Product-centric or product-service design? Design for sustainability strategies in the manufacturing field

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Abstract: Nowadays, the growing emphasis toward sustainability has led manufacturing companies to pay more attention to social, environmental, and government aspects, while striving to boost their revenues. Companies approach sustainability to meet different needs such as responding to the increasingly stringent regulations of policymakers, satisfying customers who are more focused on sustainable practices, making efficient use of resources, and gaining a considerable advantage over competitors. In this context, different design for sustainability (DfS) strategies are becoming a relevant aspect for manufacturing companies. Among the DfS strategies, it is worth mentioning the focus on refining product design or the development of completely new products by means of choosing sustainable materials or adopting cleaner technologies. Another increasingly popular DfS strategy relies on the shift from the traditional product-sale models to Product-Service Systems (PSS), since recognized by several literature studies as more sustainable, considering the potential to extend the useful life of assets and improve resource efficiency through the reuse and recycling of components. This paper aims to understand the strategic approaches in terms of DfS that manufacturing companies are adopting to comply with sustainability goals. An explanatory design has been adopted to understand the main company drivers affecting the different strategies of design for sustainability. Firstly, quantitative results derived from the analysis of 215 Italian companies are displayed, followed by qualitative interview interpretation. From the analysis, the dimension of the organization and the sector seem to affect the design for sustainability approaches. Qualitative research focused on large companies, more dedicated to sustainability matters, identifies additional factors influencing such strategies, including external and internal drivers, product typology, digital technologies, and core business considerations.

Keywords: Sustainable strategy, Design for sustainability, Product-Service Systems (PSS), Manufacturing.

1. Introduction

Our society is nowadays going through a fast decline of the ecosystems we are living in, because of the pollutant emissions we are delivering into the atmosphere and the increasing consumption of natural resources, constituting the main cause of climate change and resource depletion (United Nations Global Assembly (UNGA)., 2015). Due to these circumstances, a variety of industrial sectors, including manufacturing, have been pushed to adopt more sustainable production methods in order to comply with more stringent regulations set by policymakers (The European Commission, 2019). Beyond the regulatory motivation the industrial context has grown over time increasingly aware of the need to adopt more sustainable practices and has identified additional benefits. These benefits include: (i) satisfying customers, who are becoming more conscious of sustainable practices throughout the entire supply chain (Westin et al., 2022); (ii) making efficient use of resources, which lowers long-term operating costs (Despeisse et al., 2012); and (iii) becoming more competitive (Morioka et al., 2017).

Companies are approaching sustainability by following different strategies: some focus on improving the design of their products, trying to make the production phases more sustainable or to improve performance during the use phases of the product itself. Other companies, on the other hand, are trying to improve their sustainability performance by adopting novel business strategies (Ceschin and Gaziulusoy, 2016), (Galimberti et al., 2023). For example, offering integrated product and service solutions has proven potential benefits in terms of economic, social, and environmental perspectives, as companies improve resource utilization and competitiveness (Gaiardelli et al., 2014). Research on this phenomenon is discussed largely under the topic of Product-Service Systems (PSS) (Baines et al., 2007).

With a specific focus on Italian companies, the paper aims to understand how industrial enterprises approach sustainability at a strategic level, considering, in particular, their orientation towards Design for sustainability practices, involving both products, services or a combination of the two. Specifically, the intent is to understand whether there are trends or common points among companies that approach sustainability in the same way, in terms of, for example, size, market orientation or industrial sector. The objective of the article will be tackled through a mixed method research combining quantitative and qualitative approaches. Quantitatively, exploiting data from a group of Italian companies, while qualitatively, by harnessing two case studies: one in the steel and another one in the automotive and electrification manufacturing sectors.

This paper is structured as follow: Section 2 presents the background of this study, highlighting the links between PSS and sustainability. Section 3 presents the

methodology employed, while section 4 the quantitative analysis, based on the insights coming from 215 Italian companies. The two case studies are discussed in Section 5, where two different companies are presented and analyzed. Finally, Section 6 discusses the main outcomes of the research, while Section 7 summarises the conclusions of the work, focusing on the limitations of the study and the further research avenues.

2. Literature background

The current climatic conditions on our planet suggests an urgent call to action by all countries to transform how human society operates to achieve global development while balancing social, economic, and environmental sustainability (Hristov et al., 2023).

