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Integrating Product-Service Systems and Energy Efficiency: A Systematic Literature Review of Business Model Innovation and Circular Economy Strategies

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ABSTRACT: This review argues that Product-Service Systems (PSS) offer a strategic business model for achieving energy efficiency by integrating circular economy principles and leveraging Industry 4.0 technologies. Through a systematic assessment of 591 peer-reviewed articles, the study finds that result-oriented PSS models, such as Energy-as-a-Service (EaaS) and Cooling-as-a-Service (CaaS), outperform product-centric approaches across environmental and economic outcomes. Effective implementation demands robust digital infrastructure, risk-sharing, and cultural change. The synthesis connects PSS typologies, circular economy frameworks, and technological advancements, while highlighting persistent challenges, including the service paradox, rebound effects, and consumer acceptance. This integrated framework provides actionable insights for stakeholders seeking sustainable energy consumption transitions.

KEYWORDS: Product-service systems; Energy efficiency; Business model innovation; Circular economy; Servitization; Industry 4.0; Sustainable consumption; Energy-as-a-Service

I. INTRODUCTION

Energy efficiency is now a strategic priority for industry due to climate change. Despite advances, barriers like high capital costs, split incentives, information gaps, and resistance to change persist. Traditional ownership models fail to adequately align provider and user interests for sustained efficiency. Product-Service Systems shift business from selling physical products to delivering functional outcomes. In energy efficiency, they include EPC, EaaS, and performance-guaranteed leasing. PSS providers retain asset ownership, incentivising energy optimisation and continuous improvement. PSS draws on converging frameworks: Resource-Based View, socio-technical transitions, and circular economy principles, which promote closed-loop material flows and regenerative design. Research is fragmented across operations, environmental science, strategy, and engineering. This review addresses three gaps: a rare comprehensive synthesis of PSS and energy efficiency; the need to analyse the integration of Industry 4.0 technologies into PSS models; and the need for a critical examination of the causes of varied PSS success. Six research questions guide the review.

RQ1: What are the key attributes and typologies of PSS business models that enable effective energy efficiency improvements?
RQ2: How do value propositions in PSS models align provider incentives with customer expectations and sustainability objectives?
RQ3: To what extent do PSS business models integrate circular economy principles and contribute to environmental sustainability?
RQ4: What role do Industry 4.0 technologies play in enabling PSS performance monitoring, risk allocation, and value delivery?
RQ5: What are the critical success factors and persistent barriers to PSS adoption in energy efficiency contexts from practitioner perspectives?
RQ6: How do organizational maturity and cultural transformation influence the transition from product-dominant to service-dominant business models?

II. THEORETICAL FRAMEWORK

2.1 Defining Product-Service Systems

Goedkoop et al., (1999) defined PSS as a mix of products and services that meet user needs. The idea combines physical products and services to deliver value while reducing environmental harm. This includes three basic parts: products as things to sell, services as actions that add value, and systems as groups of related parts (Mont, 2002; Annarelli, Battistella, and Nonino 2019; Pacheco et al. 2016; Reim et al. 2017). PSS developed alongside concepts such as servitization, functional economy, service thinking, and Industrial Product-Service Systems. The main idea is always the same: move from selling ownership to giving useful results. This changes the link between producer and consumer by changing one-time sales into ongoing relationships. Tukker (2004) grouped PSS into three types: product-oriented, use-oriented, and result-oriented models:

1. **Product-oriented PSS:** The provider sells products along with services, such as maintenance, payment plans, or take-back programs for old products. The customer owns the product but receives ongoing support from the provider.

2. **Use-oriented PSS:** The provider keeps ownership and offers products for lease, rent, sharing, or pooling. Customers pay to use the product rather than own it. This supports efficient use and longer product life.
3. **Result-oriented PSS: Here, the provider sells a service or result, not the product. Payment is based on the performance given, such as lighting, cooling, or energy saved. This approach encourages providers to focus on customer value and more efficient resource use, rather than on results or** ownership.

2.2 PSS and the Circular Economy

The circular economy helps us see how PSS can do more than save energy. Circular economy ideas focus on keeping materials useful for as long as possible—by reuse, repair, remanufacturing, and recycling. PSS models support this by having providers retain ownership and responsibility throughout the entire product life cycle. This lets providers create value through repairs and recovery, leading to more durable, upgradable products. This approach is different from planned obsolescence in traditional models. Also, using recycled materials reduces the energy required to produce new materials. When PSS and the circular economy come together, they create sustainable systems that cut environmental harm and deliver real value. This approach shifts companies from waste management to designing systems that protect resources, making businesses resource stewards rather than just sellers.

