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Reaping What WEEE Sow: The potential for harvesting spare parts for repair and refurbishment

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Abstract: A Circular Economy (CE) calls for the value of materials and products to be maintained and recovered through narrowing, closing, and slowing loops. However, there remain challenges in moving up the waste hierarchy and not only recycling materials from products, but also capturing value through reuse of components in refurbished and repaired products. In this paper, we examine the practice of “harvesting” spare parts from discarded white goods and consumer electronics in Norway, Sweden and California. Through literature review and interviews, we examine the sources of WEEE and potential spare parts, the use and markets for harvested spare parts, and the harvesting process itself. We identify key conditions, actors, and barriers and discuss how spare part harvesting could be upscaled to support increasing repair and refurbishment activities, which can increase product lifetimes and reduce waste.

Introduction

A Circular Economy (CE) aims to retain the value of materials and products as long as possible. However, there remain challenges in moving up the waste hierarchy, from waste and recycling to increased repair and reuse of products and their components. Globally, high-income countries like Sweden, Norway and the US demonstrate correlated high consumption of electronic products and white goods (Forti et al., 2020). The Nordic countries are considered to be at the forefront in Europe when it comes to the recycling of waste electrical and electronic products (WEEE) (Yllä-Mella et al., 2014) and California was a pioneer in adopting e-waste legislation in 2003 (Biedenkopf, 2020), but less is known about the practice and potential of repair and refurbishment in these contexts. The End-of-life (EoL) treatment of WEEE may present a potential solution to the lack of available spare parts, which is a significant barrier constraining the upscale of repair and refurbishment (see Svensson-Höglund et al., 2021).

Spare parts (“spares”) used in repair, refurbishment and remanufacturing can be: 1) original, newly manufactured OEM parts; 2) third-party manufactured aftermarket parts (“copy”), and; 3) directly reused or refurbished original spares harvested from products.,

Securing high-quality new spares can be a time consuming affair; harvesting is an alternative (Hansen & Revellio, 2020; Thierry et al., 1995). EoL products that cannot be reused may still contain valuable components (Tecchio et al., 2019), especially original parts that may be difficult to source elsewhere (Hansen & Revellio, 2020). Further, increasing prices of spares are a threat to the business case for repairers (Türkeli et al., 2019), which harvesting can potentially address. Harvesting of spares has a long tradition in the automotive industry, however, there is little in academic literature about the current state of this practice with electronics and appliances.

Research approach

This research seeks to improve understanding of: 1) the source of waste products harvested for spares, 2) how harvested spares are used, and 3) the harvesting process. The focus is on the regulated waste stream (as opposed to unregulated or informal scavenging - this issue is explored, e.g. in Magalini & Stillhart, 2017). In addition, we briefly discuss how spare part harvesting can be upscaled.

Data was collected to address the research aims through: 1) a broad literature review, and 2) case studies of practice in Norway and Sweden (“Nordics”), and California (CA) in the

US. In addition to academic literature, legal and policy documents were reviewed for these contexts as well as grey literature, company documents, websites and other media (e.g. blogs and podcasts). Eleven semi-structured interviews were conducted with key stakeholders. These included producer responsibility organisations (PROs) (2 in the Nordics), repair, refurbish, and reuse organisations (4 in the Nordics and 2 in CA), recyclers (1 in Sweden, 1 in CA) and an OEM (1 in the Nordics).

Harvesting spare parts

Sources of Supply of Devices to Harvest

The sources of spares from regulated e-waste/WEEE streams depend on the regulatory system and which actors are responsible for collecting and recycling. In the Nordic system there are some limited OEM take-back systems but most WEEE collection is controlled by PROs, who contract recyclers to manage the waste and may allow or collaborate with some reuse organisations. In contrast, in the absence of PROs, recyclers in CA are often buying WEEE from individual organisations to reuse, harvest spares and recycle for materials. In addition to the revenue from these activities, recyclers are also compensated from the CA state fund for the management of the WEEE.

The potential for harvesting from WEEE is limited by the volume and quality of WEEE that consumers voluntarily drop-off at collection sites. Collection rates are decreasing and some WEEE is also removed from collection sites by consumers or third parties (Bratten, 2020; Bergin & Ohlfeldt, 2020). One Nordic recycler estimated that ultimately less than 1% of WEEE has reuse potential to begin with, including for harvesting. Low volumes were problematic for several of the organisations interviewed and the demand for spares exceeded the available supply. A CA repairer and Nordic refurbisher found that access to harvestable spares had decreased due to OEMs starting to take back their own used or waste products.

