DOI: 10.1111/jiec.13406

APPLICATIONS AND IMPLEMENTATION

JOURNAL OF INDUSTRIAL ECOLOGY WILEY

Characterizing IT asset disposition flows for the circular economy

A case study on export for reuse from Ireland

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Editor Managing Review: Vered Blass

Funding information
EPA Research Programme 2014–2020, Grant/Award Number: 2018-RE-DS-11

Abstract

Understanding flows of resource-rich electrical and electronic equipment throughout its life cycle is increasingly important in the development of global circular economies, reflected by heavy legislative focuses on waste prevention and resource use efficiency. This research facilitates broader material flow analysis by characterizing flows of professional IT equipment within the Republic of Ireland, emphasizing the flow of legal exports for the purposes of refurbishment and reuse. The analysis of transboundary movement of non-waste used equipment contributes to a less often measured, but influential, facet of material flows. Eight key exporters of used equipment, comprising original equipment manufacturers, information technology asset disposition companies, and waste treatment facilities, were interviewed to characterize the sector, map the flow of materials, and identify gaps in existing reporting. Interviewed organizations declared exports of used equipment by category using a voluntary declaration form. Two key flows were identified representing currently unreported and unmeasured flows of non-waste professional equipment. A total of 441,261 units of equipment were declared to be exported for reuse from the Republic of Ireland through these previously unmeasured flows in 2019. Product keys developed by United Nations University were used to estimate the weight of total units exported as approximately 576 metric tons, amounting to an additional approximately 9% of the weight of IT equipment collected in the Republic of Ireland in 2018, or 0.1 kg per inhabitant. These quantifications of IT equipment exported for reuse will be a key component of future material flow analyses in the development of a circular economy.

KEYWORDS
circular economy, exports, industrial ecology, information and communications technology, material flow analysis, reuse

1 INTRODUCTION

Around 54 million metric tons (t) of waste electrical and electronic equipment (WEEE) are generated globally per year, an amount forecasted to rise to 111 million tons by 2050 (Forti et al., 2020; Parajuly et al., 2019). Within the category of electrical and electronic equipment (EEE), information technology (IT) equipment has consistently grown in popularity and use with the still increasing ownership of smartphones, the internet, and now with the necessity of working from home and virtual connections. To meet these needs, it is predicted that by 2023 data centers in Western Europe will account for 20% of the market share of global public cloud services. In Ireland, the market for data centers was estimated to value at $2.27 billion in 2020 and is expected to rise to $3.27 billion by 2026.[1] Research in the transboundary movement and treatment of EEE, especially WEEE, is increasingly topical as legislative bodies worldwide further regulate flows (Song et al., 2017). Developing legislation attempts to balance potential environmental and health impacts on informal waste treatment workers and their communities against the economic and social benefits, opportunities, and quality of life improvements communities experience when gaining access to affordable electronics.

The European Union (EU) has set targets for the collection and treatment of WEEE, predicting volumes of WEEE to enter the official preparation for reuse and recycling schemes based on the volumes placed on the market 3 years previously. However, reaching these targets has proved challenging for some member states due to volumes of WEEE not arising in official schemes when expected. In fact, the Global E-Waste Monitor reports that only 42.5% of WEEE is documented as collected and recycled in proper waste streams on the European continent (Forti et al., 2020). The destination of the remaining volumes is largely unknown, however, can likely be attributed to practices such as waste dumping, improper disposal in household waste, improper recycling, and export. The recent Global Transboundary E-Waste Flows Monitor (Baldé et al., 2022) estimates that 5.1 Mt of e-waste crossed borders in 2019. Of that, the report estimates that 65% was shipped in an “uncontrolled” manner such as illegal waste shipments or mixed in with legal exports shipped as used EEE (UEEE), thus emphasizing the importance of further study in these flows of both WEEE and UEEE.

In 2019 and 2020, Ireland failed to reach the updated collection target of 65%, collecting only 61% and 60% of WEEE, respectively.[2] In anticipation of rising targets, recent studies have explored the unknown destinations of this missing WEEE finding that more than 10 t of WEEE is improperly recycled in scrap metal collections (Casey et al., 2019), while a much smaller 17 t is exported to West Africa by consumers for reuse (McMahon et al., 2021b). This study joins these others in characterizing and quantifying one flow of EEE that is not arising in official collection schemes, this time examining business-to-business (B2B) export for the purposes of refurbishment and reuse abroad.

Companies managing IT equipment used in corporate or otherwise professional settings, referred to herein as professional IT equipment, often utilize IT asset disposition services (ITAD) to adhere to legislative requirements for the disposition of equipment at end of use (Schiller et al., 2016). This stream of equipment and the need for ITAD services increases in demand and use with the growth of the internet, cloud computing, and data consumption across Europe and globally. Regulatory obligation as well as increased attention to good public perceptions and corporate social responsibility (CSR) have resulted in a relatively transparent pathway from use to recycling through required reporting. However, significant portions of the reuse routes in the professional IT equipment lifecycle remain publicly unknown.