The role of companies in the Sustainable Development transformation has been the object of attention of both academics and practitioners (Leonidou et al., 2024; Mio et al., 2020) which have stressed, among others, the importance of the designers (Rocha et al., 2019). The terms Design for Sustainability (DfS), "eco-design", and "life cycle design" emerged early in the 1990s (Walker and Giard, 2013) referring to design approaches specifically oriented to reduce the life cycle environmental impacts (inputs and outputs) of the products of our production processes. DfS embodies the three pillars of sustainability – economy, environment, and society – but it goes beyond simply defining green products to embrace how to satisfy consumer needs in a more holistic, sustainable way (Crul and Diehl, 2006). In the last decades, exploration of DfS approaches has broadened this field (Ceschin and Gaziulusoy, 2016), which no longer covers product innovation level (i.e., design approaches targeting improving existing or developing new products with better environmental performances) but also the way production and consumption are organised, thus at the PSS innovation level (i.e., integrating products and services to better fulfil customer needs).

The most cited definition of PSS (Haase et al., 2017) specifies the environmental benefits of this "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" (Mont, 2002). In addition, PSS can increase revenues and competitiveness of companies, and establish longer and stronger relations with customers (Neely, 2008). Finally, there is also the recognition that PSS offers social benefits (Ness, 2009). However, PSS models are more difficult to develop and the sustainable benefits cannot be guaranteed by definition. Within the context of DfS, Sustainable PSS design challenges are identified (Hernandez, 2019; Vezzoli et al., 2015).

However, product level innovation is not less important but is still a requirement for the product-service system level (Ceschin and Gaziulusoy, 2016). This because the products included in the PSS have to be properly designed (i.e., with a low environmental impact in the various life-cycle phases) (Ceschin and Gaziulusoy, 2019).

3. Methodology

To understand the strategic approach that industrial enterprises are adopting to improve sustainability, a mixed method research approach was selected (Gelo et al., 2008). Both quantitative and qualitative data were used to gain useful insights and achieve the research objective. Specifically, quantitative data are embedded within a primarily qualitative design (i.e. a grounded theory design). This is because the empirical studies addressing the research objective are mainly qualitative, thus we suggest that quantitative data could improve the understanding of the phenomena. Quantitative analysis was performed, firstly, identifying a list of companies interested in servitization topics, i.e., businesses involved in a network working on topics related to servitization. Then, secondary data of these companies were collected from the ORBIS database, often used for gathering data such as industrial sectors, number of employees, turnover, etc., and, directly, from the companies' websites. Specifically, business characteristics such as sectors, number of employees, gross profit, and market orientation were gathered being possible variables moderating the discussion. The companies' websites were screened to collect their servitization level and their strategies for sustainability. For this purpose, we distinguished between the sustainability approaches focused on product design and product and service design. Following, the qualitative research was conducted through two representative case studies selected among the sample analysed in the first step of the methodology to deepen the understanding of drivers and barriers connected to different strategic approaches to sustainability. The information provided is based on the extensive experience of two authors of this article, who have spent over two years working closely with the mentioned companies. They have actively participated in research projects and engaged with individuals across various departments, ranging from research and development to technical sales engineers and service department representatives.

4. Quantitative analysis

The sample is representative for Italian companies that have a strong commitment to services and PSS culture. A total of 215 companies were analysed. Companies were classified according to three main business characteristics: dimension, sector and market. By looking at their turnover and number of employees, the dimensions of the companies were identified. The sample is distributed among SMEs (defined by <50M$ turnover), and large >50M$ turnover), among which we also distinguished very large enterprises (defined by >1000M$ turnover). The sample is thus constituted as follows: 33% of SMEs (71 companies), 45% of large (96 companies), and 22% of very large (48 companies) enterprises. The majority of the sample is characterized by the companies involved in the Industrial, electrical and electronic machinery sector (99 companies, 46%), followed by Wholesale trade (19%), Services to business (9%), ITC (8%), Metallurgy and metal products (5%), and others. As far as the sector is concerned, the companies were divideed according to the

