pp. 3191–3200. [CrossRef]
75. Ingemarsdotter, E.; Jamsin, E.; Kortuem, G.; Balkenende, R. Circular strategies enabled by the internet of things-a framework and analysis of current practice. *Sustainability* **2019**, *11*, 5689. [CrossRef]
76. Schoonover, H.A.; Mont, O.; Lehner, M. Exploring barriers to implementing product-service systems for home furnishings. *J. Clean. Prod.* **2021**, *295*, 126286. [CrossRef]

77. Sassanelli, C.; Urbinati, A.; Rosa, P.; Chiaroni, D.; Terzi, S. Addressing circular economy through design for X approaches: A systematic literature review. *Comput. Ind.* **2020**, *120*, 103245. [CrossRef]
78. Bocken, N.; Strupeit, L.; Whalen, K.; Nußholz, J. A review and evaluation of circular business model innovation tools. *Sustainability* **2019**, *11*, 2210. [CrossRef]
79. Ceschin, F.; Gaziulusoy, I. Evolution of design for sustainability: From product design to design for system innovations and transitions. *Des. Stud.* **2016**, *47*, 118–163. [CrossRef]
80. Mesa, J.A.; Gonzalez-Quiroga, A.; Aguiar, M.F.; Jugend, D. Linking product design and durability: A review and research agenda. *Heliyon* **2022**, *8*, e10734. [CrossRef] [PubMed]
81. Pigosso, D.C.A.; McAloone, T.C. Maturity-based approach for the development of environmentally sustainable product/service-systems. *CIRP J. Manuf. Sci. Technol.* **2016**, *15*, 33–41. [CrossRef]
82. Chen, C.W. Guidance on the conceptual design of sustainable product-service systems. *Sustainability* **2018**, *10*, 2452. [CrossRef]
83. de Kwant, C.; Rahi, A.F.; Laurenti, R. The role of product design in circular business models: An analysis of challenges and opportunities for electric vehicles and white goods. *Sustain. Prod. Consum.* **2021**, *27*, 1728–1742. [CrossRef]
84. Abuzied, H.; Senbel, H.; Awad, M.; Abbas, A. A review of advances in design for disassembly with active disassembly applications. *Eng. Sci. Technol. Int. J.* **2020**, *23*, 618–624. [CrossRef]
85. Rosa, P.; Sassanelli, C.; Terzi, S. Towards Circular Business Models: A systematic literature review on classification frameworks and archetypes. *J. Clean. Prod.* **2019**, *236*, 7696. [CrossRef]
86. Khan, M.A.; Stoll, O.; West, S.; Wuest, T. Equipment upgrade service provision in the context of servitization: Drivers, capabilities, and resources. *Prod. Plan. Control.* **2022**, 1–19. [CrossRef]
87. Bracquené, E.; Lindemann, J.; Duflou, J. Implementation of circularity indicators in a household product manufacturing company. *Procedia CIRP* **2022**, *105*, 660–665. [CrossRef]
88. Kaddoura, M.; Kambanou, M.L.; Tillman, A.M.; Sakao, T. Is prolonging the lifetime of passive durable products a low-hanging fruit of a circular economy? A multiple case study. *Sustainability* **2019**, *11*, 4819. [CrossRef]
89. van Loon, P.; Diener, D.; Harris, S. Circular products and business models and environmental impact reductions: Current knowledge and knowledge gaps. *J. Clean. Prod.* **2021**, *288*, 125627. [CrossRef]
90. Tunn, V.S.C.; Van den Hende, E.A.; Bocken, N.M.P.; Schoormans, J.P.L. Consumer adoption of access-based product-service systems: The influence of duration of use and type of product. *Bus. Strategy Environ.* **2021**, *30*, 2796–2813. [CrossRef]
91. Li, A.Q.; Rich, N.; Found, P.; Kumar, M.; Brown, S. Exploring product–service systems in the digital era: A socio-technical systems perspective. *TQM J.* **2020**, *32*, 897–913. [CrossRef]
92. Blüher, T.; Riedelsheimer, T.; Gogineni, S.; Klemichen, A.; Stark, R. Systematic literature review-Effects of PSS on sustainability based on use case assessments. *Sustainability* **2020**, *12*, 6989. [CrossRef]
93. Negri, E.; Holgado, M.; Wagner, D.; Grefrath, C.; Macchi, M.; Gudergan, G. Continuous improvement planning through sustainability assessment of product-service systems. *Int. J. Product. Qual. Manag.* **2016**, *16*, 168–190. [CrossRef]