The Global E-Waste Monitor (Forti et al., 2020) report highlights that legal exports for reuse are an important tool to extend product lifetimes as part of the development of a circular economy. However, it is also highlighted that export for reuse in the EU is almost entirely unavailable. Currently, a recent study in the Netherlands represents the only study examining export of professional IT equipment from an EU country. This research presents a previously unexplored part of the flows of professional IT equipment in Ireland, using interviews and surveys of experts including compliance authorities in the Environmental Protection Agency (EPA) Ireland, producers, and ITAD companies to characterize flows of B2B IT equipment, identify key pieces of flows that are currently unmeasured, and subsequently estimate the quantity of material flowing through these existing knowledge gaps.

2 BACKGROUND

2.1 Reuse as a means of lifetime extension

While much of the existing export literature focuses on illegal shipments of waste and its associated impacts, non-waste UEEE is also shipped legally for the purposes of refurbishment and reuse, as is the case of UEEE exported from the Republic of Ireland illustrated in this research. In these cases, assuming similar regulatory environments, legislation regulating the treatment and movement of UEEE aims to support higher levels of resource efficiency and waste prevention through reuse while maintaining high standards of environmental and health safety.

The influence of the EU’s Waste Framework Directive’s prioritization of reuse above waste treatments such as recycling, energy recovery, and disposal persists within newer legislation, including the WEEE Directive (recast 2012) and the Circular Economy Action Plan (2020). However, reuse is often still disregarded when EEE enters recycling after a first use (Cole et al., 2019). Although separate targets are under development in the EU to achieve higher rates of preparation for reuse, defined here as the reuse of material previously designated as waste, systems are still under development with low outputs in some member states lacking a previous infrastructure and culture of preparation for reuse (McMahon et al., 2019). In these member states, recycling has often been used as the major contributor to reach legislative targets under the previously combined targets for recycling and preparation for reuse. Among other things, some producers are also apprehensive toward reuse, fearing potential risk for what can be known as "demand cannibalization," where reused equipment could displace sales of new equipment, although not much research has been conducted to identify the significance of this risk (Cooper & Gutowski, 2017). Lifetime extension of EEE contributes to the conservation of energy and water used in production (Williams, 2004), resources used in transportation of new products, and, significantly, of critical raw materials (CRMs) that are often not recoverable under current technological methods of recycling. Due to the extraction, production, and transportation of materials used to produce EEE, these products also contain a high level of embodied carbon (Allwood et al., 2012; Norman et al., 2016). Therefore, reuse and other means of lifetime extension have the potential to reduce greenhouse gas (GHG) emissions associated with the manufacturing of products, although, for EEE, these benefits may be somewhat affected where new products have significantly improved energy efficiency over the use phase (Edenhofer, ; Ekins & Hughes, 2017; Hertwich et al. 2019).

In addition to environmental benefits of lifetime extension, reuse has also been shown to contribute economic benefits. Research by Pini et al. (2019) and McMahon et al. (2021a) illustrate the job creation potential of additional labor-intensive steps in the treatment of EEE including refurbishment, preparation for reuse, and recycling. A 2011 study of a major United States (US) educational institution demonstrated the retained value of refurbished desktops and laptops at an average of $20–100 per unit and up to $250–350 when sold to individuals (Babbitt et al., 2011). This is further demonstrated by a 2009 study showing that used computers imported into Peru were of a higher value as a product than the value of recycling the constituent materials as a waste (Kahhat & Williams, 2009). Reuse, and particularly export for reuse, can also provide economic value in destination communities by providing access to in-demand, affordable electronics with the potential to increase employment and educational opportunities as well as quality of life. For example, 17 t of UEEE exported from Ireland to West Africa in 2019 was estimated to input a value of €150,000 if sold in the destination market (McMahon et al., 2021b). This influx of value in the communities provides an additional opportunity for lower economic level households, which are significantly less likely to own a computer and more likely to own used equipment when they do (Kahhat & Williams, 2010), to be able to afford at times life-changing products. However, downstream effects on the destination communities when equipment is shipped as waste or later becomes waste in informal recycling systems is still a major health and environmental concern (Williams et al., 2008).

Acknowledging these benefits, a broad range of legislation and legislative tools, in addition to the Waste Framework and WEEE Directives, Circular Economy Action Plan, and Green New Deal, attempt to facilitate the practice of reuse within the EU and globally. In fact, the Global E-Waste Monitor (2020) reports that 71% of the world population, spanning 78 countries, are under some policy, legislation, or regulation governing the treatment of e-waste, which often incorporates waste prevention and reuse. The global focus of waste prevention through reuse can be highlighted by the United Nations (UN) Sustainable Development Goal (SDG) 12, Target 12.5, which states the target to "substantially reduce waste generation through prevention, reduction, repair, recycling, and reuse."

