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# Supporting circular economy through use-based business models: the washing machines case

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**Abstract**

The circular economy paradigm is being widely studied as a possible path to a sustainable development, decoupling economic growth from material consumption and environmental impacts. The introduction of new business models, based on use rather than ownership, has been identified as one of the possible enabling actions for the implementation of circular economy strategies. Thus, product-service systems (PSS) can represent a viable way for companies and customers to switch from a linear to a circular scheme, keeping together the advantages of a customer-oriented offer to those of dematerialization. In this work, an example of innovative, circular business model for the large appliances sector is proposed, based on a PSS and a closed-loop supply chain. A context study, supported by a deep literature analysis, is performed to identify the main changes involved in the transition from a traditional to a circular supply chain in the sector, as well as the main impacts on the actors involved, through causal loop diagrams. The study is a first step for the realization of a system dynamics model, for a further research on impact assessment.

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*Keywords:* Circular economy; PSS; closed-loop; impacts evaluation; supply chain.

## 1. Introduction

The increasing environmental burden related to economic growth has been pushing institutions and governments worldwide to seek for more sustainable economic models. In this context, increasing attention is being given from both academics and businesses to the circular economy (CE) paradigm, which has been defined as a way to decouple economic growth and environmental burden [1]. Unlike linear systems, CE models are based on resource conservation and material flows valorisation through reuse, recovery and recycling, but the path towards the implementation of a CE is still long [2], [3].

Business model innovation has been widely recognized as one of the levers that can effectively support a transition towards the CE [2]–[4]. In particular, business models based on refurbishment and product life extension have been already tested in the electronic and electric equipment (EEE) sector [2], [5], which is crucial both for the volume of e-waste generated annually [6] and for the composition of end-of-life products, which contain high value materials, as well as hazardous substances [7].

This work is an attempt to evaluate the potential impacts and benefits of CE tools, in particular combining business model innovation through product-service systems (PSS) and closed-loop schemes, on the EEE sector on a supply chain (SC) level, identifying the main actors involved and the challenges related to such a strategy.

## 2. Literature review

The scientific interest about the Circular Economy paradigm has been growing in the last decades, several applications have been studied, some more successful than

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others, and some barriers and challenges have been identified [8]. In this section, the role of closed-loop schemes and PSS business model as enabling actions for the implementation of CE has been investigated.

### 2.1. Closed-loop towards CE

A recent review on reverse logistics and closed-loop (CL) systems outlines the need for integration of environmental objectives in the design and assessment of closed-loop models [9].

On a strategic level, the role of closed-loop production systems in the realization of both economic and environmental goals is underlined by Winkler [10], who stresses in particular the potential of sustainable supply chain networks (SSCN) in the transition to a CE. The author underlines the importance of realizing closed-loops at a supply chain level, as single companies cannot implement effective closed systems on their own. Similarly, Sheehan et al. [11] explore the role of closed material loops for the implementation of CE, analysing material waste forms and their interdependencies. From this study, a causal-loop diagram is derived for future analysis through system dynamics simulation, as a tool to support decision-making in waste minimization. Jawahir and Bradley [12] outline the lack of technological elements to implement CE strategies, and propose the framework of sustainable manufacturing as a starting point to realize closed-loop systems based on the 6-Rs (reduce, reuse, recycle, recover, redesign, remanufacture). De los Rios and Charnely [13] focus on the transformation needed in production and consumption systems to implement CE, analysing the role of design in the transition towards closed-loop systems. Starting from some multinational enterprises case studies, they provide a list of capabilities required and some guidelines for companies for a successful implementation of circular systems.