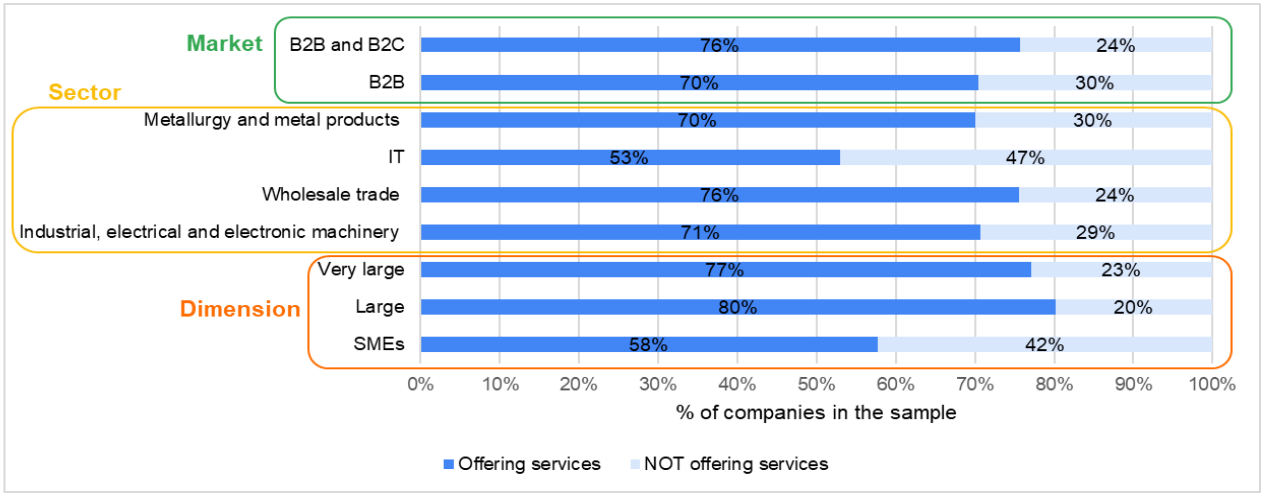

Figure 1: Companies offering services (referred to Table 1)

classification already provided by the ORBIS database. The market orientation is predominantly B2B (149 companies, 69%) with the remaining combining B2B and B2C.

4.1 Service offerings

Even though the analysis was performed on a selected sample of companies interested in the servitization process, only 72% of the total sample of companies have services in the business portfolio (155 companies out of 215), as detailed in Table 1. Figure 1 shows how this average level changes when considering the dimension, the industry and the market orientation. SMEs show lower adoption of services than the other two dimensions, only 58% of the SMEs provide services to their customer. While large (80%) and very large (77%) enterprises provide more services than the total average. It is also possible to observe that the companies operating in both B2B and B2C markets have a higher provision of services (76%). The Industrial, electrical and electronic machinery sector has the same adherence of the average (71%).

The different service packages offered were also analysed. Most of the services offered are product-oriented and life-prolonging services, such as after-sales support, maintenance, spare parts, repair, modernization services, and refurbishment or remanufacturing. It is important to underline that these services are not sustainable *a priori* but are necessary to have sustainable integrated PSS. It was observed that some companies that are offering "green" services (Gaiardelli et al., 2014) specifically geared towards sustainability goals play a very marginal role within the business landscape. These services are mostly environmental energy efficiency services at the product level but also production process and supply chain (SC) levels, consultancy on sustainability, take-back and disposal of end-of-life products and special products, services related to the design of sustainable solutions and infrastructure, sustainable logistic services, and sustainability or energy management services. Digital services which partially support sustainability goals are also a part of the service portfolio of the analysed sample, among them we can find remote monitoring of the product and process automation. Use-oriented services such as renting and leasing are still not spread. Table 1 shows this analysis of the service offerings.

Table 1: Service offerings and their orientation (Orient.), focus (Focus), and nature of interaction between provider and customer (Inter.), adapted from Gaiardelli et al., 2014. (P) product-oriented; (U) use-oriented; (T) transaction-based; (R) relationship-based.

