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EXPLORING THE LINK BETWEEN SERVICE BUSINESS MODEL AND SUSTAINABILITY: LITERATURE ANALYSIS AND EXEMPLARY CASES

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Sommario

ABSTRACT

This master's thesis explores the relationship between servitization and sustainability, with a specific focus on digital servitization. The first chapter is a comprehensive literature review, critically examining periods both preceding and following Industry 4.0. The overarching goal is to provide an understanding of how this late digital revolution has shaped and influenced the relationship between servitization and sustainability. The second and final chapter provides an empirical analysis of four in-depth case studies. These case studies scrutinise key aspects of the complex relationship among digitalization, service-based business models and sustainability. The findings offer valuable insights into the process of digital servitization in enhancing sustainable business practices. This body of work concludes by highlighting the managerial and theoretical significance of the research and providing insights into the potential future of the dynamic relation between digital entrepreneurship and sustainability.

INTRODUCTION

During the most recent years, a lot of businesses that gained their success through a product-centric business model are undertaking a servitization strategy. We can define servitization as a shift made by a company towards revenues from services and solutions as a new revenue source (Ulaga, 2018). This transformation into service economies can be noticed even looking at some GDPs of some very industrialised Countries such as Germany (70% of GDP provided by services), but also USA, United Kingdom and France (between 75 and 80%) (Kowalkowski and Ulaga, 2017).
At the same time, climate change and other environmental issues we are going through pointed attention to the sustainability topic. There is the need for developed industries to think about sustainability impacts of their business decisions, as they are now called to create wealth without compromising the environment or the disadvantaged communities.
This body of work tries to contribute to a literature that is still quite young and lacking in some respects regarding technological benefits.
In this scenario, our research fits. It is an exploratory and qualitative work that aims to clarify the link between servitization and sustainability, with a specific focus on how the implementation of Industry 4.0 technologies has contributed to it. We have done it through a literature review followed by an empirical investigation.
Now we are going to provide a basic theoretical framework to create a knowledge base for the reader and a common specified language; at the end of this introduction, we will briefly anticipate how this research is developed.
At this point it is quite useful trying to understand why we are witnessing this spreading tendency in developed economies. It is due to different forces, some external from the reference firm, and some other internal (Kowalkowski and Ulaga, 2017). Outside-generated forces are: saturated and commoditized markets, pressure from customers and proliferation of competitors (Kowalkowski and Ulaga, 2017; Yang and Evans, 2019). The first point refers to the fact that the Installed-based factor keeps decreasing year after year (Neely, 2008; Kowalkowski and Ulaga, 2017). This late factor is the ratio between the number of new units sold in the market every year and the already present units (the Installed Base). Since this number is constantly going down, businesses have to start working on what they already sold instead of focusing on selling new units, and this leads to a shift in the business model. The second mentioned factor refers to the fact that customers are continuously more professionalised and their expectations versus supplier performance are very high (Kowalkowski and Ulaga, 2017; Yang and Evans, 2019). They interact with fewer suppliers than in the past, but they do

not demand only for a physical good anymore, they want to receive a complete high standard of performance. The last of these 3 points is the proliferation of competitors. Specifically, this proliferation has four origins: incumbents from the same industry, competitors from emerging markets, players that are moving up in the value chain and disruptive innovators that come from other industries providing advanced services (Kowalkowski and Ulaga, 2017).

Now internal servitization-drivers forces are examined; these are: the opening of new market opportunities, the exploitation of technological expertise and the possibility to catch more value from relationships with customers (Kowalkowski and Ulaga, 2017). The first force is the possibility to land in not yet explored markets with a disruptive effect and possibly great margins for profit. The second is about the possibility to exploit technological skills not only in the product design phase but also during the whole product lifecycle. Moreover, this knowledge is useful also for thinking about value adding services since the very first phases of the product thinking. The last point to be addressed refers to the possibility to capture greater value from relationships with customers, since providing services entails a more frequent interaction and a better reciprocal knowledge (Kowalkowski and Ulaga, 2017).

The combination of product and service offered by a firm will be also called Product-Service System (PSS), a concept originated in the Netherlands and Scandinavia in the late 1990s (Aurich et al, 2010). As it almost always happens in the literature, we do consider PSS and servitization as synonyms, ignoring the very thin difference running between them concepts. The most quoted and cited definition is the one provided by Mont in 2002 that refers to it as "A system of products, services, supporting networks and infrastructure that is designed to be: competitive, satisfy customer needs and have a lower environmental impact than traditional business models" (Haase et al, 2017). Talking about PSS we have to recognize different business models based on that. From the literature 3 different kinds emerge with more intensity: product-oriented, use-oriented and result oriented (Tukker, 2004; Aurich et al, 2010; Hänsch Beuren et al, 2013; Reim et al, 2015; Yang and Evans, 2019). This distinction will be better specified now, and it will be recalled in the analysis by Tukker during the first chapter, investigating their different potential for sustainability achievements. During the time, other valid classifications were proposed (Yang and Evans, 2019), but we decided to keep only this one because we find it more functional and clearer.

Product-oriented PSS based business models entails that the manufacturer beside producing an item offers a service strictly related to this item (Reim et al, 2015; Yang and Evans, 2019). A proposed example is a hospital equipment manufacturer that takes care of the end of life of its disposals, retrieving and recycling them, once they are not needed anymore; in this case the producer gets paid for the equipment and for the extra service provided (Reim et al, 2015). To this same category belong all the insurance and maintenance contracts provided for example by smartphone sellers or household appliances manufacturers. The focus stays on the sale of a physical product with an upselling of services.

Use-oriented category is based not on selling a physical product but on conceding its use to multiple customers through leasing or rental agreement (Reim et al, 2015; Yang and Evans, 2019). All the electric vehicles (Bitt, Dott, etc.) sharing companies are examples of this business model, exactly as Software as a service (Saas) business model. Through these, tech companies offer access to software and applications managed through a cloud by paying a subscription fee.

The last type under examination is *result-oriented* business model. Here the provider ensures a certain outcome or certain results to the customer (Reim et al, 2015; Yang and Evans, 2019). This is the business model with the largest chance of being environmentally successful (Tukker, 2004; Chierici and Copani, 2016) for what will be explained later on. An example can be a cleaning company that ensures a certain degree of cleanliness without specifying the tools adopted nor transferring any property (Reim et al, 2015). Another example can be an electric vehicles company who pays another company to manage the end-of-life and recycle phase of its batteries.

Introduced the concept of PSS and the drivers of servitization, we should now see which are the barriers and the main obstacles. For example, servitization can be hindered by the fact that the organisations are stuck in their product-centric mentality. They are focused on efficient and effective production and on technological innovation as they excel in selling features and items. In services the focus shifts on outcomes achieved (Neely, 2008; Kowalkoski and Ulaga, 2017), providing solutions and not tools to get rid of the problems. Changing mentality means also learning the rules of a 'service factory'. This involves the risk of losses in productivity and standardisation. That's due to the high involvement of the customers in the service production phase, something that is not proper for a pure manufacturing organisation. Companies must learn to gain more customer insights, in order to co-create the services with them. All these activities are necessary to develop an efficient servitization strategy. Another important point is to rethink the distribution channels and marketing approach (Neely, 2008). This is because services cannot be put on a shelf for everybody's disposal, since they require a wider degree of personalization and the demand changes quite rapidly, and all the supply chain (so external actors) must be aligned to this service centric mindset (Mont, 2002; Kowalkoski and Ulaga, 2017). These changes in relation to customers and partners sometimes mean to create a new network and infrastructure (Mont, 2002). Breaking away from CAPEX (CAPital EXpenditure) logic and moving into OPEX (OPerational EXpenditure) logic is crucial too. In this way customers obtain the desired result (outcome-oriented mentality) without massively investing in goods, avoiding being locked up by these huge expenses and freeing up capital for what is more needed elsewhere

now or in the future (Kowalkoski and Ulaga, 2017). This is a change in the revenue streams for the service providers too and it must be considered.
In the second part of the first chapter, we will properly introduce the main factor of our analysis: digital servitization. We can provide a definition as the transformational process by which a product company changes its product-centred business model into a service-centred business model with the support of digital technologies, enabling the reconfiguration of its business processes, capabilities, products, and services to improve the value for customers and increase the company's non-financial and financial performance (Favoretto et al, 2022). This basically means empowering servitization strategy by adopting the most recent Industry 4.0 technology such as IoT, Big Data, Analytics, Cloud Computing, etc. That enables firms, among the others, to gain a better knowledge about customer and product usage, helping design the best-fit service-based strategy. For the sake of knowledge, we can define Industry 4.0 as "a family of technologies that entail the use and the coordination of information, automation, computation and sensing activities" (Kamp and Gamboa, 2021). Digital servitization will be the main subject later on in this body of work.
A relatively new line of studies is trying to link this business phenomenon with another predominant topic: sustainability. This is a very important matter for our society, it's fundamental to associate new revenue streams for companies with environmentally friendly action. Profit and sustainability cannot go in opposite or separate directions anymore. Just for notice, we can define this concept as "meeting the needs of the present without compromising the ability of future generations to meet their own needs", quoting the United Nations Brundtland Commission (1987). This idea, the first largely adopted definition, can be expressed under 3 dimensions: Economic, Social and Environmental. This model is called 'Triple Bottom Line model' and it is sometimes referred to as the '3P Model' where the Ps stay for Profit, People, Planet. That's very useful when it comes to analyse a policy or a project because it covers almost all the interests touched by an intervention, whether this is a business decision or a government act.
During this research activity we will try firstly to catch what literature has already understood and realised, particularly relating to the impact of Industry 4.0 technologies. More specifically, we will see what literature told us about the link before the digital revolution, focusing more on the potential negative aspects and the predominant doubts. After that, the literature comprehensive of Industry 4.0 technologies will be taken into account, with a particular look on what they brought new to the table. This can be considered the ratio under the chapter 1 body of work.
The chapter 2 will follow, with its case studies analysed through the interview methodology. Four highly digitalised firms and their servitization strategy will be deeply studied and the findings told after that.

In the very last section of this research, we will draw our conclusion and our acknowledgements will be summarised, underscoring the value of this work both from managerial and strategic point of view and trying to anticipate and suggest future trends and scenarios on this hot topic.

CHAPTER 1

LITERATURE REVIEW

INTRODUCTION AND METHODOLOGY

Once the theoretical basis has been set and the scenario well introduced, it's time to start the literature review that links service-based business models with sustainability. More specifically, we wanted to point our focus on how the new digital tools can impact this topic. For this reason, the following literature review is not just a collection of papers. It has been made with the intention of underscoring first the predominant doubts and uncertainties, to shed light on the industry 4.0 technologies in the second part, trying to highlight how they changed the thought on the matter. Anyway, we don't mean to say that literature is cut in half by the digital revolution, with negative opinions before and positive after; but we decided to get this perspective to point out the technological impact.

For sure Industry 4.0 technologies and a renovated sensibility for sustainable development are the two strongest forces. Some academics have coined a new expression to synthesise this link between servitization and Industry 5.0 environment: Servitization 5.0 (Nicoletti and Apolloni, 2023). As the name suggests, it combines digital servitization with the characterising features of Industry 5.0: Resilience, Human Automation Machine Collaboration and sustainability (Nicoletti and Apolloni, 2023). In fact, the European Commission says that Industry 5.0 completes Industry 4.0 by investing in research and innovation in order to transition towards a sustainable, human centric and resilient European Industry (European Commission, 2021). Something coherent has been told until now. We will see how smart technologies foster this transition.

In the first paragraph we'll see the most dominant position before the introduction of Industry 4.0 technologies. We will check their points and opinion, trying to understand where their uncertainty comes from even if the potential benefits of servitization were recognized. This analysis was conducted on papers that were not considering the existence of Industry 4.0, so some rebound effects were seen as more dangerous than more recent analysis and some opportunities not recognized yet. Some case studies found in the literature will be provided in order to see actual dynamics. Nevertheless, the future impact of those technologies was in some way predicted and the potential benefits recognized in a survey presented at the ending part.

In the second paragraph instead, we will see different ways in which servitization fosters sustainability and some case studies retrieved from the literature to have practical examples. One turning point was the implementation of Industry 4.0 technologies, it means Artificial Intelligence (AI), Internet of Things (IoT), Big Data, Analytics, Cloud Computing, Virtual simulations systems, augmented reality, Additive manufacturing/3D printing, Cyber-physical systems, Robotics and cyber security (Kamp and Gamboa, 2021). These technologies will be analysed, and their different impacts will be brought to light (e.g. Circular Business Model enhancers). For length reasons and debate topics the paragraph is divided into smaller sub-paragraph (as shown in the index). Contents of this part constitute the basis for the empirical investigation elaborated in chapter 2.

From a temporal point of view, we consider 2015 as the reference year for the separation between pre and post Industry 4.0/5.0 era, following the methodology adopted by one of the most important historical literature reviews on servitization made by Kohlbeck et al in 2023 (Kohlbeck et al, 2023). Anyway, it’s impossible to distinguish one clear cut year which previous papers ignored Industry 4.0 technologies while following literature unanimously consider it. So, we couldn’t ignore research works post-2015 which don't take into account all the new digital technologies and they for sure contributed to the first half of the next chapter. The most important thing for us was to understand how technology implementation can contribute to achieving sustainability in our research field, more than what happened from one year to another.

Anyway, even looking at research engines, the materials after that year are more abundant. For example, just by shifting the time period of the research from 2000-2014 to 2000-2015, the number of results increased from 862 to 1140 (32% increase) just for the research string “digital servitization AND sustainability”. That’s another confirmation, also for future researchers, that the time period considered is valid.

Google Scholar has to be considered as the information database. To perform this literature review we used the following research strings, ordering the results by relevance: “Servitization AND sustainability”, “PSS AND Sustainability”, “Servitization AND Industry 4.0”, “PSS AND Industry 4.0”, “Digital servitization AND sustainability”, “Digital Servitization AND Industry 4.0” and “Smart PSS and Sustainability”. We ended up with the 75 cited in the literature review.

PRE-INDUSTRY 4.0 LITERATURE

Introduction and Tukker's analysis

When we think about sustainability and servitization we should not take for granted that the literature unanimously agrees on a positive relationship between them two. In fact, even if PSSs were already recognized as possible sustainability tools, some academics have pointed out some doubts and worries, mainly some years before the diffusion of Industry 4.0 technologies. Just for instance, one main preoccupation was the so-called rebound effect (Manzini and Vezzoli, 2002; Neely, 2008; Chen et al, 2015) for which PSSs risks to alter customers behaviour, making them spend saved money and time in not sustainable activities; some other concerns were about the sustainability impact of the PSS per se (Gottberg et al, 2010). Just to put here an example, a study conducted by Neely in 2008 shows, on a sample of 12521 firms, economic advantages of servitization were not so clear (Neely, 2008). This research pointed out that larger firms (in terms of number of employees and turnover generated) find it difficult to get the expected financial benefits of servitization (Neely, 2008). Recalling some of the points discussed in the Introduction, Neevy suggests a list of different factors that can hinder the servitization shift for larger firms, grouped in 3 macro categories: the challenge of shifting mindset, the challenges of timescale and the challenge of business model/customer offering (Neevy, 2008).

As told before, we do not want to state that the literature before the digital revolution did not recognize the possible sustainability benefits of servitization. From an economic perspective, Aurich et al see service-based business models as a tool to achieve greater customer satisfaction in a more customised way, prolonged in time (Aurich et al, 2010). This translates into customer loyalty, unique relationships with them, differentiated solutions and so into a situation of economic sustainability for quite a long time (Aurich et al, 2010). Environmentally, the sustainability was thought to be enhanced by consumption reduction by alternative product use, increased dematerialization and a more efficient life cycle management of the products by service providers that keep ownership (Neely, 2008; Aurich et al, 2010; Hänsch Beuren et al, 2013).

To properly start our discussion about the less positive considerations, we consider an important paper that suggests, at the best, a marginal environmental improvement through PSS is the one made by Tukker in 2004. The first point touched is the fact that, at least at the time, there was no evidence of a positive impact on the environment by a PSS, even if the European Union funded these kinds of programmes. This Institution dedicated money to these investments, but SusProNet analyses didn't provide any positive confirmations. Profitable PSS resulted in not environmentally helping while some specific sustainable-designed ones did not survive in a competitive market (Tukker, 2004).