A few case studies on specific sectors have also been analysed in the last years. Reuter [14] highlights the importance of the metallurgic sector for CE, underlining the necessity of exploring new business models to realize effective closed-loop systems. Accorsi et al. [15] focus on the design of a closed-loop network in the furniture industry, considering economic and environmental optimization functions in a mixed-integer linear programming model, and including all the actors of the supply chain, from raw materials suppliers to recyclers and disposal centers. The authors aim at providing some guidelines to practitioners for the transition to a CE scenario. Niero and Olsen [16] compare the environmental impacts of a closed loop versus a traditional recycling strategy for aluminium cans through LCA, elaborating some recommendations to improve the environmental performance of this sector towards the implementation of CE strategies. On the same case study, Niero et al. [17] explore and compare the efficacy of the Life Cycle Assessment (LCA) methodology and the Cradle-to-Cradle (C2C) certification in supporting the implementation of CE strategies, identifying both their benefits and challenges. Richter and Koppejan [18] analyse the application of the Extended Producer Responsibility (EPR) as a tool to support eco-design and closed-loop for gas discharge lamps, in a CE perspective. Their study reveals best practices in the sector in the Nordic countries, and identifies some key challenges for the implementation of EPR strategies. Sinha et al. [19] propose a system dynamics simulation model to explore the main paths and drivers for closing material flow loops in the global mobile phone product system. They identified four main drivers that could possibly support the transition to circular economy closed-loop systems: (i) improving collection systems, (ii) longer mobile phone use time, (iii) improved informal recycling in developing countries and (iv) shorter mobile phone hibernation time. Finally, Silva et al. [20] describe three case studies of policy support to sustainable waste management (San Francisco area, Flanders and Japan), comparing the policy directions observed and suggesting some further developments in policy, planning and behaviour change to realize effective closed-loop systems.

### 2.2. PSS towards CE

Focusing on the potential of PSS to support CE strategies, in his recent review about PSS Tukker underlines the high potential of this business model in the journey towards CE [21]. However, he also points out that PSS are not by definition more resource efficient and sustainable than the sole product: it is necessary to evaluate the sustainability of such systems since the design phase, to ensure their economic, environmental and social viability. Moreover, some main barriers in the diffusion of PSS (such as the consumer’s need to keep control over the product) were identified. Lewandowski [22] provides an overview of different possible circular business models, including PSS, contributing to the definition of a framework for supporting companies in the business model design phase. Catulli and Dodourova [23] explore the challenges related to the adoption of PSS, as well as the benefits entailed, underlining the necessity of an innovation-oriented approach for businesses, institutions and policy makers. They identify cooperation as one of the keys to a successful PSS business model.

Some examples of CE-oriented PSS are also provided in literature. Iung and Levrat [24] describe and analyse the role of maintenance in PSS offers as a way to guarantee service continuity towards circular economy paths. Johansson et al. [25] describe the PSS business model for the urban mining segment, as a path towards circularity, defining the key topics to address and a set of guidelines to follow when developing the business model. Lelah et al. [26] discuss the use of a machine-to-machine PSS solution in glass waste collection for recycling, analyzing its main environmental impacts and benefits through LCA. Moreno et al. [5] present two case studies of circular-oriented PSS applied in the large household appliances sector, displaying the results of a workshop aiming at identifying the main barriers, drivers and benefits related. Finally, Pialot et al. [27] explore the concept of upgradability as a way to contrast product obsolescence, combining it with the PSS business model. In the so called “Upgradable PSS”, optimized maintenance, refurbishment and offer servitization can open new perspectives for businesses and customers, facilitating the transition to a CE. The authors underline how the advantages of such an offer could push the customer to choose use-based models rather than ownership-based ones, helping the business to increase control over products and components flows.

Although the potentialities of PSS to foster sustainability paths have been widely recognized, researchers have been raising concerns about the rebound effect, which might cause an overestimation of the impact of new technologies or business models on sustainability [28], [29]. In particular, research on the rebound effect in the PSS context is still in its early stage [30], [31].

Despite the interest shown towards the application of closed-loop and PSS as suitable ways for a transition to CE, none of the works analysed consider the joint effects of both tools on a supply chain level, and only a few of them attempt to evaluate the impacts of these actions on sustainability. Therefore, the aim of this work is to perform a preliminary analysis of the main impacts and relationships that a closed-loop-PSS business model would elicit on the three main dimensions of sustainability on a supply chain level, considering the case study of large appliances.

## 3. The circular business model proposed

The washing machines market is currently heavily dependent on product lifetime and prices. Similarly to other mass customized products, one of the main drivers influencing the customer's choice is the price: very often, this pushes the user to opt for entry-level machines. However, considering the operating cost in the long period, high-end machines tend to be more efficient, with a user cost per washing cycle 55% lower than entry-level devices [2]. Despite this, traditional ownership-based business models orient the customers towards entry-level machines, which are usually characterized by a short lifetime and lower value components. Switching to leasing offers, where the user can defer the payment through monthly instalments, could facilitate the access to high-end products, while guaranteeing a stricter control of the manufacturer over the product during its lifetime.