Service offerings	%*	Orient.	Focus	Inter.
After-sales, remote support	52	P	product	T
Preventive, predictive maintenance	52	P	product	T/R
Spare parts	50	P	product	T
Repair, substitution, upgrade, refurbishment, remanufacturing	34	P	product	T
Training	33	P	product	T
Energy efficiency, energy optimisation	30	P	product, process, SC	T/R
Digital services	23	P	product, process	T
Consulting on sustainability	17	P	process	R
Warranty	12	P	product	T/R
Take-back, disposal services, hazardous waste	12	P	product	T
Design of sustainable solutions	10	P	product, process, business	R
Leasing, renting services	9	U	product	R
Test, audit services	8	P	product	
Management services	7	P	product, process	R
Sustainable logistics	5	P	SC	T
Energy/ sustainability management services	5	P	product, process	R
Risk management	2	P	business	R
Carbon credits	1	P	business	R
Others	3	P		

* % is calculated considering only companies offering services (N=155)

4.2 Sustainability approaches

The previous analysis was complemented by gathering information on the specific services on the companies' websites to deepen their strategic intentions. Services are not necessarily introduced with the clear intention of achieving greater sustainability, except the green services as detailed in Section 3.1. From the conducted analysis we collected that 51% of the total sample (i.e., of 215 companies) is definitely offering services to promote sustainability and this aligns with their sustainability strategy.

The provision of services does not exclude the attention to product design for fulfilling sustainable goals. This is confirmed by the higher number of companies which are offering the market a product through production processes that comply more restrictive rules compared to current pollution regulations and with increasing recycled materials (71% of the total sample). They are then pursuing sustainability at the product design level.

Table 2: Sustainability strategies

		Product level (%)	Service level (%)	Product + service level (%)
Overall		71	51	46
Dimension	SMEs	48	41	31
	Large	81	59	57
	Very large	85	50	44
Market	B2B	68	46	41
	B2B, B2C	79	62	56
Sector	Industrial, electrical and electronic machinery	76	51	49
	Wholesale trade	78	61	59
	IT	29	41	18
	Metallurgy and metal products	80	30	30

Therefore, from the quantitative analysis of the sample companies seem to rely more on product design than product-service system design for sustainability goals confirming that design challenges for sustainable PSS are still present. However, there exist companies that are approaching sustainability at both product and service levels (46% of the total sample). These companies are mainly, large enterprises, from the Wholesale trade and operating in the B2B and B2C markets. Table 2 shows the above-described comments. Since the largest companies are the most developed in terms of service offerings (Adrodegari et al., 2018), it is surprising that there was a greater commitment among them towards sustainability at the product design level rather than PSS, as well as manufacturing companies of the Industrial, electrical and electronic machinery.

5. Case study

From the previous analysis, what was most surprising was that very large companies were not the ones with a sustainability approach more focused on the integration of sustainable products and services, demonstrating instead a strong focus on product sustainability. Additionally, it was expected that the "Industrial, electrical and electronic machinery" sector, being traditionally the one with the most services offered, would predominantly approach sustainability from the services side (Adrodegari et al., 2018), which did not emerge. For these reasons, to deepen the understanding of the phenomena, it was decided to analyze in more detail the case of two of the companies outlined in Section 3. Specifically, two very large companies operating in the "Industrial, electrical and electronic machinery" sector were chosen to try to identify other differences within the same category and understand if there were other aspects, besides the sector and size, influencing the approach that companies have to sustainability.

Although in the same sector and with the same size, the two companies show substantial differences. Company Alpha produces products for medium and low voltage electrification and operates both in the B2B and B2C market; it counts around 4.500 employees in Italy, with a turnover of 2.780M$. On the other hand, company Beta is smaller in size, with around 2.500 employees and a turnover of 801M$, characteristics that make it fall under 'very large companies' anyway; Beta operates in the B2B market, designing and developing technologies for the steel industry.

Both companies currently provide a range of services to their customers. Company Beta focuses exclusively on product-oriented services, including installation and commissioning, remote and on-field technical support, remote monitoring engineering and consulting, training, spare parts provision, maintenance (both corrective and preventive), product upgrades, retrofitting, and end-of-life services. A similar service portfolio belongs to Company Alpha which in addition, offers customer service agreements which encompass a variety of business needs, from skills development, condition assessment and regular maintenance, to emergency assistance and sustainability services, tailored on the basis of the customer needs.

Both companies demonstrate a keen awareness of sustainability issues, driven by both external and internal drivers. Among the external influences, stringent regulations from policymakers push them to improve sustainability performance. Additionally, they recognize increasing customer demands for better sustainable supply chain practices. Internally, both companies see improving sustainability as a way to gain a competitive advantage over competitors.