This analysis continues firstly depicting eight types of Product-Service Systems (Table1), starting from the 3 most known categories explained above, and then studying the possible relation with sustainability for each of them.

This study is based on those factors that, for each service, bring to modest (10/20%), to an average to high (up to 50%), or to a potentially very high (up to 90%) impact reduction. The first factor is the more efficient energy use that can drive a longer product life cycle or lower energy consumption during the use phase. The second is about proper consideration of the life cycle costs by the provider as an incentive to save on energy and consumables and try to recycle. It's also about intensified use or longer life cycle for capital goods, saving on energy and consumable during the use phase and the use of a technology way more efficient through economies of scale. The third mechanism that can potentially cut emissions the most is the future application of a significantly more advanced technology that will lower the environmental impact a lot (Tukker, 2004), but this was mentioned as a vague hypothesis. In any case it is worth noting how technological development was predicted to be potentially very impactful in this field even in a paper dated 2004, many years before the actual digital revolution.

Going on with PSSs categorization this is what we have. Inside product-oriented classification we find: *product-oriented service*, in which a set of basic services related to the item's use phase are provided, and *advice and consultancy* when the provider gives advices and any kind of help for the best use of the product sold.

For the first one there is no technological implementation, at the best some maintenance stuff performed well but the expected sustainability impact can be no more than incremental; similar story for advice and consultancy service with the only benefit of the provider suggesting the most efficient way to operate the item sold (Tukker, 2004)

Inside the use-oriented category we have: *product lease*, *product renting or sharing* and *product pooling* (Tukker, 2004).

The first one implies that the producer keeps the ownership of the product together with maintenance and repairing duties, while the actual user pays a regular fee having unique and complete access to the item. In this case it is difficult to say whether there is a positive impact on the environment because with the provider designing its product, keeping the ownership and controlling maintenance, the life cycle should be longer. However, it happens very often that the leaser buys the product from a third party avoiding sustainable design and the other positive effects of the user not being the owner are marginal; sometimes it seems to be that the user does not care about the object and so uses it irresponsibly, shortening its life cycle.

Product renting is very similar to the previous situation with the difference that the possibility of using the product is not individual but sequential, in the sense that when a customer is not using it another one can. This situation is seen to have a positive effect on the environment. The use is somehow discouraged since the customer has to pay the integrated cost each time, they use it and the access is generally a little bit more complicated. This can lead to a more intensive product use or to increase ecological alternatives (Tukker, 2004)

The last category is similar to the previous cases but here the use of the product is not sequential or individual but simultaneous among different customers. The impact analysis is similar to the one depicted above but with the possibility to have even a more significant impact reduction since the product is used by many customers at the same time (Mont, 2002; Tukker, 2004).

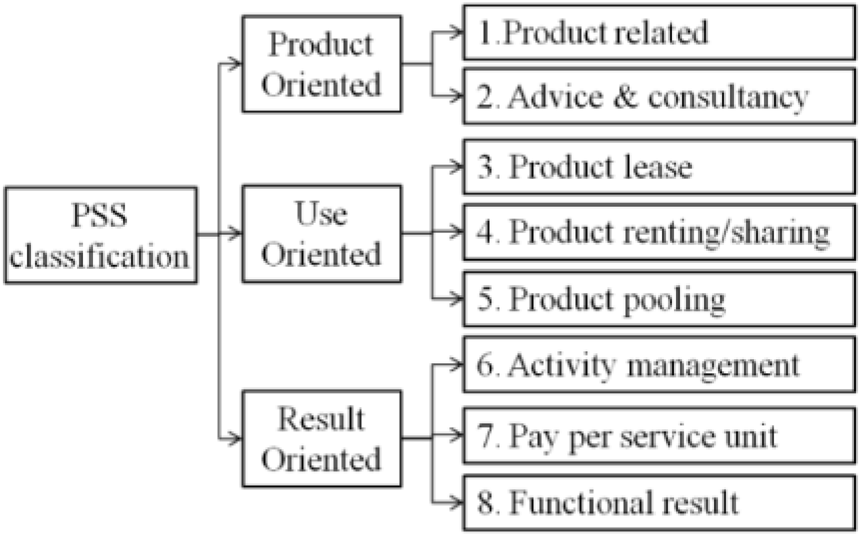
Tukker then moves on with analysis of the impact of result-oriented kinds of services. These are *activity management/outsourcing*, *pay per service unit* and *functional results* (Tukker, 2004).

Outsourcing means delegating a business activity to a third party from outside organisational borders. We see that there is no change from organisational or technological point of view that should bring an environmental gain, but it's possible that the outsourced activity is performed more efficiently by the service company, anyway still with a very marginal impact reduction (Tukker, 2004).

In the pay for service unit category, we have all kinds of PSSs in which the customer does not pay specifically for using the product but instead they pay for the output they obtain, after product use terms are agreed on. Here two main aspects are to be considered. First, since the provider is bearing the life cycle costs of the product that generates the output, it should design it in the most efficient way. Second, sometimes the customer is incentivized to exploit the service in a more conscious way. Both these two aspects are useful for an impact reduction, even if in a marginal manner since there is no organisational or technological significant improvement (Tukker, 2004)

The very last category is functional results. In this case the provider assures specific results generally without any determinations on how to achieve it. The potential for impact reduction is very high here (Tukker, 2004; Chierici and Copani, 2016). This is because the provider is fully free and so it's very incentivized to invest in technology and to organise itself with the aim to deliver in the most efficient and sustainable way (Tukker, 2004).

Table 1- 8 types of PSSs, (Yang et al, 2013)



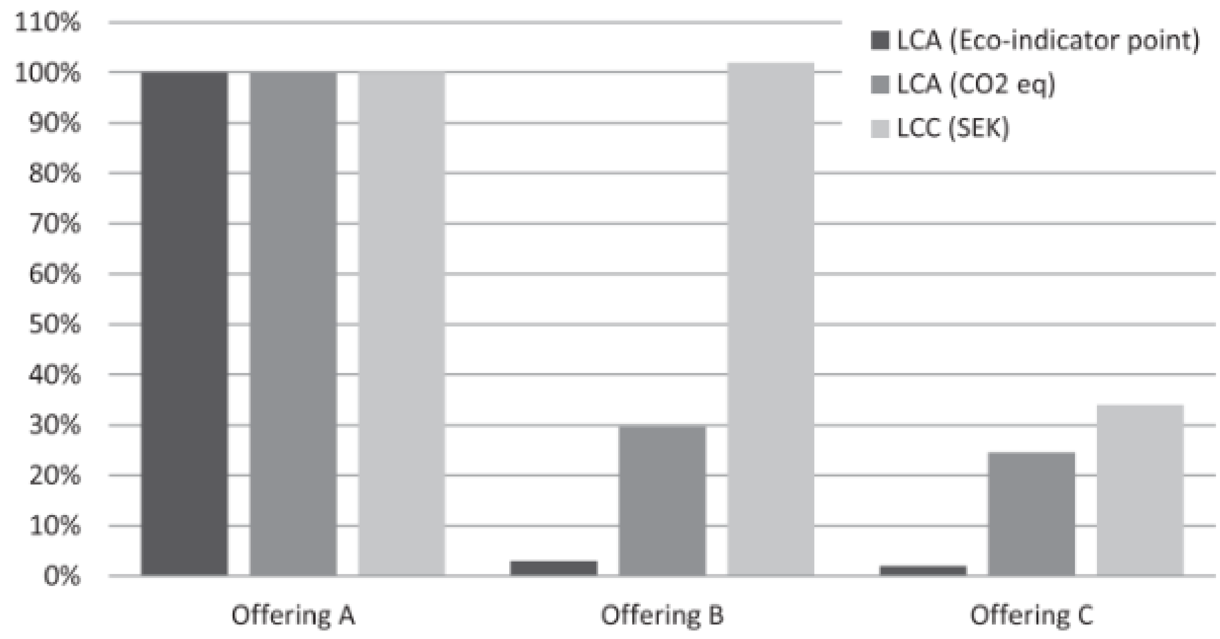
Summing up this analysis, product-oriented services, advice and consultancy and product leasing have a very low impact reduction potential if not, in the worst case, a negative impact. The use-oriented category can have for sure good effects, mainly if the negativities for the environment are associated with the production phase. Outsourcing and pay per service unit gain only marginal benefit because there is no significant technological or organisational development, positive effects are associated with the external provider's efficient practices. PSSs with most potential are surely functional results since the provider has complete freedom and high incentive to invest in technology and organise the most efficient processes (Tukker, 2004).

What we can observe is that in those years it was generally agreed that Product-Service Systems don't mean automatic sustainable solutions (Manzini, and Vezzoli, 2002; United Nations Environment Programme, 2002, McAloone and Andreasen, 2004), especially if design and social implementation are not considered as very fundamental activities (Mont and Linqhqvist, 2003; McAloone and Andreasen, 2004; Chen et al, 2015; Souza and Cauchick Miguel, 2015; Bertoni, 2019).

Case studies from literature

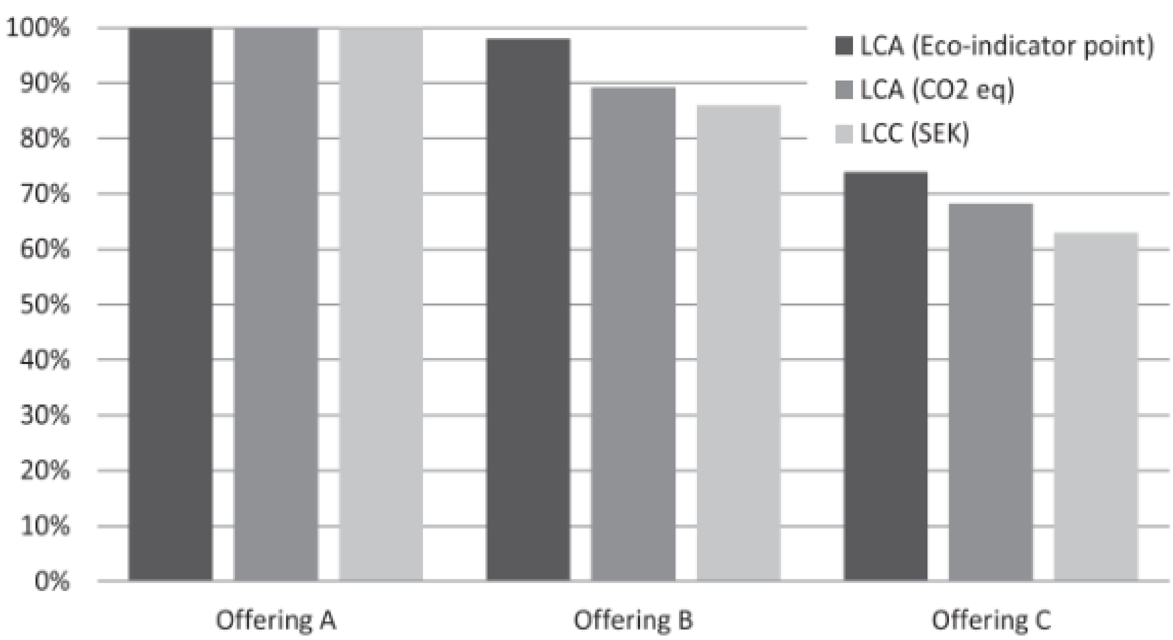
Some confirmations about Tukker's analysis arise from empirical case studies.
Specifically, positive environmental impact was found both from functional results services and from product-leasing, but the magnitude was completely different (Lindahl et al, 2014). The first business case, about a functional result-oriented service offering, is about an exterior building cleaner: Qlean. They developed a very innovative method (Qlean water or 'QW') based on a very filtered and pure water applied through; this allows the entire operation to be completed very quickly and so the wall is available for further work the day after, saving 6 days on average against competitors (Lindahl et al, 2014). Environmental performance is absolutely positive here, with a reduction between 95% and 65% (offering C in table 2) of some sustainability indicators (see the table below) against offering A and B, respectively a product sales offer provided by an actual competitor and an hypothetical application of QW made by an hypothetical customer (Lindahl, Sundin, Sakao, 2014).

Table 2- Sustainability performance indicators (Lindahl et al, 2014).



The second case is about a leasing service. It is provided by Swepac International, a Swedish firm active in soil compactor. They offer compactors adaptable even in very difficult environments and a very fast spare parts supply chain, technical support and service are offered too, with a very good maintenance and remanufacturing. Sustainability performances are evaluated against 2 other offers. Offer A is made by the same product, but not provided through a servitization business model (so without maintenance and remanufacturing that prolong product life cycle) (Lindahl et al, 2014). Offer B has a leasability of 6 years (against 5 of A and 8 of C) and uses a different material of C but the same of A (Lindah et al, 2014). Sustainability positive effects are still present but with a very reduced percentage (see table 3) since they range from 25% to 35% (Lindahl et al, 2014).

Table 3- Sustainability performance indicators (Lindah et al, 2014).



We notice what was already discussed above: different kinds of service offers have very different impacts on sustainability and a major role is played by technological innovations. Clearly, the environmental gains are present in both the discussed situations, but their power differs significantly. Technology will be fundamental some years later with the shift to digital servitization, diminishing the uncertainty about the link between servitization and sustainability and exploiting new different levels of servitization. In the empirical analysis we'll present both result-oriented and product lease smart PSSs that provide optimal environmental and economic revenues.

We go on now showing a case study that explains some major concerns about the above-mentioned link. It's important to remember that there were way more people with a positive opinion than those with a negative one (United Nation Environment Programme, 2002; Lee et al, 2012; Hänsch et al, 2013; Lighfoot et al, 2013; Blüher et al, 2020) about servitization linking to sustainability even before Industry 4.0, but the impact was not considered so strong and before digitalization some doubts were still present. Uncertainty was surely much higher than today's literature after technological upgrades, even thanks to the opportunity unlocked by the new technologies.

The case in question comes from Brazil, it shows how good the potential of this PSS is, but some non-correct unpredictable consumer behaviours and misapplication of the system drive to bad results (Hänsch Beuren et al, 2013; Souza and Cauchick Miguel, 2015). This South American business provides purified water through a reverse-osmosis process, in substitution to selling water bottles and filters; water is purified at the moment of the purchase directly from the public water network (Souza and Cauchick Miguel, 2015). We are talking about a 'result-oriented' PSS, because the customer pays for the purified water while the installation, maintenance and replacement are on the company.

Our analysis starts with a theoretical framework on how this solution should drive sustainability improvements and then we will see how the theory matches reality. From an environmental point of view the gain consists in reusable water tanks without encouraging plastic bottles use and a reduction in emissions due to transportation of potable water. Plastic use reduction should also bring less plastic production, a process that is environmentally negative since fossil fuels and a lot of energy are consumed. Waste diminishing is another positive point (Souza and Cauchick Miguel, 2015). Economically, we expect to see a reduction in cost and an increase in sales for all the stakeholders involved (Souza and Cauchick Miguel, 2015). Socially, this PSS provides potable water in areas where the access is not easy and where people suffer economic struggles. At the same time, it creates new job positions but with potential job losses in the plastic industry. Anyway, it's important to add that working in plastic production is quite dangerous for human safety, since the constant contact with toxic gases and liquids (Souza and Cauchick Miguel, 2015).

Do we find all these positive consequences in the actual application of this PSS? Not exactly. In fact, it's noticed that plastic use stays the same, denying most of the gains given by the PSS. This happens because consumers automatically make the association water-plastic as it's consolidated in their lifestyle and mindset (Souza and Cauchick Miguel, 2015). Most of the positive effects are so eliminated. What is important here is that social behaviours should be taken into account when designing a sustainable PSS to substitute a product and probably service provider should have considered working with a tank producer/distributor too. This analysis points out the importance of service design and the factors that drive implementation; for sure big technological development of

recent years has facilitated these activities. Particularly, the process of getting customer insights and collaborating with them was clearly underestimated. This case analysis will be even more clear after the presentation of the Celli group business model, run in the second chapter.
Until now, we have seen a specific service categorization with the related potential on sustainability, followed by 2 case studies that showed us different level of sustainability for 2 different kinds of PSSs and then another case study, very useful to catch the importance of design and implementation phases in order to exploit the above-mentioned potentials. All of this has clarified the degree of uncertainty about servitization driving sustainability, even if the good potential was agreed between most of the studies even before the emergence of new technologies. Another interesting example is the total care program by Rolls Royce was marketed way before Industry 4.0 technologies introduction, but now it works better thanks to IoT, big data analytics and remote monitoring. They help to proactively detect maintenance needs and ensure top engine performance constantly, facilitating circularity and resource efficiency (Moorthy and Rapaccini, 2023).
Now, we proceed with our literature review, pointing out other criticisms shared by academics and, in the last part, we will see some predictions about servitization made before the diffusion of Industry 4.0.

