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Definition of generic re-use operating models for electrical and electronic equipment

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ABSTRACT

This paper aims to define a typology for the most common re-use operating models for electrical and electronic equipment (EEE). The scope of the study is Information and Communication Technologies (ICT) and Large Household Appliances (LHA). To describe and categorize re-use operating models, an analytical framework was defined, which consists of the four dimensions supply chain, offer, customers and financial structure. Based on this framework, standardized telephonic and personal interviews were conducted with 28 case study partners.

Four re-use operating models for ICT and LHA were identified:

- The Networking Equipment Recovery Model
- The IT Asset Management Model
- The Close the Digital Divide Model
- The Social Enterprise Model

The first two models are for-profit, whereas the last two are not-for-profit. Moreover, models differ in terms of customer segments and products and services offered to these customers. The Networking Equipment Model processes Information Technology Networking Equipment for original equipment manufacturers (OEMs) as main customers. IT Asset Management organizations specialize in refurbishment of desktop and notebook computers for resale to distributors and retailers. The Close the Digital Divide Model provides used computers to eligible recipients in developing countries. Social Enterprises prepare computers and peripherals or large household appliances for re-use and sell them through retail shops to individual users.

The identified models constitute generic ways to structure re-use operations along the four dimensions of the analytical framework ("supply chain", "offer", "customers", "finance"). Different entities can utilize one or multiple combinations of these models.

1. Introduction

1.1. Background

Re-use is regularly discussed as a means of moderating the environmental impacts of electrical and electronic equipment (EEE) (Williams et al., 2008; Devoldere et al., 2009; Truttmann and Rechberger, 2006). It is seen as a progressive response to the shortening of product life times which is leading to greater pressure on resources and other manufacturing burdens in addition to the burgeoning quantities of e-waste which must be dealt with. Re-use, essentially, attempts to optimize the use phase of a product in order to achieve greater resource efficiency.

Over the last decades, the re-use sector for (EEE) has been growing steadily. Despite facing different challenges, many organizations have established successful operating models for the collection, preparation for re-use and redistribution of used EEE both in the profit and in the non-profit sector. Nonetheless, the

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re-use sector is considered to have a lot of latent potential. For example, with the increasing prevalence of lease-based models where product life spans are shortened the case for increasing the amounts of re-use, particularly for computing equipment, are compelling (Intlekofer et al., 2010). Likewise, as large institutional users are increasingly giving environmental considerations greater emphasis in the process of disposition of EEE, it presents an opportunity to promote better outcomes through re-use (Babbitt et al., 2011), particularly as the life-spans are decreasing (Babbitt et al., 2009).

The practice of re-use also manages to generate another wide range of ancillary social and economic benefits. These range from providing employment and training opportunities for people with disabilities or the long-term unemployed to providing access to good equipment for people on low incomes in both the developed and the developing world thus helping to bridge the digital divide (O'Connell et al., 2010; Anon., 2012a, 2012b). It is also a major source of IT equipment for businesses and educational establishments in the developing world helping to promote vitally needed economic development (Streicher-Porte et al., 2009; Kahhat and Williams, 2009).

However, while many diverse stakeholders are supportive of greater levels of re-use it is difficult to identify policy instruments that can be used to do so without the risk of creating expensive systems with the potential for inefficient outcomes. This was particularly apparent in the process of recasting the WEEE Directive when the European Parliament had ambitions to promote re-use through the inclusion of a separate 5% re-use target which was resisted by the European Council of Ministers whose national governments would be responsible for delivering on these targets. This impasse is evident in the general lack of specific supporting measures (with a few notable exceptions) for re-use globally.

One of the contributing factors to this roadblock is that the re-use sector globally has come to be discussed as a single entity when it is in fact a very diverse industry with a complex structure and differing requirements. Likewise, the different operating models which have emerged have done so for differing reasons; some out of plain economic opportunity, others as a means of achieving domestic social goals and others for the purpose of overseas developmental assistance. Any attempts to stimulate or mandate these diverse activities will require very different types of instruments to overcome the specific barriers that they face.

This work aims to make a contribution by creating a better understanding of the complex structure and dynamics of the re-use sector by offering a typology that can help to provide a more concise description of different re-use activities. In doing so it hopes to help create an image of the EEE re-use sector that is not homogeneous and should not look for "one size fits all" approaches when aiming to promote re-use.

1.2. Scope

The study investigates both not-for-profit and for-profit operating models. Despite the differences in the financing, many good practice showcases of re-use operations exist for both sectors. However, the informal sector has not been included in the scope of this study, which investigates legal entities preparing EEE for re-use in a comprehensible and transparent way.

Table 1 summarizes the scope of the study.

Several electrical and electronic product types are suited for re-use (e.g. medical equipment, large photocopiers). However, the study focuses on ICT products (excluding large photocopiers) and on large household appliances. For these two product categories, large and steadily growing commercial and non-commercial markets have developed in the past decade. This situation offers an excellent opportunity to investigate different operating models that dominate these sectors. Moreover, an analysis of the technical, social, economic, environmental and legal re-use potential of the different EEE-categories supports a clear fitness for re-use for ICT and large household appliances (O'Connell et al., 2010).

Table 1
Scope of study.

Dimension	In scope	Out of scope
Operating model	– For-profit and not-for-profit legal entities organizing an operating model	– Informal sector for re-use of EEE – Sheer trader, private seller
Product category	– Information and Communication Technologies (ICT) – Large Household Appliances (LHA)	– Small household appliances – Consumer equipment – Lighting equipment, (including electric light bulbs and household luminaries) – Electrical and electronic tools – Toys, leisure and sports equipment – Automatic dispensers – Medical equipment
Geography	– Operating models from Africa, South America, North America, Europe	– Operating models from Asia and Australia

As organizations engaging in re-use operations face different challenges in industrialized and in developing countries, the analysis included operating models from both contexts. The case study set was compiled through members of the Solving the E-Waste Problem (StEP) Initiative and their contacts. The StEP Initiative is an initiative of various UN organizations together with prominent members from industry, governments, international organizations, NGOs and academia with the overall aim to solve the e-waste problem (Anon., 2012c).

It represents operating models from Latin America, Africa, North America and Europe. Whereas the StEP community has well established relations to the re-use sector in the above mentioned regions, so far, little contacts have developed to Asian re-use organizations. Due to this hindered access to concrete data no Asian case study was included in this analysis. However, this does not imply that no re-use operating models and no good re-use practices may exist in Asia.

2. Method

2.1. Inductive research based on case study analysis

As this study pursues an exploratory purpose an inductive design is applied; the aim is to derive generic operating models by analysing specific successful re-use cases. The results are based on 28 case studies, listed in Table 2. A separate study of the respective barriers and success factors identified by these case studies is also being undertaken.

60% of the case studies are non-profit, the rest for-profit organizations. As for geographic distribution, 20% of the case study partners are headquartered in developing countries. Six of the non-profit organizations located in industrialized countries engage in the export of ICT equipment to developing countries. Whereas four organizations process LHA, the great majority of the case study partners focuses on preparing and redistributing ICT equipment for re-use.

This great variety in the case study set poses limitations to the generalizability of the results. However, the analysis enables the identification of typical patterns by investigating specific good practice case studies.

Table 2
Case study set.

	HQ in Africa	HQ in Latin America	HQ in North America	HQ in Europe	Total	In %
ICT						
for-profit	• 2	• –	• 4	• 4	10	37
not-for-profit	• 2	• 2	• 5	• 4	13	48
LHA						
for-profit	• –	• –	• –	• –	0	0
not-for-profit	• –	• –	• –	• 4	4	15
Total	4	2	9	12	27	100
In %	15	7	33	44	100	

Semi-structured interviews were conducted with representatives from each case study partner to derive a generic typology of re-use operating models.

2.2. Procedure for derivation of results

The different generic re-use operating models for ICT and LHA were derived by following a five-step process shown in Fig. 1.