Under these policies and regulations, reuse is to be supported and encouraged. However, challenges and barriers to reuse, such as lack of access to equipment, poor perception from illegal reuse practices, and legislative or product design challenges, as well as the legislative incentivization of innovation in recycling have resulted in a relatively neglected reuse system in many countries (Cole et al., 2019; Kissling et al., 2013; McMahon et al., 2019). Transboundary shipment of UEEE for reuse has been shown to be particularly inhibited by differences in applications of regulations for transboundary shipments of WEEE across countries and regions (Milovantseva & Fitzpatrick, 2015). Research into the amount of reuse, both formal and informal, and the flows of reused material will be essential in achieving legislative goals and targets on national and international levels.

2.2 | Transboundary movements of EEE

The Global E-Waste Monitor 2020 report acknowledges the challenges in comprehensively pulling together existing literature to quantify transboundary flows of UEEE and WEEE due to differences or discrepancies in categorizations, definitions, reporting, or data (Forti et al., 2018). However, several attempts to measure such flows are discussed within the report, concluding that approximately 7%—20% of e-waste generated is exported from its origin as UEEE or WEEE.

Specifically, in the United States, 8.5% of UEEE generated in 2010 was estimated to have been exported, followed by 7% in 2011 (Duan et al., 2013; Lasaridi et al., 2016; USITC, 2013). In the EU, research suggests several similar estimates, namely, that a minimum of 10% of EU e-waste is exported illegally, while another 10%—15% is exported legally as UEEE for the purpose of reuse (BIO Intelligence Service, 2013; Huisman et al., 2015; Illés & Geeraerts, 2016). Additionally, a study conducted by Baldé et al. (2020) showed that 8% of e-waste generated in the Netherlands is exported for reuse.

A 2019 review by Islam and Huda examined the recent applications, trends, and characteristics of material flow analysis of e-waste in 55 papers, while presenting both challenges and future research possibilities based on existing gaps in the literature. Of these 55 papers, few specifically addressed the recent export of either UEEE or WEEE. An MFA of e-waste transported from OECD member countries to non-member countries estimated that an average of 5 Mt per year were transported for the reference year 2005 (Breivik et al., 2014), an analysis of e-waste collectors in Hong Kong estimated an export of approximately 65,000 tons to developing countries (Lau et al., 2013), and a US analysis measured domestic flows and exports of used computers, finding that in 2010 approximately 7 million used or scrap computers were exported from the United States (Kahhat & Williams, 2012).

The authors of the 2019 review present a number of opportunities for new research stemming from identified gaps in the existing literature, for which this paper quantifying flows of UEEE exported from Ireland provides insight. Namely, the review highlights the importance of accumulating national or regional level, product or product group specific, and source-specified (e.g., small and medium enterprises, large multi-nationals, public bodies, etc.) assessments as well as estimations for reuse as a means of lifetime extension and regular reporting of transboundary movements of UEEE (Islam & Huda, 2019). This research contributes to each of these areas of literature identified as essential for future growth in the understanding of EEE flows, presenting an up-to-date national, product-group-specific, transboundary analysis of used professional IT equipment exported from Ireland for the purpose of refurbishment and/or reuse, using replicable methodology adaptable to other EU member states (currently in use in the Netherlands) as well as other countries or regions.

2.3 | ITAD processing

ITAD is the process by which businesses and organizations deal with professional IT equipment at end of use, which is not necessarily end of life. The goal of ITAD services is largely to provide compliant treatment of UEEE and WEEE that also minimizes the negative environmental and social impacts of waste disposal, recovers value out of disposed assets, obtains cost savings, and generates returns while guaranteeing clients' data security (Schiller et al., 2016). While the ITAD process can be carried out by the affected business, considerations such as logistics, environmental hazards, and confidential data handling require a well-planned strategy that specialized ITAD companies can often better facilitate (CompuCom, 2020). Around the world, sustainability is becoming a strategic priority for businesses. A well-managed ITAD program can promote corporate sustainability or CSR initiatives and, as such, can be viewed as an essential activity of an enterprise.

Choosing a third-party ITAD service provider successfully addresses two major challenges faced by enterprises: the rapid growth of aging and obsolete IT asset generation and compliance with complex regulations, including data security regulations, under which penalties for defaulters can be severe. Careful adherence to regulatory compliance therefore drives the application of strict standards and controlled processes (Schiller et al., 2016).

The IT asset disposition market is projected to be worth $27.9 billion by 2025, with a forecasted annual growth rate of 10.8% between 2019 and 2025 (Grand View Research, 2019). With a growing focus on the ethical management of the generated WEEE, particularly in relation to transboundary shipments, as well as the focus on promoting a circular economy, evaluating ITAD management is increasingly important. Consequently, despite its growing popularity and importance, it remains an understudied area in WEEE management and as such existing literature is scarce (Schiller et al., 2016).

2.4 | ITAD regulatory compliance

Regulatory policies and legislation surrounding the ITAD process are numerous and complex, varying on global, regional, or national levels. The basic categories of regulations include corporate governance and privacy as well as environmental protection, while others include worker safety, export, copyright, and contract law (Schiller et al., 2016). For the purpose of this paper, environmental protection and export laws are of particular importance. The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal aims to protect human health and environment against the adverse effects of hazardous wastes by limiting the generation of WEEE and the strict restriction of its movement across borders.

