

# Implementation Of Sustainable Product-Service System (S-PSS) Design: Critical Barriers And Overcoming Strategies

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## Summary

*Sustainable Product-Service System Design (S-PSS) provides solutions to complex problems, such as the hardships caused by climate change to vulnerable populations. This research is the result of a study that identified methodologies, through a Systematic Literature Review (SLR), for the development of S-PSS projects, whose scope is scenarios affected by floods and landslides. What was found, together with the articles found in the previous research, were the critical barriers, such as cultural, institutional, political, economic barriers, etc. that, if not considered in the initial stages of an S-PSS project, may compromise the results expected by the actors involved. Among the barriers found, those that will be highlighted are the “wicked problems” and regulatory failures due to their high degree of interference in projects, as well as the “lock -in” barrier, as a result of the development of previous research. It is a systemic phenomenon, which encompasses issues that compromise social innovation by negatively interfering in multiple contexts. This paper aims to present the three barriers considered critical to S-PSS, emphasizing the “lock -in” barriers and regulatory failures, as well as possible solutions to mitigate them at the beginning of projects, as these practices can anticipate risks, optimize resources and align expectations.*

**Keywords:** *Sustainable Product-Service System Design. Climate change. Critical barriers. Innovation.*

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## I. Introduction

Climate change is causing events that lead to economic, social and environmental losses, which compromises the sustainability of the planet. According to the *Intergovernmental Panel on Climate Change* (IPCC) or the, if climate risks are not controlled, through the reduction of greenhouse gases, billions of human beings will have their lives threatened in less than 50 years (IPCC, 2023).

However, according to Monteiro and Zanella (2019), large-scale climate events have somehow contributed to public authorities, institutions and communities adopting strategies to recover the affected areas, as well as taking actions to mitigate and prevent such events. The crises generated in such scenarios have provided “a new posture and adaptation of communities, enabling a culture of coexistence, with communities that are more organized and prepared to deal with disaster situations and adapt to adverse situations” (Monteiro; Zanella, 2019, p. 47).

In turn, the *Sustainable Product-Service System* (S-PSS) can present solutions to complex problems, such as preserving life on the planet, as it presents three premises based on the dimensions of sustainability, which are: environmental, economic and socio-ethical (Vezzoli, Parra, Kothala, 2021).

The premises or principles that involve the methods that will enable the application of S-PSS must be the following: the centrality of human being in their approaches; they must be collaborative, interdisciplinary and iterative, making use of research, prototyping and “a set of easily understood activities and visualization tools to create and orchestrate experiences that meet the needs of the business, the user and the *stakeholders*” (Stickdorn, 2020, p. 27).

It is noted that, for the implementation of S-PSS, some paradigm shifts will be necessary, since in order to obtain the expected result, the demands for adjustments or even transformations will be intrinsic to the process. For this reason, it may be necessary for cultural changes to occur, such as the need to reduce consumption. This can occur through the acceptance of a new scenario, that of product-service, in which the user does not acquire a product, but, above all, acquires integrated solutions that meet their needs (Mitake *et al*, 2020). Dewit, Jacoby and Matthyssens (2021) state that business innovation lies in product-service integration, with a focus on the user.

However, Tukker (2015) estimates that 72% of product-service system initiatives fail in the pilot phase due to some cultural and economic barriers, which are elements or situations that hinder or even prevent the implementation of an S-PSS from achieving the planned results. Therefore, they must be considered from the

initial phase of the project in order to enable the delivery of the proposed solutions to be in accordance with what is expected by users (VEZZOLI *et al.*, 2015).

Barriers are generally associated with social innovation, local policies to be implemented or even failure to observe and listen to *stakeholders* involved (Siveira ; Santos, 2020). Among some barriers, we can find “wicked problems”, *lock-ins*, which can be translated as “imprisonment” or “dependence” and regulatory failures.

The barriers addressed were selected because they presented theoretical relevance, due to the evidence found in a previous research, whose objective was to search and select methods aimed at an S-PSS project, aimed at populations vulnerable to climate change (Périgo ; Duarte; Barata, 2024), through a Systematic Literature Review. As an outcome of the research, the *lock-in barrier* was included, as it reinforces the existence of perverse problems in the implementation of product-service systems, with regard to the necessary paradigm changes, as well as being connected to regulatory failures. The criterion for delimiting the present research to these three barriers was due to the interdependence between them and the critical approach in relation to the implementation of the S-PSS.