PSSs features and related criticisms

Specifically, now we analyse some service features and the possible criticisms related to their sustainability impact.
For instance, products substituted by services (Hüer et al, 2018) can have different impacts on different sustainability dimensions. If this means adopting new information technologies, we find a gain from an economic point of view but that can be more than compensated by losses due to energy consumptions and job places lost (Doualle et al, 2015). An example of this late case can be the adoption of cloud computing as a service, so a company decides to not invest in and maintain physical services. There is an economic gain avoiding big capital expenditure but with the risk of job losses in the IT company infrastructure. From the environmental standpoint, Software as a service should lead to energy efficiency gains but with the risk of having a higher overall energy demand. Another interesting characteristic of PSSs is its ownership, if it stays with the provider, we should expect some advantages such as better maintenance, sustainable design, better recycling (Tukker, 2004; Hüer et al, 2018). Anyway, the fact that the user is not the owner can stimulate bad behaviour that translates in a shortened life cycle (Barquet et al, 2016; Chierici and Copani, 2016). In these situations, it’s

important to design an efficient responsibility structure with the right incentives to drive adequate user behaviour (Hüer et al, 2018). If the service consists of a shared product, a similar analysis to the ownership one can be done (Hüer, et al, 2018). Here, the potential is even higher since sharing means that the product can be used by any customer at the moment it stays unutilized (Tukker, 2004). The problem arises when emissions due to transportation become too much since there are a lot of customers and the product is constantly needed (Gottberg, et al, 2010); this overutilization destroys the advantages of having one product for multiple users. That can be the case of electric bikes or scooters sharing service, where the transportation emissions are due to the need to recharge and redistribute the vehicles.
The fact that products' life cycle can be prolonged thanks to PSSs adoption brings some advantages, such as resource saving and waste reduction. However, there was not complete agreement on the overall positive impact on sustainability, due to the so-called rebound effect (Chierici and Copani, 2016; Hüer et al, 2018). Specifically, the concern here is the fact that keeping old products alive can cause an environmental damage even bigger than making new products that are designed to be less impactful (Chierici and Copani, 2016). This risk, present mainly in fast-changing technologies, can be avoided by upgrading products when they are re-manufactured, in order to meet a good level of sustainability performance (Chierici and Copani, 2016). This will be better shown in the paragraph about digital servitization impact.

Future perspectives from academics and practitioners

It's clear that many years before the introduction of Industry 4.0 technologies, academics had an intuition that servitization could drive sustainability improvements; however, there were more discordant opinions, and the impact was not that clear. At that time, it was not easily predictable how technology would evolve, mainly in the first years of the century. Meanwhile, sustainability was just at the beginning of its life as a very hot topic, as can be noticed by the constant increase in literature material. Some years later, literature had developed a better understanding of these 2 topics and started to interrogate itself about future scenarios. Particularly, they were interested in what would be the most impactful technologies on servitization.
According to some academics, who have a long-term range of analysis, these would be the most impactful technologies in the future (Dinges et al, 2015): predictive analytics, remote communications, GPS or Geo spatial technologies, consumption monitoring and very advanced mobile phones. Another panel, composed of Capital Equipment Manufacturers, proposed this

alternative ranking (Dinges et al, 2015): predictive analytics, improved analysis of existing data sets, remote communication exploited for remote interventions, dash boarding technologies to provide Key Performance Indicators (KPIs), better use of historical data. Another interesting point is which were considered the drivers of these new adoptions. The most significant for our purpose are: improving service resource efficiency and effectiveness (for 25% of the 85 technologies cited as most determinant in the future), improving maintenance efficiency and effectiveness (22%), improve product performance like reliability (14%), improve spare parts supply chain structure/performance (9%) (Dinges, et al, 2015), all coherent with economic and environmental sustainability effects.
So, even if literature was not fully into the sustainability-servitization link, it recognized the future role of these innovations (Neely, 2008; Dinges, et al 2015) that we'll see as fundamental to drive environmental benefits in service-based business models. This is useful to have a clue about the impact of these technologies on the topic, as we have basically divided this literature review in 'before' and 'after' shared implementation of Industry 4.0.
What should we take from this literature review? As we have already discussed above, the potential of servitization on sustainability is not something new. Since the beginning, it was considered a strategy well aligned with sustainability objectives of the firms and governments.
Throughout this whole paragraph we investigated the relationship between servitization and sustainability trying to underline the position who was more sceptical and not fully convinced of the potential benefits of it, particularly before the Industry 4.0 and 5.0 revolution. This also had the function to better highlight the content of the next paragraph.
First of all must be clear that not every PSS type is the same, even in relationship with sustainability. Product oriented PSS, advice and consultancy and product leasing have for sure a limited impact; on the contrary, use-oriented and even more result-oriented PSS show greater potential. Users relationships and behaviour, misapplication, unexpected circumstances and bad overall design in general can cause undesired results.
Case studies emphasise a key aspect of our analysis and one of the main points of this body of work: Product-Service Systems do not have sustainability benefits per se, but they can guarantee them if they are specifically designed for (Hänsch Beuren et al, 2013; De Pauda Pieroni et al, 2017; Saranic et al, 2022).
Even if this literature recognizes scepticism and uncertainty on the topic, it is just able to predict the impact of new advanced technologies. These are remote communication and monitoring, predictive analytics and improved data collecting, along with other Industry 4.0 technologies and enabled technologies.

In essence, the paragraph highlights the importance of design phase and technological adaptation and implementation in order to exploit service-based business models to achieve sustainable development, trying to reduce the rebound effects.
In the next paragraph we will see how, in the following years, the debate has evolved with the integration of advanced technologies and in which ways digital technologies can help to grab servitization potential sustainability gains.

LITERARY LANDSCAPE IN THE AGE OF INDUSTRY 4.0

Introduction

The introduction of digital technologies plays a pivotal role in enhancing the positive environmental impact of servitization, as highlighted by Ari et al (Li and Found, 2017; Ari et al, 2022). Notably, the integration of Internet of Things (IoT), cloud computing, and predictive analytics is recognized as a significant knowledge-generating factor within the service offering (Sassanelli et al, 2022).

In examining the recent perspectives of academics and experts and considering the transformative effects of the latest industrial revolutions on the relationship between Product-Service Systems (PSSs) and sustainability, it becomes essential to dive into the critical factors that contribute to achieving sustainable outcomes. For organisational and length reasons, we decided to break down this paragraph into shorter sub-paragraphs, as recognised in the Index.

Starting with the relevant aspects introduced by the digital revolution, the adoption of smart PSS allows manufacturers to maintain or regain visibility on the Installed Base. This visibility is crucial as the absence of control over it may cause a downgrade towards a product-centred strategy (Chowdhury et al, 2018). This entails monitoring and diagnosing remote equipment, necessitating the design of services to minimise breakdowns and downtime, reducing transport of physical goods with the consequent reduction of carbon emission (Opresnik and Taisch, 2015; Li and Found, 2017; Chowdhury et al, 2018; Yang and Evans, 2019). Related to the remote-control aspect, Chowdhury et al. (Chowdhury et al, 2018) observed that it encourages customers to become proactive co-creators of value by making decisions based on real-time data. A key aspect, able to foster recyclability and prolong products lifecycle, already mentioned before and that will be better discussed in the end part of this paragraph is significantly empowered by Industry 4.0 applications: PSS design (Li and Found, 2017, Yang and Evans). Dematerialisation is another important point here (Li and Found, 2017; Yang and Evans, 2019): the replacement of mechanical components with software increases sustainability; for example, John Dere shifted from producing different engines for different levels of horsepower to changing the level of horsepower in a single engine through software (Li and Found, 2017). PSSs will have a key role also in fostering circularity and circular business models (Li and Found, 2017; Opazo-Basaez et al, 2018; Yang and Evans, 2019, Chauhan et al, 2022).

Another noteworthy aspect, illustrating the impact of digital technologies on both firm organisation and sustainability services, is the boundaries-spanning effect (Chowdhury et al, 2018). Traditionally defined as someone located at the boundaries of an organisational unit, this role is crucial for efficient service delivery, fostering waste reduction and energy savings through streamlined planning and design processes (Chowdhury et al, 2018). All these aspects will be crucial in the future analysis throughout this literature review.

Not only the environmental side of sustainability is enhanced by smart PSSs, but also economic and social. Closer customer relationships, cost and lifecycle risks reduction, faster response times, bigger streams of revenues, more labour-intensive jobs created and better accessibility to some products/services are all economic and social sustainability positive factors (Yang and Evans, 2019).

A first illustrative actual application of these concepts can be found in Josip Marić and Marco Opazo-Basaez's examination of green servitization and reverse logistics in manufacturing firms. Green servitization, as defined by Opazo-Basaez et al. represents a business strategy aiming for sustainability goals and guiding the design, development, and implementation of green services (Opazo-Basaez et al, 2018). Reverse logistics, on the other hand, involves the efficient flow of materials and information for the purpose of recapturing value or proper disposal (Rogers and Tibben-Lembke, 2001). A case study in the semiconductor industry involving e-Supply Chain Management (e-SCM) shows the role of digital solutions, keys in collecting and analysing data with the results of shortening time-to-market activities, reducing production costs, enhancing organisational responsiveness, and ensuring a higher quality of final products (Hwang and Lu, 2018). These improvements contribute to a more sustainable business, promoting waste reduction, improved recycling capacity, and longer product life, along with the economic advantages gained.

This example illustrates how the implementation of digital technology, alongside a service-oriented and sustainability-sensitive business approach, facilitates informed and successful decision-making.

Here we have seen just a brief introduction, useful to understand the potential of the technology implementation. Following with this chapter, we will provide a more detailed analysis of this impact, with information and examples found in the literature, explored with the aim of deeply understanding how advanced technologies make the difference in this research field.

Industry 4.0, Circular Economy and Circular Business Model

A very interesting way in which digital servitization can enhance sustainability is through Circular Economy and Circular Business Model (CBM) (Li and Found, 2017; Yang and Evans, 2019; Zeng et al, 2019; Chauhan et al, 2022). Although it's probably a known concept, we refer to Circular Economy as "an economic system that is based on business models which replace the end-of-life concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes [...] with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations" (Kirchherr et al, 2017). So, it is quite clear why Circular Economy (CE) has received an increasing interest from literature and managers in the last years: recent studies state that application of CE principles could increase the EU GDP by 11% corresponding to a gain of 1,8 trillion of euros by 2030, preserving the environment (Bressanelli et al, 2018). Coherently, for Circular Business Models we can say that "are business models that are cycling, extending, intensifying, and/or dematerialising material and energy loops to reduce the resource inputs into and the waste and emission leakage out of an organisational system" (Geissdoerfer et al, 2020). How modern technologies enhance sustainability through circularity is what comes next in our analysis.

There is more than one way through which digital technologies can foster circularity (Nicoletti and Appolloni, 2023), and PSS is considered a well-fitted business model to capture the most possible value (Chauhan et al, 2022). IoT is the first technology to be discussed. It's important because it is key to exploit all other technologies (Frank et al, 2019; Chauhan et al, 2022). Smart objects are fundamental for tracking reasons and data harvesting, on which predictive and remote maintenance are based, such as sustainable design and re-manufacturing decision making.

Collecting information through Big Data assures more efficient and effective group decision making (Modgil et al, 2021) allowing to address linear economies faults implementing circular economy's techniques and principles (Modgil et al, 2021). Big Data are, according to the European Parliament, sets of data collected, so vast and complex that they require new technologies, such as artificial intelligence, to be processed (Big Data: European Parliament, 2023). These technologies are the so-called Analytics. The impactful utility of these technologies is the possibility to design advanced services such as predictive maintenance and always keeping track of the Installed Base, also providing upgradability if possible. In the next chapter, exhaustive examples will be provided.

Big Data can be useful to get quick and precise classification of wastes other than understanding the most fitted operations to be done together with supply chain partners (upstream and downstream) (Modgil et al, 2021). In addition, having big amounts of real time data are useful to better understand which are the main product features in the production phase (Chauhan et al, 2022), driving resources efficient consumption that means a gain under economic and environmental sustainability. At the same time, during the recycling circle, Big Data with cloud computing is very useful in the waste collecting activity, keeping track of quantity, type and location of wastes (Nascimento et al, 2019). This information will be useful also in the waste sorting phase, making it faster and more efficient (Nascimento et al, 2019).

Machine learning and Artificial intelligence (AI) are the next technologies to be examined. We can adopt this general definition for the latest concept: "the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings" (Jarrahi, 2019). Another definition is given by Mikalef et al and it states "AI is the ability of a system to identify, interpret, draw inferences from, and learn from data to achieve predetermined organisational and societal goals" (Mikalef and Gupta, 2021). The two most significant advantages carried by AI are augmentation and automation (Jarrahi, 2019). With the first term we refer to humans and machines closely collaborating to achieve something (Raisch and Krakowski, 2021), improving human decision-making capabilities (Jarrahi, 2019). For instance, AI can help in elaborating data to stipulate the most appropriate financial contracts or even assess the compliance of the new service offers with current regulations (Nicoletti and Appolloni, 2023). Even from a sustainability perspective, AI can assist human operators to elaborate data and predict outcomes based on available data while playing an important part also in Additive Manufacturing, predicting printability and detecting defects (Nicoletti and Appolloni, 2023). Meanwhile, automation is about machines substituting humans in some specific operations (Raisch and Krakowski, 2021), bringing efficiency and cost reduction, enhancing again the sustainability performance (Sjodin et al, 2023). Anyway, from a social sustainability perspective, AI is still a hot topic at the moment of this review, and it will surely catch the attention of future literature. It's clear now how big AI support can be in the Servitization 5.0 scenario, where the Everything-as-a-Service (XaaS) mindset spreads. Moreover, as we were discussing above, automation leads to some very positive effects for circularity. These are dematerialisation, extended product life cycle and intensified asset usage (Sjodin et al, 2023). Dematerialisation of resources consumed, since no person is physically needed to complete a task there is a consistent save in energy and concrete resources. The second point, prolonged life span, is because autonomous vehicles can optimise asset maintenance and diminishing wear and tear, leading to less resource consumption. The intensified resources used is given by the fact that autonomous

machines are planned to do their stuff in the most efficient way, heavily reducing energy consumption (Sjodin et al, 2023). Once the concept has been clarified we have to analyse deeply how Artificial Intelligence empowers Circular Business Models. AI can be useful to forecast future material needs and flows while it improves the end-of-life strategies, and at the same time it can help planning the best usage life for a product, improving circularity effectiveness and efficiency throughout its entire life cycle (Sjodin et al, 2023). This points out another critical feature: its capacity to recognize patterns and work efficiently it's fundamental for adaptive reasons and keeping business competitive, enhancing economic sustainability (Sjodin et al, 2023). This description leads us to mention the 3 AI capacities that are critical for circularity and sustainability: perceptive capabilities, predictive capabilities and prescriptive capabilities (Sjodin et al, 2023). With the first one we mean the AI's ability to have a continuously better perception of what is happening on industrial items during customer operations. The second one refers to AI skill to analyse big amounts of data, recognize patterns and make accurate forecasts on future trends; while prescriptive capacity helps manufacturers to think of a more efficient use of their resources during the usage phase (Sjodin et al, 2023).
Alongside with AI we mentioned, some lines above, Machine learning technology. Here it's the definition, "Machine Learning (ML) is a subset of Artificial Intelligence (AI) that deals with creating systems that learn or improve performance based on the data they utilise" (Oracle Italia, 2024).
When we discussed about big data some lines above, we talked about the relevance of enhanced group decision making. This is facilitated by another technology: the blockchain (Chauhan et al, 2022). It can be defined as "a shared, immutable ledger that facilitates the process of recording transactions and tracking assets in a commercial network" with the main features of being trustable, safe and efficient (IBM, 2023). These characteristics foster transparent and quick communication, other than resources at lower costs of transactions (Chauhan et al, 2022). All these advantages lead to improved CE sustainability performances.
Now it's time to understand how PSS is a possible right tool to connect all these ideas. This is because the above-mentioned digital technologies are already part of the PSS design and it comes easy to slide into Circular Economy principles. In fact, digital servitization adopts IoT to keep track of performances and collect Big Data to be analysed; at the same time knowing customer habits and needs is essential in the design phase (Chauhan et al, 2022), as we will see better later on. At the same time, servitization strategies are often designed to market products that are easily repaired, remanufactured and recycled.
This new way of thinking about the business and the product life cycle has some criticisms that make some people feel sceptical. The main concerns regard the possibility of the recycled products to 'eat' the market of the still unsold items (recycled PSS with lower margins cannibalise primary sales

products), leading to economic unsustainable situations (Chierici and Copani, 2016). Another preoccupation derives from the risk of reused products to not be feasible for technological improvements, even losing the sustainability advantage of circular economy principles (Chierici and Copani, 2016). The last big worry is the uncertainty about quantity, quality and time of products that come back through reverse logistics, losing economies of scale. It's notable that these are some of the preoccupations pointed out in the previous paragraph (Chierici and Copani, 2016), where Industry 4.0 technologies were not involved. Now, we can consider how some Industry 4.0 technologies, such as Iot, Big Data and Analytics can be adopted to overcome these issues (Bressanelli et al, 2018). Applying this, device conditions, operative status and data collected are monitored in real time and the firm understands faster how customers use the product and what they demand and expect. At this point it becomes easier for the firms, once devices are 'smart', scheduling upgrading on digital components, enhancing the value of the service provided while following the principles of Circular Economy (Bressanelli et al, 2018). At the same time these kinds of sensors are useful for tracking reasons, improving recovery of spare parts while reducing uncertainty (Pagoropoulos et al, 2017). Application of IoT technologies comes with Big Data and Analytics.