The WEEE Directive (2012/19/EU) is the principal regulation on the management of WEEE in the EU. The Directive aims to promote reuse, recycling, and recovery of WEEE by improving collection rates in member countries, also regulating transboundary e-waste shipments. While the transboundary shipment of WEEE is largely prohibited under global, regional, and state legislation, it can be legitimate to do so under certain circumstances. The WEEE Directive permits transboundary shipments of assets within the framework of a B2B transfer arrangement under the appropriate derogations outlined in Annex VI (2a–c). Namely, in countries where the Organisation for Economic Co-Operation and Development (OECD) control system for waste recovery applies, assets under a valid contract and with the intention of reuse are permitted to be sent to the producer or a third party for refurbishment or repair.

A certified ITAD provider also requires third-party certifications in three major categories: international management standards, ITAD best practices, and data security standards, which may include certifications from the International Organization for Standardization (ISO), Occupational Health and Safety Assessment Series (OHSAS), Recycling Industry Operating Standard (RIOS), and/or others (Investment Recovery Association, 2019).

3 | METHODS

This case study characterizes the flow of non-waste professional IT equipment through Ireland, identifying material pathways and B2B points of export, and quantifying the flow through these export points by use of interviews and surveys with experts including producers, ITAD companies, and the authorities to which they report. A flow diagram illustrating the flow of B2B professional IT equipment through stakeholders in Ireland was created from the data collected through interviews with expert stakeholders. Subsequently, a survey was conducted with stakeholders who export professional IT equipment to determine how much and what type of equipment was exported. Results from the survey were also incorporated into the flow diagram. The analysis was conducted within the scope of units of professional IT equipment that was first placed on the market in the Republic of Ireland and was exported for reuse in the year 2019 either prior to or after refurbishment.

3.1 | Qualitative system characterization

The research team collaborated with the EPA Ireland office for waste statistics to examine existing declaration forms for reporting of WEEE handling and treatment, and how these forms might be used or adapted for reporting of non-waste exports applicability to the reporting of exported professional UEEE. Initial interviews with the EPA offices for waste statistics and producer responsibility team also ensured that new methods of reporting would not duplicate data that is already reported.

Through existing reporting relationships, the EPA additionally began the process of identifying stakeholders and companies exporting materials from the system boundary, whether for the purpose of or after refurbishment. This was further achieved through a mixed application of snowball sampling, by which identified stakeholders suggested and provided contact information for companies conducting relevant business activities within the system boundary. This method of sampling was continued until no further collaborators or competitors were identified by participating organization and allowed for a representation of the key players in the Irish market. Semi-structured interviews and site visits were conducted during this stage for the purpose of characterizing stakeholder behavior and the movement of material within the system boundary. Interviews were structured through the use of a questionnaire (Appendix A, Supporting Information), which provided qualitative information on organizational type and relevance to the study, clarified exports reported to this study were used (but non-waste) equipment originally placed on the market in Ireland, and reviewed the pathways equipment takes between organizations and for export. Pathways of equipment flow through identified stakeholders during the analyzed time period of 2019 were then mapped as a flow diagram, with particular emphasis on the quantities of UEEE exported for reuse and its routes of export.

3.2 | Quantitative data collection and analysis

An existing model for reporting export of UEEE currently in use in the Netherlands was identified. Research by United Nations University (UNU) and partners represents an ongoing analysis of WEEE flows, from EEE placed on the market to the WEEE generated along both compliant and non-compliant pathways or WEEE treatment (Baldé et al., 2020). As a part of the Dutch analysis, researchers developed a voluntary registration system to collect reported data on exports for reuse, piloted in 2017 and 2018. For the purpose of this study, the existing reporting form used in the Netherlands by the National WEEE Register was translated and adapted for the deployment to participating stakeholders in the export of professional IT equipment from Ireland for the purpose of refurbishment and reuse. Exporters were identified based on the results and input from the aforementioned stakeholder interviews.

Through snowball sampling, researchers identified a total of 25 organizations that broadly participate in the B2B professional IT market. On contact with the organizations, a total of eight, including original equipment manufacturers (OEMs), waste treatment operators, ITAD companies, and social enterprises were identified as potential exporters and asked to participate in the voluntary declaration survey in order to report quantities of UEEE exported within determined categories (see Appendix B, Supporting Information for adapted form). Where the other 17 organizations were, indeed, in use of professional IT equipment, most fell upstream up the export activity, for example, leasing equipment from OEMs or partnering with ITAD companies who would take equipment at end of use. In these cases, the OEMs, ITAD companies, etc., take control of the equipment and serve as the exporter for these consolidated amounts and reported these amounts to the study. Through the snowball sampling with expert stakeholders participating in the study, it was validated that the eight surveyed organizations represent all those participating in professional IT export market in Ireland that are currently known to competitors, national authorities, and other involved stakeholders. Despite this, there remains the possibility that some organizations participating in export of B2B IT equipment remain unidentified by this study, likely managing small quantities of equipment.