2.3 Servitization and Business Model Innovation

Servitization describes the organisational transformation through which manufacturers add services to their core product offerings, ultimately evolving toward service-dominant business models (Vandermerwe and Rada, 1988). This transition represents more than incremental service additions; it requires a fundamental reconfiguration of value-creation and capture mechanisms, organisational structures, competencies, and cultural mindsets (Haber et al. 2018; Oliva and Kallenberg 2003; Reim 2018). Sajadieh and Noh, (2025) identified the downstream profit imperative, arguing that manufacturers should migrate from commodity product sales toward higher-margin product-related services. Empirical research supports this proposition, demonstrating that service-intensive firms often achieve more stable revenue streams, deeper customer relationships, and enhanced competitive differentiation (Ang et al. 2010; Baines et al. 2007, 2009). However, the transition proves challenging, with many firms encountering the service paradox, in which investments in service capabilities fail to generate expected returns due to organisational complexity, cultural resistance, and misaligned performance metrics (Gebauer et al., 2005).

The Business Model Canvas (Bland and Osterwalder 2019; Osterwalder et al. 2014; Osterwalder and Pigneur 2009, 2010) provides a strategic tool for analysing PSS value architectures. PSS business models typically feature distinctive characteristics: value propositions emphasising outcomes over ownership, revenue streams shifting from one-time sales to recurring payments, key resources expanding to include service delivery capabilities, and customer relationships deepening through ongoing interaction. This reconfiguration fundamentally alters how firms create, deliver, and capture value in energy efficiency markets.

III. METHODOLOGY

3.1 Research Design

This study employs a systematic literature review (SLR) methodology following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol (Moher et al., 2009). The SLR approach ensures transparency, replicability, and comprehensiveness in identifying, evaluating, and synthesising existing research. This methodology is particularly appropriate for mapping the fragmented PSS literature across multiple disciplines and identifying research gaps requiring further investigation.

3.2 Search Strategy and Data Sources

A comprehensive literature search was conducted across three major academic databases: Scopus, Web of Science, and Google Scholar. These databases were selected for their extensive coverage of peer-reviewed literature across engineering, business, and environmental sciences. The search strategy utilised Boolean operators to combine key terms: (Product-Service System OR PSS Servitization OR Product-service) AND Energy Efficiency OR Energy Management OR Energy Performance AND Business Model OR Business Strategy. The search was conducted using the Publish or Perish software (Version 7) for initial screening and citation analysis. The following search parameters were applied: 1,000 top-ranked articles from Google Scholar based on citation count and journal reputation, 200 articles from Scopus prioritising peer-reviewed journals, and 200 articles from CrossRef focusing on recent publications (2016-2025). The search was executed on October 27, 2025, with updates conducted through January 2026 to capture emerging trends.

3.3 Inclusion and Exclusion Criteria

The process of choosing what to review was very strict to ensure that the reviews were high-quality and useful. The sources used were peer-reviewed journal articles, conference proceedings, and authoritative technical reports that met certain quality standards. The publications had to clearly discuss PSS, servitization, or related concepts in the context of energy efficiency, and they had to be directly related to the research focus. Moreover, only empirical studies, theoretical frameworks, or exhaustive reviews were deemed acceptable, provided they were published in English and featured transparent methodology and verifiable results. On the other hand, to maintain the review's integrity, several types of sources were systematically excluded. We excluded non-peer-reviewed sources, such as blogs, opinion pieces, and trade publications, because they lack rigorous review processes, and we were concerned about their quality. Investigations excluded studies lacking explicit links to energy efficiency or PSS concepts. Additionally, duplicate publications and prior iterations of subsequently published works were eliminated to prevent redundancy. Finally, studies that lacked sufficient methodological transparency or made unsupported claims were excluded to ensure the findings in this review were reliable.