From the sustainability point of view, the main difference between the two companies lies in the fact that company Beta approaches environmental sustainability exclusively on the product side, implementing initiatives to reduce the environmental impact of its products. The main focus is

Table 3: Companies comparison

	Company Alpha	Company Beta
Dimension	Very large size: 150.000 employees, with a turnover of 2.780M$	Very large size: 2.500 employees and a turnover of 801M$
Sector	Industrial, electrical and electronic machinery	Industrial, electrical and electronic machinery
Industry	Medium and low voltage electrification industry	Steel production industry
Product	Full range of voltage solutions for the utility, industrial and commercial customers including switchgear, circuit breakers, switching and limiting devices.	Technological solutions for metal processing from ironmaking to rolling equipment.
Services	Product-oriented, product-focused, and transactional-based: Installation and commissioning; (on-field and remote) Technical support and Repair; (on-field and remote) Training; Spare parts; Corrective Maintenance; Extensions, Upgrades, Retrofit, Replacements; End-of-life services; Engineering and consulting; Life Cycle Management. Product-oriented, product-focused, and relationship-based (i.e., long-term involvement of the customer): service agreements, including Technical support, Training, Spare parts, (preventive, and predictive) Maintenance, and Life Cycle Management.	Product-oriented, product-focused, and transactional-based: Installation and commissioning; Technical support and Repair; Training; Spare parts; Maintenance (corrective and preventive); Extensions, Upgrades, Retrofit, Replacements; End-of-life services; Engineering and consulting.
Sustainability initiatives	Reduce environmental impact of their products and services: EPDs (Environmental Product Declarations) of products and ecolabel. Promotion of machine connectivity remote services (e.g., trainings, technical assistance); increasing recyclability of products supported by end-of-life services; EPD of the retrofits; measuring footprint of services.	Reduce environmental impact of their products: Heat recovery, metals recovery, reducing CO2 and NOx emissions, limiting water consumption and consumables. The initiatives only regard products (design, use phase and disposal).

therefore on heat recovery, metals recovery, reducing CO_2 and NOx emissions, limiting water consumption and consumables. Company Alfa, on the other hand, does not only focus on the optimization of the production process through renewable energy sources and manufacturing more sustainable products, it also follows initiatives such as measuring the footprint of services for increasing customer awareness and providing a decision-supporting tool, promotion of the machine connectivity and of those services delivered from remote for reducing emissions, and increase of the recyclability of the products supported by end-of-life services. Table 3 summarizes the main characteristics of the two companies.

An interesting aspect emerging from the comparison of the two companies, lies in the fact that although in some cases they both offer similar services, these are communicated differently on their website: Beta's communication is more focused on profitability and economic advantages, whereas Alpha emphasizes the environmental value added by the considered services.

Alpha, for instance, stresses the importance of services to extend the useful life of its product and ensure cost reduction over the product lifecycle while promoting greater sustainability. Leveraging digital technologies, they present themselves as more sustainable during product usage, implementing services such as take-back programs at the end of life and promoting retrofitting over complete replacement. They are also trying to monitor the impact of their services to communicate the environmental value to customers and aid them in the decision-making process.

Beta also shows great enthusiasm for digitalisation, describing its digital services as being able to improve communication and data exchange with customers, reduce production costs, improve maintenance efficiency and reduce transportation costs. It is therefore easy to see how all these benefits would inevitably lead to greater environmental sustainability, but this is not communicated. Conversely, much emphasis is placed on the many technological innovations that can reduce greenhouse gas emissions, recover heat from the production process, promote the circular economy and reduce energy consumption.

6. Discussion

The quantitative analysis confirms that companies are approaching sustainability by following different strategies. Even though limited, some companies are integrating products and services to reach sustainability goals, thus they are following a sustainability approach at Product-Service System (PSS) innovation level. Among

these services, we can observe mainly traditional product-related services and green services, even though to a lesser extent. However, not all the services are sustainable *a priori* (González Chávez et al., 2021) and the green services still are a limited part. Companies that deliver services with a clear strategic motivation toward sustainability constitute only half of the sample.