The data collection and feedback obtained from returned voluntary declaration forms was anonymized, consolidated, and summed to protect the identity of participating organizations as well as the confidentiality of their data, which may be commercially sensitive. Collated data was separated by type of equipment and was reported in units. Furthermore, and similarly to Baldé et al.'s research in the Netherlands, each equipment type was assigned a weight per unit based on the associated UNU key (Forti et al., 2018). This system was utilized in order to allow for both consistency in determining the weight of equipment and to facilitate replication in future studies.

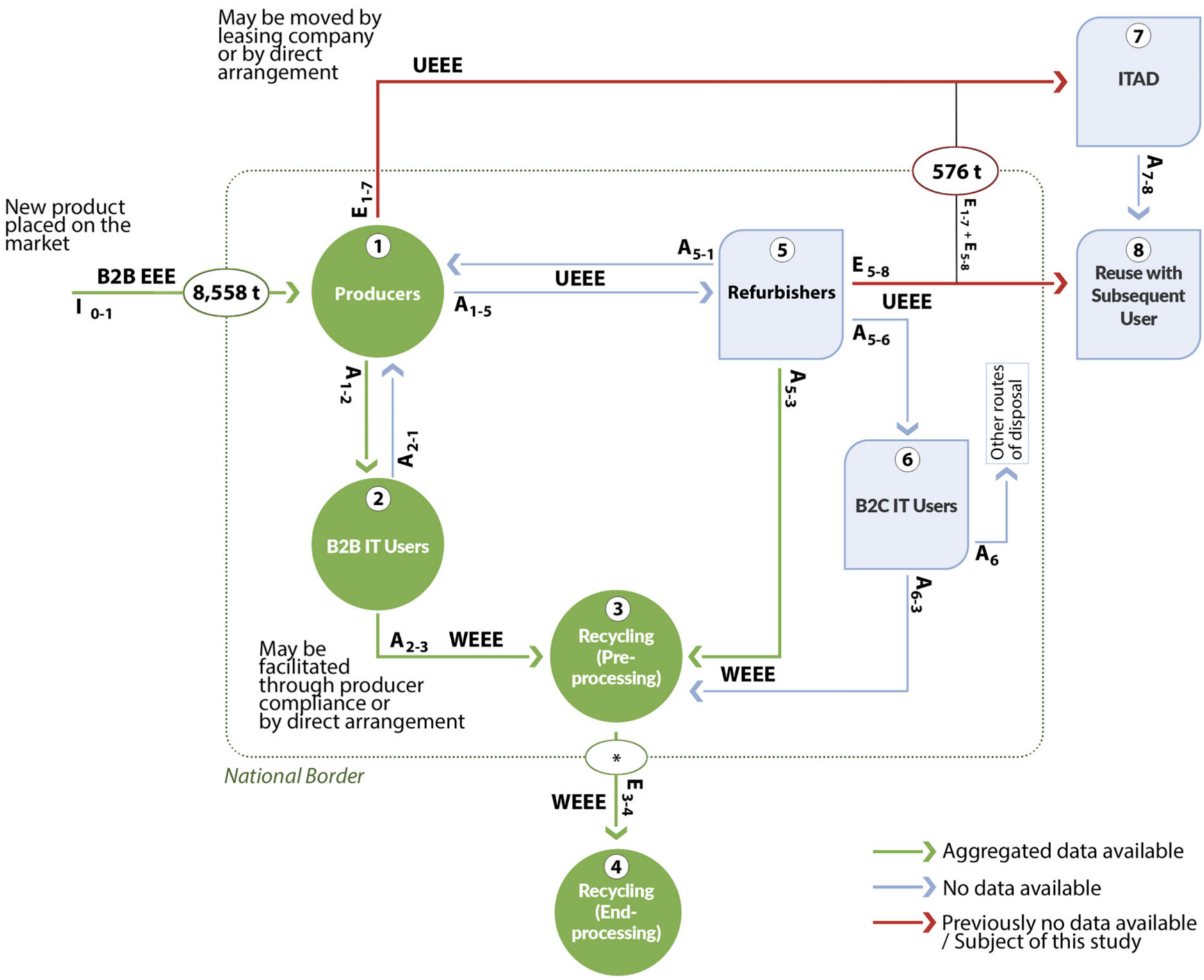

FIGURE 1 Potential pathways of acquisition and disposal of information technology assets, including existing reporting of electrical and electronic equipment movement between stakeholders. *Quantities of B2B WEEE exported for end-processing in 2019 not yet publicly available.