Starting from these premises, a new SC model for washing machines is proposed, based on the integration of a leasing-based PSS and closed loop models for managing the reverse logistics flows. Figure 1 shows the actors and the main processes involved.

The PSS offer would be based on a leasing contract that enables the customer to benefit from a product for a fixed amount of time (e.g. 5, 10 or 20 years) removing the cost barriers and distributing the costs over time. A maintenance service would provide interventions when necessary, as well as programs upgrading after the first sale, which would contribute to increase the energy efficiency with minimal effort. A closed-loop strategy would be crucial to manage the reverse logistics of the model, collecting the used devices at the end of the leasing contract and recovering the components and the materials for recycling and remanufacturing, when economically viable. Refurbished products could be addressed to a secondary market, while the materials recovered could be used again for the production of new washing machines.

Unlike the traditional SC, the main actor would be the Service Provider Company (SPC), in charge of managing the leasing contracts and the maintenances activities, which would replace the 'traditional' retailer, usually responsible only of sale activities. A third party Logistic Service Provider (3LSP) would be designated for collection and transportation of used devices, which would be then sent to refurbishment processes (when viable), managed directly or indirectly from the producer. Refurbishment usually involves the replacement of common break points (e.g. motor, pump, bearing etc.) and programs upgrading, allowing multiple consecutive leasing, or in alternative distribution on the secondary market, always under control of the SPC. When refurbishment is not economically or technically viable, end-of-life materials are recycled. The SPC is also responsible for secondary raw materials markets and scrap disposal.

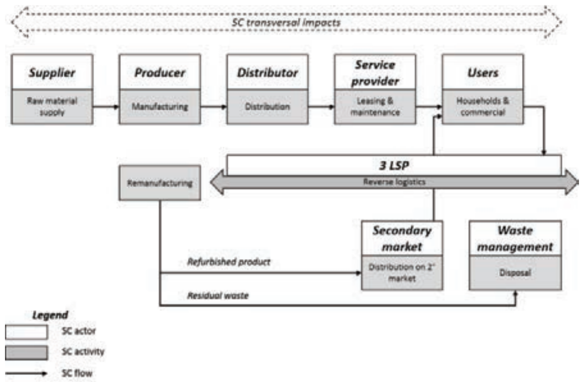


Fig. 1. The leasing-based SC

## 4. Classification of expected impacts

The main impacts related to the SC actors have been identified and reported as follows. This classification is based on a literature analysis, starting from the case study presented by the Ellen MacArthur Foundation and other works on PSS. A summary of the impacts is reported in Table 1, where they are also classified according to the dimension involved. Next to the three widely recognized dimensions of sustainability (economic, social and environmental), a third category has been considered including the more technical aspects of the PSS implementation, which also have some indirect influence on the other three.

### *4.1. User's perspective*

The Ellen MacArthur Foundation [2] reports that a transition to new business models based on leasing could be a viable way to overcome the entry barriers for high-end devices related to the higher price. Therefore, users can benefit from lower overall costs and wider access to high-end machines. At the same time, the maintenance and upgrading activities on one side increase the customer service level, on the other allow a spread of technologically updated products without buying new devices, also causing an increase in the energy efficiency of the appliances (and consequently lower $CO_2$ emissions) [32], [33]. Another effect of the leasing-based model would be the increase of products used for an efficient time (time use efficiency), due to the time constraint included in the contract and to the maintenance service that keeps the device in good operating conditions. Increasing the return rate of the products, the illegal market size would also decrease, contributing to a higher normative compliance on a policy level. Indeed, the EU's Waste Shipment Regulation forbids the export of WEEE to non-EU countries, but still a considerable quantity of European e-waste is shipped to foreign countries each year, China being the most popular destination [34]. Finally, the ownership rate would decrease, which might represent a possible barrier to the diffusion of such models [32], [33], [35]. This requires further studies on the customer's acceptance of a PSS solution, in order to ensure a successful implementation of the model. All the benefits described would contribute to increase the public acceptance of such a business model, fostering a virtuous cycle.

