Enabling More Sustainable Enterprise Consumption of Information Technology

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Introduction

As a commodity and enabler, information and communication technologies (ICT) products drive data-centric decisions and contribute towards all 17 Sustainable Development Goals (ITU 2018; Hausfather 2018; Wu et al 2018; Kostoska and Kocarey 2019). ICT products further enable the digitization of various industries with the capacity to track energy emissions and help limit environmental degradation (Attaran 2023; Maslei et al 2023; Ursacescu et al 2019). ICT also increases awareness of socio-economic issues, ranging from local- to systems-level, for governments, industries, and people around the world (see Kostoska and Kocarev 2019). On one hand, the lifecycle of ICT products, from raw material extraction to manufacturing, as well as usage to disposition, poses detrimental impact on the environment and the local communities. However, it also creates economic opportunities that contribute to social development (see Ahmed, Bryant, and Edwards, 2021; Hund et al 2013; Perks 2011; Sovacool 2019; Goodenough 2018; Fang et al 2020; Chang et al 2022; Wang et al 2021; Gregson and Crang 2015).

ICT products encompasses hardware ranging from computers and phones to data storages and servers that support software ranging from the Internet (UIS 2009, 120) to today's artificial intelligence (AI). Its development has drastically changed the way society functions and evolves. ICT products are ingrained in today's economy as physical products with industries linked to every step of its lifecycle, but also as commodities to be traded and built upon that enables other industries (Rothe 2020, 657). Its many roles are all linked to and impact the three pillars of sustainable development with environmental, social, and economic implications (ITU 2018). Consumer consumption behaviors and potential solutions for change have been largely researched. However, there are limited literature pertaining specifically to enterprise ICT consumption. The ingrained nature of ICT products in today's businesses and organizations, as well as enterprise purchasers' procurement and operations, suggest that changing enterprise ICT consumption may change consumption behavior at scale.

As the demands for new ICT continue to increase, both software and hardware development is inevitable and necessary. However, the sustainable development tradeoffs in ICT's role may be resolvable by addressing efficient reuse on a systems-level. Software ranging from the operating systems to cloud- and web-based applications innovate and upgrade at an accelerated and continuous rate that differs from hardware (Kim, Lee, and Kopal 2022, 1284), which begins to depreciate with each reiteration of product features and composition (Zhou and Gupta 2020, 7235). The ingrained concept of depreciation can be further illustrated by the standard tax depreciation of ICT hardware in enterprise capital and fixed assets management (EY 2023). While software innovation can take place virtually anytime and geographically anywhere, hardware requires innovation throughout its value chain, from mining minerals and creating new alloys, to research and testing new graphics processing unit. Figure 1 shows a high-level overview of a ICT product value chain.