The other strategy focused on the product innovation level, as defined by the literature (Ceschin and Gaziulusoy, 2016), on the contrary, represents the most adopted by the sample. This can be explained by the fact that this is a necessary first step in addressing environmental challenges. Through sustainable practices such as the reduction of carbon emissions, the use of recyclable materials and the responsible management of natural resources in the production process, companies are demonstrating a growing awareness of the environmental impact of their activities and products . Other findings of the quantitative analysis suggest that the dimension of the companies and the sectors in which they are operating constitute two elements that may influence the different approaches. To investigate beyond this finding, a consequent qualitative analysis was performed, in which two very large companies, both belonging to the same sector, were analysed. As already pointed out, one of the most interesting differences that emerged from the comparison between the two companies concerns the way they communicate the sustainability of their services. The limited communication by Company Beta regarding the sustainability of its services, despite their presence, may be due to the belief that the environmental advantages of services are not as great as those that could be obtained by product-side improvements, also considering the sector where the company works in, which is one of the more pollutant. In other words, Company Beta probably prioritizes enhancements in sustainability at a product level over those pertaining the service level, recognizing a greater potential for positive impact, as shown by the significant emphasis on sustainability initiatives related to their products. Another explanation for this phenomenon could be Beta's strong focus on technological innovation, which leads to the increased stress of this aspect in corporate communication channels. The limited discussion about Beta's services' potential for sustainability may therefore just reflect a different prioritization of sustainability issues compared to digitalization. Whatever the case, it is evident that Beta shares Alpha's strong commitment to sustainability; only the focus changes, which in one case is on the product and in the other on the combination of products and services.

One of the main reasons for the disparity in the two companies' approach to sustainability could lie in the fact that Alpha company produces goods with inherently less environmental footprints than the products of company Beta. This is probably the main reason why Alfa is also focusing on increasing the sustainability of its services; Beta, on the other hand, still has opportunities to improve the inherent sustainability of its products and has therefore not yet paid attention to the sustainability of its services.

For companies like Beta, it is unlikely that sustainability considerations for services will be a priority in the short term, as the impact of their services is relatively marginal compared to their products. Nonetheless, such companies can still strive for sustainability, primarily focusing their efforts on the product front.

Therefore, it can be concluded that a company's initial priority often lies in enhancing the sustainability of its products. Once this is achieved, attention can then shift towards enhancing the sustainability of its services. This evidence from the case study confirms what already mentioned in the literature (Ceschin and Gaziulusoy, 2019).

7. Conclusions

To achieve the objective of this study, i.e., to determine whether there are any trends or common points among companies adopting similar approaches to sustainability, in terms of size, market orientation or industry sector, a mixed method research approach was employed. What emerges from the study is that the sector in which companies operate can primarily influence their approach to sustainability. Qualitative analysis has also shown how, even within the same sector, there can be different approaches, likely linked to the type of product being marketed.

Moreover, company size also appears to influence their approach to sustainability. Among SMEs the commitment to sustainability is still limited and it seems to be a balance between approaches, even though they have a limited adoption of services compared to large and very large companies. On the other hand, these last two, seem to be more focused on product improvements and less on service improvements.

From a theoretical point of view, this article cannot indicate a generalisable formula on the most suitable strategy to deal with sustainability issues: a larger sample would be needed to try drawing such conclusions. However, the indication that emerges from the study is to adopt a sequential approach to sustainability within companies, where initial efforts focus on enhancing product sustainability, followed by attention to service sustainability once product-level goals are defined. Surely a strong service culture and service strategy within a business affect the sustainability approach.

From a managerial perspective, the gathered information suggests that a careful evaluation of the environmental impact of a company's products and services could help determine where to concentrate efforts to improve sustainability and identify opportunities to reduce the overall impact of the company. Furthermore, it should be considered how companies could benefit from integrating strategies related to product and service sustainability to more quickly achieve their sustainability objectives.

Among the limitations of the study, it is necessary to mention the sampling criteria for quantitative analysis which can be addressed by extending the analysis to other businesses interested to servitization topics. Additionally,

the qualitative study was restricted to case studies alone, which may have affected how broadly the findings could be applied. However, this laid the foundation for future study which may involve other industrial realities.

Acknowledgements

This paper was supported by the project National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.3 – Call for tender No. 341 of 15/03/2022 of Italian Ministry of University and Research funded by the European Union (NextGenerationEU), Award Number PE00000004, Concession Decree No. 1551 of 11/10/2022 adopted by the Italian Ministry of University and Research, CUP F13C22001230001 MICS (Made in Italy - Circular and Sustainable).

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