The existence of recycling targets can disincentivise spare reuse by favouring recycling (Bergin & Ohlfeldt, 2020). A CA repair organisation mentioned that OEMs also try to influence access to spares to harvest though direct contracts with recyclers and indirectly through pressure on retailers who have contracts with recyclers, often stipulating that

their products should be recycled for materials and prohibiting harvesting. One Nordic PRO's guidelines restricted access to only professional reuse companies to ensure that the waste is treated in an environmentally sound manner with high quality assurance. Previous research confirms that PROs often lack incentives to engage in reuse and are hesitant to provide access to interested third parties, primarily due to manufacturers' concerns about cannibalization of new product sales, product liability and risks to brand-value (Dalhammar et al., in review).

A Nordic PRO's own investigation revealed that the way WEEE is collected (e.g. in cages or in containers) and handled (often roughly) strongly influenced the functionality of the products. The PRO concluded that the solution was to divert reusable products before they entered the waste stream (El-Kretsen, 2015), but a Nordic recycler also noted there was pressure to handle the waste more carefully. In particular, it was noted that white goods are often squeezed and handled roughly to save space. This was an important reason for why a Nordic refurbisher did not consider sourcing from the WEEE stream, but would consider this if the treatment improved.

Use of harvested parts

Refurbishing and reuse companies, repairers and DIY enthusiasts often use harvested spares, (Hansen & Revellio 2020; Lechner & Reimann 2015). Harvested spares are often a viable strategy to access lower cost spares (see Ijomah & Danis 2012) or reduce delivery time compared to ordering newly manufactured spares (Wittig 2018). Interviews suggested that the increased price of some products has made repair more interesting for consumers (with resulting increases in spare part value). In closed-loop supply chains, spares are used internally by the manufacturers e.g., to honour warranty commitments (Chari et al., 2016).

All the refurbishers interviewed use the spares internally to some extent, and a few also sold externally to consumers via e-platforms. The recyclers interviewed did some limited refurbishment themselves using parts harvested from their recycling process and one CA recycler was considering expanding its spare part harvesting to sell more externally, while the Nordic recycler considered expanding refurbishment by sourcing parts beyond their

internal operation. Refurbishers and recyclers in both case contexts sell parts B2B, sometimes even working specifically with an OEM (one CA recycler). Another market for some parts is outside of the Nordic and CA context, especially for consumer electronics (e.g. computer spares and Apple parts were mentioned by a Nordic refurbisher); screens with scratches that lack a domestic market can be sold elsewhere in the world. The CA repair organisation also noted there was a flow of spares to Asia from CA. As mentioned, the supply of spares is limited and uncertain. To address this, the recyclers often have dedicated resources to keep track of the market flows and dynamics, including the type of spares customers are demanding.

Sought-after spares are either “versatile” (i.e., can be used in a range of products) or “specialised” (i.e., unique applications) (Debnath et al., 2016). A CA repair organisation and a Nordic refurbisher mentioned that spares not made available by the OEM are in high demand. Age and condition of the product determines the harvesting potential, and a Nordic refurbisher noted that high-speed development in design and software upgrades often makes spares irrelevant, either because the products themselves are obsolete (Linton et al., 2004) or the spares are not compatible with newer models (Bergin & Ohlfeldt, 2020). This aligns with the issue of time-sensitivity in the value of spares, where sometimes just a few months matter. Thus, getting consumers and businesses to return products promptly (vs. storing them) is a key “bottleneck” in the system noted in interviews and literature (Wilson et al., 2017). For one Nordic refurbisher, this time-sensitivity made spares harvested from WEEE too old for their main market (refurbished mobile phones). However, for other products the demand for older models has increased lately, making the WEEE stream more relevant.

Refurbishers and recyclers in both the Nordic and CA contexts noted that quality concerns can be a barrier to using harvested spares from WEEE. For example, one repair organisation in CA was restricted by requirements from insurance companies not to reuse parts in covered repairs. According to a Nordic refurbisher, insurance companies there had similar policies, but have relaxed this requirement to realise both cost and environmental savings. On the demand side, customer requirements and preference for

reused spares can be difficult to predict (Bergin & Ohlfeldt, 2020), with certain consumer segments often preferring new spares, while DIY consumers are more likely to seek out harvested spares (Türkeli et al., 2019; Lechner & Reimann, 2015). Another barrier to using spares generally, noted by a Nordic refurbisher, is when it results in an error message that indicated unauthorised repair or decreased functionality of the product - thus, making it more difficult to sell or return the refurbished product to a customer.

The Harvesting Process

A Nordic refurbisher and CA recycler both described similar processes for selecting parts for harvesting. Essentially, they look for parts they need internally for refurbishment, and parts with an external market. Thus, the sorting process is typically oriented towards what there is a market: either for frequently used spares or for more unique items. The latter are identified through requests from customers. The choice to harvest spares from WEEE is impacted by the condition, brand, and age and an effective grading process is essential for the profitability of the operation (Lechner & Reimann, 2015).