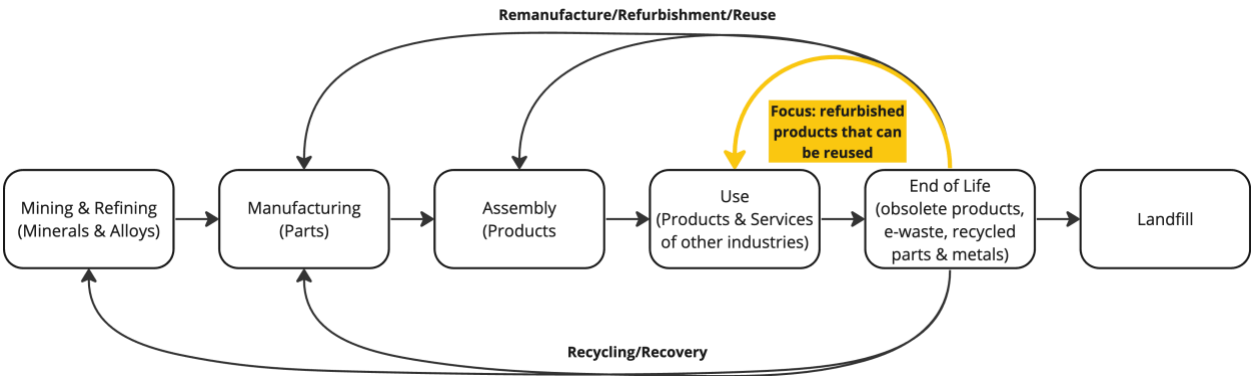

Figure 1. Overview of ICT Product Value Chain & Focus of Paper

Many barriers of redistribution have previously been identified (see Ongondo et al 2013, 2603). However, these barriers may also be interpreted as opportunities for ICT product redistribution at scale. This paper will specifically focus on examining challenges of redistributing and reusing refurbished products (highlighted in Figure 1). All products must go through the refurbishment process before it can be reused by another entity or enterprise. Refurbished product in this paper is defined as pre-owned products that have passed all refurbishment criteria. Redistribution in this paper is used to describe the facilitation of moving a refurbished product; while reuse is used to describe the product's nth usage life. Through literature review, the paper identifies unique attributes of enterprise ICT consumption and disposition that pose opportunities and challenges for systems-level reuse of ICT products. Recognizing the immense diversity in enterprise ICT procurement and operations, the literature review in this paper is not exhaustive. Further research is necessary to build upon the current understanding of enterprise-specific ICT consumption and disposition. The paper is divided into the following sections, 1) context on enterprise ICT, 2) method, 3) findings, and 4) conclusion.

Context of Enterprise ICT

The role of enterprise information technology (IT) departments has evolved since its incorporation in almost all organizations today (Hsu, Tsaih, and Yen 2018, 1). Responsibilities of IT departments can be categorized into three main functions (Indeed Editorial Team 2023). First, the governance of systems is the administration and operations of ICT products, as well as employee usage. Governance actions include purchasing, deployment, disposition, and training for the entire organization. Second, infrastructure maintenance is to care for the overall architecture of organization network. Maintenance actions include surveying employee and enterprise needs to support products and services, adding to or offloading enterprise capabilities, as well as ensuring data security. Thirdly, functionality is to maintain operational applications and software, which covers the development, security, and storage of data, as well as internal ICT related research or development. Organizations of varying sizes may have different level of ICT incorporation depending on their product and/or service offerings, operational budget, and geographic reach. The top four industries with highest average IT budget as a share of revenue are banking and securities (7.88%), technology and communications (6.47%), insurance (4.80%), and business and professional services (4.64%) (Kark 2020, 2).

The concept of green IT originated from the late 1990s, encompassing a wide range of actions, tools, and guidelines that focus on reducing an organization's carbon footprint (O'Neill 2010, 4-6). Green IT has evolved from energy and emission reductions to more holistic approach that also includes hardware asset replacement cycles and efficient deployment (Bokolo 2020; Dao, Langella, Carbo 2011, 69). While there is limited data on the reusability of enterprise ICT

products at the end of their first usage; several studies show or imply significant reuse potential of small consumer electronics comparable to enterprise ICT products (see Shittu, Williams, and Shaw 2022, 9; Dietrich et al 2014, 127; and Ogondo et al 2013, 2602).

A study in 2018 on Waste from Electric and Electronic Equipment (WEEE) in the Netherlands found that of approximately 66,000 tons of ICT products in the waste stream, only 13,100 tons were exported for reuse (Baldé et al 2020, 11). A separate study in Ireland in 2019 found that of 8,558 tons of new ICT products placed on the market that may pass through the usage and disposition phases, only 576 tons were documented to have been exported for reuse (McMahon, Uchendu, and Fitzpatrick 2023, 7). Acknowledging diligent tracking of transboundary e-waste movement and classification remains a challenge, the volume of ICT products exported specifically for reuse purposes is low. Ongondo et al (2013) identified many barriers that hinder reuse on a systems level, such as lack of confidence in refurbished products, unintended consequence of legislature on recycling, higher cost related to reusable product with limited guarantee on return, as well as limited staffing and time-consuming processing of refurbishment and reuse process. Facilitating proper reuse on a systems-level require extensive and almost seamless collaboration between stakeholders ranging from those on the receiving end (i.e. transports and refurbishment firms), as well as those on the supply end (i.e. enterprise purchasers, original equipment manufacturers, and retailers).

Methods

Literature review was conducted specifically on topics related to the purchasing and disposition of ICT products and their reuse potential. This paper is an extension of previous research from the author's graduate capstone project. As there is currently a gap in the literature, further research is necessary in this area. This paper gathers a variety of perspectives for a coherent understanding of ICT product procurement, consumption, and disposition. These perspectives range from ICT product market analysis and forecast to organizational structure and job descriptions, as well as IT asset disposition (ITAD) industry and operations in electronic waste streams. Three structured interviews were also conducted in 2022 to understand the perspectives in practice with tailored interview questions for each interviewee, including an enterprise IT manager, a representative from an ITAD firm, and an ICT product end-user of large corporation.