4 | RESULTS AND DISCUSSION

4.1 | System characterization

The routes of movement and refurbishment of UEEE in Ireland have been identified within the scope of B2B scenarios. Figure 1 illustrates the pathways of movement for professional IT equipment and the two identified pathways analyzed in this research for the export of professional IT UEEE. While the movement and stock of equipment inside of the system boundary was of qualitative interest and is illustrated and discussed below, only quantities of EEE, WEEE, and UEEE entering or leaving the system boundary were within the scope of this study, with a specific interest in quantifying the previous unknown: B2B export for reuse. Additionally, current reporting capabilities have been highlighted, with particular attention to pathways through which the movement of UEEE is not reported at this time. Equipment was found to be exported by both end-users, for example, an OEM, for refurbishment abroad and by Irish refurbishing firms for resale abroad. Small amounts of originally B2B equipment may also cross the system boundary through export by B2C exporters who purchased refurbished equipment. However, an adjacent study found that the share of total IT export from Ireland on roll-on roll-off vehicles was found to amount to only just over one metric ton in a 12-month period beginning in 2019 and, therefore, the previously B2B sourced equipment is unlikely to be significant (McMahon et al., 2021b). The previously unreported and unknown quantities of UEEE exported were declared to total 576 t during the year 2019. The quantities are not separated between the two categories of refurbishment prior to export (E_{2-7}) or refurbishment after export (E_{1-6}) in order to maintain confidentiality. Table 1 describes each pathway of EEE, UEEE, and WEEE import (I), export (E), or other movement between processes (A).

For many of these models, equipment was reported by companies to be classified as product throughout its movement and refurbishment and never as a waste. As such, in certain cases end of first use is often a more fitting description of the stage at which a company "disposes" of, or relinquishes ownership of, IT assets. EEE placed on the market in Ireland follows one of several potential pathways at end of first use, including being (1) sent to domestic refurbishers, who are receiving UEEE both directly from companies and from producer compliance collections, (2) sent to

TABLE 1 Descriptions of professional information technology flows in Figure 1

Flows	Description
I_{0-1}	New products placed on the market (EEE)
E_{1-7}	Export of used equipment by producers/sellers for refurbishment
A_{1-5}	Used equipment going for domestic ITAD processing
A_{5-1}	Refurbished equipment returning to producers/sellers for reuse
A_{2-3}; A_{5-3}; A_{6-3}	End of life equipment entering official recycling route
E_{3-4}	Export of materials by recyclers for end processing
A_{7-8}	Exported equipment refurbished outside system boundary going for reuse
E_{5-8}	Export of refurbished materials for reuse
A_{5-6}	Refurbished equipment going to B2C users for reuse
A_6	Other unknown routes of disposal, including informal pathways
E_{1-7}–E_{5-8}	The sum of equipment exported through pathways E_{1-7} and E_{5-8}

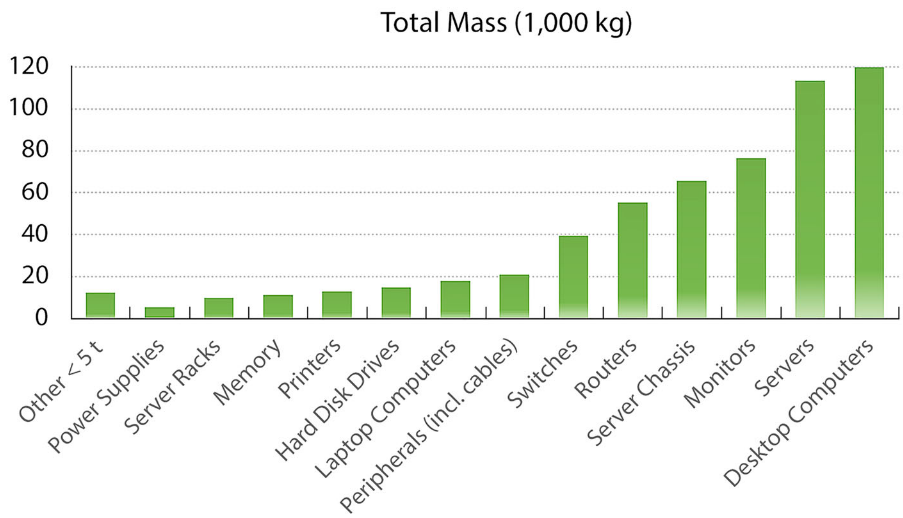

FIGURE 2 Breakdown of exported professional information technology categories by mass exported for reuse in 2019. Data available in Appendix C, Supporting Information.

leasing companies before UEEE is sent abroad to collection hubs, and (3), perhaps presenting a larger challenge, sent to international refurbishers that receive UEEE from Irish companies. Interviews with Irish producers and ITAD companies indicated that UEEE exported was then sold to either businesses or individual consumers, often in a third country, and was very unlikely to return to the Irish market.

4.2 | Data collection and analysis

Examination of EPA reporting documents confirmed that existing reporting of exports prior to this study were only required for WEEE. Thus, quantities of EEE exported for or after refurbishment, affirmed by participating organizations to be exported as product, are not previously reported in existing documentation requirements.

