

Improving sustainability performance of the Italian professional printers supply chain

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Abstract: Because of excessive use, resources are becoming scarcer and more expensive. This calls for a shift from our current economic model, based on the linear approach of “take, make, consume, dispose”, to the paradigm of circular economy, which maintains the value of products, materials and resources in the economy while eliminating waste. Printers for professional use, which are printers that are sold to public or private organizations, are perfect candidates for the application of circular business models. Since decades, these printers have been rented with a “pay-per-use” business model, where customers do not own the printers but pay depending on utilization. Professional printers’ supply chains are, however, scarcely studied in literature, and little is known on how to reap the full potential of circular business models. Therefore, this research sheds light on the supply chain of these products, discusses strengths and weaknesses of the current situation, and derives suggestions to the sector how to move towards a wider application of circular economy, while reaching higher environmental sustainability performance. To this aim, we conducted 14 interviews with all types of actors in the professional printer supply chain. With the collected data, we could map the whole supply chain and draw conclusions on how to improve circular economy and sustainability performance. Although retailers are key actors in the Italian second-hand market, as they contribute to the collection of products at the end of their lifecycle, the shift to circular economy requires the active involvement of all supply chain actors. Moreover, given that many printers are exported, we advocate high attention to how printers are disposed at the end of their life at global level.

Keywords: Supply chain, Circular Business Model, Professional Printers

1. Introduction

Due to excessive use, resources are becoming scarcer and more expensive. This calls for a shift in our economic model from linear-based approach of “take, make, consume, dispose”, to a circular economy, which maintains the value of products, materials and resources while eliminating waste (e.g. Farooque et al. 2019).

During the last two decades, the matter of waste of electrical and electronic equipment, also referred to as ‘WEEE’ or ‘e-waste’, has become a relevant field of analysis amongst several disciplines and research contexts. This is due to the very specific nature of this waste, which contains hazardous as well as valuable materials. Moreover, among the whole range of urban solid waste, e-waste is comparatively rising at the fastest pace, and this trend is expected to continue in the future due to the quality and quantity of hi-tech product consumption (Forti et al., 2020).

In Europe, e-waste management is regulated by the WEEE Directive (2002/96/EC; recast 2012/19/EC). In 2007, such framework introduced the Extended Producer Responsibility (EPR) principle. In other words, producers are requested to take financial responsibility of the end of life (EoL) of the electronic appliances they put on the market. This gave rise to EPR schemes, which turned into

the backbone of the e-waste management supply chain in many European countries.

The WEEE Directive has also introduced e-waste collection targets, based on a step-by-step approach. Today, European countries are requested to collect 65% of the Put on the Market (PoM). Despite differences in the levels of accomplishment of such targets within Europe, the reverse supply chain of domestic e-waste has witnessed the major evolution, while the professional one is mostly out of the EPR schemes and barely captured by national statistics. In this context, the Italian case is not an exception, because the average collection rate of EPR schemes is still at about 40% (approximately 400,000 tons), out of which 28% consists of professional flows (Baldé et al., 2020).

Currently, information on the mutual interactions between PoM and e-waste generation is barely available. Therefore, the general objective of this paper is to fill this gap and to better understand the reverse flows in the Business To Business sector of e-waste. In particular, we focus on the professional printing sector in the Italian context, which is taken as our case example.

Printers for professional use are printers that are either sold to public or private organizations. Since decades, these printers have been rented on a “pay-per-use” basis,

where the customers do not own the printers, but pay according to the level of utilization. Professional printers are perfect candidates for the application of circular business models. First, they are owned by producers that must collect them after usage. Second, they are likely to be reused different times before disposal. Third, many actors -in addition to producers and users- do intervene within the reverse chain.

From a research viewpoint, the professional printing sector is particularly interesting, at least in two different ways. On the one hand, we aim to identify the 'untracked' stakeholders that contribute to e-waste management. On the other hand, we want to detect all relevant flows that are accountable to reach the European targets. In addition, professional printers supply chains are scarcely studied in literature. Little is known on how to reap the full potential of circular business models in this sector.

Therefore, this paper aims to shed light on the supply chain of these products, to discuss strengths and weaknesses of the status quo, and to derive suggestions for moving towards a wider application of circular economy as well as reaching higher environmental sustainability performance.