Findings

Procurement & Usage

Enterprise ICT management encompasses three major aspects: procurement, use, and disposal; all of which are influenced by the way information is exchanged, stored, and modified by end-users (i.e. employees) and systems-level needs (Philipson 2010, 6). Overall enterprise ICT product consumption is increasing due to increased spending, increasingly shorter replacement cycle and insufficient focus on sustainable ICT management. Enterprise ICT spending growth rate has fluctuated over the past decade, it shows general upwards trend and is projected to reach $5.12 trillion U.S. dollar by 2024 with devices, such as personal computers, tablets, mobile phones, and printers, accounting for $748.15 billion U.S. dollar (Gartner 2023). Furthermore, with ICT products serving as the platform for software markets, increasing AI adoption and user cases may have a compounding effect on consumption of hardware and parts (Senn-Kalb and Mehta 2023; Nestor et al 2023, 115-122). For example, increasingly lower product prices and quicker reiteration of technology has led to a decrease in enterprise ICT product replacement cycle years, with enterprise personal computers (PCs) being replaced every 4.99-5.62 years in 2019 to every 3.51-4.71 years in 2022 and projected to continue decreasing (Daniel Research Group 2023, 85; See Figure 2). Over 75% of a Lenovo ThinkPad

E15's carbon footprint stems from the manufacturing phase of its lifecycle and has a 381 kg of CO_2e carbon footprint value over the course of its product life cycle (Lenovo 2020, 1). Using its 381 kg of CO_2e carbon footprint as a proxy, the Scope 3 emission of a 500-employee digitized company before including other infrastructure emissions, can be 190,500 kg at the time of procurement. With the average replacement cycle length decreasing, the frequency of the

Enterprise

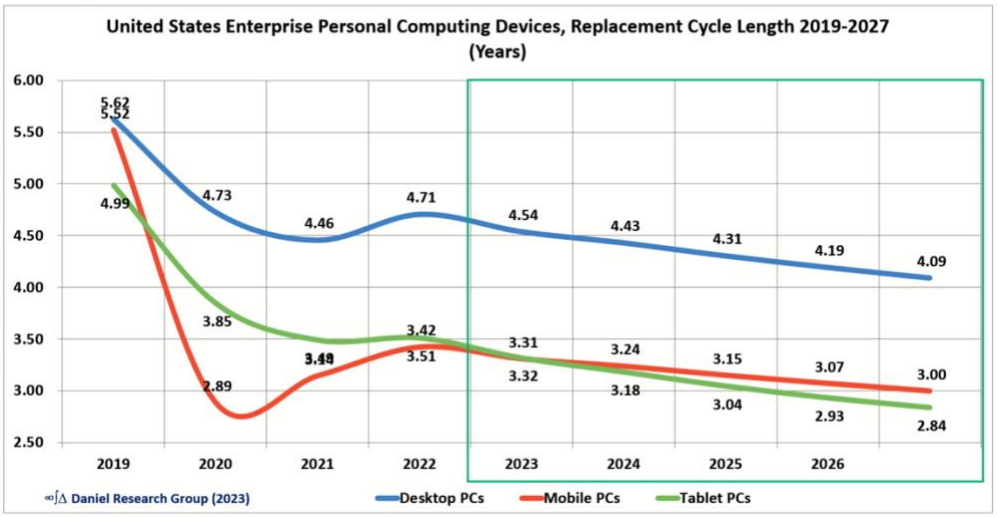

Figure 2. Decreasing Length of Replacement Cycle (Daniel Research Group 2023, 85)

product acquisition and its consequential emission can increase and have a compounding effect on the company's total scope 3 emission over time.

Despite increasing general incorporation of corporate social responsibility (CSR) frameworks, such as greenhouse gas emission accounting and overall sustainability reporting, sustainable ICT management is rarely incorporated in CSR reports and remain a low priority (Fujitsu 2011, 7). This low prioritization may be attributed to a variety of factors, such as unregulated nature of Scope 3 emission and lack of tangible accountability in supplier responsibility and green procurement. ICT management has capacity to somewhat exert control over end-user's consumption behavior and at a scale beyond energy efficiency through the different management aspects. In purchasing sustainably, many have adopted different product certification and eco-labels. However, changing enterprise internal policy to encourage longer usage timeframe may decrease purchasing and replacement frequency in the long run. Acknowledging the need to maintain utmost productivity, enterprise ICT management teams need to further understand and measure replacement frequency to help increase product usage before retiring the products. Examining the replacement cycle and end-user usage more closely may also align with ICT management teams' objective of increasing operational efficiency.