Each of these steps is described in detail below.

2.2.1. Definition of success for re-use operating models

In the StEP White Paper on Common Definitions re-use is defined as follows (StEP, 2009):

> "Re-use of electrical and electronic equipment or its components is to continue the use of it (for the same purpose for which it was conceived) beyond the point at which its specifications fail to meet the requirements of the current owner and the owner has ceased use of the product"

Three aspects are important to understand the concept of re-use as promoted in the StEP white paper. First, re-use involves a change of product ownership; another owner begins use of the EEE or its components and this continued use then substitutes the use of a new product. Second, re-use can be applied both on the whole-product level and on the component level. And third, re-use should contribute to the environmental, social and economic optimization of the product life cycle. By extending the use phase of EEE or its components with a potential for re-use and, thus, substituting for the use of newly produced EEE or its components, re-use can enhance resource and energy efficiency over the entire product life cycle. Thereby, potential for re-use is defined as the ecologic, economic and social advantageousness of re-use compared to direct product recycling and disposal. This definition recognizes the fact, that re-use does not always constitute the optimal solution at a product's end-of-life as the product type, the product condition, the energy-efficiency of comparable new substitute-products and other contextual factors impact the re-use potential.

Since this study aims to identify successful re-use operating models, first the meaning of success needs to be clarified. Derived from the definition outlined above, this study defines two criteria of success for a re-use operating model. First, a re-use operating model is successful, when it contributes to the extension of the use phase of products with an environmental, economic and social potential for re-use and thus to the partial avoidance of e-waste. Second, a re-use operating model is successful, when it is financially viable, i.e. capable to generate a stable income through the sale of products and services or through other income streams such as public or private donations, which enable it to properly perform and develop its operations in the long term.

2.2.2. Definition of the re-use value chain

A generic value chain for electrical and electronic equipment (EEE) serves as a frame of reference for the identification and analysis of the different re-use operating models (Luger, 2010). As shown in Fig. 2, in this value chain, six consecutive value chain processes can be distinguished, which, in an ideal scenario, form a closed loop system. The value chain starts with the production process, where the function of the product is installed. The product is then distributed to private and corporate users. Depending on the operator of the distribution channel, different after-sales services, such as technical support, user training or lease-financing, are offered to the customers. Once the product reaches its end-of-use and is disposed of, it is collected by public or private institutions. In this ideal system the products are then tested for function and product safety and, based on the determined re-use value, sorted for preparation for re-use or recycling and disposal. Re-use organizations often offer collection in combination with specific after-use services like data destruction, refurbishment for remarketing or environmental compliance certification. Even though these services are mainly offered to corporate suppliers (B2B), individual users (B2C) may also demand some of them (e.g. data deletion).

Whereas recycling is responsible for the recovery of materials, which can be returned into production, preparation for re-use is to recover the function, for which a product originally was designed. These are quite distinct operations and involve very different practices in terms of collection, transportation and treatment. While re-use organizations may offer recycling services in conjunction with their re-use offering this will mostly involve some separation and disassembly for value added purposes before transferring the material to a recycler who will conduct the actual material recovery. The distinction between the two activities is important as the different logistical arrangements used means that the re-use value will be rapidly destroyed if equipment is first handled by a primarily recycling oriented operator. Preparation for re-use of EEE typically involves disassembly, inspection and cleaning, electrical safety and function testing, component retrieval, component repair, component exchange, software installation and reassembly (Luger, 2010).

After the preparation for re-use process, products or components, which could not be brought up to re-use requirements, are forwarded to recycling and disposal. Re-usable products and parts are redistributed either directly to end-users, to distributors and retailers, back to the original user for redeployment or to repair service companies as spare parts or components. As for the distribution channels, equipment is either distributed via direct delivery or via retail outlet shops (mostly for B2C sales). Many re-use organizations also use the Internet as a sales channel by running own shops on their websites, or by offering the products on electronic market-platforms like ebay, BrokerBin and others.

Fig. 2 depicts the value chain and the actors potentially involved in its different stages. Re-use organizations typically engage in collection and after-use services, preparation for re-use and re-distribution. These three processes, together with the linkage to recycling, constitute also the focus of this study. They either operate all of these processes in-house or focus on one or two

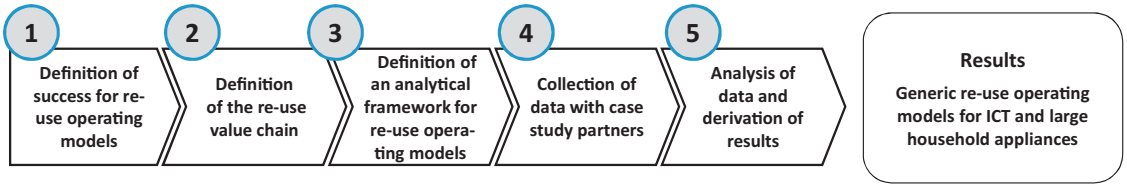

Fig. 1. Methodical procedure for derivation of results.

core processes and outsource the others to strategic partners. It is important to note, that Fig. 2 makes no geographical differentiation for processes and actors. Depending on the concrete re-use operating model, processes are performed at different geographic locations. Products might, for instance, be collected and prepared for re-use in Europe and then shipped to Africa, where they are redistributed to eligible recipients for further use and then, ideally, recollected for local recycling or for export to recycling companies in Europe or in the US.

As discussed above, the sequence of the processes in Fig. 2 makes clear, that re-use does not compete with recycling as an end of life solution but ideally optimizes economic and ecologic efficiency of the entire product life cycle by extending the use phase to its optimum duration. Therefore, it is particularly important, that re-use organizations transparently manage the link to proper recycling and disposal once their products have reached the definite end of life.

2.2.3. Definition of an analytical framework for re-use operating models

A descriptive framework for business models defined by Osterwalder et al. was used to derive generic re-use operating models from the case study analysis (Osterwalder et al., 2005). This paper suggests four dimensions to categorize business models: the "value proposition" refers to the products and services offered to the customers. The "infrastructure" subsumes the configuration of the value chain processes and technologies to deliver the products and services. "Marketing" corresponds to the distribution channels and market segments served by an organization. "Finance", finally, refers to the financing model, i.e. an organization's cost-revenue-structure.

For the application in this study, the four categories were slightly adapted to the context of EEE-re-use as shown in Fig. 3.

As for the infrastructure, the focus was given to the "*supply-chain*", i.e. the types of suppliers delivering used EEE to a re-use