A total of eight companies were identified by the EPA or other exporters as participating in the export market and engaged with the voluntary declaration form for reporting exported UEEE, reporting a range of >1 t to approximately 190 t of used professional IT equipment exported for reuse, with a median of approximately 66 t.

The analysis revealed a reported 441,261 units, or approximately 576.3 t, of professional IT equipment exported from Ireland in 2019 for the purpose of refurbishment and/or reuse. For analysis within the context of waste regulations and prevention, this number of units has been converted into weights based on the categorization of equipment laid out in the keys developed by UNU (Forti et al., 2018). ITAD companies as a whole reported the highest quantities of exported UEEE and accounted for 94% of exported equipment. Figure 2 illustrates the breakdown of exported equipment type, where servers, desktop computers, and server chassis account for approximately 50% of exported professional IT equipment by weight. Monitors, routers, and switches account for an additional nearly 30%, while the remaining 20% includes a range of peripheral and small equipment.

Stakeholder interviews with OEMs, ITAD companies, and waste treatment facilitators indicated this equipment is sourced from a variety of inputs including, but not limited to, leasing schemes, producer take backs, and ITAD activities. Equipment was screened and sorted into disposition pathways. All equipment underwent data sanitization. Organizations differed in where further treatment takes place, as shown in the pathways of Figure 1, with some undergoing refurbishment in Ireland and subsequent export for sale and some exporting prior to refurbishment. Organizations diverted waste materials into appropriate treatment flows. Where determinable prior to refurbishment, and/or where refurbishment occurs within Ireland, these wastes were diverted into Irish waste streams. These waste pathways are currently monitored through reporting by the EPA. The used equipment exported is reportedly shipped as non-waste product to centralized facilities in the EU where final treatment of the equipment takes place, followed by sale of equipment abroad. Although destination for refurbishment and/or resale varied by organization, the majority of the exported equipment was sold within the EU or in neighboring European countries, in fewer cases, the equipment was further destination countries in Asia, Africa, and the Americas. Specific destinations are withheld to protect the confidentiality of the participating organizations.

4.3 | Regulatory WEEE targets and export of UEEE

The recast of the WEEE Directive requires member states to transition from a target of 45% of the average weight of EEE placed on the market over the previous three years to a rising target of 65% by 2019. While this target may be more easily attainable for some member states, data from Eurostat (2020) showing that all but three EU member states fell short of 65% collection in 2017 suggests that meeting these new targets may present a challenge for many others.

In order to reach and exceed these targets, Irish waste collectors must address a number of reasons for WEEE not arising in the compliant WEEE treatment system, including improper disposal in household waste and recycling collections or in scrap metal facilities, dumping, illegal export, and long-term storage of end of life equipment, a frequent behavior of consumers due to a lack of awareness or accessibility to proper collection sites or due to a perceived residual value (Casey et al., 2019; Hickey & Fitzpatrick, 2008). These inhibiting factors to WEEE treatment are likely to be addressed through facilitation of increased awareness, access, and enforcement of proper WEEE disposal. However, legal export may also be a significant contributor to WEEE not arising in Irish compliant treatment facilities. Legal export of UEEE for the purpose of refurbishing and resale, often within the EU, contributes to resource efficiency and the sustainable benefits thereof through reuse and the lifetime extension of EEE. Importantly, only quantities of equipment classified as waste are reported under the current framework. The quantities of UEEE exported for reuse, and therefore no longer available for collection at end of life in the Irish system, despite being placed on the Irish market, are classified as product at all times and are not captured under the current reporting model. In order to calculate the appropriate quantities of WEEE required to meet collection and recycling targets it is necessary to measure, and potentially apply, these quantities.

Currently, the movement of WEEE within and away from Ireland is carefully reported to the EPA in line with the treatment requirements laid out by the WEEE Directive and Statutory Instrument (S.I.) 149. However, the characterization of the UEEE sector conducted in this study revealed a lack of current reporting for exported UEEE. Currently, only EEE classified as waste (WEEE) is reported for use in target calculations. Due to this distinction of equipment as product when exported, certain pathways of EEE traveling out of the Irish market, as indicated in Figure 1, are not required to be reported and are therefore missed under the current structure. The methods utilized in this study offer a solution to fill these gaps through the introduction of voluntary reporting, which interviews with producers and ITAD companies in Ireland have indicated would be well received, particularly as several companies already participate in such a system in the Netherlands.

The most recent EPA data shows that in 2018 Ireland achieved a 61% collection rate for WEEE placed on the market, a rise in 20% compared to the collection rate for 2017 (EPA, 2019). Despite the increase in collection between 2017 and 2018, an additional 4% increase remains required to achieve 2019 targets, which will continue to rise. Illustrating the contribution of research quantifying categories of WEEE not arising in previous collections, recent research by Ryan-Fogarty et al. (2021) estimated mixed waste streams to contain approximately 10,900 tons of WEEE, amounting to more than 10% of the figure of EEE placed on the market used in 2018 targets. Assuming for these purposes similar figures between 2018 and 2019 are used for EEE placed on the market and collections, application of the estimations of exported professional IT equipment reported in this study to target calculations would contribute to an increase of 9% in the category of “IT and Telecoms” equipment.