The next section introduces some background literature on circular business models. The third section provides details about the interview-based methodology used in this research. The fourth section deals with the main findings of the interview study. Section 5 discusses the results from managerial and research perspective, whereas the last section concludes and provides directions for future research.

2. Circular Business Models

As the business model concept itself (e.g., Osterwalder and Pigneur 2010; Abdelkafi et al. 2013), the term circular business model has been defined in different ways, and researchers do not agree on a unique definition. For instance, Nußholz (2017, p. 12) describes a circular business model as "how a company creates, captures, and delivers value with the value creation logic designed to improve resource efficiency through contributing to extending useful life of products and parts (e.g., through long-life design, repair and remanufacturing) and closing material loops." Lüdeke-Freund et al. (2019, p. 37) provide a shorter but concise definition and describe a circular business model "as a means to redefine how companies create value while adhering to CE principles." Similarly, Zucchella and Previtali (2019, p. 275) argue that circular business models primarily aim "...to incorporate the CE principles into a design or redesign of business activities and partnerships and to create a cost and revenue structure, which is compatible both with sustainability and with profitability." A recent definition has been proposed by Geissdoerfer et al. (2020, p. 3) who, based on a comprehensive literature analysis define circular business models "...as 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. This comprises recycling measures

(cycling), use phase extensions (extending), a more intense use phase (intensifying), and the substitution of products by service and software solutions (dematerialising). Although this definition details interesting characteristics related to circular business models, it does not incorporate elements of the business model such as value proposition, value creation, etc.

In this paper, however, we use The Ellen Mac Arthur Foundation's framework called ReSOLVE. The framework lists different CE models that implement the principles of the CE. The model captures all relevant aspects of circular business models and fits perfectly the purpose of our research. This framework is meant to guide organizations in the road to implementing CE. In particular, the models are:

- Regenerate: this model calls for the use of renewable energy and material.
- Share: this model requires the shift to a shared economy perspective, in which the ownership of the goods and assets is no longer important, but the sharing of the products and the assets. This calls for a product design with longer lifetime, and for availability of maintenance that allows re-use and extension of the product lifetime.
- Optimize: this model aims to improve the performance of products and supply chain, also leveraging emerging technologies such as big data, automation and remote sensing and steering.
- Loop: this model suggests the recycling of materials and remanufacturing of components.
- Virtualize: this model refers to a service-focused strategy that aims to dematerialize directly (e.g., DVD) or indirectly (e.g., online shopping) the products.
- Exchange: this model calls for substituting old and not-renewable products with advanced and renewable ones.

Furthermore, the research literature shows that the circular business model is by no way a concept that is restricted to a particular industry. It is rather important for different sectors such as automotive (Urbinati et al., 2021), food (e.g., Ciccullo et al., 2021), and home appliances (e.g. Sigüenza, 2021), just to name a few.

3. Methodology

To investigate how professional printers' supply chain can improve its sustainability performance and increase the adoption of circular business models, the methodology used was single case study, where the analysed case is the supply chain of professional printers.

A protocol to guide the research was defined. In particular, the questionnaire was composed by questions on: (i) the role played by the interviewees in the professional printers' supply chain; (ii) the management of the printers' flows; (iii) the different types of contracts, with a focus on leasing solutions; (iv) the printers'

lifecycle, with a focus on the decisions concerning their reconditioning and disposal.

14 interviews were conducted to all the actors of the professional printers' supply chain, from the producer downstream. Table 1 specifies the number of organisations interviewed, the number of interviews (in brackets) and the role of the interviewees. Each interview lasted about 1,5 hours. After the interview follow-up phone calls or emails were sent to collect missing information. Moreover, data and supporting documents were collected when possible. Each interview was transcribed, to be coded and the results of the analysis of the interviews were summarized in a report, that was discussed among the researchers to reach agreement on the interpretation of the data. For the mapping, Signavio software was used.