The network

Another important 'player' for achieving sustainability while implementing a digital-based service-oriented business model is the network (Opresnik and Taisch, 2015; Paiola et al, 2021). We refer to this term as "a set of roles and interactions in which organisations engage in both tangible and intangible value exchanges to achieve economic or social good" (Evans et al, 2017). But how is networking relevant for our purpose? According to case study analysis on 4 different Italian firms by Paiola et al (2021) it is for two main reasons.

The first one is the key role played by key customer and pilot users that creates an environment where innovations are thought, tested and defined (Paiola et al, 2021; Paiola et al, 2021). One of the firms examined, triggered their digital business model innovation because one key customer was not able to find someone who could help them to exploit their large installed base. This explicit need pushed the company R&D department to apply IoT technology, collecting important data then used to develop proper effective strategies. Results were surely positive both from an economic and environmental perspective (Paiola et al, 2021). Customer role is key in another way: value co-creation (Li and Found, 2017). As mentioned in the introduction, closeness to customers is essential in a servitization strategy and this factor is key not only for economic profitability but also to create social and environmental partnerships (Li and Found, 2017).

This key role can be even analysed as a pull effect, not only as push as the case mentioned above. Two other firms under analysis in the same paper show a more proactive attitude. They decided to exploit some specific customers to pilot new service versions and gain useful feedback. For example, a firm offered a contract with fees based on actual effective energy reduction rate, implementing in their PSS Industry 4.0 technology in a very extensive way (Paiola et al, 2021).

The second reason for considering networking as a boost for digital green servitization effectiveness is the role of high-tech oriented firms present in the value network. This is because developing IoT technology, platforms and devices, alongside Analytics and computer devices is something complicated from a technical point of view, almost impossible for manufacturing firms that have always operated in different sectors. The nearness and level of collaboration within the network is a crucial point for the success of business model innovation; it allows to have solutions as soon as required and a continuous upgrade of the technological advanced resources. These reasons and dynamics bring us back to the drivers of servitization presented in the introduction chapter (Paiola et al, 2021).

Application in energy management field

Across the different ways in which digital servitization can enable sustainability efficiencies, some academics and professionals have pointed their focus to the link between PSS and Industry 4.0 in order to get a model that enables efficient energy management. About this point our analysis starts from an innovative model presented by Sassanelli et al. that designs some promising guidelines to link digital enhanced PSS and energy management (and so sustainability). This model is thought to deliver a result-oriented PSS in the energy and residential sector adopting technologies such as IoT, Artificial Intelligence and Cyber Physical Systems (Sassanelli et al, 2022). These are "an integration of different kinds of systems whose main purpose is the control of a physical process and, through feedback, its real-time adaptation to new operating conditions. This is achieved by the fusion of physical objects and processes, computational platforms and telecommunications networks" (www.internet4things.it , 2020). Traditionally, Energy Management is a core activity in larger companies even if the technological potential is not fully exploited, while it's basically ignored in SMEs mainly due to lack of resources (Sassanelli et al, 2022). The potential key role of advanced digital technologies is enlightened even by the European Commission, according to which the so-called Smart Building can drive energy efficiency, safety and security efficiency and employee productivity (European Commission, 2017). Energy efficiency can be achieved by reducing electricity consumption and reducing energy losses for unused spaces; the American Council for an Energy Efficient Economy estimated a cost saving between 24% to 32% adopting smart Heating Ventilation Air Conditioning (HVAC) and smart lighting systems (European Commission, 2017). Increasing safety and security refers to both physical and informatic aspects that can be improved through better monitoring systems and better authentication procedures. The last point refers to improved wellness, comfort and convenience ensuring a better quality of living and consequently more productivity (European Commission, 2017). Another interesting fact pointed out by the EU Commission report is about the economic sustainability of smart buildings. These advantages are numerically shown in the following table 4.

Table 4- Sustainable economic advantages of smart buildings (European Commission, 2017)

Energy-efficient commercial buildings demonstrate
• 2 -17 % increase in resale value
• 8 - 35% increased rental rates
• 9 - 18% higher occupancy rates
• 30% lower operating expenses
• 9% higher net operating income
Source: Global Real Estate Sustainability Benchmark[7]

So, energy management is a topic dear to institutions that are investing in it and it’s an interesting field to investigate because it touches everybody, regardless of the business they are involved in. Once we have understood the actual potential of an efficient smart energy management, we can better explain the connection with PSS. Particularly, we start our analysis from a specific result-oriented PSS elaborated by Evogy Srl in collaboration with Politecnico di Milano, called ‘Simon the digital energy specialist’ (Sassanelli et al, 2022). This very specific model can be adapted to other contests and other organisations will be able to provide this kind of product-service systems once they are set in the production of smart household furniture and have acquired skills in energy management.

We will try to extrapolate important general guidelines from the specific ‘Simon’ case told by Sassanelli et al. What is surely needed is a data gathering system based on IoT embedded in existing devices, a simulation of the building (connected with the CPS of the equipment) and an AI based algorithm able to replicate operators’ competences in order to optimise energy management. Once it’s all set, the technology measures the environmental comfort, made by lightness, CO2 levels, temperature and some other factors allowing remote monitoring and adjustments, bringing a 20-to-40% in energy saving. The PSS, along with all the features illustrated, should be composed also by technology installation after floor plans analysis, proactive energy management and ordinary and extraordinary maintenance.

In the following tables (table 5), extrapolated from Sassanelli et al original paper, a resume of the Simon model is made. We re-propose them in order to provide a detailed and more technical explanation of the case, underling the key role of advanced digital technologies and considering that it can be a good starting point for similar companies to grab all environmental and economic advantages of this business model. These tables allow a case investigation from an engineering perspective, something that we are ignoring for technical reasons but that is worth mentioning.

Table 5 - resume of the Simon model (Sassanelli et al, 2022)

Service delivered	Digital technology used			Smart capability enabled	Type of PSS enabled	Benefits for customer	Benefit for service provider	Benefits for transmission system operator (TSO)
	IoT	AI	CPS					
Consultancy on the modelling and design of the building infrastructure	-	-	-	-	Product-oriented	• Customized design of the system • Digitized building planimetry (CAD).	Complete knowledge of the building and of the system to be installed (BIM).	-
Installation/start-up and commissioning of the required technologies	X	-	X	-	Product-oriented	System installed and kick-off.	• Complete understanding of plants' issues; • Virtualization of the physical plants and virtual test of different models; • Availability of data for simulation analysis.	-
Plant geolocation	X	-	-	Monitoring	Product-oriented	Ease of geolocation in particular for multi-site plants.	Database of both projects and plants for remote monitoring of internal and external conditions.	Detection and mapping of existing plant for VPP definition and creation.
Diagnosis and reporting: dashboard and graphic features	X	X	X	Monitoring	Product-oriented	Customized KPIs, EnPIs and reports.	Continuous monitoring of the systems.	-
Help desk for product, process and business	X	-	X	Monitoring	Product-oriented	Remote and/or on-site assistance based on the gathered data.	Possibility to optimize assistance based on data gathered.	-
Updates/upgrades of HW and SW	X	X	-	Control	• Product-oriented • Result-oriented	Always updated EM system.	Possibility to upgrade the system based on the system monitoring leading to an easier achievement of target consumption results on contracts.	Possibility to activate Demand Response mode of plants thanks to updated/ upgraded HW and SW.
Remote control from centralized platform	X	-	X	Control	• Product-oriented • Result-oriented	• Personalization of the user experience and of the comfort level; • Plants control.	Remote control of system functions and reduced on-site interventions; Plant dynamic set-up.	-

Table 5 continues

Service delivered	Digital technology used			Smart capability enabled	Type of PSS enabled	Benefits for customer	Benefit for service provider	Benefits for transmission system operator (TSO)
	IoT	AI	CPS					
Alarm management and sending of commands in single and aggregate formats	X	X	X	Control	• Product-oriented • Result-oriented	• Enabling of predictive diagnostics, service and repair; • System performances enhancement; • Plants shut-down avoidance; • Building environment discomfort avoidance.	• Reduced maintenance/ control interventions on-site; • Preventive maintenance.	-
Advanced data analytics and model construction and autonomous remote control of the entire building	X	X	X	Autonomy	Result-oriented	• Autonomous improvement of consumption and of the performance of energy systems; • Autonomous system personalization.	• Ordinary maintenance avoidance; • Knowledge of the entire operative life of the system; • Self-diagnosis and service; • Autonomous product operation; • Self-coordination of operation with other products and systems.	Real-time monitoring and possibility to activate Demand Response mode: dynamic plant management as a function of the electric grid balancing needs.
Demand Response mode for balanced grid congestion and electricity network services	X	X	X	Autonomy	Result-oriented	• Effective/efficient EM. • Possibility of creating real VPPs (Virtual Power Pools) of plants, to participate in the electricity services market and to intercept economic advantages both in terms of power and of energy.	Easier achievement of target consumption results on contracts.	• Balanced grid congestion; • Power and energy provision through VPPs in a dynamic economic way.

Starting from the Simon model presented by Sassanelli et al, we have seen a possible direction that smart household manufacturers and energy management companies can take. Providing this type of PSS, based on advanced digital technology, leads to consistent cash inflows for the company since it brings a constant saving for the customers that do not have resources, organisational or technological, to grab these environmental and economic advantages.

Another possible declination of digital servitization in the energy management sector is provided by Signify (previously known as Philips Lights) that offers light as a service. Through consistent implementation of Industry 4.0 technology (IoT just to mention one) they are changing the energy market while providing undoubted benefits for the environment. This case will be better discussed during the empirical research in the second paragraph. Anyway, it's a testimony on how manufacturers in the industry are shifting towards a service-based business model to embrace sustainability principles and to exploit technology advancements.

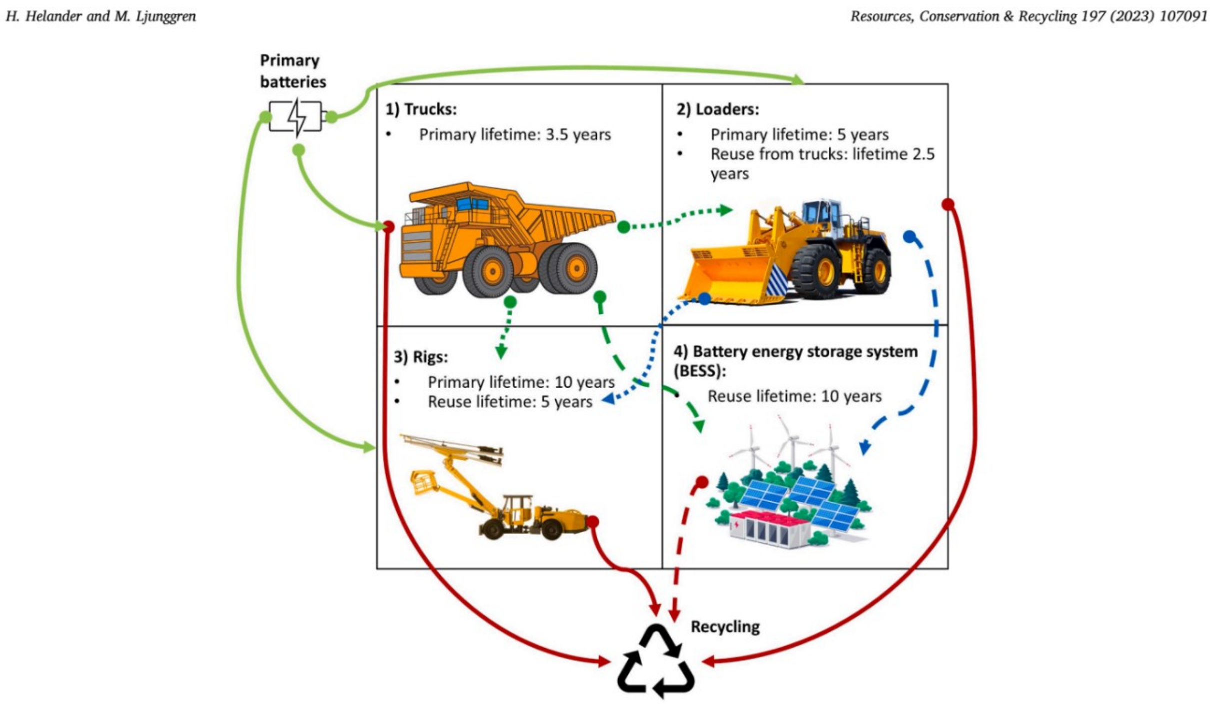
Case study for economic sustainability from automotive industry

As we have already seen along this literature review sustainability does not decline only from an environmental perspective, but also from social and economic. We have already seen something while we were discussing smart building advantages, but at this point we should provide some other evidence of the link between servitization principles and operational performance. Our starting point is a paper from Opazo-Basaez at al who investigates productivity gains coming from implementation of digital and green servitization. This study takes as a unit of analysis the automotive sector with data from 2015-2016 (Opazo-Basaez et al, 2018). The choice of the sector taken into consideration is quite important because in recent years it had to deal with a lot of regulations and a significantly increased sensibility for sustainability matters (Opazo-Basaez et al, 2018); this pushed every actor involved to rethink the business model and intervene along the whole value chain. Moreover, the electric branch of this sector is constantly growing in relevance, opening up new more sustainable business models, as it will be properly shown throughout this research. So, it is a good example of an economic sector that combines environmental dynamics and economic long-term sustainability. Now the point is to investigate whether servitization can be a right tool and if there actually is significant evidence of positive correlation. Furthermore, this is for sure a technologically evolved industry that fits well with the concept of applying ICT and Industry 4.0 on service design. Going on now with our case analysis, we define green servitization as "a service concept specifically designed to enhance digitally sustainable initiatives in both product development and product life cycle" (Opazo-Basaez et al, 2018). The aim is to achieve environmental benefits through specific service propositions and going straight to the result of this investigation we notice something very interesting. In fact, implementing digital servitization results to be fundamental in order to obtain productivity gains from green servitization (firms adopting both have a productivity advantage of 36,9% against those who adopt only green servitization) (Opazo-Basaez et al, 2018). On the other hand, green service strategy itself does not provide any particular advantage or disadvantage, while digital servitization alone does (Opazo-Basaez et al, 2018). This is very significant for the purpose of this paper because it confirms that servitization is not a perfect synonym for sustainability, but adopting advanced technology for service design and implementation is a great path for achieving it. In the very following sub-paragraph, we will present a new business model linked with service innovation that is strictly related to what we just said. Further in this body of work, even more specific details and cases of analysis will be presented.