5 | CONCLUSIONS

This study characterizes and quantifies a previously undermeasured and unreported flow of used EEE exported from Ireland for the purpose of refurbishment and reuse, finding that at least 576 t of professional IT equipment was exported from Ireland by OEMs, ITAD companies, and other stakeholders in 2019. Similar to the research of Baldé et al. (2020) in the Netherlands , the analysis presents a clearer view of the movement and reporting of EEE throughout its life cycle in the country of study, revealing quantities of EEE no longer available for collection in the origin country, but also quantifying reuse of UEEE. The methods and results of this study contribute to the identification and continued monitoring of a key piece of future studies on material flow analysis of the entire professional IT system, which will be necessary for the development of a successful circular economy.

The results of this study join prior studies determining the destination of volumes of WEEE that do not arise in the expected streams for proper collection and treatment in Ireland. This is increasingly important as Ireland strives to reach rising collection and treatment targets for WEEE, illustrated by the fact in the previous section that the 576 t of UEEE found to be exported in this study equates to a 9% increase in IT and telecoms equipment collected, based on 2018 numbers. As a recommendation of this study, the methodology used has been adopted by the EPA Ireland to continue data collection annually for consideration in target calculations. This ongoing monitoring and reporting will allow for awareness of changes and trends in the market as well as for the possibility of identifying stakeholders and potential exporters that were unknown at the time of this study but may contribute to exported quantities. This study is limited in scope to professional IT equipment exported from Ireland. While the flow from being placed on the market was characterized, the quantification was limited to the equipment that crossed the border out of Ireland. Future studies into a full material flow analysis of the flows characterized herein are a logical extension. Additionally, replication of the straightforward and adaptable methods used in this study is strongly encouraged in other EU member states, as we begin to fill in the gaps in literature and knowledge on the movements of used electronics. In the absence of individual country assessments, the results of this study can be used along with those of Baldé et al.'s Dutch WEEE Flows study to estimate flows of B2B IT equipment exported for reuse, adjusted for key influences such as population size and WEEE generation per capita, especially in countries with similar regulatory and economic environments. However, it should be noted that business activities and factors influencing them are likely to vary from country to country.

In the interest of continuing to collect this data on the quantities of UEEE exported for refurbishment and reuse, the authors present the following set of recommendations for regulators and reporting bodies in Ireland. First, the estimated amounts of used professional IT equipment exported from the Republic of Ireland for the purpose of resale and reuse abroad should be reported and considered in the calculation of regulatory targets. This data collection should be conducted on an annual basis, as annual reporting is of particular importance considering external factors that may affect export. For example, Covid-19 was reported to impact exports of professional IT equipment for some interviewed stakeholders in one of the two ways: decreases in shipments due to restrictions or increases in demand for affordable office equipment during lockdowns. Brexit was also reported by some organizations as a concern for unknown effects regulatory changes could have on export and import business between the United Kingdom and Ireland.

Future quantifications supported by these recommendations contribute to a growing body of research enabling decision makers in government, industry, and the public to better understand the movement of materials and how they fit into the circular economy. More research studies that involve collaborative works between scholars and practitioners are encouraged, and it is essential that these cover the two core components of the ITAD industry: process and policy. While this study made every effort to capture data from a broad representation of professional IT export, there is potential for annual reporting to create an established norm that will allow collection of further data from organizations that may have declined to report for this study, resulting in higher reported quantities of export. Further research in these areas will help policymakers evaluate and improve policies that enhance the life cycle management of IT assets (Schiller et al., 2016).

Particularly, research such as this exploring the extent of reuse and providing support to encourage reuse of EEE, and across other product categories, supports the hierarchy of waste treatment laid out in the previously mentioned Waste Framework Directive. The reuse of UEEE, including the export for reuse examined in this study, is important to achieve both legislative goals and the associated goals to improve resource efficiency and the circular economy, decrease impacts of pollution on environmental and human health, and mitigate climate impacts of the manufacture and treatment of EEE and WEEE.

ACKNOWLEDGMENTS

The authors would like to thank the project steering committee and the EPA waste statistics and producer responsibility teams, as well as the organizations who engaged with the research. Additionally, the authors would like to thank Keshav Parajuly for his assistance and expertise.

Open access funding provided by IReL.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the supporting information of this article.

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NOTES

[1] https://www.mordorintelligence.com/industry-reports/ireland-data-center-market

[2] https://www.epa.ie/our-services/monitoring--assessment/waste/national-waste-statistics/weee/#:~:text=Ireland%20collected%20a%20record%2064%2C856,with%2061%25%20in%202019

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: McMahon, K., Uchendu, C., & Fitzpatrick, C. (2023). Characterizing IT asset disposition flows for the circular economy: A case study on export for reuse from Ireland. *Journal of Industrial Ecology*, 1–11. https://doi.org/10.1111/jiec.13406