Silveira and Santos (2020), when referring to barriers as adverse situations to the application of S-PSS, mention “wicked problems”, as those that consist of greater levels of complexity and diversity. What differs a simple problem from a wicked one is that *wicked problems* are problems that are not known by the actors involved in a project, who may share “conflicting interests and values”, what prevents the recognition of such problems and consequently, their solution (SILVEIRA; SANTOS, 2020, p. 154, our translation). A simple problem can be defined as one that is known and shared by all actors involved, a condition that facilitates finding a solution (Silveira; Santos, 2020). Wicked problems can prevent a holistic vision necessary for S-PSS, which will result in fragmented solutions that do not achieve the expected social or environmental benefits.

*Lock-ins*, in turn, can be understood as systems that generate user dependency, making it difficult for users to leave or migrate from such a system. For Geels (2002), *lock-ins*, which involve a network sociotechnical system are in a state of systemic rigidity, when infrastructures, regulations and habits reinforce each other, preventing innovations or sustainable alternatives (Geels, 2002). The author considers these systems as “traps” that hinder transitions to innovative models, due to high past investments, institutional norms and cultural practices. It is important to understand what “sociotechnical” means, since it involves verifying its objective, which consists of uncovering “the main requirements of any technological system and the possible influences of these on the performance of the social system, so that the effectiveness of the total productive system would depend on the adequacy of the social system in meeting the requirements of the technical system” (GARCIA, 1980, p. 72). The *lock-in barrier* indicates resistance to behavioral change and regulatory failures, which are based on the culture of a given population (Santos; Fukushima, 2017).

Regulatory failures are laws, decrees, contractual rules, etc. that prevent innovation or interfere in processes related to public bidding, for example (Kemp ; Loorbach ; Rotmans, 2007). They occur when a regulatory body fails to adequately perform its duties, whether in creating standards, in their application or in its own organization. Failures can manifest themselves when an organization violates established rules, resulting in significant legal penalties. Such regulatory deficiencies often arise from problems such as unclear standards, internal contradictions or disconnection from the real demands of the regulated sector and consumers (Medeiros, 2012).

To identify possible strategies for overcoming barriers, a review was carried out of the results of the RSL, from the aforementioned methodological study (Périgo ; Duarte; Barata, 2024), highlighting the barriers listed in this work and the proposed solution, presented theoretically or practically. Silveira and Santos (2020), for example, suggest the *Blueprint matrix*, a tool that “makes it possible to map the entire service cycle, including the different points of contact, customer actions and all company interactions for the service to occur, whether visible or invisible” (Silveira; Santos, 2020, p. 155). These authors state that the *Blueprint matrix* has the ability to systematize creative processes, which, in turn, are capable of solving complex problems, in addition to mapping points of conflict and prioritizing solutions with communities, visualizing scenarios in a holistic way.

Co creation was addressed and employed in a project to intensify bicycle use in Berlin, Germany, by Alexandrakis (2021), as it is a method with collaborative processes that involves different *stakeholders* for the development of product-service systems. The objective is to obtain results that serve a collective, a community, by bringing together diverse knowledge and experiences, in order to generate relevant and innovative solutions, proposing cultural changes to users.

Inagaki *et al* (2022) presented a barrier related to the rules contained in service system rental contracts: one for furniture rental, and the other for bicycle rental. In both cases, the lack of rules in the contracts left users insecure, as they were unaware of the problems that such services could cause when using them. This problem was, to a certain extent, solved by inserting all the necessary demands for the rental of products, without losses for customers/users or for suppliers.

Despite the solutions that the article presented, it became clear that some tools and methods, such as strategies for overcoming barriers were not presented as this was not the scope of the previous research.

Therefore, through systematic reviews, approaches to the *lock-in barrier* and its possible solutions were sought in databases, as well as methods and tools to address the adversities in the implementation of PSS, related to regulatory failures. It is expected that this research will present practical solutions, aiming to anticipate risks, optimize resources and align expectations, in the initial phases of S-PSS.

## II. Objective

Demonstrate strategies for overcoming *lock -in barriers* and regulatory failures that occur at the beginning of S-PSS projects.