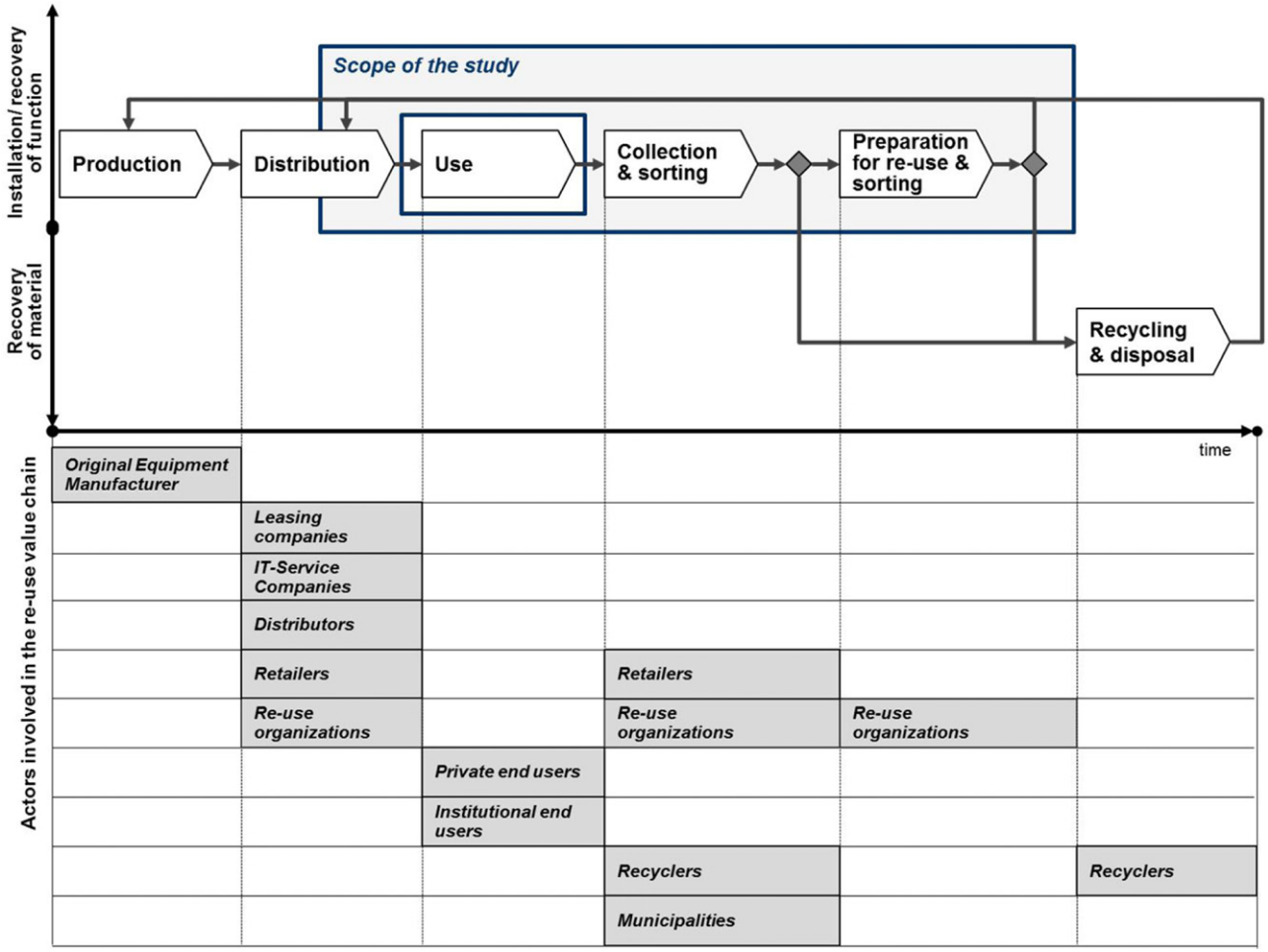

Fig. 2. Generic EEE value chain and potential actors.

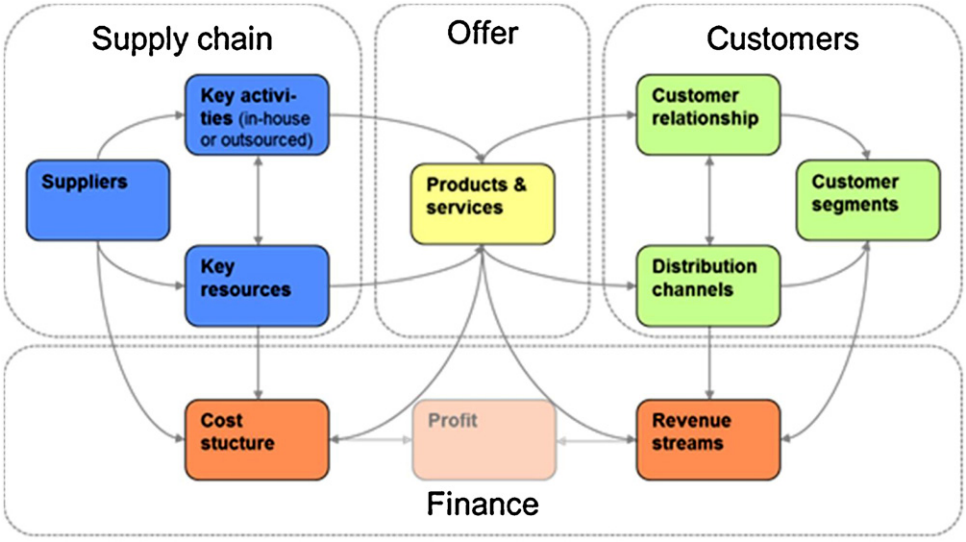

Fig. 3. Business Model Framework.

Adapted from Osterwalder et al. (2005).

operating model and the specific configuration of the EEE-value chain. In the context of re-use, suppliers may also be considered customers as services such as data erasure are often offered. For the dimension "value proposition", the analysis concentrated on the "*offer*"; what products and services does a re-use organization offer to its suppliers and to the customers buying or receiving the EEE, which it has prepared for re-use? The marketing-dimension looks at the segments of "*customers*" served and analyses how the relationship to them is organized. Under "*finance*" the main cost positions and revenue streams of the re-use organizations were investigated. Revenues can either stem from sales of products and services, from sales of sorted material for recycling or from public or private funding. With regards to the financial dimension, it is important to consider, whether an organization pursues a for-profit or a not-for-profit purpose, since this decision also impacts the other framework categories.

Based on these four dimensions, a standardized framework was developed to analyse and categorize generic re-use operating models are listed in Tables 3 and 4. These lists see some small changes from Fig. 3 where aspects of the dimensions were considered to possibly be overlapping they were placed in one or other of the dimensions and not both. For instance, many of the customer relationship categories were considered to be part of the key activities in the supply chain as it became evident that this is where the key part of relationship building lies for re-use organizations. Also, to further clarify this, customers are now described as being receiving customers.

By analysing the case studies with this framework, four main re-use operating models could be identified, which are explained in detail in Section 3.1.

2.2.4. Collection of data with case study partners

Most information was collected through personal interviews, which were conducted either per telephone or through personal visits. A standardized interview-guide (see Appendix 1), which was structured along the analytical framework outlined above, served as a basis for all interviews. This enabled the comparison and a systematic analysis of the results.

Internet-research, mainly by investigating information and documents publicized by the case study partners on their websites, complemented the information gathered through the interviews.

2.2.5. Analysis of data and derivation of results

The generic re-use operating models were identified by comparing the results from the interviews based on similarities and differences in the dimensions of the analytical framework.

The authors, in consultation with the StEP membership, created an order of priority by which these dimensions were analysed, with the highest priority given to the parameter which was deemed to most fundamentally differentiate between organizations and so on as deemed in order of importance until the collection of organizations were deemed to have sufficient similarities or connections to be deemed part of a single business model.

The finance-dimension, and specifically corporate function, was identified as the first level differentiating criteria and all organizations were divided among for-profit and non-profit models. The next level of sub-division was based on their customers, the product- and services-offer and the configuration of the supply chain. With the for-profit organizations this easily deconstructed into "Networking Equipment" and "IT Asset Management". At this point the organizations were deemed to be sufficiently similar to end the sub-division process. Within the non-profits the second level of differentiation was deemed to be based on the function that the organization sought to serve. This led to a breaking down between "Close the Digital Divide" which seeks to provide IT equipment to under served communities or countries and "Social Enterprises" where the act of preparation for re-use (with its associated employment and training opportunities) was the raison d'être. One further sub-division was considered among the social enterprises based on the specific products that were being prepared for re-use but it was decided not to further dissect this operating model as the essence of all of the organizations within this sub-division was considered to be sufficiently equivalent.

3. Results

3.1. Re-use operating models

As discussed in Section 2.2.5 based on the case study analysis four generic re-use operating models could be distinguished:

1. The Networking Equipment Recovery Model
2. The IT Asset Management Model
3. The Close the Digital Divide Model

Table 3
Analytical framework for case study analysis (supply chain and offer).