Table 1. Classification of impacts for each SC actor.

| SC actor | Impact | Dimension |
|---|---|---|
| Suppliers | Suppliers' orders | Economic |
| Producer | Raw materials flow | Environmental |
| | Remanufacturing processes cost | Economic |
| | Net recovered materials | Economic |
| | Landfilling cost | Economic |
| | Producer profit | Economic |
| | Refurbishment products volume | Technical |
| | Recycling rate | Environmental |
| | Extension of product lifetime | Technical |
| | Production volume | Technical |
| Distributor | Traceability and take-back forecasting effectiveness | Technical |
| Service provider | Leasing contracts | Economic |
| | Service provision and maintenance | Technical |
| 3LSP | Reverse logistics flow | Technical |
| | 3LSP commissions | Economic |
| Secondary market | Refurbished products sold | Economic |
| User | Illegal market size | Social |
| | Product's ownership | Technical |
| | Customer cost | Economic |
| | Customer service level | Technical |
| | Time use efficiency | Technical |
| | Access to high-end machines | Social |
| | Spread of technologically updated products | Technical |
| Waste management | Waste generation rate | Environmental |
| Transversal impacts | Tax incentives | Economic |
| | Emissions | Environmental |
| | Public involvement in CE | Social |
| | Leasing public acceptance | Social |
| | Normative compliance | Technical |

### *4.2. SC's perspective*

On the producer and distributor's side, a leasing-based PSS would increase traceability and the effectiveness of take-back forecasts, leading to more stable reverse logistics flows and guaranteeing a stronger control on the products' flow and lifecycle [33], [36]. Moreover, allowing an easier recovery of the end-of-life product, which has benefited from a controlled maintenance over the years, this business model ensures a higher quantity and quality of the recovered materials, enabling higher recycling and remanufacturing volumes [2], [36]. This would have an impact on the secondary market, which could increase through the introduction of more refurbished devices, and on the waste generation rate [33]. The extension of the product lifetime would negatively influence the production volumes, and consequently the raw materials flow and the orders to suppliers. Therefore, the higher costs deriving from remanufacturing process, service and maintenance activities and commissions to 3LSPs, would be balanced by the value of materials recovered and the avoided landfilling costs [2], [32], [33], [36]. All of these voices have an impact on the company's profit, which needs to be deeply investigated in order to ensure the economic sustainability of the business model proposed.

### *4.3. Possible drivers for the transition to a circular model*

Finally, two possible drivers have been identified that could support the transition to a PSS-closed-loop based business model. On one side, to ensure the economic sustainability for the producer, the introduction of tax incentives could foster the adoption of this solution from the users. This would increase the producer's revenues flows, and consequently the attractiveness of this option for companies [32]. On the other side, awareness should be raised among users towards the topics of sustainability and CE, helping to drive a shift in the mind-set and overcome the barriers related to the lack of ownership in a PSS solution.

### *4.4. Relationships and interactions*

The interactions described in this section and derived from literature have been mapped through causal loop diagrams, with the aim of highlighting the main effects caused by the implementation of a PSS-closed-loop based strategy for washing machines. In order to improve readability, three main diagrams have been derived: the first shows the impacts from a user's perspective (Figure 2), the second from a producer's perspective (Figure 3), and the third one summarizes the other main impacts on sustainability (Figure 4).

In the user's perspective diagram, product's ownership has not been included, because its impact on the public acceptance of the leasing model is still not clear, as previously explained. A virtuous cycle can be identified regarding the cost for customers, decreasing with the adoption of leasing contracts, which increases the public acceptance, consequently encouraging new leasing contracts. The same dynamic can be observed with the customer service level, increased by the maintenance services, the wider access to high-end machines and the spread of technologically updated devices. A further push to the diffusion of leasing contracts can be reached through the introduction of tax incentives and the diffusion of policy measures for increasing public awareness and involvement in CE issues.