Battery-as-a-service

Another interesting field in which servitization is revealing as an important tool to increase sustainability is the electric vehicles sector. For sure, the highly digitalization and the environmental friendliness propensity of this kind of products plays a remarkable role. This following case is reported by Helander and Ljunggren (2023) and is a good example of the connection between circularity, servitization and sustainability. The paper utilises materials flow (MFA=Material Flow Analysis) to investigate the impact on the demand of new products and items caused by the growth of a Product-Service Systems (PSS). The time period considered is from 2020 until 2050. The situation under attention is about an hard-rock mining-equipment manufacturer whose PSS is based on lithium-ion batteries offered as a service (Battery-as-a-Service), that can significantly reduce greenhouse gas emissions replacing Internal Combustion Engines. Additionally, it saves cost from reducing ventilation requirements and improving working conditions for machine operators, so the sustainable benefits appear clear under every dimension. 3 are the different vehicles commercialised for which the batteries are applicable: Trucks, Loaders and drilling rigs. Since batteries in different kinds of vehicles are exploited until different degrees of State of Health (SoH), batteries reuse and circularity are fostered; for instance a battery that is no more useful for a truck can still easily support a specific loader for additional time. Here we have in what we’ll call table 6 a schematic representation of the battery's possible journey.

Table 6 - schematic representation of battery possible journeys (Helander and Ljunggren 2023)



It's important to say that battery life cycle and degradation pace are not easily predictable and 3 different battery-flow scenarios are taken under consideration: 1) Business As Usual (shortened BAU) when battery subpacks are just sent to recycling at their end-of-life without any kind of reuse on different vehicles 2) Reuse: when batteries are reused exactly how it's depicted in the above figure and 3) Reuse-BESS when extra subpacks are used as BESS (Battery Energy Storage System).

Results of the investigation are now provided for different units of analysis, considering this specific situation as a closed loop in a growing market, with no external inflows needed.

In Reuse and Reuse-BESS scenarios there is a gradual increase in new subpacks displacement per year, compared to BAU. By 2036, the supply of subpacks for reuse is forecasted to get bigger than the demand, with a percentage of 13% of new subpacks displaced throughout this period. Clearly a lot of factors influence subpacks demand: rigs are the ones with the highest request (they are the most) but they need fewer subpacks per battery and fewer batteries per vehicle compared to truckers and loaders. Moreover, until 2025 almost 70% of the market for bigger trucks and loaders shouldn't have emerged yet and this brings to the fact that a significant supply of reuse subpacks shouldn't occur until 2035. This means that there is expansion potential of PSS offer (as depicted in the figure above) because a large number of subpacks become available from trucks and loaders and the annual supply of reuse subpacks for rigs surpassed demand.

By 2050, the yearly demand for new subpacks is estimated to be 8k units inferior for Reuse and Reuse-BESS than for BAU. With an increase of trucker-to-loaders reuse, the demand for reused subpacks increases and becomes saturated later. If all truck battery subpacks could be reused in loaders, the annual displaced new subpack demand is 31% (20 k units) by 2050, against 8% if there is no truck to loaders. Since reused subpacks have shorter life, higher inflows are required to match demand, so by 2050 annual replacement is 10% higher with reuse than in BAU case. This substitution rate increase is mainly due to rigs, because in the reuse scenarios subpacks have a 5 years lifespan (compared to 10 in BAU).

After this analysis of new battery supply, we move on talking about the raw material demand.

In the Reuse scenario, the raw materials availability starts to go up in the second half of the time period considered, because it is when the supply of recycled items becomes bigger than the demand. For Reuse and BAU cases, in the late 2030s a lot of recycled materials become available while the inflow of reused materials slows down, here the primary materials demand peaks. Considering Cobalt as an example material, during the considered period, adopting reusing and recycling practices can reduce the overall demand for new materials from 13% (just with reusing without recycling) to 58% (by high recycling efficient processes in BAU situation) compared to the Business As Usual without recycling scenario. Efficient and effective recycling has a way bigger potential than subpack reusing for primary materials demand reduction. Subpack reuse leads to a diminishing of new subpacks demand, but also to fewer subpacks that reach the end of life than BAU. Standing with the cobalt example, the following tables 7a and 7b show and clarify the different scenarios depicted just above, with the legend right after.

Table 7a - Recycled content cobalt: BAU, RU and RU-BESS scenarios (Helander and Ljunggren 2023)

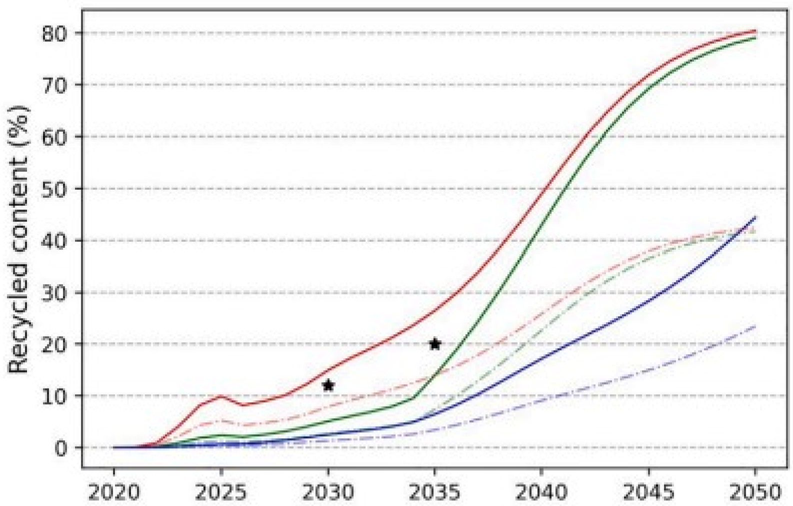
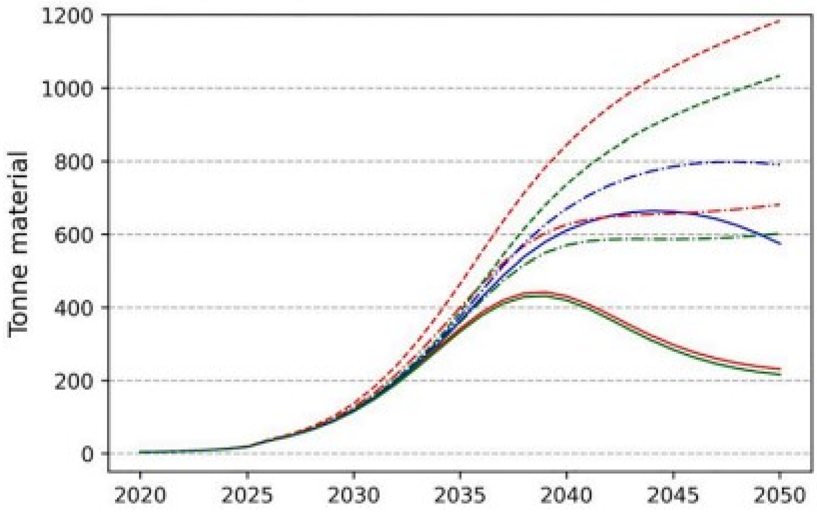


Table 7b - Primary material demand for cobalt (Helander and Ljunggren 2023)



Legend

From this specific case we can take some important observations. Once again, the role of the PSS design is crucial. All the reasoning about reuse and recycling make sense because batteries are thought to fit in every mining machine. Moreover, we can assume that recycling has, at the beginning, a smaller impact because it's delayed by battery reuse, which could become significant thanks to BESS applications. These BESS applications can, at the same time, be a feasible way to extend PSS offering, even if it could be a dangerous operation that requires good demand and supply forecast analysis and recycling efficiency.

It's not difficult to imagine the crucial role that Industry 4.0 technologies can play in this kind of situation, mainly for tracking reasons keeping demand and supply under control and monitoring battery status from remote, empowering all the possible scenarios effectiveness and efficiency.

Another Battery-as-a-Service case can be found looking at NIO, a Chinese electric cars company recently landed in some European markets. Its peculiarity stands on the battery offering, that's separated from the rest of the vehicle. They are indeed offered as a service, and they are chargeable, swappable and upgradable. The role of digital technologies is once again determinant to foster circularity and sustainability, but we'll analyse it deeper in the second chapter being NIO one of case studies reported.

In conclusion, these were a good example of a service-based business model that works as an enabler for the Circular Business Model that is supposed to drive sustainability results in the long run, with the facilitating help from new digital technologies. That specific situation is particularly interesting because it gives us food for thought, as it allows us to envision how smart servitization could involve critical components of complex products enhancing sustainability performances.

PSS design and upgradability

Now it's time to address an important point that has been already mentioned multiple times: the PSS design. The literature about this topic is still vague (Saranic et al, 2023) but it remains a key activity to actually grab the sustainability advantages of this business model, since this phase determines about 90% of the material use and 70/80% of the total cost of the product (Yang et al, 2013; Chen et al, 2015). In the literature it's possible to find different techniques to address its related issues (De Pauda Pieroni et al, 2017). To have a better understanding of the whole process, it's useful to cut it into 5 different components: value proposition, value creation, value delivery, value capture and value network (Moro et al, 2022). Value propositions can be considered the proposal from the company to the customers, what is offered (Moro et al, 2022) and in this phase some aspects are relevant since the early phases are the most important because changing the design here is less expensive. Anyway, it's crucial to rely on systematic methods and not just on experience to have better odds of success, because it's also the phase where the least is known (Chen et al, 2015; Bertoni, 2019; Saranic et al, 2023). The value propositions aspects more worth the consideration are the proposal of collaborative consumption without ownership (Cherry and Pigeon, 2018), promoting less material consumption, a more intensive product use and all the advantages that derive from close relationships with customers. These are for instance: providing cost and time savings, promoting a decrease in consumption, educating the customer about the use phase and adding specific service to enhance customer experience and prolong product life cycle (Moro et al, 2022). Value creation is a crucial phase too. For a sustainable PSS it's important to change processes, resources and skills involved, in order to integrate sustainable practices and choices (Cherry and Pigeon, 2018). Just for example products can be redesigned to influence customer behaviour and to push dematerialization (Moro et al, 2022). Value delivery is about how the PSS will be actually provided to the customer, with all the different possible interactions (Moro et al, 2022). Sustainability can be embedded with different interventions along the product life cycle, for example with effective maintenance, empowered by advanced technologies such as IoT (Suppatvech et al, 2022) and all those interactions that can lead to the best possible product usage and treatment (Moro et al, 2022). The next unit of analysis is the value capture. This can be defined as "as the process of securing financial or nonfinancial returns from value creation" (Toroslu et al, 2023). Here we can say that the offer extension aims to create sustainable value inflows through new contracts; cost efficient operations and risk sharing are crucial along with assessing lifecycle costs and risks of a product (Moro et al, 2022).

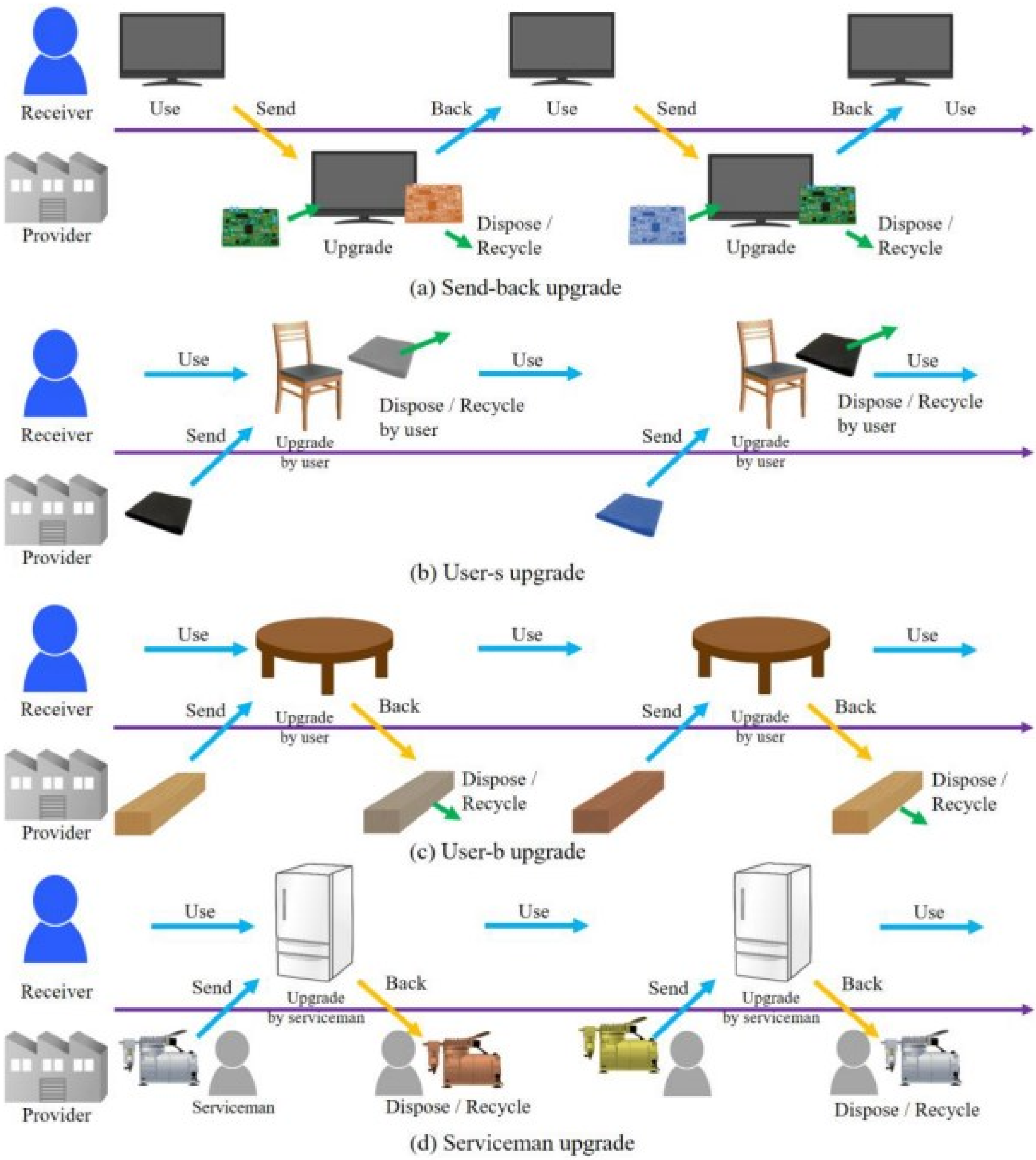
Another kind of analysis, not so different from this one, which is not rare to be found in the literature about PSS lifecycle, divides it in Beginning of Life (BoL), Middle of Life (MoL) and End of Life (EoL)/End of Use (EoU) (Saranic et al, 2022). The first consists of procurement, production and distribution, the second of maintenance, repair, use phase, insurance and all after sales services while the last point relates to all the activities after the use phase as collection, disassembly, recycling and others (Saranic et al, 2022).

Anyway, the first crucial step is moving from product-centric to system-centric design thinking and this implies such changes as considering downstream objectives as serviceability, upgradability and recyclability (Bertoni, 2019).

Design activity, even if it's crucial to embed sustainability features in the PSS, is something literature needs to investigate more in the future, since a sustainability evaluation method considered unanimously the best is still missing, also due to the difficulty of this multidisciplinary task (Chen et al, 2015; Bertoni, 2019; Liu et al, 2020; Saranic et al, 2022). Different approaches were proposed in the literature, but no one is considered flawless. One of the main issues is that firms see social and environmental sustainability as functional to economic gains and not, as should be, as standalone values (Saranic et al, 2022). For sure, when manufacturers decide the kind of PSS to offer, they should know that product-oriented PSS have bigger sustainability potential than use-oriented and result-oriented (Tukker, 2004; Yang and Evans, 2019). Considering the life cycle perspective of a PSS is another obvious aspect to consider during design and sustainability assessment, as already emerged in the above value delivery analysis. 2 key instruments for that are Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) that estimate environmental and economic impact of the product-service system (Saranic et al, 2022). For sure, a very helpful technology for sustainable design can be Additive Manufacturing (AM) or 3D printing. Since AM enables the production of just specific components of the end product, this can be exploited for maintenance and upgradability purposes, enhancing sustainability and long-lasting relations with customers (Chaney et al, 2022). Signify case study will provide useful insights on how 3D printing can be the right tool to access sustainable design.