## III. Materials And Methods

With the aim of presenting overcoming strategies, both for the *lock -in barrier* and for the barrier related to regulatory failures, the *Systematic Literature Review (RSL)* was carried out and conducted by the CAPES and Scopus Journals databases, which compile academic works produced in several countries.

### Search Strategy

The search for the *lock -in barrier* was performed using the following descriptors in English: a) *design AND sustainable AND service-product AND system AND lock -in*; and b ) *sustainable AND service-product AND system AND lock -in*. For the regulatory failure barrier, an unsystematic review was performed in the Google Scholar search engine in order to reproduce, in English, the correct version of the term, used in related research. Descriptors for the regulatory failure barrier: *design AND sustainable AND service-product AND system AND regulatory barriers*; and b) *sustainable AND service-product AND system AND regulatory barriers*. In both searches, in a second search of the databases, the descriptor “design” was removed, in an attempt to increase the number of related articles.

The search was carried out on November 23, 2024, with the aim of identifying relevant articles, limited to the period from 2015 to 2025. All records found were initially filtered to eliminate duplicates and ensure the relevance of the articles, by reading abstracts and the articles themselves.

### Exclusion criteria

Duplicate articles, those without open access and those that were not peer reviewed were excluded. There was no language restriction.

### Data organization table

Table 1, adapted from Périgo , Duarte and Barata (2024), identifies the articles resulting from the searches, presenting: authors, date of publication, country of origin, title and category of analysis.

## IV. Results

The searches carried out in both the CAPES Journals database and *Scopus* resulted in a reduced number of articles: for the *lock -in barrier*, 2 articles were found with the descriptors: *design AND sustainable AND service-product AND system AND lock -in* ; and only 1 without the descriptor “design”. Three articles were found for the regulatory failures barrier, two of which with the descriptors *design AND sustainable AND service-product AND system AND regulatory barriers* , and 1, by omitting “design”.

**Table 1:** Articles resulting from searches in CAPES Periodicals databases and Scopus, Source adapted from Perigo, Duarte and Barata (2024).

Authors	Publication date	Country	Title	Barrier Type
HANNON; FOXON; GALE	2015	United Kingdom	<i>'Demand pull' government policies to support Product-Service System activity: the case of Energy Service Companies ( ESCos ) in the UK</i>	Regulatory Failures Barrier
PETRULAITYTE; CESCHIN; P.E.I.; HARRISON	2017	United Kingdom	<i>Supporting Sustainable Product-Service System Implementation through Distributed Manufacturing</i>	Lock -in barrier
SOPJANI; AREKRANS;	2020	Switzerland	<i>Unlocking the Linear Lock-in: mapping research on barriers</i>	Lock -in barrier

LAURENTI; RITZÉN		d	transition	
PETROLAITYTE; CESCHIN; P.E.I.; HARRISON	2020	United Kingdom	<i>Applying Distributed Manufacturing to Product- Service System Design: A Set of Near-Future Scenarios and a Design Tool</i>	Regulatory Failures Barrier
KUSUMANINGDYAH; TEZUKA; MCLELLAN	2021	Indonesia/ Japan	<i>Investigating Preconditions for Sustainable Renewable Energy Product-Service Systems in Retail Electricity Markets</i>	Lock -in barrier
AZCARATE-AGUERRE; CONCI; ZILS; HOPKINSON; KLEIN	2022	United Kingdom	<i>Building energy retrofit-as-a- service: a Total Value of Ownership assessment methodology to support whole life-cycle building circularity and decarbonisation</i>	Regulatory Failures Barrier

Although the descriptor “design” was removed, with the aim of increasing the scope to obtain a greater number of articles, in a second search, both databases presented some works in addition to those found, but without relevance to the research.

It is important to highlight that, on numerous occasions, the acronym that appears in the articles found is “PSS”, as it is not common sense among researchers to use the acronym “S-PSS”, even when sustainability is the central theme of their research.

After reading the six articles in full, the barriers and their contexts were identified, as well as the proposed solutions outlined by the authors.

### Lock -in barrier

The article by Kusumaningdyah , Tezuka and McLellan (2021), in which they present a hypothetical study using computational simulation, whose scope was electricity markets, with a high incidence of renewable energy, used models based on heterogeneous agents, to simulate interactions between consumers, providers and regulators.