Table 1: the interviewees

Role in the supply chain	Number of organization interviewed	Role of the interviewee (number of interviews)
Manufacturers	2	Printing commercial channel sales manager (1); Technical Director (1)
Dealers	1	The two name partners (1)
Distributors	2	Investor Relations Manager & Head of Group Vendor Management (1); Chairman (1)
Reconditioning Brokers	2	CEO, Department Director and Logistics Manager in Italy; CEO (1)
Financial companies	1	Vice-president, Marketing and Communication Representative (1)
Final customers	1	CONSIP Responsible for rental and purchase tenders of multifunction printers, Expert in sustainable procurement, Expert in green public procurement, Account (1)
NGOs	1	Chairman (1)
Scrapping companies	3	Executive Director (1), Logistics and Production Control Manager (1), Commercial Director (1)
Customs agency	1	Statistics and open data office (1)

4. Results

This section presents the main results: first the mapping of the professional printers supply chain and second the challenges that emerged from the interviews.

4.1 Mapping of the professional printers supply chain

The professional printer supply chain mainly consists of three parts: first hand market, second hand market, and

end-of-life management (figure 1). After the end of the first lifecycle, it is quite common that these printers have a second life. They usually go through a reconditioning process and then re-sold in the secondhand market in Italy (home country), outside Italy (export), or donated to NGOs. Printers that stay in Italy at the end of their life are collected, dismantled and disposed of by specialized actors.

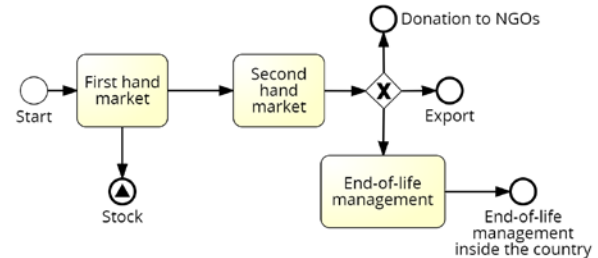


Figure 1: the overall supply chain

4.1.1 The supply chain of the new products

The firsthand supply chain that makes and delivers new products consists of five actors: manufacturer, distributor, dealer, financial company, and final customer (figure 2). The manufacturer puts professional printers on the market through direct sales or rental. Rental may also include the provision of the printer under so-called "pay-per-copy" contracts, which charge a price to the client proportionate to product use. To reach professional clients (i.e., companies, institutions, or public administrations), manufacturers can follow two channels: the *direct channel* and the *indirect channel*.

The manufacturer leverages the direct channel when he sells or rents the printers directly to the final customer. If the customer needs financial support for the purchase, financial companies, owned by the manufacturers, can intervene.

The manufacturer can also sell printers via the indirect channel, in other words through an intermediate actor, which is either a large distributor or a small dealer, who in turn sells or rents the printers to the final customers. In Italy, the number of resellers is around 18.000, mostly small companies. Also, in this case, customers buying from dealers can get loans from financial companies to fund the rental or purchase of goods. Since dealers are usually small companies, they do not keep printers on stock; they first collect the orders and then source the products from the manufacturers or the distributors. Furthermore, a typical dealer manages just one or a few brands.

In contrast to dealers, distributors are bigger and can afford to deal with a variety of different products and brands. They may sell to a dealer or directly to customers, but neither collects the professional printers at the end of their lifecycle, nor take care of their reconditioning. This is why distributors do not appear in the second-hand market. Moreover, the stock of printers in the indirect channel is kept at a relatively low level that ranges between 4 and 6 weeks of inventory.

Once the printer reaches the end of its first lifecycle (3-4 years on average), customers, be they companies or public administrations, can follow two paths. They can either rely on actors as manufacturers, resellers, reconditioning brokers, or non-profit organizations (NGOs) to take back the product and - in almost all cases - replace it with a new or reconditioned one. Hence, the products enter the secondhand market case. Or customers can decide not to return the printer, thus creating internal stocks. The creation of stocks is typical in public administrations that buy professional printers with a sales contract.

When involved in a transaction, financial companies could remain owners of the assets after the expiry of the contract. In almost all cases, however, the financial company does not manage the printers' end of life. It can sell them to dealers, who can arrange new rental contracts, to reconditioning brokers, who refurbish the product, or just put the printers on the second-hand market.