At this point it is coherent to talk about another PSS feature that can play a key role in enhancing sustainability and that can be integrated in the design phase: the upgradability. Here is a definition of upgradability of an item: “something that can upgrade its functionality during operations and/or remanufacturing phase” and upgradable design means adding this feature to products since the very first phases (Shimomura et al, 2009). This hits probably the main sustainability issues of our society: overconsumption and over wasting. At the moment Europe’s material footprint has doubled the sustainability level, this means that in our Continent the total amount of fossil fuels, biomass, metals and minerals consumed is two times the level considered sustainable (Friends of Earth Europe, 2023). Upgradable PSS (Up-PSS) leads to an increased value offered without adding much material (dematerialisation of value) and rationalising material use and waste over time (Pialot et al, 2017).
Talking about ‘upgrades’, some academics have identified 2 kinds of: functional, easier to integrate but more difficult for foreseen, and parametric (Pialot et al, 2017). The first one refers to adding or removing functionalities to the item in question, while the parametric is about improving performances of something that the item is already making (Pialot et al, 2017). These upgrades do not need to be scheduled with large advancements (Pialot et al, 2017); particularly if the products are equipped with technologies such as sensors and IoT enablers that allow remote status monitoring and remote intervention. As we saw previously even in this case, AI can play a strategic role in the decision-making process like how and when to intervene (Pialot et al, 2017). That’s important because a customer that constantly requires the latest possible version of a product means a negative impact on the environment and another customer who does not require needed upgrades makes losing all the upgradability advantages (Pialot et al, 2017).
Clearly, not all components of every item can be upgraded in the same way. Up-PSS designers must consider costs and environmental impact when the PSS is thought of. In the next table (Table 8) 4 different ways are presented: send back upgrade, user-s upgrade, user-b upgrade and serviceman upgrade (Yamada et al, 2018).

Table 8: 4 different strategies to provide Up-PSS (Yamada et al, 2018)



In the first case the service provider, when it comes the time to update, collects the item from the user and a specialised technician does the work; then the updated product goes back to the user. This way ensures high standard quality since every upgrade is made by a professional but it's very costly since the whole product is sent back and forth between user and manufacturer. This transportation also has an environmental impact (Yamada et al, 2018).

Case (b), user-s upgrade and case (c), user-b upgrade, are so called because the upgrade is made by the users themself. The provider only sends upgradable components, reducing environmental and economic costs of the transportation. The difference between these two ways of action stands on the fact that in case (b) the waste disposal is made by the user (as common household garbage), while in user-b upgrade it is done when the user sends the disposed components to the service provider. Here a crucial role is played by waste disposal laws (Yamada et al, 2018).

The last scenario, Serviceman upgrade, means that a serviceman is sent to the user location where the upgraded components are installed. This situation fits well when you have to deal with massive machines which transport is very complicated (Yamada et al, 2018).

We can intuit that there are a lot of conditions that determine which kind of upgrade is actually the most recommended, the following table (table 9) schematizes and exemplifies these fitting conditions. For each upgrade way corresponds a value, High Middle and Low, that can be further converted in a number, respectively 1, 0 and -1; clearly the upgrade way with the highest cumulative score is supposed to be the best choice to apply (Yamada et al, 2018).

Table 9: Upgrade way decision matrix (Yamada et al, 2018).

Criterion \ Upgrade way	Send-back	User-s	User-b	Serviceman
Necessary technique	High	Low	Low	Middle
Influence on receiver's life or work by upgrade-operation time	Low	Middle	Middle	High
Weight of entire product	Light	Heavy	Heavy	Middle
Weight of target component	Middle	Light	Light	Heavy
Size of entire product	Small	Large	Large	Large
Size of target component	Large	Small	Small	Middle
Reusability of exchanged component	High	Low	High	High
Disposal cost occurrence of exchanged component	Yes	No	Yes	Yes
Inclusion of hazardous substance in exchanged component	Yes	No	No	Yes

In summary, PSS design, a crucial determinant to achieve sustainability through servitization, can be analysed under five key components: value proposition, value creation, value delivery, value capture and value network. The early design phases build the fundamentals for sustainable practices, such as reduced material use, shared consumption without ownership and enhanced customer relationships, vital for the sustainability perspective. Value creation is critical to integrate sustainable principles into making practices, while value delivery incorporates IoT skills promoting a sustainable and prolonged product life cycle. Value capture is more focused on economic sides, pointing on long term profitable relationships and cost-efficient operations. Even if other similar interpretations are proposed, life cycle analysis, even by means of instruments such as LCA and LCC, is fundamental to enhance design sustainability assessments.

During extended PSS life cycle, a pivotal role to contrast non-sustainable practices is played by upgradability. The choice of the upgradability strategies, that can be performed by a professional or by the user themself, is based on a series of environmental, technical and economic circumstances.

Even if the key role of the design phase is well acknowledged regarding the link between PSS and sustainability, the literature is quite lacking especially when it comes to design sustainability assessments methods. Keeping integrating AI, IoT, others Industry 4.0 technologies and upgradability is vital to progress in PSS design for a more sustainable future.

FINAL CONSIDERATIONS CHAPTER 1

In conclusion, our extensive literature investigation unveils a complex and evolving landscape, particularly shaped by the transformative influence of the Industry 4.0 revolution and its technological integration and implications. A prevailing theme, constantly found throughout this review, is the consistent acknowledgment of servitization as a power force for enhancing sustainability. Yet, historical literature was more filled with uncertainties, especially regarding the scale of sustainability benefits linked to Product-Service Systems (PSSs) and potential rebound effects. PSSs manifest in diverse forms, each carrying diverse potentials: while product-oriented ones exhibit limitations, use-oriented and result-oriented PSSs emerge powerful tools for effectiveness, with the seconds even more than the firsts.

This is because of a technological lag and the still non predominance of sustainability as a research and societal topic. In contrast, contemporary investigations present a more optimistic and assured perspective and a continuous increase of these factors unlocked by the Industry 4.0 revolution.

A focal point of this narrative is the critical role assigned to the design phase, emphasising that the sustainability of PSSs is strictly dependent on precise, technical and ad hoc design. While the importance of this phase is clearly highlighted, there exists an imminent need for more deep and accurate exploration in the next future. This urgency stems from the real potential the design phase holds, particularly in terms of upgradability, and its pivotal impact on resource consumption and conservation. This confidence is even more pronounced since the integration of advanced technologies like AI, IoT, Analytics, and others. These technologies not only paved the trajectory of servitization but also diversified its contributions for positively affecting sustainability, with Circular Business Models enhancing being particularly strong.

These conceptual analyses find robust support in empirical examples positioned throughout the chapter. Some examples serve the purpose of clarifying key concepts, while others, such as the 'Simon' case, carry profound implications for shaping the trajectory of future developments in this dynamic environment.

The next section (empirical investigation) will articulate in the following manner. First, work methodology will be briefly described, setting up the rules and modalities. Then, the collaborative companies will be presented, providing some numbers, and explaining their main projects and initiatives. After that, the findings paragraph will find light and all the knowledge acquired previously will be reorganised and presented coherently with our work and with what has been depicted in chapter 1.

CHAPTER 2

EMPIRICAL INVESTIGATION

In the following chapter we are going to run the proper empirical investigation, based on case studies analysis represented by actual companies. In the first paragraph the methodology will be explained, then the chosen companies briefly presented and then the crucial Findings paragraph will see light.

METHODOLOGY

The methodology adopted for the empirical investigation is qualitative and it is based on case studies analysis. According to Voss classification (Voss et al, 2002), we are working on multiple-longitudinal case studies. The case sample, that is theoretical and not statistical, is built to replicate literature analysed above. The chosen analysis method is the interview, run through calls and video-calls. Some reference authors are Voss, Tsikriktsis, Frohlich (Voss et al, 2002) and Glaser and Strauss, who contributed to case study analysis by developing the grounded theory model.
Companies for our work were selected to represent some crucial topics touched in the second part of the first chapter. Only firms adopting digitised service-based business models were selected, since we opted to point the focus on the different impacts these technologies can have in different sectors, more than underscoring what these organisations can do better than service organisations that do not adopt Industry 4.0 technologies. This late comparison can be done even discovering the potentials of advanced technologies, as it has been done here. Furthermore, we believe that in the future the trend that links servitization and sustainability will go in the same direction as technological innovation, so we will witness a modernization of the firms still applying non-traditional servitization depicted in the first half of the first chapter. A sample containing more firms were selected and approached, but only the ones presented in this paper have answered and accepted our interview request. For example, it could be interesting having some words with consulting organisations, but they did not give us the interview in the due time. Anyway, we are satisfied with the companies we have here, since they cover enough points to consider our empirical investigations profitable.

Chainable provides a fantastic example of sustainability achieved through circularity, thanks to a servitization business model strongly digitised. All of this in a sector that has not been widely servitized yet, but that can gain important results under this perspective thanks to digitalisation.
Celli group represents a service-based organisation already active in a sustainable field that increases its value network efficiency thanks to big investments in digital technologies. The network results to be an important actor to exploit sustainability potentials.
NIO is into the electric cars industry. This is an already sustainability centred economy in which the company is starting a very innovative strategy, commercialising batteries as a service. This can be a starting point for new markets, where modularity is applied even in contests where it was never supposed to be present until very now. This is an important case study because electric mobility will be a central topic in developed economics for the coming years, and the batteries are the components that concerns users the most.
The last company involved in this work is Signify. They are well known players in the energy management field. They offer light as a service in a sector that is significantly impacting on the environment, and thanks to their highly digitised servitization business model they are trying to make it more sustainable. It's even more interesting because it is a sector which everybody has to deal with.
Table 10 summarises what has been explained above and cites the managers who collaborated.

Table 10 - Summary of managers interviewed

Company	Interviewee	Role	Research interest
Chainable	Jordy Van Osch	Co-founder and CTO (Chief Technological Officer)	Circularity through digital servitization (Kitchens-as-a-service)
Celli group	Cesare Schiatti	Head of Celli digital solutions	Servitization strategy empowered by smart products, with network centrality
NIO	Daniel De Groot	Head of Nio Power Europe Infrastructure	Battery-as-a-service
Signify	Gianni Coppari; Stefano Magni	Marketing Manager; Innovation manager and marketing and communication director	Energy management field (Light-as-a-service)

The interviews are semi-structured and do not differ so much from one interviewee to another. We aimed to reach specific information on how digital technologies foster sustainability achievements. So, we firstly asked which digital technologies, particularly from Industry 4.0, are adopted in the servitization strategy and how they make a positive impact. Then the relationship between companies and customers are investigated if something particularly relevant was pointed out during the previous questions, and the most important results and initiatives highlighted. The last part of the interview is similar for each company, we try to understand the biggest obstacles in the sustainability-aimed business and which they think their future scenarios will be, in terms of technological investments and business strategy. After the interview, the record is transcribed and the codification is done. In this paper, for authors' choice, there will not be transcriptions and single codifications, but just one codification comprehensive of all 4 interviews. NIO interview has not been recorded for licensing reasons. The transcription was made by Word a part for the Celli's one personally made by the authors. Interview codification follows the technique depicted by Voss et al (2002) and by Corley and Gioia (2004). The process starts with open coding, pointing out emergent narratives from the interview. Then these are transformed into second order themes throughout the axial coding phase, focusing on specific actions, decisions, resources, capabilities, opportunities, challenges and other important aspects for the research. Finally, with the selective coding the aggregate dimensions are drawn. This pyramid scheme goes from detail to general considerations and from operative to strategic.

The interviewed managers and companies will be better presented in the next paragraph: they will be Cesare Schiatti by Celli Group, Jordy Van Osch by Chainable, Daniel De Groot by NIO and Stefano Magni and Gianni Coppari of Signify. After these presentations there will be a Findings paragraph, followed by the codification working for all the 4 interviews made. The findings paragraph will be aligned with the codification, and it will be useful to collect what has been learnt during the interviews in relation to what is written in the chapter 1; it will also provide interesting points for the very final discussion and conclusion.

CASE STUDIES

In the following section we are going to present the companies which collaborated on our empirical research, depicting some basic business characteristics and achievements of them. A particular interest in sustainability performance is pointed out. These introductions will be followed by the Findings paragraph, where the empirical evidence from the interviews is collected and properly presented. At the end of it, interviews codification will be attached, comprehensive of all four interviews conducted.

CHAINABLE

Chainable is a Dutch start-up, funded in 2020, involved in the kitchen production and servitization. They build high quality kitchens for housing cooperatives and institutional investors (Woonpartners was the first Dutch company to choose circular kitchens for their renting properties), and they offer them as a service, providing full maintenance and total care even after the end of the kitchen's life.
Every year, 13 millions of kitchens are substituted around Europe, which have a life span of 15 to 20 years and are not made of materials thought to be recycled or reassembled. This obviously translates into damage to the environment. To get their construction materials, Chainable uses 90% of recycled wood and 10% of recycled roadside waste. For every 'installed' kitchen, they plant 24 trees around the world in collaboration with their partner; this leads to 0,24 to 0,84 tons of $CO2$ absorbed every year. Their main objective is to achieve environmental sustainability through circularity in their business model and for this reason modularity is a key part of their design activities. According to the Alba's Product Circularity Index, Chainable's kitchens are 88% circular. Alba Concepts is a consultancy company for circular construction, and its Product Circularity Index is based on materials origin, waste scenario, technical lifespan and volume (bootle2bathroom.com).
Table 11, translated from the company's website, shows us a good comparison between Chainable modular kitchens and regular ones.

Table 11 - Traditional kitchens vs Chainable KAAS comparison (https://www.chainable.nl/kitchen-as-a-service)

FEATURES	TRADITIONAL KITCHENS	CHAINABLE KAAS
Cooking	V	V
Assembly	V	V
Service and maintenance	X	V
Control over energy consumption	X	V
Circularity guarantee	X	V
Sustainable materials	X	V
No unforeseen costs	X	V

All this data and information are retrieved from Chainable official website (https://www.chainable.nl/en/over-ons-chainable/) or company's LinkedIn page (https://www.linkedin.com/company/chainableofficial/).

Even from social inclusivity, Chainable is active. In fact, they build their kitchen in collaboration with the Diamant group, a Dutch association for people whose access to the labour market is not guaranteed, so they work for their inclusivity.

We had the opportunity to get a 14-minute-long interview through Google Meeting with Jordy Van Osch, Co-Founder and CTO (Chief Technology Officer) of Chainable. We were able to better investigate what matters the most for our body of work. That's the core of the first chapter: service-based business model and its link to sustainability gains with the presence of digitalization.

CELLI GROUP

The second case study of this second chapter is about Celli Group. Celli SpA was established in Rimini, Italy in 1974. They commercialise beverage dispensers for water, alcoholic drinks and soft drinks, through a servitization strategy.