Supply chain			Offer	
Suppliers	Key activities	Vertical integration	Products	Services
Individual users	Collection (industrial countries)	Collection in-house	ICT equipment	Reemployment
Corporate users	Collection (developing countries)	Collection by partner	Large household appliances	Asset recovery
Equipment manufacturers	Preparation for reuse (industrial countries)	Preparation for reuse in-house	Whole products	Certified data security
Retailers & distributors	Preparation for reuse (developing countries)	Preparation for reuse by partner	Components	Technical support & maintenance
Technical service companies	Distribution (industrial countries)	Distribution in-house		Take-back for compliant recycling & disposal
Non-profit organizations	Distribution (developing countries)	Distribution by partner		
Commercial refurbishers	Recycling & disposal (industrial countries)	Recycling & disposal in-house		
Public collection sites	Recycling & disposal (developing countries)	Recycling & disposal by partner		

4. The Social Enterprise Model

These are operating models, which do not necessarily mean they are company specific models. That means, different companies and entities can utilize one or multiple combinations of these models.

Table 5 shows the distribution of the case studies per re-use operating model and per region.

Each model is described in detail in the next sections. All quantitative and qualitative data and information contained in these descriptions are based on the interviews conducted with the case study partners. All data and information refer to the period 2009–2010. In the description of the different models, all quantitative information are indicated as ranges, which show the difference between the lowest and the highest value within the group of case studies for the respective operating model. The entire set of data acquired during the interviews is available as a Supplementary file.

3.1.1. *Networking Equipment Recovery model*

Fig. 4 depicts the actors and flows of products and e-waste for the Networking Equipment Recovery model.

3.1.1.1. Supply chain. Networking equipment, e.g. rack servers, routers or switches, constitutes the majority of supply processed by IT Networking Equipment Recovery companies.

They receive a good portion of their input directly from equipment manufacturers (25–85%), who supply often new equipment consisting of excess or obsolete production that has never been used. New equipment accounts for 25–40% of total input.

The rest (10–75%) is collected from corporate commercial users; these corporate users are either customers of an Original Equipment Manufacturer (OEM), and the Networking Equipment Recovery company takes the equipment back on behalf to the OEM, or the corporate users hire the Networking Equipment Recovery company directly for asset recovery or internal redeployment services.

The Networking Equipment Companies, who participated in this study, collect several 100,000 units per year. The reuse rate is 10–50% of supply. This portion is redistributed for re-use mostly in form of parts and components. The rest goes to further treatment as e-waste. The rather low re-use rate can be explained by the fact, that networking equipment can be up to 15 years old (e.g. telecom base stations), when it is swapped, and, therefore, has a lower potential for reuse as a whole product. This explains why Networking Equipment Recovery organizations only harvest components and parts from a large part of the products received.

3.1.1.2. Offer. Networking Equipment Recovery organizations offer three main services:

- Internal remarketing of whole products: for this service, Networking Equipment Recovery organizations refurbish the equipment and sell it on behalf of the supplying customer to internal users within the supplier's organization; these are typically other business units, which do not need the newest equipment, or which can employ used equipment for training and education. But OEM repair and maintenance service centres constitute also an important customer segment; they use the refurbished equipment for replacement of broken products in maintenance contracts.
- Internal redeployment of components and parts: this service consists of dismantling large networking equipment taken back from OEM-customers and harvesting components and parts for re-use. These components and parts are typically sold back to internal or external OEM repair and maintenance service centres where they are used to provide repair services in maintenance contracts.
- External remarketing: this is a classical asset recovery service where the Networking Equipment Recovery organization either buys the used products or components and parts, prepares them for reuse and sells them to distributors on own account, or it sells them on behalf of the supplying customer and keeps a portion of the resale profit.

Table 4
Analytical framework for case study analysis (customers and finance).

Customers	Finance		
Receiving customers	Corporate purpose	Revenues	Costs
Individual users	For profit	Income by sale of products	Costs for procurement
Corporate users	Not for profit	Income by lease of products	Costs for employee compensation
Equipment manufacturers		Income by sale of services	Costs for operations & logistics
Retailers & distributors		Income by donations	Costs for overhead
Technical service companies			
Eligible recipients			

Table 5
Number of case studies per re-use operating model and country.

	Africa	Latin America	North America	Europe	Total	In %
Networking Equipment Recovery	0	0	2	2	4	14
IT Asset Management	3	0	2	2	7	25
Close the Digital Divide	2	0	2	3	7	25
Social Enterprise	0	2	3	5	10	36
Total	5	2	9	12	28	100
In %	18	7	32	43	100	

Brand protection is an important concern for OEMs. They make sure, that all refurbished products are sold only to controlled certified distributors. Some OEMs even require the Networking Equipment Recovery companies to dismantle all products taken back on their behalf and prepare only proprietary spare parts and components for reuse, for which there is an internal demand from OEM service repair and maintenance or education centres. As for the rest of the collected equipment, the Networking Equipment Recovery companies are allowed to refurbish and resell only non-proprietary commodities. These are usually sold to international distributors or traded on international online market platforms like BrokerBin.

In order to be able to offer their services in the different national markets of their global customers, most Networking Equipment Recovery companies run international networks of collection- and preparation-for-reuse-locations.

3.1.1.3. Customers. As described above, the equipment prepared for reuse is either redeployed by the OEMs or OEM service partners for repair services or internal training and education programs (15–100%). In this case, the Networking Equipment Recovery company is paid a processing fee per item. The rest is sold as commodities or certified refurbished products to distributors and retailers (0–65%). Typically, Networking Equipment Recovery organizations can generate higher profits by selling refurbished products and parts to distributors or retailers on the open market compared to the profit made by redistributing them to OEM customers. However, as mentioned above, many OEMs try to strictly control the distribution of own used products to the open market. But they allow the Networking Equipment Recovery companies to harvest precious materials from the equipment taken back from OEM customers. The Networking Equipment Recovery companies can sell these materials to processors at a profit.