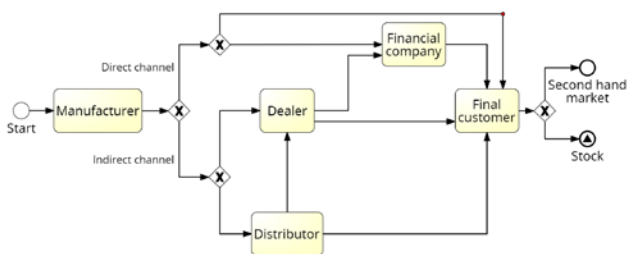


Figure 2: the supply chain for first-hand products

4.1.2 The supply chain of the used products

The final customer who owns a professional printer and wants to dispose of it or replace it at the end of its first use stage can refer to four different actors: manufacturers, dealers, reconditioning brokers, or NGOs.

Manufacturers can refurbish the printers to be sold in the second-hand market both in Italy and abroad. Alternatively, if the collected machines are completely exhausted, manufacturers can send them to actors specialized in end-of-life management.

Dealers usually collect, recondition, and resell used printers in the second-hand Italian market. Like manufacturers, when it is no longer feasible or economically advantageous to recondition the printers, they are handed over to companies that manage the product's end-of-life.

Reconditioning brokers are part of an international system dealing with the recovery of various types of WEEE, among which WEEE generated by professional printers. They are the only actors able to recover large fleets of machines. Some manufacturers even rely on them to take back used printers from large clients. This suggests that the overall volumes of printers handled by the brokers are significant. Once reconditioned, these printers can be sold in both the Italian and foreign second-hand markets. Those printers that are not reusable are dismantled and disposed of.

During reconditioning it is a common practice that manufacturers, dealers, or reconditioning brokers cannibalize some printers and use their spare parts for the

benefit of those machines to be sold in the second-hand market.

At the end of the product lifecycle, customers of professional printers can also refer to non-profit organizations that recover e-equipment to make donations to other NGOs or people both in Italy and abroad.

Figure 3 shows the mapping of the second-hand market.

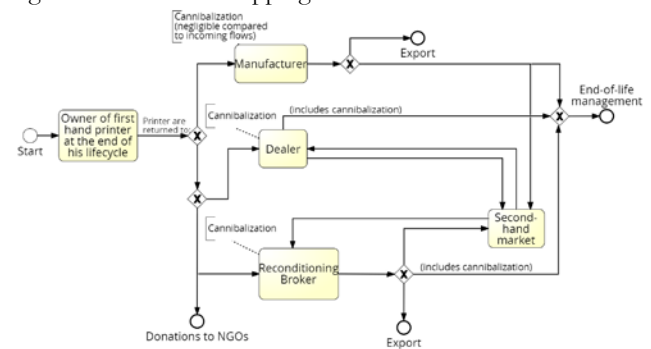


Figure 3: the supply chain for second-hand products

4.1.3 The management of the product end of life in Italy

Printers for disposal in Italy are handled by two categories of actors: extended producer responsibility systems (i.e., consortia like ERION), or companies specialized in scrapping. Because printers do not contain precious metals to be recycled, the residual value of exhausted professional printers is significantly low. This suggests a very limited unauthorized market served by non-certified actors. The following statements by interviewees support the low desirability level of professional printers at the end of their lifecycle: "...we prefer those [equipment, Ed.] with more copper and precious metal content. So yes, we do handle printers, but as little as possible, because they are poor in these materials" (a company responsible for end-of-life treatment).

4.2 Uncovering the challenges

4.2.1 Untracked export

Export seems as a very frequent exit for second-hand printers. For example, the financial company interviewed stated: "saying that [this type of product, Ed.] is sold abroad means, mainly, that it is sold in Africa, and therefore that from that moment on, there are no more records of it; this is why Italian disposers do not receive a significant number of printers to dismantle". Reconditioning brokers also point out that manufacturers are encouraging the sale of secondhand printers abroad to reduce competition on the Italian market. A major distributor says: "it's mainly the manufacturers who don't like the product coming back to the Italian market because they obviously want to sell the new product. At the moment, it is not so much the reseller that wants to sell abroad but, above all, the financial companies and the manufacturers: at the end of the "pay-per-print" contract, the printer is reconditioned and sold abroad - we are talking about Arabic countries and not Europe".

Previous studies support this observation and suggest that in the electrical and electronic equipment (EEE) sector a high amount of equipment is exported, either as waste or as a product that can be reused. A study conducted in France on professional equipment showed that about half

of used professional EEE is exported (Aurez et al., 2018). Another study by Forti et al. (2020) estimates that about 7% to 20% of the WEEE generated is exported.