3.4 Screening and Selection Process

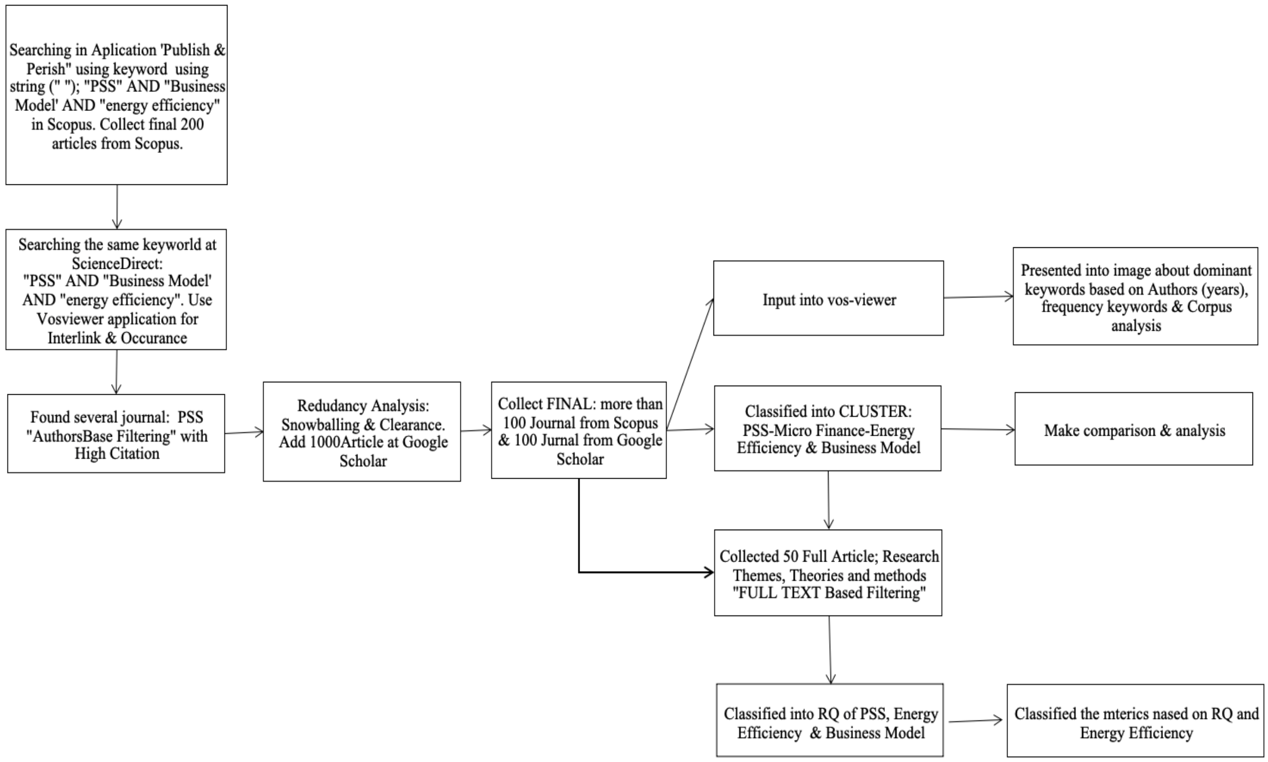

Figure 1. PRIMS Method

The selection process followed a three-stage approach (Figure 1). Stage 1 involved automated screening based on keyword matching, citation thresholds, and publication venue quality indicators, yielding 1,400 potentially relevant articles. Stage 2 required manual review of titles and abstracts by two independent reviewers, with discrepancies resolved through discussion, resulting in a reduced pool of 591 articles. Stage 3 involved full-text review of these 591 articles against inclusion/exclusion criteria, ultimately selecting 150 articles for detailed analysis. The snowballing technique was applied to identify additional seminal works cited frequently within the selected literature, adding 20 foundational articles to ensure comprehensive coverage of theoretical developments.

3.5 Data Extraction and Analysis

A structured data extraction protocol captured: (1) Bibliometric information (authors, publication year, journal, citation count); (2) Research methodology (quantitative, qualitative, mixed methods, conceptual); (3) PSS typology examined (product-oriented, use-oriented, result-oriented); (4) Industry sector and geographic context; (5) Key findings regarding energy efficiency impacts, business model attributes, success factors, and barriers; (6) Theoretical frameworks employed. Analysis proceeded through thematic synthesis and co-occurrence network analysis. VOSviewer software was employed to map co-authorship networks, keyword co-occurrence patterns, and citation relationships. This bibliometric analysis identified research clusters, evolving themes, and influential scholars. Thematic coding of full-text articles employed an iterative process combining deductive coding based on research questions and inductive coding, allowing emergent themes to surface from the data.

IV. RESULTS

4.1 Bibliometric Overview

The systematic search identified 591 relevant publications spanning from 2002 to 2025, with publication frequency accelerating dramatically after 2015. This growth coincides with increasing policy attention to circular economy frameworks and the maturation of Industry 4.0 technologies. The *Journal of Cleaner Production* emerged as the dominant publication venue, accounting for 38% of the highly cited articles, followed by *Business Strategy and the Environment*, *International Journal of Production Economics*, and *Sustainability*. Citation analysis reveals three foundational scholars dominating the field. **Mont, (2002)** with 2,085 citations for clarifying PSS concepts, Baines et al., (2007) with 1,991 citations for a state-of-the-art PSS review, and Tukker (2004) with 1,869 citations for establishing PSS typology (Figure 1). These seminal works continue to anchor contemporary research, though recent publications increasingly integrate circular-economy and digital-technology perspectives. Co-authorship network analysis identified nine distinct research clusters, with Chinese scholars dominating recent publications (2017-2025), particularly in industrial applications of PSS within manufacturing sectors. European researchers maintain a strong presence in policy-oriented and sustainability-focused studies, while North American scholarship emphasises business model innovation and organisational transformation aspects (Figure 2).