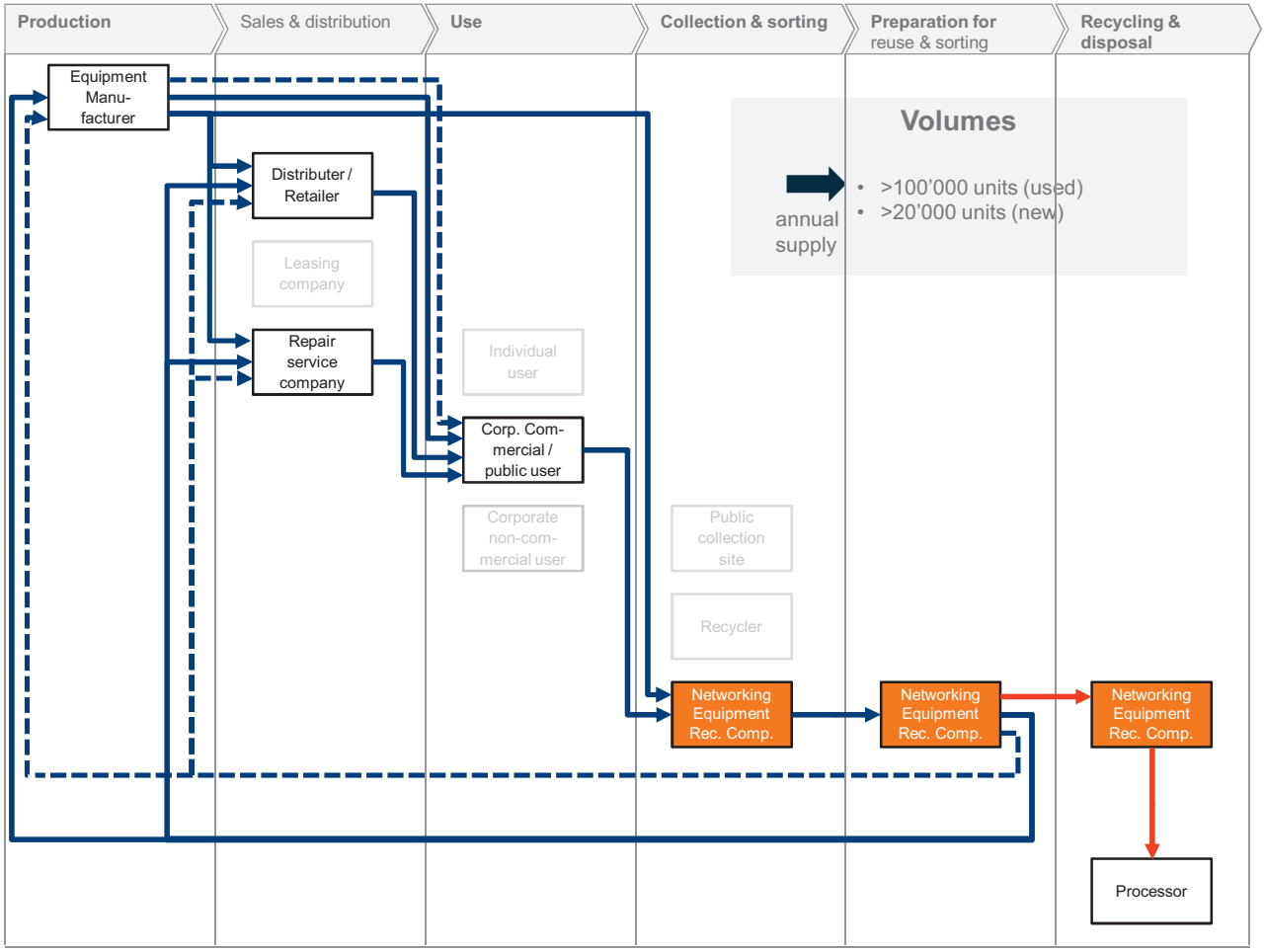

Fig. 4. Networking Equipment Recovery model. Geographical Scope: Europe and North America; Number of Organizations: 4; Temporal Scope: 2009–2010.

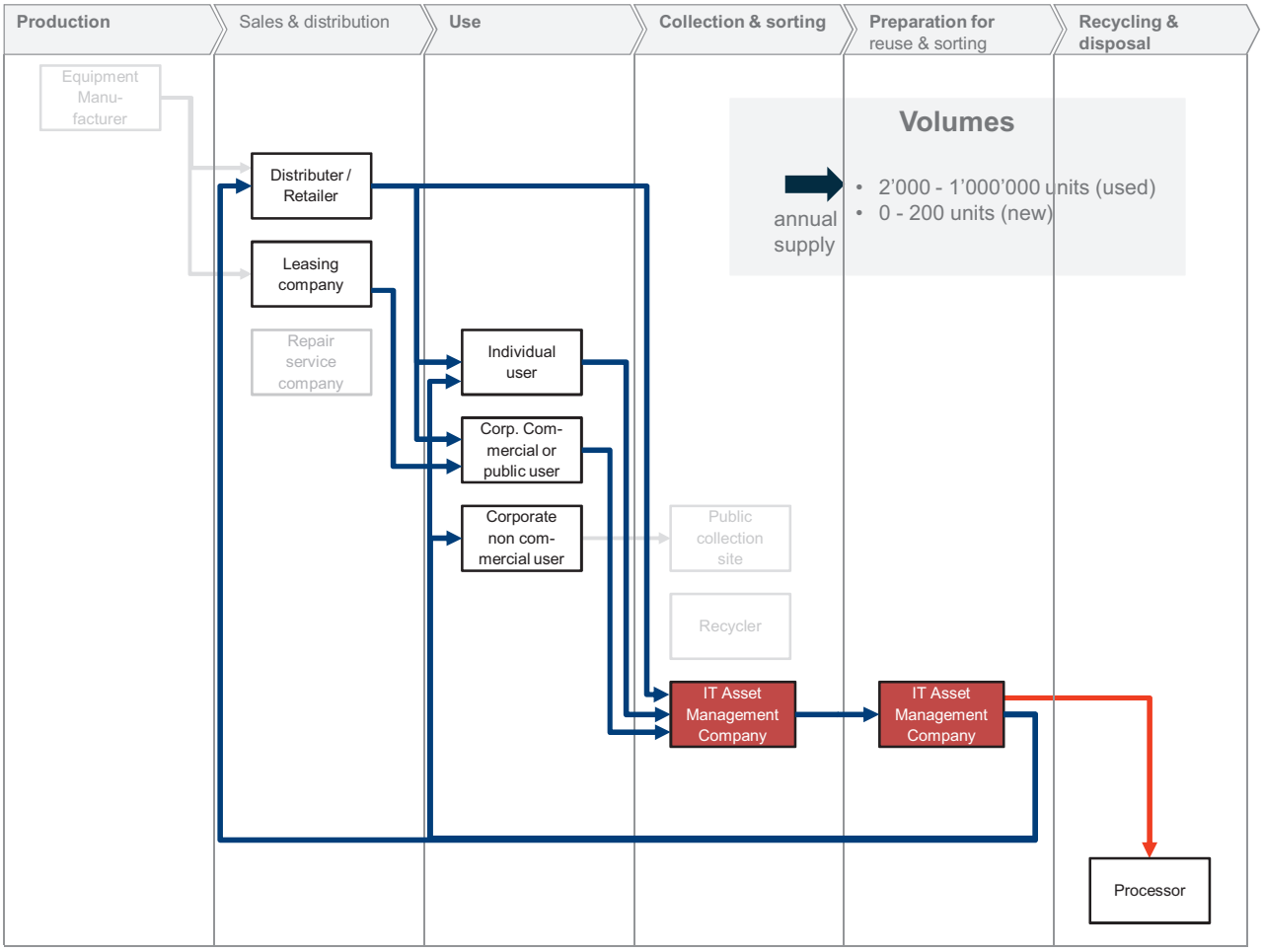

Fig. 5. IT Asset Management model. Geographical Scope: Europe, North America, Africa; Number of Organizations: 6; Temporal Scope: 2009–2010.

3.1.1.4. Finance. The Networking Equipment Recovery case studies, who participated in this analysis, have an annual income between 10 and 20 Mio. USD. 50–60% of revenues stem from sale of products, 25–30% from sale of sorted materials for recycling and 10–25% from sale of services (collection, processing fees, certified data destruction).

3.1.2. IT Asset Management Model

Fig. 5 depicts the actors and flows of products and e-waste for the IT Asset Management model.

3.1.2.1. Supply chain. In contrast to Networking Equipment Recovery companies, IT Asset Management companies specialize in the refurbishment and remarketing of desktop and laptop computers (together these two product groups account for 60–85% of equipment processed).

They receive the majority of their input from commercial corporate users (30–100%). The equipment from commercial corporate users is either owned by an OEM or a leasing company, which offers a take-back service to its customers and contract an IT Asset Management company for collection, refurbishment and remarketing of the equipment, or the equipment is owned by the corporate user, who directly contracts the IT Asset Management company for asset recovery.

One company in the case study set imported 70% of its input from other IT Asset Management companies due to a lack of local supply.

As corporate users swap their IT equipment on average every 2–3 years, this equipment comes with a high potential for re-use (25–95%).

Whereas the small enterprises, which participated in this study, process between 2,000–20,000 assets per year, the medium sized enterprises with a global network of locations for collection and refurbishment, process 500,000–1,000,000 assets per year.

3.1.2.2. Offer. IT Asset Management companies are specialized in offering asset recovery services. They collect used equipment from corporate users, refurbish it and remarket it prevailingly to retailers, who sell it to individual users. The IT Asset Management company either buys the used equipment from corporate users and remarkets it on own account or sells on behalf of the supplying customer and keeps an agreed share of the resale profit. Data sanitation and certification for compliant re-use, recycling and disposal respectively build a crucial part of an asset recovery service, since corporate users are particularly concerned about secure destruction of all information and data stored on the used equipment.