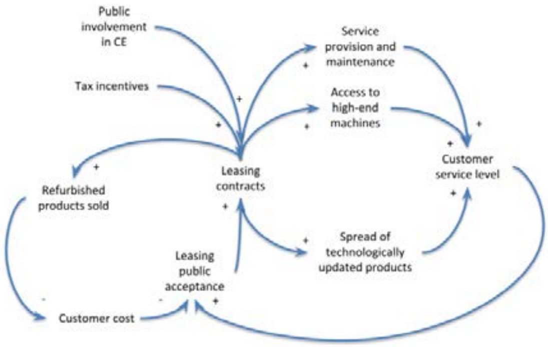


Fig. 2. Causal loop diagram – customer's perspective

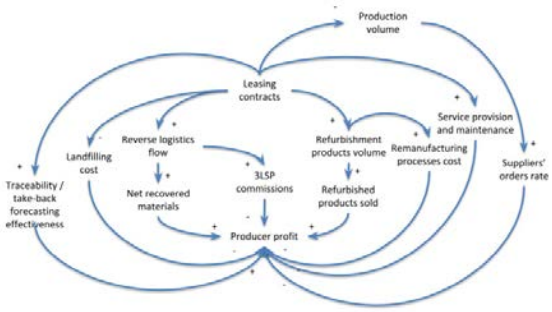


Fig. 3. Causal loop diagram – producer's perspective

On the producer's side, several economic impacts have an effect on the producer's profit. Positive impacts are given by the increase of reverse logistics flows, therefore of net recovered materials, and the higher volumes of refurbished devices produced and sold. The higher traceability and forecast reliability also represents an economic advantage for the producer, who can manage his resources more efficiently. The decrease of landfilling costs constitutes a further benefit for the producer, as well as the decrease of orders to suppliers (thanks to lower production volumes and higher material flows recovered). On the other side, remanufacturing and service provision costs are expected to increase, as well as logistics providers' commissions. Therefore, the economic sustainability for the company needs to be further explored, in order to balance costs and revenues deriving from the new business model, ensuring its viability and diffusion.

Looking at the other impacts on sustainability, the environmental, social and technical benefits of the new business model are even clearer. The higher material recovery causes a decrease in raw materials extraction, while recycling increases and less waste is produced. This concurs in decreasing the emissions, which are also influenced by the spread of technologically updated (therefore more energy efficient) products. A better time use of the product and its lifetime extension also contribute to increase material recovery and decrease waste production. Moreover, on the social side, the illegal market size decreases thanks to the efficient reverse logistics. This, together with emission reduction and waste minimization, contributes to reach a higher compliance of the normative enforced.

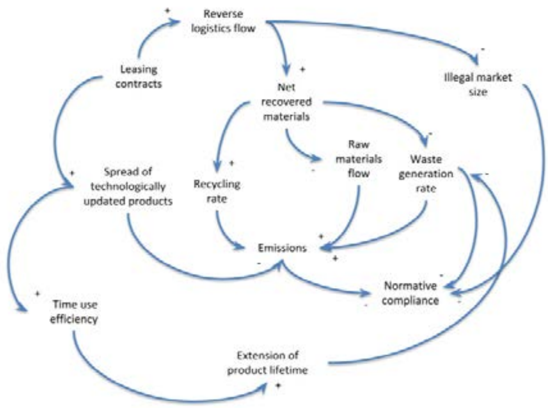


Fig. 4. Causal loop diagram – other impacts on sustainability

The causal loop diagrams shown represent a starting point for the elaboration of a system dynamics model that can help to quantify the main impacts on sustainability of a joint PSS-closed-loop strategy applied to the EEE sector.

## 5. Discussion and conclusions

Starting from the need to identify strategies for minimizing the waste from EEE, in this study the impact of a CE strategy based jointly on business innovation through PSS and closed-loop schemes on the sustainability dimensions of a supply chain has been explored. A literature review has highlighted the lack of instruments for the impact assessment of CE strategies, in particular related to the introduction of the two tools described, as a few works in literature explore in detail the role of enabling actions for the implementation of CE on a supply chain level. Starting from a case study proposed by the Ellen MacArthur Foundation on the washing machines segment, a new circular business model based on leasing and product recovery and recycling has been described. The main impacts on the configuration of the SC and on its actors were identified through a literature analysis and classified. Finally, the main relationships among these impacts have been depicted using some causal-loop diagrams, with the aim of identifying the main benefits and challenges related to the introduction of the new business model proposed. The benefits on the environmental and social sides seem to be clear and well understood: material recovery, remanufacturing and recycling strategies that would decrease waste generation and emissions, while a wider access would be guaranteed to high-end and technologically updated products, increasing also the customer service level and decreasing the size of illegal secondary market. On the economic dimension, some other considerations should be made: while the cost for customers is expected to decrease, the costs bore by the producer need to be further explored, in order to ensure the economic sustainability for the company and the successful diffusion of the business model. Rebound effects should also be considered when evaluating environmental and economic benefits. Moreover, further research is needed to understand the impact that the lack of ownership would have on the customer's acceptance.

This work is a preliminary analysis and the first step for the elaboration of a system dynamic model: further developments include the model validation and application, to allow a deeper quantitative analysis of the impacts identified and the evaluation of possible strategies to support the implementation of use-oriented business models for CE.

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