94. Kim, K.J.; Lim, C.H.; Heo, J.Y.; Lee, D.H.; Hong, Y.S.; Park, K. An evaluation scheme for product–service system models: Development of evaluation criteria and case studies. *Serv. Bus.* **2016**, *10*, 507–530. [CrossRef]
95. Kühl, C.; Bourlakis, M.; Aktas, E.; Skipworth, H. How does servitisation affect supply chain circularity?—A systematic literature review. *J. Enterp. Inf. Manag.* **2020**, *33*, 703–728. [CrossRef]
96. Linder, M.; Williander, M. Circular Business Model Innovation: Inherent Uncertainties. *Bus. Strategy Environ.* **2017**, *26*, 182–196. [CrossRef]
97. Priyono, A. Understanding the benefits of product-service systems for parties involved in remanufacturing. *J. Ind. Eng. Manag.* **2017**, *10*, 323–351. [CrossRef]
98. Johnson, E.; Plepys, A. Product-service systems and sustainability: Analysing the environmental impacts of rental clothing. *Sustainability* **2022**, *13*, 2118. [CrossRef]
99. Zhang, X.; Dong, F. How virtual social capital affects behavioral intention of sustainable clothing consumption pattern in developing economies? A case study of China. *Resour. Conserv. Recycl.* **2021**, *170*, 105616. [CrossRef]
100. Martin, M.; Heiska, M.; Björklund, A. Environmental assessment of a product-service system for renting electric-powered tools. *J. Clean. Prod.* **2021**, *281*, 125245. [CrossRef]
101. Laurenti, R.; Singh, J.; Sinha, R.; Potting, J.; Frostell, B. Unintended Environmental Consequences of Improvement Actions: A Qualitative Analysis of Systems' Structure and Behavior. *Syst. Res. Behav. Sci.* **2016**, *33*, 381–399. [CrossRef]
102. Kambanou, M.L.; Sakao, T. Using life cycle costing (LCC) to select circular measures: A discussion and practical approach. *Resour. Conserv. Recycl.* **2020**, *155*, 104650. [CrossRef]
103. Santamaria, L.; Escobar-Tello, C.; Ross, T. Switch the channel: Using cultural codes for designing and positioning sustainable products and services for mainstream audiences. *J. Clean. Prod.* **2016**, *123*, 16–27. [CrossRef]
104. Tunn, V.S.C.; Bocken, N.M.P.; van den Hende, E.A.; Schoormans, J.P.L. Business models for sustainable consumption in the circular economy: An expert study. *J. Clean. Prod.* **2019**, *212*, 324–333.
105. Catulli, M.; Cook, M.; Potter, S. Product Service Systems Users and Harley Davidson Riders: The Importance of Consumer Identity in the Diffusion of Sustainable Consumption Solutions. *J. Ind. Ecol.* **2017**, *21*, 1370–1379. [CrossRef]
106. Labbate, R.; Silva, R.F.; Rampasso, I.S.; Anholon, R.; Quelhas, O.L.G.; Filho, W.L. Business models towards SDGs: The barriers for operationalizing Product-Service System (PSS) in Brazil. *Int. J. Sustain. Dev. World Ecol.* **2021**, *28*, 350–359. [CrossRef]

107. van der Laan, A.Z.; Aurisicchio, M. Archetypical consumer roles in closing the loops of resource flows for Fast-Moving Consumer Goods. *J. Clean. Prod.* **2019**, *236*, 117475. [CrossRef]
108. Vezzoli, C.; Ceschin, F.; Osanjo, L.; M'Rithaa, M.K.; Moalosi, R.; Nakazibwe, V.; Diehl, J.C. Sustainable Product-Service System (S.PSS). In *Green Energy and Technology*; Springer: Cham, Switzerland, 2018; pp. 41–51. [CrossRef]
109. Harrat, M.; Belkadi, F.; Bernard, A. Towards a modelaing framework of collaboration in PSS development project: A review of key factors. *Procedia CIRP* **2020**, *90*, 736–741. [CrossRef]
110. Hobson, K. Closing the loop or squaring the circle? Locating generative spaces for the circular economy. *Prog. Hum. Geogr.* **2016**, *40*, 88–104. [CrossRef]
111. Bhamra, T.; Hernandez, R.J.; Rapitsenyane, Y.; Trimingham, R. Product Service Systems: A Sustainable Design Strategy for SMEs in the Textiles and Leather Sectors. *She Ji* **2018**, *4*, 229–248. [CrossRef]