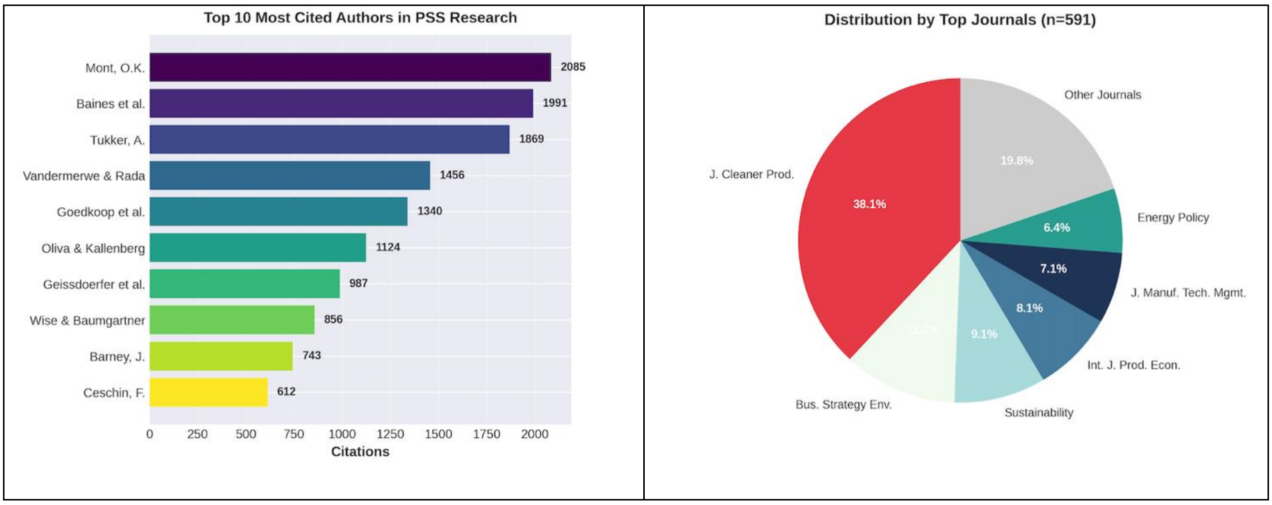

Figure 1. Most Cited Authors & Distribution By Top Journals

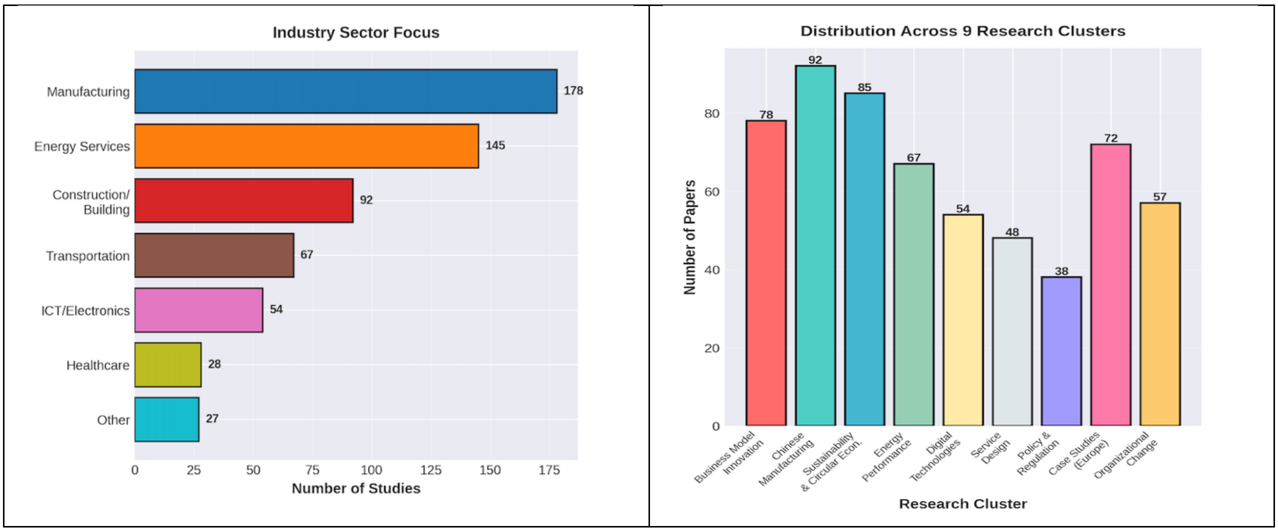

Figure 2. Industrial Sector & Distribution Research Cluster

4.2 PSS Typologies in Energy Efficiency Contexts (RQ1)

Analysis of empirical studies reveals that result-oriented PSS models demonstrate superior energy efficiency outcomes compared to product-oriented or use-oriented alternatives (Figure 3). Energy-as-a-Service (EaaS) arrangements, where providers guarantee specific energy performance outcomes while retaining ownership of efficiency equipment, create the strongest alignment between provider profitability and customer energy savings (Rosa, Sassanelli, and Terzi, 2019; Sassanelli et al., 2016). Cooling-as-a-Service (CaaS) exemplifies the potential of result-oriented PSS. Basel Agency for Sustainable Energy (2020) analysis demonstrates that CaaS implementations achieve 40-49% reductions in cooling energy consumption compared to conventional ownership models through deployment of high-efficiency equipment, optimised maintenance schedules, and continuous performance monitoring. The provider's retention of operational cost responsibility creates direct financial incentives for efficiency maximisation, absent in traditional sales models. Energy Performance Contracting (EPC) is another mature, results-oriented model, particularly prevalent in public-sector buildings and industrial facilities. EPC arrangements typically guarantee specific energy savings percentages, with provider compensation tied to verified savings achievement. The International Performance Measurement and Verification Protocol (IPMVP) has emerged as the dominant framework for savings verification, reducing transaction costs and enabling standardised risk allocation (Alozie, 2025).

4.3 Value Proposition Alignment (RQ2)

Successful PSS implementations demonstrate clear alignment of the value proposition across multiple stakeholder groups. For customers, PSS models eliminate high upfront capital expenditures by converting them to operational expenses, reducing adoption barriers for efficiency upgrades. Performance guarantees transfer technical and operational risks from customers to specialised providers with superior technical capabilities and economies of scale in service delivery Baines et al., 2007). For providers, PSS creates recurring revenue streams less volatile than one-time product sales, improving financial predictability and enabling long-term strategic planning. Ongoing customer relationships facilitate data collection on usage patterns and performance, informing continuous improvement and product development (Annarelli et al., 2019). However, providers face significantly higher capital requirements to build and maintain owned equipment fleets, extending payback periods and increasing financial risk exposure. From societal and environmental perspectives, PSS value propositions include reduced resource consumption through extended product lifespans, optimised utilisation of existing capacity through sharing models, and decreased environmental impacts from improved operational efficiency. The circular economy dimension adds value through closed-loop material flows, reducing virgin resource extraction and waste generation (Geissdoerfer et al., 2017).