Their aim is to offer to all human beings a new way to consume drinks, based on a new engaging experience and a total environmental sustainability, by leveraging their digital technologies and their industrial heritage. Specifically, they want to be a 'Beyond the bottle company', pushing for the plastic overcoming in the beverage industry. In fact, some reliable sources such as Guardian (2017) and British Petrolium (Statistical review 2017 of World Energy) tell us that plastic pollution is mainly caused by plastic bottle life cycle. This is because just to produce 1 L bottles are consumed 80 grams of carbon, 42 litres of natural gas and the 10% of the bottle itself in oil. Translating this data into carbon footprint it results 0,7% for a 1 L bottle. Meanwhile WWF reports that every minute, 30 thousand plastic bottles end up in the Mediterranean Sea. Recycling is not sufficient anymore. Celli's offer is based on total asset management, significantly exploiting digital solutions. Leveraging Iot and other digital technologies, they produce intelligent dispenser components like fountains, pumps and taps. After that they lease them to their clients (that are for example Carlsberg, Coca Cola, Forst, Sprite, Heineken, etc.) instead of selling them as a product-centric solution. Thanks to data and information collected from devices, they can provide a high-level service-based offer. All these dynamics will be clarified throughout the following interview. Worth to be underlined here is the role of the network in creating sustainable value. At the beginning of this digitalisation strategy the company was not able to develop a proper platform and other actors as Microsoft and PTC emerged as ideal partners. Thanks to their collaboration, a safe and easy to use platform has been created, perfectly fitting Celli's needs and offering. Also, customers are key for fully exploited sustainability potential. Celli's contribution in reducing plastic production and use is great but if the business customer uses their intelligent products to develop other sustainable strategies and initiatives, as reported in the Findings paragraph, results are even better.

We interviewed Cesare Schiatti, Head of Celli Digital Solutions, who provided us with great information and important reflections on Celli's business and impact on sustainability. Here are some Celli sustainability metrics and sources provided by doctor Schiatti himself during the interview.

Celli sustainability metrics and sources

- *Bottles Saved: 1 bottle saved per 500ml poured*
- *CO2: 1 CO2 kg every 4.5 poured litres*

This calculation considers, for both a kiosk and a plastic bottle for:

1. *Production*
2. *Packaging*
3. *Transportation*
4. *Maintenance*
5. *Waste management*

The delta comes from the CO2 kg per 100 litres: 0.09 for kiosks vs 22 for bottles.
We participated in a study in 2017 making a comparison among 3 main mineral waters and Celli water kiosks in the cities.
Some work has been done for beer and soft drinks also with Carlsberg and Pepsico in the EU.
Here some references:

- *Towards Lower Carbon Footprint Patterns of Consumption: The Case of Drinking Water in Italy - Article in Environmental Science & Policy Stefano Botto – Valentina Niccolucci – Benedetto Rugani – C. Gaggi 2*
- *LCA study of impact assessment in seven different modes of supply of non-alcoholic beverage - G. Chiellino, F. Balzan - eAmbiente S.r.l., 30175, Marghera, Italy*
- *International EPD® System - CARLSBERG CPC code: 24310 – Beer made from malt*
- *Trees Planted: 1 tree for one year every 26 kg of CO2.*

This also is a pretty standard measure, but you can find different acceptance.
If you do not know, it is interesting to know the rationale. Here you find the story and some references.
https://www.ecomatcher.com/how-to-calculate-co2-sequestration/

The interview was run in Italian and recorded via Zoom platform on 10-01-2024 and it lasted 25 minutes and 45 seconds.
All the information and data cited in this paragraph are extrapolated from the company's LinkedIn page (https://www.linkedin.com/company/celli-group/9) or from the official website (https://www.celligroup.com/it/Home).

NIO

NIO is a Chinese company, founded in November 2014. It's a pioneer and leading company in the premium smart electric vehicles market. This means that they design, develop, manufacture and sell intelligent and sophisticated electric vehicles, always working on ultimate driving innovations involving advanced technology like autonomous driving, electric powertrains and batteries. Their last breakthrough innovation, which is also our interest focus, is the commercialization of batteries as a service (Baas) strategy. On January 17th 2024 NIO was listed in the 2024 Global 100 by Corporate Knights, ranking 50th among the 6733 evaluated companies, upgrading 29 positions since 2023 scoring the maximum possible grade in sustainable revenue and sustainable investments (data declared by Chris Chen, managing director NIO business Europe on his LinkedIn profile https://www.linkedin.com/posts/activity-7153701425271709697-QJs3?utm_source=share&utm_medium=member_desktop).

Besides a wide range of services for the electric vehicles, NIO takes care of its customers in other ways, providing a joyful lifestyle. The so-called NIO houses, 125 stores located around the world, include relaxation areas, libraries, cafes and labs. These are very fashionable places, the house at West Lake Hangzhou won ‘China real estate design silver award’. Beyond the vehicles, NIO is also advanced in providing mobile inter-based power solutions, through an extensive network of battery charging and swap facilities. Clearly all of this includes even at-home solutions such as NIO Power House 2.0 and Power Plus.

As we have told before, NIO is, through NIO Life and multiple collaborations, engaged in shaping a joyful and sustainable lifestyle for its community. Hundreds of designers are involved in this project and they contribute to bottles, bags, clothes and other everyday items. In the fashion industry, NIO has its own brand in Blue Sky Lab, with sustainability as the key value of its activities. It even adopts automotive industry items to produce clothes because they are durable, resistant and with a lower impact in the making phase. Specifically, seatbelt, airbag and haptex are widely used.

FoodLab NIO is the appendix of NIO in the food and beverage sector and it aims, in collaboration with other expert players, to build the ISO9001 quality management system and BRC food safety management system. Through other collaborations, NIO is now active in the direct wine purchase and also in the wine pricing, reviewing and evaluation.

Our interviewee from NIO is Daniel De Groot, Head of NIO Power Europe Infrastructure. The interview was run on January 19th via Microsoft Teams, it lasted 30 minutes and 46 seconds and it was not recorded for licensing reasons.

All data and information cited in this paragraph are from NIO LinkedIn page (https://www.linkedin.com/company/nio/) or from their official website (https://www.nio.com/).

SIGNIFY

Signify, known as Philips Lights until 2018, is a Dutch company over one hundred years old, world leader in lighting for professionals and consumers, active in the manufacture of electrical machineries, electrical components and electrical equipment. They gained €7,5 billion in sales in 2022, with 29% of circular revenues, counting less than 1% of wastes to landfills and about 35000 people employed in 74 countries. They achieved carbon neutrality in 2020 and they have been in the Dow Jones Sustainability World Index for 7 straight years (since their IPO). They have also been named Industry Leader in 2017, 2018, 2019. These presented in table 12 are some of the results of their sustainability program ‘Brighter lives, Better world 2025’, in relation to United Nations Sustainable Development Goals.

Table 12 - Brighter Lives, Better World 2025 - Q2 2023 Results (Stefano Magni, 2023)

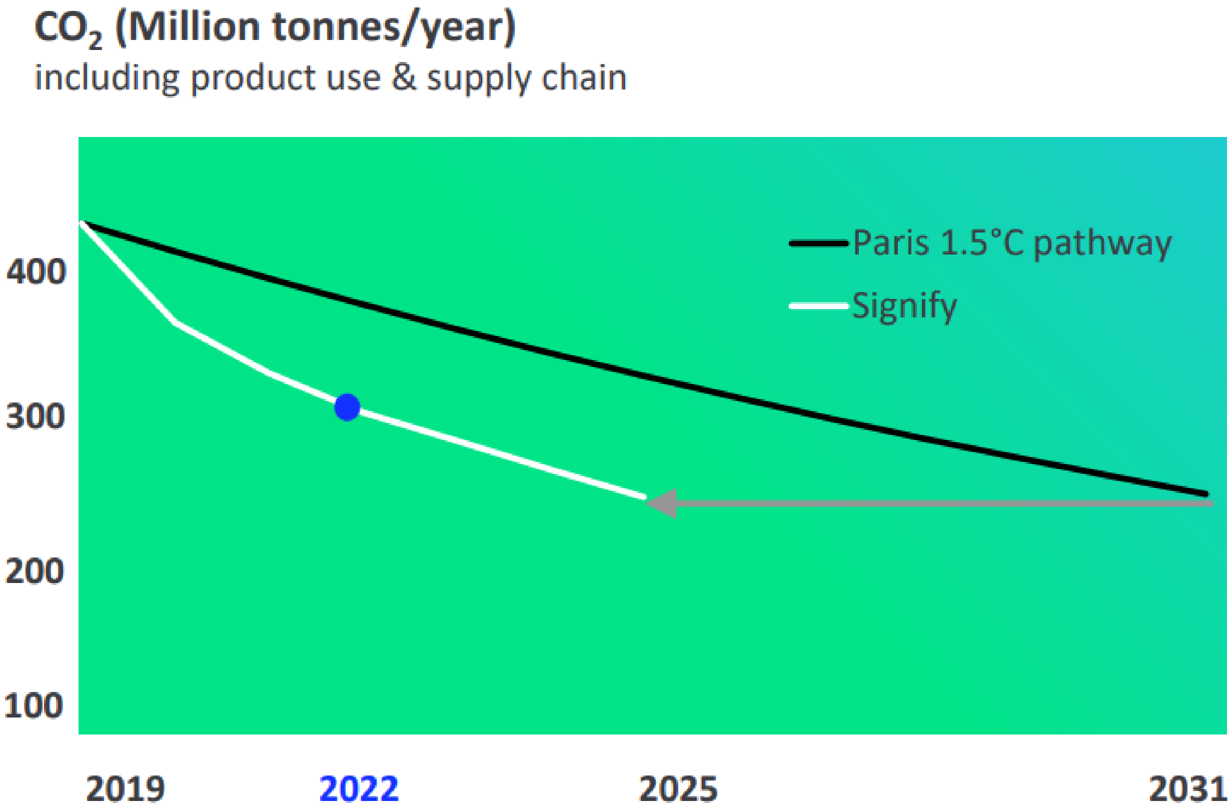
Brighter Lives, Better World 2025 – Q2 2023 results

			Target	Result
Better World	Climate action	Carbon reduction over value chain	156 MT	185 MT
Better World	Circular economy	Circular revenues	25%	29%
Brighter Lives	Food availability Safety & security Health & well-being	Brighter lives revenues	25%	28%
Brighter Lives	Great place to work	Women in leadership positions	29%	30%

Programs						
	Carbon neutral operations 100%	100% Renewable Electricity 57% covered by PPAs	% Waste to landfill <1%	Supplier sustainability 97%	Lives lit 8.7 million	Safety at work TRC = 0.17

A very remarkable point, that shows the real sustainability commitment of this company, stands on the fact that they aim to achieve the Paris agreement's 1,5°C target by 2025, 6 years earlier than 2031, the set deadline (table 13).

Table 13 - Million tons of CO2 per year (Stefano Magni, 2023)



Their business model innovation is based on light servitization (Light-as-a-service) exploiting the power of IoT technology (IoT lighting), thanks to the affiliate platform Interact. Basically, in their Light-as-a-service, they provide lighting for an annual fee, keeping the ownership and so ensuring monitoring, maintenance, repairing, upgrading and end of life management.

Signify makes great investments in research and development, like 4,8% of the revenues and owns about 20300 patents worldwide, besides collaborating with more than 100 Universities. An important recognition for Signify research activity was awarded in 2011, when the L-prize was won thanks to a 60W-equivalent light bulb that consumes only 10W. In 2012 was launched Philip Hue, the world leader system for connected lightning in the house buildings. Since that, a lot of interconnected smart products have been developed that co-work with connected house platforms and apps. In 2014 Signify invented the so-called Indoor Positioning system, by which lighting equipment sends their position through wavelength. Thanks to this, retailers can offer personalised services to increase revenues and customer fidelity. Their scientists invented the first 60W-equivalent LED light bulb, the most energy efficient in the world. More recently, in 2018, Signify became the first in the world to commercialise Li-Fi technology for office lighting systems, essential wherever Wi-Fi is absent and the connection

not stable. Thanks to the partnership with IoT Interact they have launched their connected LED lighting, that will be better explained in the next paragraph after the interview with the manager. These and other interesting data can be found in the company official website (https://www.signify.com/it-it), official LinkedIn page (https://www.linkedin.com/company/signifycompany/) and additional material attached at the end of this presentation was personally provided by Signify's Innovation manager and marketing and communication director Stefano Magni. The mentioned additional material, since it's not reachable on the web, is available at the link here that opens a Google Drive folder with the PowerPoint in it (https://drive.google.com/drive/folders/1tjKSCEcuKU9dBTkIjXHBd2nn61ok_iXp?usp=sharing).
Signify case study was analysed through a phone call with Stefano Magni and a video-call interview with Gianni Coppari, marketing manager at Signify.

FINDINGS

Explained the methodology and introduced the companies, it's time to describe the empirical evidence that was erased from our interviews, before dropping the very last words in the Conclusions chapter. The findings that will be written here find correspondence in the codification document at the end of the paragraph (Table 16). We decided to make just one codification that covers all the interviews, in order to get here a more organic analysis. Since we selected the interviewed companies in a way to explore different concepts proposed in the first chapter, specific references to them will be made throughout this paragraph.

All the companies are very focused on providing sustainability through their service-based business models and each of them rely heavily on digital technologies. This does not mean they have fully abandoned product centric businesses, but they are, at different paces, moving toward servitization. For example, NIO still gives the possibility to buy both electric cars and batteries, ignoring Battery-as-a-service proposals, while Signify is implementing Light-as-a-service mainly in the Netherlands and UK, with the demand in Italy being a little bit slow to increase. The most exploited technologies are IoT, sensors, cloud computing and Big Data analytics. Additive manufacturing, as anticipated in chapter 1, can be very effective and helpful in the design phase.

Embodying sensors into commercialised objects is resulted to be a key aspect in service offering. This is because it enables a series of opportunities such as remote monitoring, remote and predictive maintenance and remote upgradability through software, fundamental to gain environmental and economic advantages from digital servitization strategies. In fact, this allows diagnosing and interventions such as repairing without moving polluting vehicles neither once but just through software. In addition, having a constant look on components status and planning predictive and preventive maintenance avoid almost completely products downtime and emergency interventions, boosting customers and company economic sustainability. In the same way, these advanced technologies allow technicians to make upgrades on singular components from remote, which was not possible without this monitoring activity and full knowledge of product status. If the supply chain is not fully controlled by product manufacturers, this monitoring activity is helpful also to efficiently schedule components availability and furniture with partners, supporting the above explained processes. Keeping track of product performance can be useful also to monitoring marketing campaign results and to implement new ones. For this situation, a good example has been provided by Cesare Schiatti of Celli group. He told us that Getfit, a gym chain, has put Celli's dispenser in their venues that can be activated according to individual gym subscription premiumness. This works with particular bottles with a tag in them associated with singular accounts, this tag gets scanned in the digital water dispensers. At this point, the machine contacts Celli's back end that calls Getfit back-end that concedes or not the water supply. Another example, always provided by Cesare Schiatti, comes from Expo Dubai 2021. In this event Celli, in collaboration with PepsiCo, put some dispensers from which people could take water only if they previously bought a bottle associated with a determined number of refills. As the same as above, bottles were tackled with a chip to be scanned on the machine that told if and how many refills had the specific bottle left. These scanners also showed the quantity of plastic saved with these initiatives. Thanks to digital machines, it's easier to design marketing campaigns and keep track of their performances with a level of detail not possible before, fundamental to increase investments efficiency. These small examples show greatly how the network can boost sustainability in a service-based b2b relationship. Celli developed their digital world thanks to high-tech external actors and then their clients can develop sustainable strategies with their products thanks to Celli's dispenser.