The reason for the export of WEEE could be related to the non-convenience of performing certain processing activities in Italy.

4.2.2 The situation in Italy

Based on the interview study, we identify four challenging areas for sustainability in Italy: product, market, supply chain and policies (Table 2).

Table 2: the challenges to sustainability in Italy

Area	Challenge	Impact
Product	Products are difficult to disassemble	Difficulties in end-of-life treatment and costs of dis-assembly
	Toners are polluting	Environment pollution
	Products are difficult to “regenerate” (e.g., software becomes obsolete very fast)	Difficulties in re-use of products
	Products are big and heavy	High stockholding and transportation costs that hinder the collection and recovery of end-of-life printers
Market	The cost of regenerating products is higher than the value the customer is willing to pay in the EU context	Not all regenerated products can be sold in the Italian market
Supply Chain	Many distributors are just renting	Less opportunities to reach customers with re-used products
Policies	Laws and regulations are perceived as complex	Free riding

Product design has implications on the easiness of operating disposal activities or recovering components. Companies involved in end-of-life treatment mention that *“even after the toner is removed, there is the recovery tray where the toner that has fallen is collected. These trays are not easy to extract”* and *“the recovery of these printers is not profitable: most of the components have no market anymore. The components are so complex to disassemble that it is no longer economical to do such work and, therefore, they have no place in the recovery market”*. It is also noteworthy that leaving the cartridges with toner inside the printer at the disposal stage is dangerous because toner *“is a dusty, flammable material and if shredded, [...] the cloud of toner created by the dust can cause a flame”*.

For retailers, who are also active in the collection and reconditioning of second-hand products, the cost of consumables and rapid obsolescence of software can make it unprofitable to recondition machines. In their words: *“a lot of equipment would still be valid, but consumables cost a lot of money and therefore it is uneconomical to repair them”*...*“not to mention that software is constantly being updated and needs updated machines which can connect to all platforms and mobiles”*. The issue of software obsolescence was also

raised by the reconditioning brokers: *“There are many products that would have a market if it was not for the software”*.

For the dealers, end-of-life management of the printers incurs significant costs, since disposal is *“difficult and very expensive”*. These issues have been also reported by other actors such as the financial company, and the company specialized in end-of-life treatment: *“the problem is mainly related to logistics and storage. It’s a problem also found by talking to dealers. When they pick up the machines, these machines occupy too much space, and this has a cost. This issue is also related to the design of the printer.”* A reconditioning broker also notes: *“My colleagues prefer to deal with PCs, which are simpler, while the printer is voluminous, and has a transportation cost...”*

The incentive of dealership to resell the printers in the Italian market is relatively low, because *“the commercial value of reparations is too high compared to a commercial value with which they could be re-introduced on the market”*. Therefore, they are sold abroad or disposed of. In this regard, a case that is worth noting comes from the public administration, which has its own peculiarities that can make the collection of end-of-life products more complex: *“one problem with the management of this type of waste in administrations is that when the asset stops being used, it must be removed from the list of assets of the institution. This activity causes an administrative difficulty that administrations do not want to deal with.”* (CONSIP)

Heavy regulation and policies do not seem to facilitate the reuse of printers and to support secondhand market. The bureaucratic aspects of the process are apparently challenging, and the supply chain actors can encounter many difficulties in this regard. Hence, supply chain actors look for *“less bureaucracy and less cost for disposal”*, and for *“making it easier and less bureaucratic for those working in the sector to become a focal point for disposal”*.

5. Discussion

Results highlight that the actual situations present strengths and weaknesses. This section discusses the results highlighting the actions that are needed for moving towards a wider application of circular economy and improving environmental sustainability performance.

5.1. The situation in the Italian market

Within Italian borders, the supply chain of professional printers is characterized by good sustainability performance. There is a high percentage of reuse and refurbishing of professional printers, and a high percentage of used printers are treated by legally authorized plants at the end of their life. In particular, as it is shown in table 3, the data collected through the interviews suggest that Italian companies all along the supply chain already implement practices that can be linked to the circular economy-based business models indicated by Ellen MacArthur Foundation (2015; 2017). For instance, printers are already used and re-used many times and offered with a pay-per-print contracts, as suggested by “Share” business model.