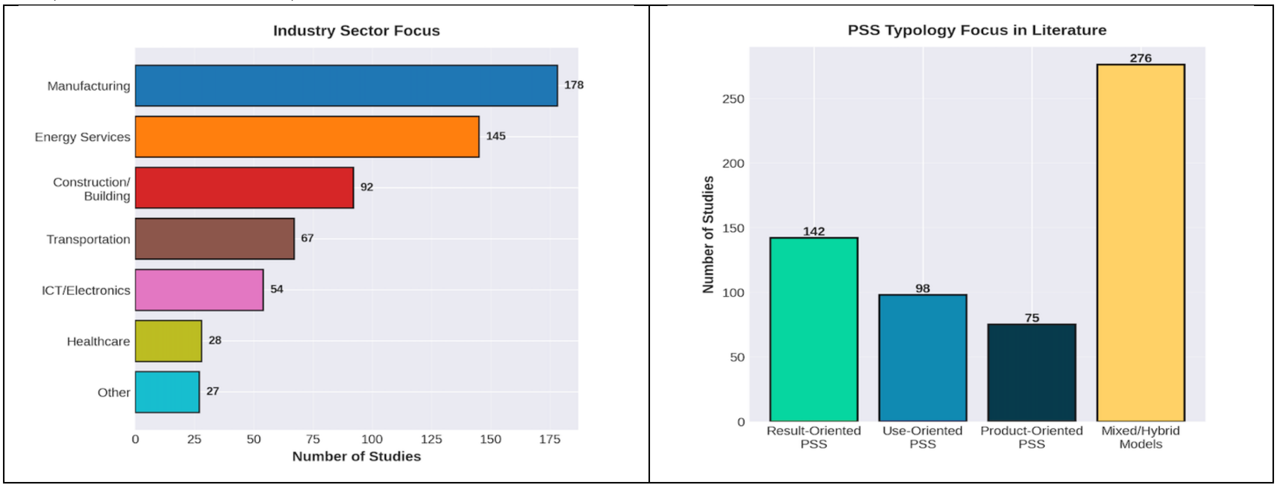

Figure 3. Industry Sector & PSS Typology Focus

4.4 Integration with Circular Economy Principles (RQ3)

The synthesis reveals strong theoretical and practical synergies between PSS and circular economy frameworks (Figure 4). Result-oriented PSS inherently supports the circular economy through provider ownership, incentivising design for durability, modularity, and upgradeability (Pialot, 2017). When providers capture residual value through refurbishment, component harvesting, and material recovery, product lifespans extend significantly beyond typical ownership model scenarios. Empirical evidence from lighting PSS implementations demonstrates these principles in practice. LED lighting-as-a-service providers design modular fixtures where driver electronics, LED arrays, and optical components can be independently replaced or upgraded without discarding entire fixtures. This approach reduces embodied energy consumption from manufacturing while ensuring customers benefit from technological improvements without equipment replacement (Vezzoli et al. 2015).

However, not all PSS models inherently support circularity. Product-oriented PSS, by adding services to traditional sales, may increase environmental burdens through additional transportation for service delivery and potential rebound effects, where cost savings from efficiency enable increased overall consumption (Moro, 2020). The literature emphasises that environmental benefits depend critically on specific PSS design choices rather than PSS adoption per se.

4.5 Role of Industry 4.0 Technologies (RQ4)

Industry 4.0 technologies have emerged as critical enablers of advanced PSS implementations, particularly for result-oriented models requiring precise performance monitoring and verification (Figure 4). IoT sensor networks enable real-time monitoring of equipment operation, environmental conditions, and energy consumption at granular levels previously uneconomical to achieve. This data infrastructure supports predictive maintenance algorithms that identify potential failures before they occur, minimising unplanned downtime and maintaining performance guarantees (Sassanelli et al., 2022). Artificial intelligence and machine learning algorithms optimise energy consumption through automated demand-side management, load shifting to capitalise on time-of-use pricing, and adaptive control responding to occupancy patterns and weather conditions. These capabilities enable performance levels exceeding those of static-efficiency equipment alone, creating additional value for customers while reducing provider operational costs (Basel Agency for Sustainable Energy, 2020). Digital twins are an emerging application that creates virtual replicas of physical systems for simulation, optimisation, and predictive modelling. Energy efficiency PSS providers employ digital twins to test operational strategies without disrupting physical systems, optimise maintenance schedules based on actual wear patterns, and demonstrate projected savings to customers before implementation (Sajadieh and Noh 2025).

However, technological integration introduces challenges, including cybersecurity vulnerabilities, data privacy concerns, interoperability barriers across proprietary platforms, and potentially prohibitive implementation costs for smaller organisations. The literature emphasises that technology serves as an enabler rather than a solution in itself, requiring integration with appropriate business models and organisational capabilities.

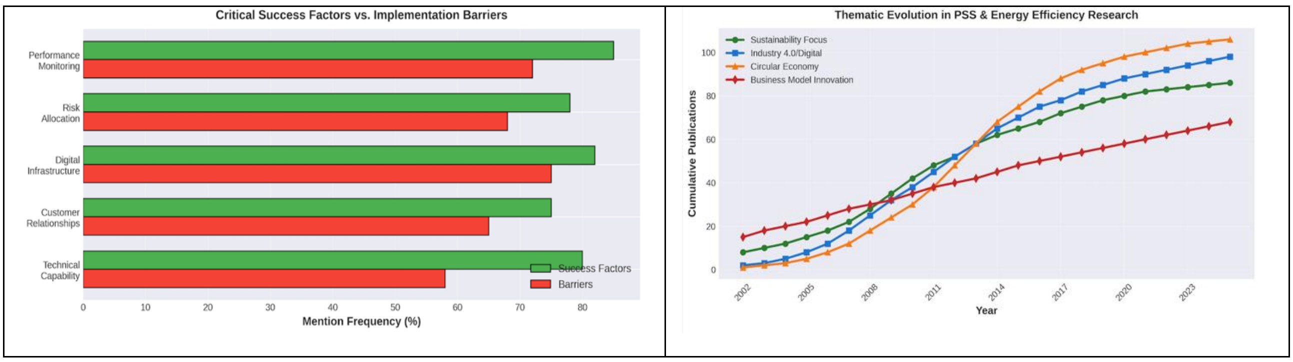

Figure 4. Critical Success Factors & Thematic Evolution

4.6 Critical Success Factors and Barriers (RQ5)

Real-world case studies show that several important factors can help PSS work (Figure 3). Clear rules for measuring and verifying performance build trust between parties and reduce arguments over how much money was saved. Standardised contract templates make transactions cheaper and less risky from a legal perspective. This is especially important when using PSS models with multiple customers. Providers can guarantee performance levels because they have strong technical skills in choosing, installing, and optimising equipment. Also, deep customer relationship management helps businesses adapt to changing needs and find new ways to create value (Oliva and Kallenberg, 2003)