Refurbishment for redeployment is another service, where the collected equipment is refurbished and redeployed back in the supplier's organization, either by distributing the equipment to other organizational units, which do not need the newest equipment, or by selling or donating it to the employees.

Some IT Asset Management organizations also offer refurbishment for donation programmes, where the refurbished equipment

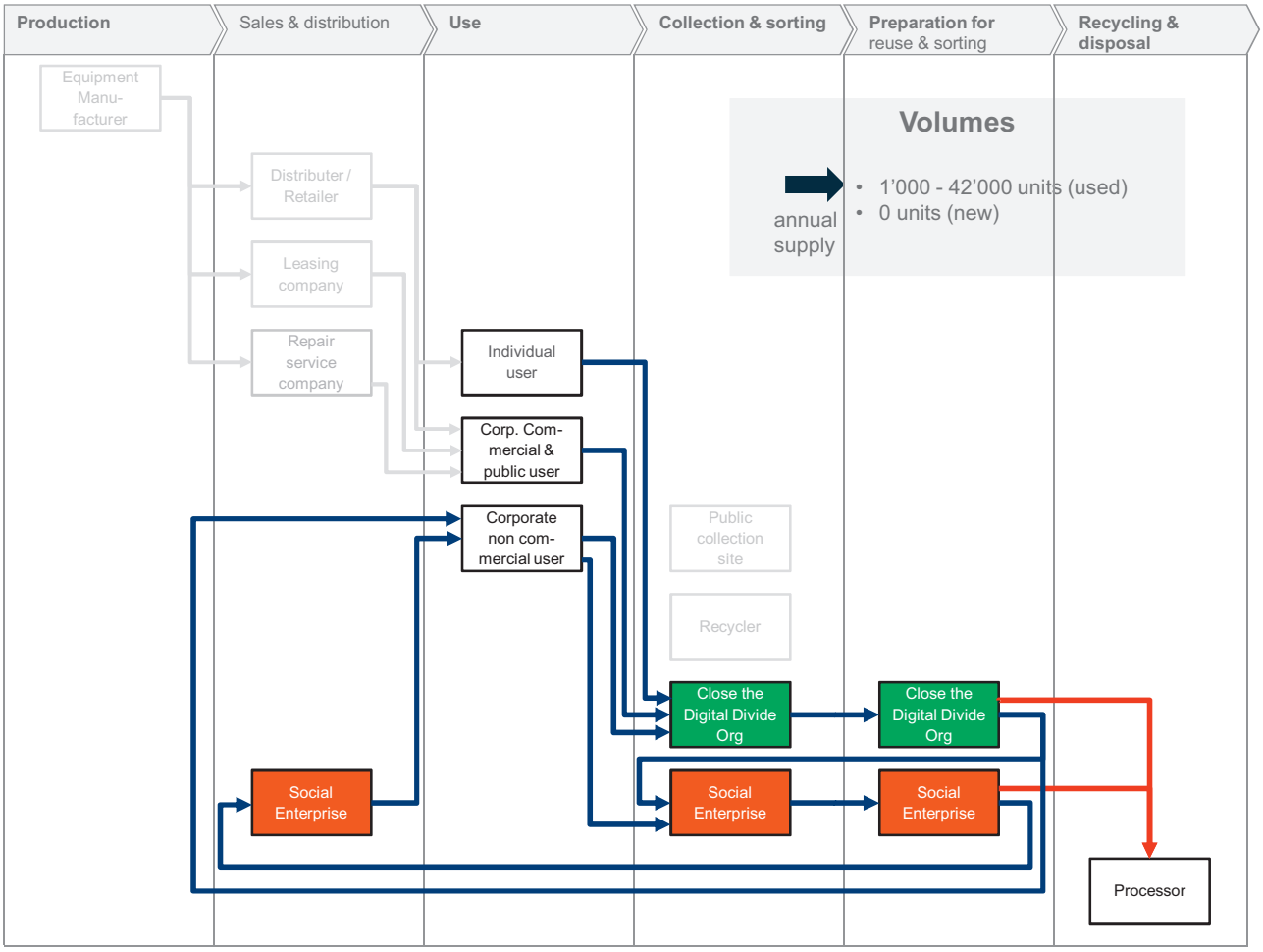

Fig. 6. Close the Digital Divide model. Geographical Scope: Europe, North America, Africa; Number of Organizations: 5; Temporal Scope: 2009–2010.

is donated to eligible recipients. Eligible recipients are defined customer segments that qualify to receive refurbished equipment for free or on special terms. Thereby, the original user, who donates the equipment, or the IT Asset Management company, who distributes it, define which users qualify as eligible recipients. Typically, these are the same groups as served by Close the Digital Divide organizations (see description below): educational institutions, health and medical institutions, non-governmental organizations or other not-for-profit organizations. Processing costs are then either covered by the eligible recipients or by the corporate user, who donates the equipment. Some IT Asset Recovery companies also charge no processing fee for refurbishment for donations but keep a portion of the donated equipment for remarketing for their own account.

3.1.2.3. Customers. IT Asset Management companies have four typical customer segments; a great part of the equipment goes to retailers and distributors for external remarketing (0–75%), some equipment is distributed back to the supplying corporate users for redeployment (0–60%), some is sold or donated to eligible recipients (5–85%), and a minor part (5–30%) is sold directly to individual users, typically through own e-shops or Internet market platforms like ebay. The great variance in these ranges can be explained by the fact that the 6 case studies for the IT Asset Management model differed significantly in terms of customer segments. Whereas most case study partners concentrated on sales to retailers and distributors, one case study partner specialized in refurbishment for redeployment and another sold most of the equipment to eligible recipients.

3.1.2.4. Finance. While the small enterprises, who participated in this study, have an annual income between 200,000 and 500,000 USD, the midsized enterprises annual income amounts to 25–30 Mio. USD. 35–90% of revenues stem from sale of products, 0–50% from sale of sorted materials for recycling and 0–20% from sale of services (collection, processing fees, certified data destruction). The great variance in these ranges can be explained by the fact that the 7 case studies for the IT Asset Management model differed significantly in terms of customer segments. Whereas most case study partners concentrated on sales to retailers and distributors, one case study partner specialized in refurbishment for redeployment and another sold most of the equipment to eligible recipients.

3.1.3. Close the Digital Divide Model

Fig. 6 depicts the actors and flows of products and e-waste for the Close the Digital Divide model.

3.1.3.1. Supply chain. Like IT Asset Management companies, Close the Digital Divide organizations focus on computers with desktop systems constituting the main share of products processed (80–90%) and laptop computers accounting for the rest (10–15%).

Most equipment is donated to Close the Digital Divide organizations by corporate commercial and public users (40–100%). Equipment supplied by individual users accounts for 0–50% of total input. One of the case study partners receives approx. 40% of the used equipment from non-commercial users (NGOs, not-for profit organizations).