Through modeling, it was possible to identify the *lock -in barrier* due to the population's dependence on conventional energy systems, based on fossil fuels, and opt for low initial costs but inefficient equipment. The result that the study pointed out, in relation to the market, was that, due to reduction in prices due to renewable energy (solar/wind), it did not encourage new investments.

The contribution to strategies for overcoming barriers, before applying the EPSS ( *Energy Product-Service System* ) model, is to anticipate them, identifying the critical preconditions to make it viable. When simulating hypothetical markets, mathematical formulas were applied to calculate consumer satisfaction, as well as using flowcharts of agents' behavior regarding the consumption of energy services and the reduction of expenses with related equipment. The result was the development of a *framework* for renewable energy markets.

Petrulaityte *et al* (2020), through a theoretical review and data collected from experts, proposed hypothetical scenarios based on combinations of PSS barriers and *Distributed Manufacturing* (DM) solutions, which are defined as presenting decentralized production or distributed manufacturing. DM promotes inventory reduction, extends product lifespan, facilitates repairs, is concerned with waste and uses local and custom-made raw materials ( Srai *et al* , 2016).

The barriers identified by the authors were: i) lack of service-oriented culture in companies; ii ) difficulty in collaborating with partners in the value chain; iii ) resistance to sharing products due to social *status* ; iv ) lack of knowledge about what a PSS is; v) lack of government incentives for sustainable PSS; vi) slow approval of innovations.

The recommended solutions were proposed under the concepts of DM, which, in addition to proposing the decentralization of production, the authors recommend systematizing barriers, already known in literature, producing a theoretical *framework* to overcome *lock-in*. It is worth remembering that this article also presents scenarios of barriers and hypothetical solutions, without practical validation. The authors admit that DM faces obstacles such as high technology costs, regulatory issues and risks to intellectual property and suggests that future collaborations with companies occur to test the proposed scenarios.

The third article when performing the RSL, presents 527 articles on barriers, related to the Circular Economy, the Sharing Economy, Collaborative Consumption and PSS. The objective was to classify research and

create a database for future reviews. The study stated that the barriers are interconnected and interdependent. Sopjani *et al* (2020) classified barriers under the following categories:

- Cultural: related to resistance to non-proprietary models, valuing possession as status;
- Market: related to the lack of viable business models, generating financial uncertainty;
- Regulatory: related to the lack of incentive policies, conflicts with existing legislation;
- Technological: design limitation for recycling and lack of location for re-manufacturing ; and
- Organizational: difficulty in collaborating in the value chain in face of rigid corporate structures.

Although the article does not propose direct solutions, Sopjani *et al* (2020) systematized the fragmented knowledge about barriers; they exposed the gaps, such as few studies on the topic in developing countries, as well as defending methodological rigor in publications.

### Regulatory Failures Barrier

Petrulaityte *et al* (2020) conducted an applied empirical study, collecting data through literature review and *workshops* with students, experts, companies and design agencies. The authors used the Design *Research methodology* to develop and test a practical tool that supports idea generation, developed to integrate the principles of DM (*Distributed Manufacturing*): the PSS+DM Design *Tool* . Its interactive development involved testing with 146 participants, validating its usability and effectiveness.

In their studies, the authors identified regulatory barriers and other failures, considered as obstacles to the implementation of PSS, which are addressed below: i) unfavorable taxation for PSS models; ii ) lack of knowledge and support from financial institutions for PSS; iii ) low cost of natural resources, encouraging the consumption of virgin raw materials instead of recycling; iv ) high labor costs, which discourages service-intensive PSS; v) lack of external infrastructure for end-of-life management of products (e.g., collection, recycling); vi) unspecified environmental externalities (social/environmental costs not included in the market price). Failures v and vi are classified in the study as regulatory failures.

The suggested solutions to mitigate the aforementioned barriers are based on DM, whose scope is: i) the decentralization of manufacturing; ii ) digital technologies such as IoT , AM, *blockchain* , aiming at transparency and efficiency; and iii ) new business models, such as digital services and shared economy.