Though these benefits have been documented, there are still problems with getting people to use PSS for energy efficiency. The service paradox refers to circumstances in which substantial investments by providers in service transformation do not yield anticipated returns, attributable to organisational complexity, misaligned incentive structures, and insufficient service delivery capabilities (Fischer et al., 2009; Gebauer, Fleisch, and Friedli, 2005). Cultural resistance in both provider and customer organisations makes it harder to adopt new technologies, especially when ownership is tied to status or control. Also, split-incentive problems still exist in some building sectors, where owners invest in making things more efficient but tenants reap the savings in operating costs. PSS theoretically solves this by using third-party financing, but in practice, it encounters regulatory hurdles and complex stakeholder negotiations. Finally, consumers are hesitant to adopt ownership-free consumption because they are worried about data privacy and feel like they are losing control. This means that companies need to be careful about how they communicate value and build trust (Vezzoli et al., 2015).

4.7 Organizational Maturity and Cultural Transformation (RQ6)

The transition from product-centric to service-dominant business models requires fundamental organisational transformation beyond simple service additions. (Federico Adrodegari et al., 2017) propose a servitization maturity model describing progressive stages: initial experimentation with basic services, systematic integration of product-service offerings, advanced service platforms with digital capabilities, and full service-dominant strategies where products serve as service enablers. Successful transitions require developing new organisational capabilities, including service design expertise, real-time operations management, customer relationship management, data analytics, and risk management. Performance measurement systems must shift from product volume metrics to service quality, customer satisfaction, and long-term value creation indicators. Compensation and incentive structures require realignment to reward service excellence and customer retention rather than short-term sales volumes (Baines et al., 2009). Cultural transformation is particularly challenging, requiring leadership commitment to the service vision, cross-functional collaboration to break down product-service silos, and workforce development to build service-delivery competencies. Organisations progressing through maturity stages demonstrate increasing financial resilience, customer loyalty, and competitive differentiation, though the transformation typically takes 5-10 years to fully realise (F Adrodegari, 2017; Federico Adrodegari et al., 2018; Federico Adrodegari, Saccani, and Kowalkowski, 2016).

V. DISCUSSION

5.1 Synthesis of Key Findings

This systematic review reveals that PSS business models represent a viable pathway to accelerate energy efficiency adoption by fundamentally restructuring value-creation, delivery, and capture mechanisms. The evidence strongly supports the superiority of result-oriented PSS over product-oriented alternatives in energy-efficiency contexts, primarily through improved incentive alignment between providers and customers. When providers retain ownership and operational responsibility, their profitability becomes directly linked to energy performance, creating self-reinforcing improvement cycles absent in traditional ownership models. The integration of PSS with circular economy principles offers additional environmental benefits beyond operational energy savings. Extended product lifespans, modular design enabling component-level upgrading, and closed-loop material flows reduce embodied energy consumption and waste generation. However, these benefits materialise only when PSS implementations explicitly incorporate circular design principles rather than simply adding services to conventional products. Industry 4.0 technologies have transformed PSS feasibility by dramatically reducing monitoring costs, enabling predictive maintenance, and facilitating transparent performance verification. Digital infrastructure creates the automated trust necessary for result-based contracting by providing objective, real-time performance data accessible to all stakeholders. This technological foundation enables new business model innovations that were previously impractical due to verification costs.

5.2 Theoretical Contributions

This review contributes to theory by synthesising previously fragmented literature streams into an integrated framework that connects PSS typologies, circular economy principles, and Industry 4.0 enablers. The framework clarifies how different PSS archetypes create value through distinct mechanisms: product-oriented PSS through enhanced product longevity, use-oriented PSS through improved asset utilisation, and result-oriented PSS through incentive alignment for continuous optimisation. The analysis extends servitization theory by identifying specific organisational capabilities required for the success of energy-efficiency PSS. Beyond generic service capabilities, energy PSS requires specialised technical expertise in energy systems, sophisticated risk assessment and pricing methodologies, performance verification protocols, and adaptive operations management responding to dynamic usage patterns. These capability requirements explain why traditional product manufacturers often struggle with PSS transitions despite strong service intentions. The review also contributes to understanding the service paradox in energy efficiency contexts. While PSS theoretically offers superior value propositions, practical implementation encounters organisational inertia, cultural resistance, regulatory barriers, and market acceptance challenges. The maturity model perspective helps explain why PSS benefits often materialise only after extended transition periods requiring sustained leadership commitment and cultural transformation.