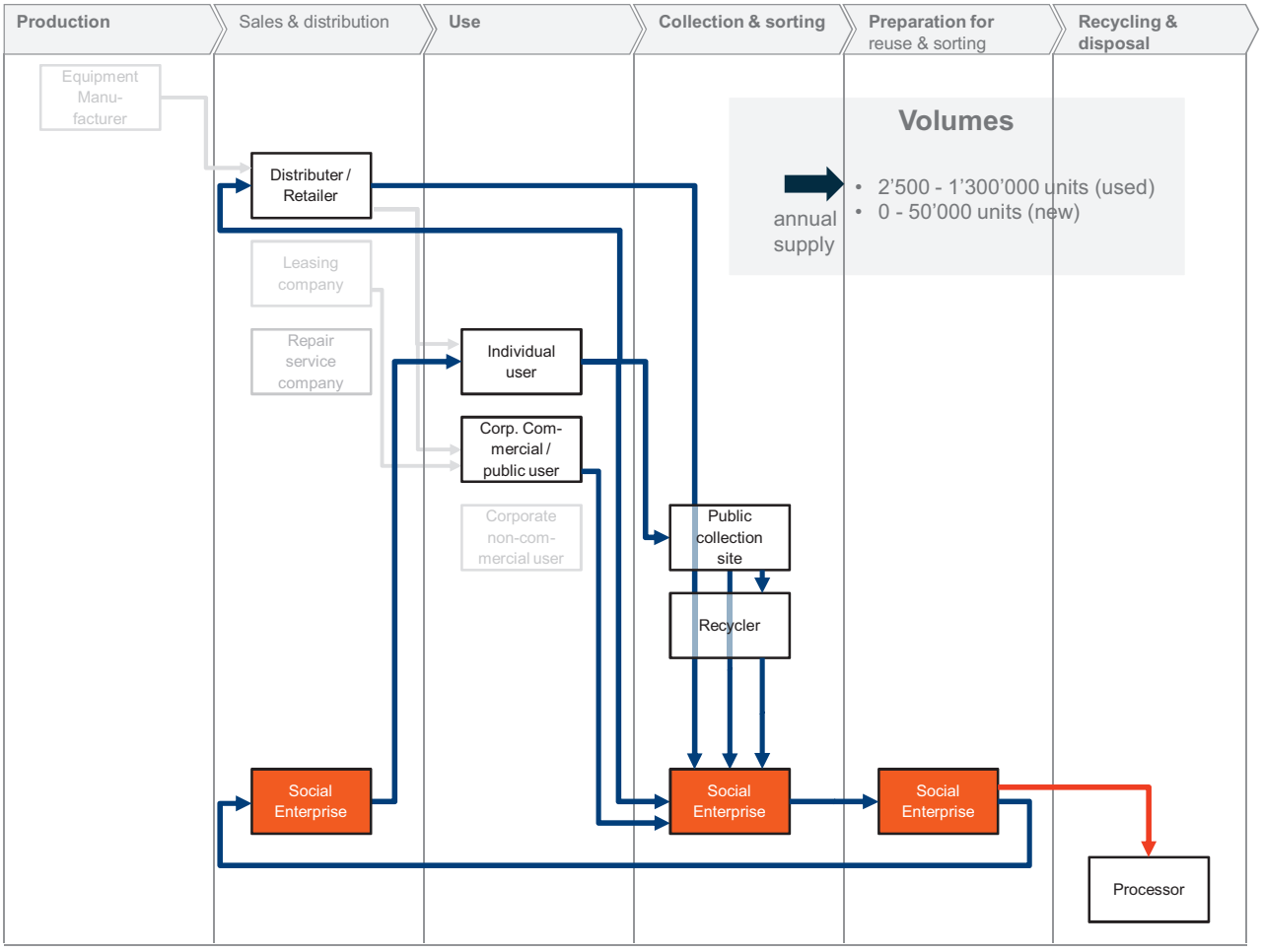

Fig. 7. Social Enterprise model. Geographical Scope: Europe, Latin America, North America, Africa; Number of Organizations: 12; Temporal Scope: 2009–10.

Due to the relatively large portion of supply by corporate commercial users, who swap their IT assets more frequently than private households, the average potential for re-use is between 40–90%.

Depending on the size of the Close the Digital Divide organization, total annual supply ranges from 1000 up to 42,000 units.

Most Close the Digital Divide organizations perform collection and refurbishment in-house. Typically, they rely on volunteer labour to keep operational costs low. Some Close the Digital Divide organizations focus only on the sourcing of ICT donations and the identification of eligible recipients and have completely outsourced all refurbishment operations to professional IT Asset Management companies. They pay their refurbishing partner a processing fee per item for the collection and preparation for re-use services.

3.1.3.2. Offer. Equipment is usually donated to Close the Digital Divide organizations. In exchange, they offer collection, secure data sanitation and certification for compliant preparation for re-use or recycling and disposal to the donators. Usually, a Close the Digital Divide organization directly provides these services to suppliers or donators. However, if it has outsourced collection and preparation for re-use to a refurbishment partner, this partner performs all services offered to suppliers or donators.

Close the digital divide organizations typically refurbish the equipment where it has been collected (in North America or Europe) and then export it to developing countries. Most Close the Digital Divide organizations ship the equipment to local distribution partners, local based not-for-profit organizations and social enterprises, which are not only responsible for local distribution but also for the provision of technical support and take-back of the equipment for final recycling and disposal at its end-of-life. Some exporters have even established own subsidiaries in the recipient countries to ensure provision of these services. Proper recycling and disposal is the biggest challenge for exporters of used ICT equipment, as developing countries still lack the infrastructure for appropriate end-of-life treatment of EEE. As a consequence, many exporters have started to engage in partnerships with local as well as international partners to develop national or regional recycling systems in the recipient countries.

3.1.3.3. Customers. As mentioned above, products are usually distributed through local partners, who perform another quality check on the equipment, sometimes install operating systems and basic software, and allocate the equipment to eligible recipients, which are mostly educational institutions, but also medical institutions or local NGOs and not-for profit organizations.

Some Close the Digital Divide organizations also ship directly to eligible recipients, if these recipients can proof to have the capacity to secure proper operability and maintenance of the equipment (e.g. through an internal technical department).

Whereas some Close the Digital Divide organizations charge cost recovery prices to the recipients, others set lower prices and finance the uncovered operational expenses through fundraising.

3.1.3.4. Finance. For the Close the Digital Divide organizations in the case study set annual income ranges from 800,000 to 2,300,000

USD. Whereas for some organizations, fundraising constitutes the major source of income (0–85%), others generate most income through sale of products (5–90%). Sale of services and of e-waste or sorted materials to recyclers account for less than 10% of total income.

3.1.4. Social Enterprise Model

Fig. 7 depicts the actors and flows of products and e-waste for the Social Enterprise model.

As stated in Section 2.2.5, the significant difference between the Bridge the Digital Divide model and the Social Enterprise" model is the intended primary beneficiary of the activity. For social enterprises, it is the social benefit such as the employment and training gained through the act of refurbishment that is the primary goal of the organizations.

3.1.4.1. Supply chain. Two sub-types of Social Enterprises can be distinguished: organizations that process ICT and such that focus on large household appliances.

- Supply chain for Social Enterprises focusing on ICT:

The main difference between the Social Enterprises who specialize in ICT equipment and the Close the Digital Divide organizations concerns the location of the market: Social Enterprises do not export outside the country where they collect the equipment. Desktop and notebook computers constitute the major product line.

Most Social Enterprises focusing on ICT products, which participated in this study, source 0–80% of used equipment from corporate users, the rest from individual users.

However, in some cases input is sourced from distributors or original equipment manufacturers. There were two case study organisations that operate in developing countries. These two social enterprises import the majority (90–100%) of their supply from Close the Digital Divide Organisations from Europe or North America.

Depending on the size of the organization, total annual supply ranges from 1,000 to 500,000 items. The potential for re-use ranges between 30% and 85%.

Table 6
For-profit re-use operating models (quantitative ranges indicate extreme poles on the scale for case studies of same re-use operating model).