Disposition

Disposal is the other aspect of enterprise ICT management that can be further addressed to ensure maximizing the value of existing ICT products. There is limited research on enterprise ICT products at the end of its usage before they exit the company inventory. A study in Ireland on ICT product at the end of first use-life found shows that 87% of liquid crystal display (LCDs), 58% of laptops, and 64% of base units all have reuse potential (O'Connell, Fitzpatrick, and Hickey 2011). This is further supported by a study of enterprise activities at end of ICT use where only 9.8% of survey participation pay sufficient attention to possible reuse (Buchalcevova and Gala 2012, 118). The ITAD market size is set to grow from $15.6 billion U.S. dollars in 2022 to around $31.8 billion U.S. dollars in 2032 (Future Market Insight 2022), indicating an increase

interest and action involving refurbishment. Meanwhile, the electronics recycling market size projected to grow from $16.2 billion U.S. dollar in 2023 to $61.1 billion U.S. dollar by 2032 (Gupta 2022). Considering that some ITAD firms also facilitate recycling, the market size of the two disposal channels signifies that ICT products are predominantly recycled rather than refurbished, and often prematurely recycled as well.

Government and legislative incentives have been heavily focused on electronics recycling and recycling technology, which undermines reuse and redistribution. A study in the UK on WEEE directive's impact across the hierarchy of waste stream found that the legislative emphasis, investment, and management system centering recycling resulted in less interest, as well as incentives, in reuse (Cole et al 2019, 422). The main barriers to reuse identified, especially in comparison to recycling, ranges from cost in refurbishment process and lack of interest and access to refurbished products options at a large scale.

The ITAD refurbishment process is stringent in ensuring data safety and compliance, as well as product. The refurbishment process includes the following: receipt of assets to be disposed of, triaging for usability and resale eligibility such as cosmetics and technical specifications, data erasure and reinstallation, testing, repair and quality check (Schiller, Merhout, and Sandlin 2016, 30-33). Successful refurbishment for reuse depends on the products meeting many, if not all, of these criteria through the process, requiring significant time and resources to meet the volume of disposed products. These processes are currently recognized and certified by entities such as R2 and e-Stewards Standard for Responsible Recycling and Reuse of Electronic Equipment (Schiller, Merhout, and Sandlin 2016, 35; see e-Stewards 2022; SERI 2020). As a result, recycling is seen as more efficient and cost-effective due to the established market size and well-developed extraction techniques (Cole et al 2019, 423). The larger market size for recycled materials compared to refurbished products can also mean higher guarantee of return for ITAD firms when prioritizing recycling over reuse. A study on consumer willingness to use refurbished smartphones showed consumers are more likely to use refurbished products for older technology and at least 40% of consumers are willing to use refurbished products, across all product model or price (Esmaeilian et al 2021, 7-9). While there is general willingness for end-users to use refurbished products, one segment of the enterprise ICT value chain that has yet to be studied closely is how refurbished products and its performance affect ICT managers' ability to manage the complete enterprise asset. ITAD firms' lacks incentives to refurbish while enterprise consumer lacks confidence in steadier supply results in a lack of reuse. The ICT refurbishment industry needs significant scaling up from a business investment perspective, as well as support on legislature that prioritize reuse, in order to create both the supply and demand necessary to divert ICT products from entering the waste stream. Table 1 presents a summary of the above findings.

Conclusion

Continuous growth in enterprise ICT consumption and reliance have both positive and negative impact on global sustainable development. With increasing ICT spending, adoption of green IT practice remains a low priority. Currently, both enterprise-internal and external governance of ICT products favors recycling. As a result, redistribution is often undermined. With limited incentives and therefore investment, redistribution remains generally cost-ineffective. ICT products are still recycled prematurely without proper redistribution, and supply and demand of refurbished products remain low.

Based on the findings above, two major themes emerge as potential starting point to tangibly build towards ICT product circular economy: better tracking and increasing investment. Current tracking of enterprise ICT product remains segmented based on product ownership. However, the enterprise purchasers possess tools like enterprise resources planning software to keep

track of its inventory. ITAD firms also have existing infrastructure for fully certified processes and audit trails that can be built upon to track reuse potential and volume more closely.