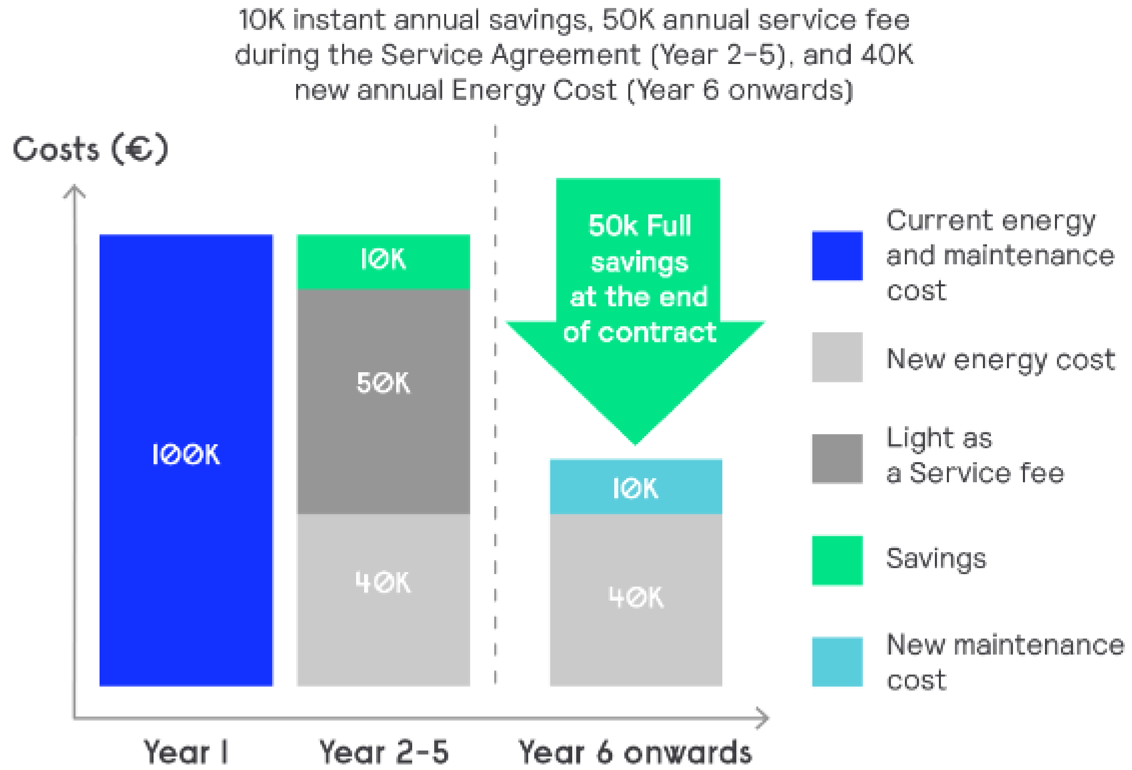
Keeping this kind of control allows manufacturers to provide another key service: products and components upgradability. With the degree of knowledge on item status it becomes easier to schedule upgrading at the perfect time and, when it's possible, perform them remotely through software. The advantages in sustainability terms are remarkable: product life is prolonged since components performance is improved, reducing breakdowns and integrating technical developments. If all of this is performed from distance through software upgrade, there is also a saving in CO2 consumption and in production of pieces.

About these later concepts, a key role is played by the design phase of the PSS. Our empirical investigation confirmed what literature suggests: it's key to embody sustainability since the very first moments and technologies can be very helpful. Using 3D printing is one possibility to engage in sustainable design and it's something relatable for every business discussed. It enables to reduce carbon footprint in manufacturing and transportation phases, enhance circularity by adopting recycled and recyclable materials, fostering easy disassembly and avoiding screws and glues. Moreover, Additive Manufacturing favours modularity. This means that final products can be easily disassembled to allow components upgradability, recyclability and remanufacturing, prolonging product lifecycle as written above. If this technology is combined with on-demand strategy it helps to make the whole supply chain greener and simpler, achieving zero waste in the production phase. Modularity, for the reasons mentioned, is something very important that should be done even without 3D printing technology. For example, in the furnishing business, Chainable adopts complete modularity without 3D printing (while Signify does), but thanks to the technology embodied into their products they have achieved great results in circularity.

Pure environmental benefits obviously depend also on singular businesses and the industry they compete in

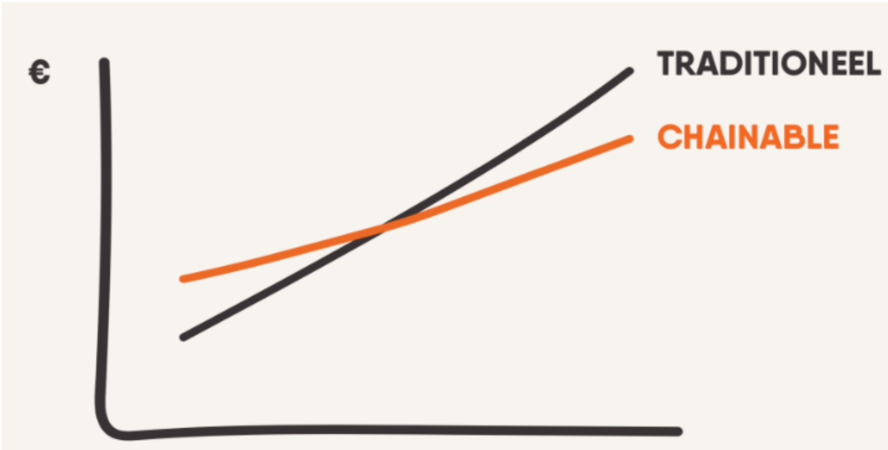
The shift from a product centric business model to a service-based one with a high level of digitalisation, opens the door to new business opportunities that were not possible before, and that can bring significant sustainability advantages, as seen in the previous chapter. Some of them we think will rapidly spread in society. The energy management field that offers a result-oriented approach is something that potentially touches everybody, since everybody consumes energy. If the gain for private residences is maybe not remarkable, for big buildings like hotels or factories it's very interesting. For example, the hotel industry has to reduce carbon emissions by 66% by 2030 to meet the Paris agreement standards (Stefano Magni, 2023). Light-as-a-service business model providers can help to reduce energy consumption to an efficient level, consequently lowering the energy fees while providing all sorts of needed service explained above: from installation to maintenance and upgradability (table 14). All of this in front of a periodic fee that eliminates the heavy upfront investments. This kind of product service system will be key for the energy management field because the lighting technology (like LED) is not supposed to develop a lot more and this can represent a viable sustainability option. That's a way to impose sustainability even in sectors where technology is developing slowly.

Table 14 - annual savings example from Signify (https://www.signify.com/global/lighting-services/managed-services/light-as-a-service)



Electric mobility is a topic that will surely dominate the public debate in the next future. This relatively new business is seen as a new frontier of environmental sustainability. Its main issues regard specific components: batteries. A way to partially mitigate this comes from a digital service-based business model: battery-as-a-service. Besides all services related with maintenance and upgradability already discussed, and some more business specific such as battery charge and swap stations, this business model is important for other reasons. Batteries are the components with the shortest life span in an electric vehicle, commercialising them separately allows them to swap or recharge them and perform upgrades and maintenance. This prolongs vehicle lifecycle with only 10% more batteries in the market (this for the NIO case, but we believe that shouldn't change drastically for other players). Moreover, thanks to this swap and recharge mechanism, batteries last longer because they are not consumed only by heavy users but also by light users. Another environmental key aspect is that, keeping battery ownership, the manufacturer can schedule components availability and properly manage the end-of-life phase, which we all know to be critical for these products.
This battery-as-a-service business model is a great case that shows how servitization applied on crucial components of complex goods can prolong their life, allowing experts to manage the critical phases for the environment and contributing to solve issues that slow environmental gain.
We have already discussed environmental sustainability impact, like prolonged product life cycle, circularity, carbon emission reductions and we have also said something about economic sustainability. The gains here stand of having a greater total life cycle cash flow for the manufacturer and not paying a huge initial investment for the customer who does not have to worry anymore about future unexpected costs. It's important to specify that not all the products are easily affordable. For example, the Chainable manager told us that their kitchens have a lower life cycle cost than regular kitchens, but the upfront investment is generally higher (table 15, horizontal axe indicates the time dimension). This can be due to the fact that high quality materials not harming the environment still have an important cost that gets recovered by the customers with no further costs and much longer lasting products.

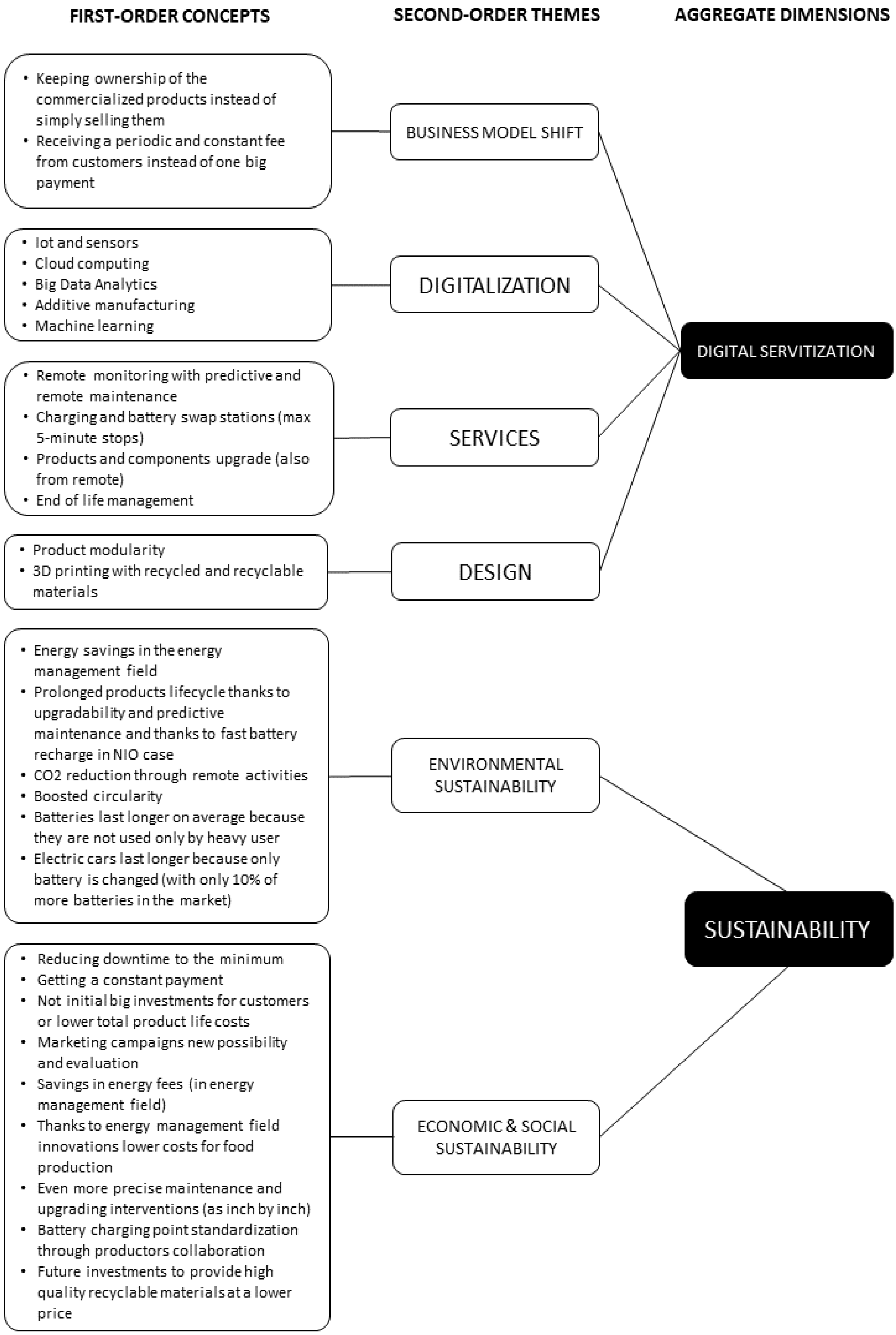
Table 15 - Chainable Total Cost of Ownership compared to traditional kitchens (https://www.chainable.nl/kitchen-as-a-service)



Digital servitization has the potential to increase the social aspect of sustainability too. Firstly, without huge investments, improving accessibility to some services and then other sustainable action can be made. For example, greater accessibility to some specific Signify's lightings reduces the costs of food production, the water utilised and the land needed, enabling the food to be distributed to a lower price for poor people without destroying territories. Furthermore, social sustainability derives from the environmental savings, production reduction and pollution decrease, since the poorest people in the society are generally those that pay more for non-sustainable actions.

About future perspectives, some common frames coming from the interviews are interesting. We can say that service-based businesses will invest heavily in technologies soon. High digitalised companies will try to get even more specific insights from products they have in the market, with a degree of precision that allows them to create new strategies and to intervene in very detailed components of the products. For example, in the kitchen-as-a-service business it will be possible to execute maintenance and upgradability inch by inch on the products. Similarly, in the energy field more precise technology will allow a more efficient consumption management. These technological improvements will come also from players collaborating with one another, as Daniel De Groot told us. In electric mobility for instance, they expect to work on a standardisation of the battery charging points and to deal with public entities in order to stabilise the power grid by lending batteries at the stations for these purposes. Again: technological upgrades to better sustainability. In this regard we have some clarification that should be done. Some businesses are, in fact, not feasible for these innovations. As Celli's manager told us, they put in the market some products that are not very expensive, this means that it will be difficult to equip them with sophisticated digital tools, because the costs for customers should increase too much. So, at the end of this reasoning of future trends, what emerges is that the digitalisation trend will not stop and, where possible, it will become even more impactful. The results will be an improvement of sustainability and the likely follow of those companies that are shifting to a service-based business model but that are lagging behind technologically. We also expect more pronounced results on social sustainability. This could derive from the lowering price of sustainable materials, in order to get sustainable smart PSS available for more people, whenever price is still a constraint factor, as it is in the Chainable case for example. Technological progress should also aim to make products accessible for poor people, reducing the production costs and offering them at a low fee, or at least avoiding big initial investments. What Signify is doing in the food production sector is going in this right direction.

Table 16 - Interviews codification



CONCLUSIONS

It's now time to collect our thoughts and depict some conclusions. This research work was meant and finalised to understand which kind of impact digital technologies had about the relationship between servitization and sustainability. That's a relatively young field of studies, and this explorative work tried to combine literature investigations with empirical case studies, in order to answer the research question.

In the first chapter we have seen how literature looks at the relationship between servitization and sustainability, with special consideration on how digital technologies have impacted, particularly from Industry 4.0.

We can say that academics have always captured the potential of service strategies, but before the digitalisation era it was blurrier. In fact, implementing technologies opens a lot of new possibilities to reach sustainability from environmental, economic and societal perspectives. This was anticipated in the literature review and then confirmed in our empirical investigation through the 4 interviews.

Digitalisation implies the possibility to keep track of the installed base, giving the chance to prolong product life thanks to predictive maintenance, remote interventions and upgrade of specific components. From the environmental side these are all positive introductions: there is a reduction in carbon emissions thanks to the possibility to work from distance through software, reduction of items produced and wasted that generate negative impacts and the possibility to manage circularity in the best way.

All these very positive activities are facilitated when the design phase is run in order to embody sustainability in the Product-Service system. In fact, we have been told how modularity is key to allow easy circularity and upgradability of products and components, thanks to the possibility to disassemble them and work through software in a very precise manner. A technology that can play an important role in this phase is the 3D printing or Additive manufacturing that when combined with an on-demand production strategy also fosters waste and overproduction elimination.

Furthermore, every business where digital servitization is applied provides specific positivises, with also the creation of new opportunities. Just to refer to our case studies, having a lighting provider which also manages the energy consumption through very sophisticated technologies allows great saving of energy.

At the same time, battery-as-a-service is a new business opportunity created thanks to technological improvements. It goes to partially solve the problem of specific components slowing down product performances in terms of sustainability unlocking new interesting perspectives.

From economic and societal sides too, digital service-based business models provide advantages, both for the manufacturer and for the customer. With the producer that manages all maintenance and upgrades stuff, machine downtime is basically avoided, products perform great for a longer period of time and when their life ends there is no worry for recycling. This is possible also thanks to supply chain simplification given by full time monitoring. The provider is fully responsible for product performance and sometimes for results obtained, with no unexpected costs for the customer anymore. This technology embodied into products also unlock new marketing opportunities and for the same reasons, permits to keep under-monitored performances of items and from investments, making companies spend money in a more efficient and effective way.

With these business strategies there is also a total cost of ownership for products that is lower with respect to owning them in the traditional way. This translates in a greater accessibility to some services, even more when there are no upfront investments but just a period fee to be paid; unfortunately, this is not always the case for now (see Chainable example). For the producer that decides to adopt this business model, there is obviously an economic advantage of having a continuous inflow of money, bigger than what they would have received before this shift into digital servitization.

Future perspectives on this topic will revolve around technology improvements and expansion of service provider networks. These new investments will, in our opinion, drive a big portion of PSS providers that are not digitalised yet, to invest in technology in order to fully exploit the business model potential. We think that there will be a spread of digital servitization strategies in almost every possible field and that this will be the dominant strategy for the new technology introduced in the market. We also expect the literature and the experts to elaborate a more shared and comprehensive way to better evaluate product service system sustainability. We also expect it to deeply investigate the role of the design phase and to achieve a shared knowledge on how to improve sustainability through it.

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