Despite the good performance and practices in the sector, we believe that new actions could be put in place to further increase sustainability performance of the industry.

Table 3. Actual situation and direction for changes

Circular Economy-based business models	As-Is situation	To-Be situation: Change in the product	To-Be situation: Change in the supply chain
Regenerate	Plastic and other material are recyclable	Ease regeneration of toner by changing the design of the printer	
Share	Printers are re-used many times (around 2-3 cycles) Retailers, manufacturers, and brokers are renting printers Pay-per-copy business model applied	Products should be designed to be “easy” to maintain Product should be designed so to make the product life longer	Distributors should change their approach to be able to rent the printers (Big) customers need to change their mindset to embrace a “as-a-service” approach
Optimize	Not investigated		
Loop	High level of collection of used printers and disassembly of them for recycling	Products should be designed to be “easy” to disassemble	New actors/producers should put in place new processes for supporting the retailers in properly managing end-of-life
Virtualize	Not Applicable		
Exchange	Printers are already highly renewable	Ease regeneration of toner by changing the design of the printer	

Specifically, the shift to circular economy requires the contribution of all supply chain actors and a change in product design to enable the transition. Table 3 shows the actions that might be the starting points for a transition towards an even more sustainable supply chain for professional printers. Two types of actions seem to be required: product- and supply chain-related. Regarding the product, a higher attention towards design for maintenance could extend the printers’ life even more, while designing the printers to ease disassembly could allow for increasing the number of recycled components and easing the proper disposal of the used parts. Because toners are highly polluting components, we suggest investing in research for new designs and processes to ease the regeneration of the toner themselves.

5.2. The hotspot of the export

The main hotspot of the professional printers’ supply chain represents the untracked export of used professional printers to foreign markets, which absorb a large part of refurbished or still to-be-refurbished printers. Selling the machines in foreign markets makes it possible to extend the life of printers, even if it shifts the problem of disposal to geographical areas beyond the control of the Italian legislator. It was not possible to collect evidence relating to the application of the procedure provided for by Legislative Decree 49 of 14 March 2014 for the case of reuse abroad. The lack of tracking tools represents a serious threat to the sustainability of the sector from a global perspective, as there is no guarantee that the exported products will be reconditioned, and subsequently treated and properly disposed of at the end of their life.

The solution to this problem calls for actions at the levels of the company and policy makers. Technologies might be useful tools for the tracking of the printers, but a normative framework should prescribe the use of these technologies, and processes should be managed at supply chain level.

6. Conclusions and directions for future research

This research investigates the supply chain of professional printers and sheds light on how these products are managed from the moment they are put in the market until they are disposed of or exported to foreign markets. 14 companies along the supply chain were interviewed. The objective was twofold. First, to reconstruct the supply chain structure in terms of nodes, roles and flows of materials. Second, to identify strengths and weaknesses of the current situation and to derive recommendations for a wider application of circular economy to improve environmental sustainability performance.

The paper provides the example of a supply chain where the concepts of circular economy-based business models have been implemented. It develops a detailed map of the professional printer supply chain, an under-investigated topic in research and gives recommendations for a further improvement of sustainability in the sector.

In Italy, professional printers are highly re-used and refurbished. The sector is already practicing the “Share” circular business model suggested by The Ellen MacArthur Foundation (2017). Changes in the product design and supply chain-related measures can further improve the sustainability performance of the sector. This requires the involvement of many supply chain actors such as producers, distributors and clients.

Many printers in their end of life are exported to foreign markets. These printers are untracked, and there is no guarantee that their disposal is done properly when they are completely exhausted. This represents a strong weakness of the supply chain and a threat to the environment at global level. To tackle this issue, policy makers and companies in the professional printer supply chains need to coordinate their actions to put in place adequate tracking systems and processes.

This research presents some limitations that open the way for further research. As the research was exploratory in nature, it considered all the circular business models at an aggregate level. Therefore, further research could be devoted to the analysis of most promising circular business models implemented in the sector. Moreover, our proposals for Improvements (To-be scenarios) can be elaborated at a higher level of detail. Finally, similar studies can be conducted in other sectors to enable a cross-sectoral comparison and learning.

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