Investment in the refurbishment sector can increase incentives for stakeholders to prioritize reuse over recycling. Both private and public investment in ITAD sector will largely help build up refurbishment capacity at scale. Consequentially, refurbishment techniques and innovation, as well as efficient processes may create pressure upstream the value chain and promote better product reparability and servicing. Finally, incentives in the form of carbon credit by purchasing refurbished products or refurbishing high volume of ICT products with high reuse potential may be another mechanism worth exploring. All of which requires further research on the market dynamics is necessary to identify and avoid unintended consequences.

Table 1. Summary of findings on barriers and factors related to systems-level ICT product reuse

Topics examined in ICT Value Chain	Key Trends	Summary of Findings	Source	Stakeholders
Procurement	*Spending has been and will continue to increase*	• Increased spending in both hardware and software and likely to continue with technological innovation and decreasing replacement cycle length. • Purchases are typically large-volume or business agreements that ensures stable supply. • Enterprise ICT products can be owned or lease, with majority of being owned. • Models and products procured influenced by changes in enterprise needs and end-user behaviors, such as increased software use and intensity, remote work servicing, and compatibility of older hardware with new technological innovation.	ITAM interview; EY 2023; Garnter 2023; Kim, Lee, and Kopal 2022, 1284; Zhou and Gupta 2020, 7235; Ongondo et al 2013; Senn-Kalb and Mehta 2023; Nestor et al 2023, 115-122; Daniel Research Group 2023, 85	Enterprise IT team Suppliers
	Green IT adoption is not a priority	• There is some adoption of green IT frameworks, however, it is generally deprioritized due to lack of IT incorporation in enterprise sustainability strategy • Locality and logistics of proper disposal or redistribution is 'nice-to-have' with limited returns • Lack of accountability and capability on tracking scope 3 emissions	ITAM Interview; ITAD Interview; Ongondo et al 2013; O'Neill 2010, 4-6; Fujitsu 2011, 7	
Use	*Governance of Systems currently favor replacement*	• Cost-effectivity are major factors that currently hinders support for older models and prioritizing repair. • Usage tracking primarily focuses on security and some level of inventory, tracking practice is typically more reactive than proactive. • Triggers of replacement are typically hardware-related. • Reparability is a major factor contributing to replacement cycle length, along with insufficient support for extended warranty and repair that is asked of the enterprise IT teams and manufacturers.	ITAM Interview; End-user interview; Ongondo et al 2013; Bokolo 2020; Dao, Langella, Carbo 2011; Indeed Editorial Team 2023; Hsu, Tsaih, and Yen 2018	Enterprise IT team End-users
	Limited Knowledge & Literacy on ICT care	• More end-user knowledge and care for ICT products may help increase reuse potential after it is no longer needed for initial end-user. • Perception of abundance of work ICT products differs from personal products, resulting in different care and usage behavior that affects replacement cycle length.	ITAD interview; End-user interview; Ongondo et al 2013; Philipson 2010, 6	
Redistribution	*Redistribution is not cost-effective*	• There is no standardized practice for reuse, while redistribution is perceived as ideal, it is not often cost effective and not feasible on an enterprise level. • The value of IT assets at the point of disposition often fluctuates based on size, servicing required and condition, as well as age of products. • Impact of reuse is often unrealized by both end-users and enterprise IT teams.	ITAM Interview; ITAD interview; Ongondo et al 2013; Fujitsu 2011, 7; O'Connell, Fitzpatrick, and Hickey 2011; Cole et al 2019, 422	Enterprise IT team ITADs & Recyclers
Disposition	*Premature recycling*	• Recycling is currently prioritized as it creates most value as opposed to more sustainable channels of disposition, including repair, refurbishment, or enterprise internal redistribution.	Cole et al 2019; ITAD interview, Fujitsu 2011	
	Limited Demand for refurbished products	• Refurbished products are more likely to have cut off points to operating systems updates • Channels for refurbished product sales ranges from wholesale to directly to end-users, taking place primarily online. • Demand for refurbished products are limited and often deemed as last resort for purchasers but seemingly makes little difference to end-users.	ITAM Interview; End-user Interview; Ongondo et al 2013; Future Market Insight 2022; Esmaeilian et al 2021, 7-9	

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