The tool operates as a practical *framework* for integrating sustainable solutions into all phases of a PSS lifecycle. Its goal is to overcome the barriers to implementing product-service systems by supporting companies and designers to explore DM opportunities at each phase of the PSS, generating ideas that address practical barriers such as cultural resistance, costs, regulations, etc.

Azcarate-Aguerre 's article *et al* (2022) is not a case study. However, the researchers used statistical data representative of the Dutch real estate sector, with the aim of ensuring that the results found are applicable to the average in northwestern Europe. The authors are concerned about the barriers that prevent the “ decarbonization ” of European real estate stock, specifically in commercial buildings. However, the proposal to decarbonize does not focus on a specific type of energy, but on changing, above all, the business model through integrated energy services.

The proposal is for Energy Service Companies ( ESCoS ) to take responsibility for energy efficiency and the transition to low carbon in buildings, operating under two models: a) energy supply contracts, which supply buildings with hot water and steam from renewable sources; and b) energy performance contracts that guarantee final services, such as lighting and air conditioning, using clean energy, as well as thermal insulation and building automation. The authors make it clear that the differential of their proposal is not specifically the energy source, but the business model or the creation of an energy services market. ESCoS would invest in clean technologies and assume operational risks, while customers would pay for energy services, not equipment.

The barriers identified for the transition to low carbon would be: i) high initial costs, due to investments in deep *retrofit* being extremely high, as it is not limited to changes, but rather a complete revitalization of buildings; ii ) conflicts of incentives between owners and tenants, since the owner bears the costs, but the tenants benefit from energy savings; iii ) insufficient valuation, as the real estate market does not adequately price gains in energy efficiency or circularity; iv ) shortage of qualified professionals in carbon neutral projects; v) regulatory uncertainties, as there are no robust policies for carbon taxation and material recovery; vi) *rebound risk effect* or energy savings being canceled out due to increased consumption, after the implementation of deep *retrofit* .

The solutions proposed by Azcarate-Aguerre *et al* (2022) are presented in Table 2.

**Table 2:** Solutions recommended by Azcarate-Aguerre *et al* (2022).

Solution	Definition
PSS (Product-Service) Model	Outsourcing of investment and technical management to specialized providers;
TVO+ Methodology	Financial assessment that internalizes carbon costs, productivity

	and residual value of materials;
Aligned incentives	Long-term contracts linked to energy performance and comfort;
Retention of property	Manufacturers retain ownership of materials, encouraging reuse/recycling (Circular Economy);
Public policies	Progressive carbon taxation + subsidies for professional training.

**Source:** prepared by the authors.

The authors demonstrate that PSS can be a regulatory insurance, since it reduces exposure to future risks, such as higher carbon or energy taxes ( Azcarate-Aguerre *et al* 2022).

The aim of the research by Hannon , Foxon and Gale (2015) is to seek patterns for public policies, based on real evidence from the British energy sector. The authors conducted 43 interviews with experts in this sector, recording the positive and negative points raised by them. This is an empirical sectoral research that uses qualitative methods to generate *insights* on public policies, without focusing on a specific case. The central problem concerns the role of government policies of "demand attraction" ( *demand pull* ) to drive sustainable service-based business models (SSPs), with a focus on Energy Service Companies ( ESCoS ).

The interviews also addressed experiences related to PSS, maintaining the theoretical character but anchored in evidence from the British energy sector. The results of this approach were the barriers mentioned in relation with the implementation of PSS in this sector, as well as the proposed solutions, presented in Table 3.