Complexities in disassembly, as well as design changes in newer product models, hamper the reuse of spares (Bergin & Ohlfeldt, 2020; Coughlan et al., 2018). Though quality products from big brands are preferably reused in their entirety, they are more cost-efficient to harvest from compared to no-brand products due to lower processing costs (Lechner & Reimann, 2015). Spares are more easily reused if there are a limited number of brands (i.e. less diversity) (O’Connell et al., 2011) and standard designs (Lechner & Reimann, 2015).

Harvesting requires intimate knowledge of product design, defect types and frequency, in addition to the logistics involved, as well as extensive collaborations with other actors (Thierry et al., 1995). The harvesting of spares entails the initial identification, disassembly, functionality testing, diagnosis, cleaning, and repair or refurbishment, sometimes by a specialist (Coughlan et al. 2018; Ijomah & Danis, 2012; Debnath et al., 2016). A repair organisation in CA mentioned the need to train staff at the recycler they sourced from and interviews confirmed the need for skilled staff.

Recyclers and refurbishers stressed the need to assure secure data destruction and test functionality. It was noted that parts are more difficult to test than entire units, and the varied models and conditions makes it challenging to create standardised, automated processes, making some manual labour necessary. The maturity of the refurbishing market has led to the development of functionality testing programs from third parties, further facilitating testing, but the process still increases costs of the operation (Türkeli et al., 2019).

Overall, the time-intensive manual work required, along with high labour taxes (particularly in the Nordic context), puts a strain on profitability. For certain products, it is more profitable to buy new spares from across the world. The market for harvested parts is growing, which enables operations of scale. A Nordic OEM mentioned the initial investment in large storage facilities was a necessary, but limiting, factor for them to harvest spares for white goods. Storage capacity is also a barrier noted in literature (Linton et al., 2004).

Concluding Discussion

Figure 1 summarizes the sources, main steps of the process of harvesting and main uses of spares harvested from WEEE, but also notes other sources.

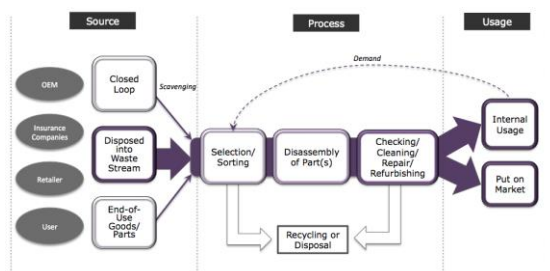


Figure 1. Flow of Parts for Harvesting

Nearly all interviewed consumer electronic recyclers and refurbishers saw a potential to increase spare harvesting and foresaw increasing demand for spares. Extended producer responsibility systems present several barriers, both in terms of the control maintained by PROs (dictating who can access and routing to recycling vs. reuse) and how the waste is handled (i.e., roughly). Similarly, in CA OEMs could restrict access through contracts.

Confirming previous studies, our findings indicates WEEE requires more careful handling

to ensure higher value retention. Value is also relative; e.g., compared to the value of the product requiring the spares, with notably higher interest for parts for high value products. Not surprisingly, there is higher value for harvested parts where there is no alternative source (e.g., where the OEM restricts supply). The value is also relative to the supply of new aftermarket parts. Hence, any externalities that would make new manufacture artificially cheap should be considered for policy measures.

Matching the supply and demand is important for upscaling parts harvesting as there may be potential customers that have not considered this source for spares. This requires good data, tracking and database systems that can be easily checked and communicated to potential customers, which also require investments. The findings also confirmed that often the market is not only domestic, and thus trade restrictions on waste and lack of clarity regarding the classification of harvested parts (e.g., cores) may pose additional impediments to the use of harvested spares.

Often harvesting spares involves partnerships and/or gap exploiters who are able to capture the value of the parts and connect these to markets. Interviewees in our study were divided on the role of manufacturers, with some seeing increased involvement as advantageous because OEMs had the technical knowledge of their products while others perceived OEMs as motivated to incentivize sales of new parts and recycling over harvesting and reuse.

There are different dimensions of value captured in harvesting spares. Non-profit organisations and socially responsible for-profit companies are often able to contribute social benefits such as employment and skill building for long-term unemployed or disadvantaged people. Harvesting can also contribute environmental value through avoided emissions and material extraction.

Building on the understanding of the processes, markets, and actors involved in harvesting spares, future research should further investigate the different dimensions of values for harvesting, potential policies, and the role of stakeholders in further upscaling the use of harvested spares.

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