5.3 Practical Implications

Companies considering adopting PSS need to know that technology alone won't make them successful. To be successful, implementation needs to combine new business models and organisational changes with new technical skills. To lay the necessary foundations, you need to systematically improve across many areas, including service design, digital infrastructure, risk management frameworks, and customer relationship management systems. Instead of trying to make big changes right away that yield big results, businesses should take a maturity-based approach, starting with basic services and adding more as their skills grow. Policy changes are also very important for accelerating the adoption of PSS across markets, while ensuring organisations are ready. Standardised performance verification protocols make it easier to scale and lower transaction costs. When public sector organisations run demonstration projects, they demonstrate that the idea works and build potential adopters' confidence in the market. Also, regulatory frameworks are important for eliminating structural barriers, especially split-incentive problems that make people less likely to invest, and third-party financing arrangements that enable implementation in the building sector. Policies that favour performance-based contracting in procurement make the stable demand conditions that PSS providers need to build successful business models even better.

Researchers need to fill the gaps in our knowledge that are holding back PSS development, even though practitioners and policymakers are responsible for making it happen. Longitudinal studies that monitor implementation across the entire equipment lifecycle would uncover trends in long-term sustainability and financial performance that shorter studies overlook. Likewise, comparative analyses across diverse sectors and geographic contexts would elucidate the specific factors that affect PSS success under varying conditions. Most importantly, it's still very important to understand how people feel about accepting things, especially when it comes to concerns about data privacy and a sense of losing control. Investigating these obstacles would yield pragmatic approaches to surmounting adoption resistance and enhancing PSS markets.

5.4 Limitations and Future Research Directions

This review faces several limitations. The systematic search strategy may have missed relevant publications in non-English languages or specialised technical venues. The rapidly evolving nature of Industry 4.0 technologies means recent innovations may not yet be reflected in peer-reviewed literature. The predominance of European and Chinese case studies limits generalizability to other geographic and cultural contexts. Future research should address several critical gaps. First, more rigorous quantitative studies comparing energy-efficiency outcomes across PSS typologies would strengthen evidence for the superiority of result-oriented models. Second, investigating rebound effects in PSS contexts would clarify whether efficiency gains translate into net energy reductions or enable increased consumption. Third, research on optimal risk-allocation frameworks that balance provider and customer interests would facilitate more equitable contracting. Fourth, exploring PSS in emerging economy contexts where financing constraints and institutional frameworks differ significantly from those in developed markets would expand its applicability. Fifth, investigation of PSS contributions to broader sustainability goals beyond energy efficiency, including water conservation, waste reduction, and social equity, would provide a more comprehensive assessment of sustainability potential.

VI. CONCLUSION

Product-Service Systems represent a transformative business model innovation with significant potential to accelerate energy-efficiency adoption and advance circular-economy transitions. This systematic review synthesises a fragmented literature, revealing that result-oriented PSS models achieve superior environmental and economic performance by aligning provider incentives with customer value and sustainability objectives. The integration of circular economy principles through provider ownership creates additional benefits, including extended product lifespans, modular design, and closed-loop material flows. Industry 4.0 technologies have fundamentally enhanced PSS feasibility by enabling cost-effective performance monitoring, predictive maintenance, and transparent verification. Digital infrastructure lays the foundation for automated trust, reducing transaction costs and enabling scalable, results-based contracting. However, technology serves as an enabler rather than a complete solution, requiring integration with appropriate organisational capabilities, business models, and stakeholder alignment.

Successful PSS implementation requires sustained organisational transformation, transcending simple service additions. Organisations must develop specialised capabilities in service design, risk management, customer relationships, and adaptive operations while navigating cultural resistance, regulatory barriers, and market acceptance challenges. The servitization maturity model provides a roadmap for this transformation, though full realisation typically requires 5-10 years of sustained commitment. Looking forward, PSS business models will play an increasingly important role in achieving global climate mitigation goals and sustainable development objectives. Policy support through standardised frameworks, demonstration projects, and enabling regulations can accelerate adoption. Continued research addressing implementation challenges, quantifying long-term outcomes, and exploring diverse contextual applications will strengthen the evidence base for PSS as a viable pathway toward sustainable energy futures.

The convergence of sustainability imperatives, technological capabilities, and business model innovation creates unprecedented opportunities for PSS to reshape energy efficiency markets. Realising this potential requires coordinated action across researchers, practitioners, and policymakers, guided by an evidence-based understanding of critical success factors and persistent challenges. This review provides a foundation for such coordinated action, synthesising current knowledge while illuminating promising directions for future advancement.

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