**Table 3 :** Regulatory Failures, Problem and Solution ( Hannon ; Foxon : Gale, 2015).

Regulatory Failure (Barrier)	Problem	Solution
Unfavorable market structures	Electricity trading arrangements favor large centralized generators and penalize small ESCos with intermittent sources ( e.g. renewables). Grid connection costs and market participation fees are prohibitive for small-scale operations;	<ul style="list-style-type: none"> <li>- Redesign market structures to accommodate decentralized generation, with differentiated rules for small participants;</li> <li>- Relax licensing limits for local generation/distribution;</li> <li>- Subsidize connection costs for community projects;</li> </ul>
Bureaucratic Regulations for Public Procurement	Public procurement procedures are complex, slow (12-18 months) and expensive, which does not encourage energy service contracts;	Adopt simplified models such as those already in place in London: <ul style="list-style-type: none"> <li>- Pre-negotiated contracts in compliance with the EU;</li> <li>- Reduction of the process to 3-6 months;</li> <li>- Create standardized contract templates for ESCos;</li> </ul>
Inconsistency in energy efficiency policies	Efficiency obligations fall only on suppliers (residential sector), ignoring commercial consumers; <ul style="list-style-type: none"> <li>- The appropriate scheme for large consumers creates "split incentives" between owners and tenants</li> </ul>	Implement complementary obligations for suppliers and consumers: <ul style="list-style-type: none"> <li>- Example: Combine efficiency obligations (suppliers) with efficiency targets for consumers;</li> </ul>
Weakness in support for local authorities ( LAs )	LAs play a central role in local projects ( e.g. planning, licensing), but lack: <ul style="list-style-type: none"> <li>- Powers to require connection to low-carbon grids;</li> <li>- Mandatory emissions reduction targets;</li> </ul>	<ul style="list-style-type: none"> <li>- Adopt the "Danish Heat Act" model:</li> <li>- Give LAs the power to mandate connection to sustainable grids;</li> <li>- Set mandatory emissions targets for cities;</li> <li>- Expand powers through community planning;</li> </ul>
Lack of Standardization of Contracts	Energy service contracts are excessively personalized, increasing transaction costs and wearing out customers;	<ul style="list-style-type: none"> <li>- Develop standard contractual models ( templates );</li> <li>- Adopt verification protocols to ensure quality;</li> <li>- Create certification schemes for ESCoS ;</li> </ul>
Regulatory Instability	Frequent changes in policies create uncertainty for investors.	<ul style="list-style-type: none"> <li>- Establish long-term political roadmaps with government commitment;</li> <li>- Avoid sudden changes and maintain rationality in changes.</li> </ul>

**Source :** prepared by the authors (2025).

In conclusion, the authors state that for the successful implementation of a PSS in the energy sector, political stability is vital to attract investors.

## V. Conclusion

Given the above, it is clear that *lock-in barriers*, regulatory failures and wicked problems are critical for the implementation of S-PSS, especially in scenarios that require prioritizing sustainability. It is also worth highlighting the interdependencies of these barriers and how they act negatively, right at the beginning of S-PSS implementations.

Some overcoming strategies for *lock-in barriers* were presented, such as use of *frameworks* for anticipating critical preconditions, related to market simulations, by Kusumaningdyah *et al* (2021). Another proposal to overcome this barrier was the integration of *Distributed Manufacturing* (DM) to decentralize production, reduce systemic dependence and promote the Circular Economy (Petrulaityte *et al*, 2020).

The regulatory failures addressed in Azcarate-Aguerre's article on carbon reduction in the UK housing stock *et al* (2022) can be solved through PSS models, such as ESCoS, which internalizes carbon costs and risks when offering energy services. Standardization of contracts, simplification of bidding processes and long-term policies are recommendations by Hannon, Foxon and Gale (2015), also for the British energy sector, which emphasizes that political stability is essential to attract investors who believe in S-PSS as a sustainable solution to complex problems.

The contributions of this study is the understanding that the initial phase of projects is crucial to mitigate barriers. To this end, the *Blueprint matrix*, intended for holistic mapping, the PSS+DM Design Tool, for the integration of sustainable solutions, and the TVO+ methodology, for financial assessment with internalization of environmental costs can be considered, with the aim of implementing successful S-PSS.

The limitations of this study are the scarcity of articles found (only six), as well as the few studies on the subject in developing countries, as mentioned by Sopjani *et al* (2020), and the presentation of still theoretical solutions or hypothetical scenarios, which requires empirical validation.

Therefore, recommendations for future research could aim to: i) test the proposed *frameworks* (DM, TVO+) in real cases of S-PSS for populations vulnerable to climate change; ii) investigate the role of digital technologies (IoT, *blockchain*) in overcoming barriers; and iii) explore specific public policies for regions affected by climate disasters.

Therefore, the potential of S-PSS to promote sustainability and resilience should be reiterated, but understanding that it is subject to addressing systemic barriers. To this end, it is necessary to emphasize the need for interdisciplinary approaches, co-creation with *stakeholders* and alignment between innovation, regulation, and local culture

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