Model	Networking Equipment Recovery (4 case studies)	IT Asset Management (6 case studies)
Supply chain		
Supplying customers	• Equipment manufacturers (production sites, labs, excess & obsolete production): 25–85% • Corporate commercial & public user (customer take-backs for OEMs, asset recovery services): 10–75%	• Corporate commercial and public users: 30–100% • Distributors and retailers: 0–15% • Individual users: 0–20% • IT service companies: 0–5% • Equipment Manufacturers: 0–15% • Other IT-Asset Management companies: 0–70%
Supply p.a.	• >100,000 units	• 2000–1,000,000 units
Re-use rate	• Approx. 10–50%	• 25–95%
Value chain	• In-house • Collection • Preparation for re-use • Recycling: dismantling and sorting of materials • Outsourced • Recycling: pre- and end-processing of materials • Disposal of hazardous waste	• In-house • Collection • Preparation for re-use • Recycling: dismantling and sorting of materials • Outsourced • Recycling: pre- and end-processing of materials • Disposal of hazardous waste
Offer		
Products lines	• IT networking products • IT networking parts & components: boards, PCBs, ICBs, Hard-disks	• Desktop computer systems (incl. monitors): 40–75% • Notebook computers: 10–40% • Others (mobiles, networking equipment, . . .): 15–40%
Pricing	• No information	• Desktop computers: 10–500 USD (depending on specs.) • Laptop computers: 200–750 USD (depending on specs.)
Min. specs	• Depend on market demand	• Pentium 3–4 (status 2011)
Services offered	• To supplying customers • Asset recovery and remarketing • Preparation for redeployment as spare products or parts for maintenance and repair services • Data security and brand protection • To receiving customers • Product warranty: 1–3 months	• To supplying customers • Asset recovery and remarketing • Data security • To receiving customers • Product warranty: 12 months
Customers		
Receiving customers	• Distributors and retailers: 0–65% • Equipment manufacturers (for internal re-use in labs or as spare parts for maintenance and service repairs provided to OEM customers): 15–100% • Others (OEM service repair companies, private users): 0–15%	• Distributors and retailers: 0–75% • Corporate commercial and public users(reemployment): 0–60% • Eligible recipients: 5–85% • Individual users: 5–30%
Market region	• Global	• National, regional, or global
Finance		
Purpose	• For profit	• For profit
Income p.a.	• 10,000,000–20,000,000 USD	• 200,000–30,000,000 USD
Revenues	• Sale of products, components and parts: 50–60% • Sale of sorted materials for recycling: 25–30% • Sale of services (collection, processing fees, . . .): 10–25%	• Sale of products, components & parts: 35–90% • Sale of sorted materials for recycling: 0–50% • Sale of services: 0–20%
Costs	• Procurement: 60% • Employee compensation: 15% • Operations (building/energy): 10% • Logistics: 10% • Admin & Marketing: 5%	• Procurement: 10–60% • Employee compensation: 15–40% • Operations (building/energy): 10–20% • Logistics: 10% • Admin & Marketing: 0–20%

Table 7
Not-for-profit re-use operating models (quantitative ranges indicate extreme poles on the scale for case studies of same re-use operating model).

Model	Close the Digital Divide (5 case studies)	Social Enterprise for ICT (8 case studies)	Social Enterprise for LHA (4 case studies)
Supply chain			
Supplying customers	• Corporate commercial & public user: 40–100% • Corporate non-commercial users: 0–40% • Individual users: 0–50%	• Corporate commercial and public users: 0–80% • Individual users: 0–20% • Distributors: 0–50% (new equipment) • Close the digital divide organisations: 0–100% • Equipment Manufacturers: 0–80%	• Corporate commercial & public users: 0–10% • Municipalities (public collection sites): 5–70% • Individual users: 0–85% • Retailers: 0–55% • Recyclers: 0–15%
Supply p.a.	• 1000–42,000 units	• 1000–500,000 units	• 2500–1,300,000 units
Re-use rate	• 40–90%	• 30–85%	• 10–70%
Value chain	• In-house • Collection • Preparation for re-use • Recycling: dismantling and sorting of materials • Outsourced • Recycling: pre- and end-processing of materials • Disposal of hazardous waste	• In-house • Collection • Preparation for re-use • Recycling: dismantling and sorting of materials • Outsourced • Recycling: pre- and end-processing of materials • Disposal of hazardous waste	• In-house • Collection • Preparation for re-use • Outsourced • Recycling: dismantling and sorting of materials • Recycling: pre- and end-processing of materials • Disposal of hazardous waste
Offer			
Products lines	• Desktop computer systems (incl. monitors): 80–90% • Notebook computers: 10–15% • Others (printers, networking equipment, . . .): 0–5%	• Desktop computer systems (incl. monitors): 50–100% • Notebook computers: 0–30% • Others (consumer electronics, networking, . . .): 0–25%	• Washing machines: 10–40% • Electrical cooking appliances: 10–15% • Dish washers: 0–20% • Cooling and freezing appliances: 0–25% • Other (ICT: 0–5%; consumer electronics): 0–60%
Pricing	• Desktop computers: 40–200 USD (depending on specs) • Laptop computers: 150–250 USD (depending on specs)	• Desktop comp.: 0 (donations)-200 USD (dep. on specs) • Laptop comp.: 0 (donations)-300 USD (dep. on specs.)	• Cooling & freezing appliances: 70–200 USD • Washing machine: 100–1000 USD • Electrical cooking appliances: 80–280 USD
Min. specs	• Pentium 4 (status 2011)	• Pentium 3–4 (status 2011)	• No standardized minimal specs.
Services offered	• To supplying customers • Refurbishment for donation • Data security • To receiving customers (provided by local partners) • Product warranty: 0-12 months • Technical support, maintenance and repair • ICT education and user training • Take-back for recycling and disposal	• To supplying customers • Refurbishment for donation • Data security • To receiving customers • Product warranty: 1–12 months • Technical support, maintenance and repair • ICT education and user training • Take-back for recycling and disposal	• To supplying customers: - • To receiving customers • Product warranty: 6–12 months • Technical support, maintenance and repair • Take-back for recycling and disposal
Customers			
Receiving customers	• Non-commercial corporate users (eligible recipients; educational institutions, health institutions, not-for-profit organizations, NGOs): 90–100% • Individual users: 0–10%	• Distributors and retailers: 0–90% • Corporate non-commercial users (educational institutions, health, institutions, NGOs): 10–100% • Individual users: 0–55%	• Individual users: 95–100% • Corporate non-commercial users (retirement homes, schools, . . .): 0–5%
Market region	• Developing countries (Export)	• Local	• Local
Finance			
Purpose	• Not for profit	• Not for profit	• Not for profit
Income p.a.	• 800,000–2,300,000 USD	• 500,000–38,500,000 USD	• 450,000–4,300,000 USD
Revenues	• Sale of products, components & parts: 5–90% • Sale of sorted materials for recycling: 0–10% • Sale of services (collection, processing fees, . . .): 5–15% • Private and public funding: 0–85%	• Sale of products, components & parts: 0–80% • Sale of sorted materials for recycling: 0–30% • Sale of services: 0–5% • Private and public funding: 0–100%	• Sale of products, components & parts: 15–80% • Sale of sorted materials for recycling: 0–20% • Sale of services (technical support, repair, . . .): 0–80% • Private and public funding: 5–20%
Costs	• Procurement: 5–60% • Employee compensation: 15–70% • Operations (building/energy): 5–50% • Logistics: 5–10% • Admin & Marketing: 5–20%	• Procurement: 5–40% • Employee compensation: 15–60% • Operations (building/energy): 10–20% • Logistics: 10–20% • Admin & Marketing: 5–20%	• Procurement: 5–10% • Employee compensation: 40–70% • Operations (building/energy): 15–25% • Logistics: 5–40% • Admin & Marketing: 5–10%

- Supply chain for Social Enterprises focusing on large household appliances:

There are three main potential suppliers of used equipment for Social Enterprises who process large household appliances; individual users (0–85%), public collection sites (5–70%) or retailers (0–5%), who transfer customer returns for preparation for re-use or recycling and disposal. One case study organization also receives equipment from recyclers (15%), where it cherry-picks the re-usable items. Total annual supply ranges from 2500 to 1,300,000 items per year with a re-use potential between 10%

and 70%. The great variance in the ranges reflects the differences between the case studies of Social Enterprises for large household appliances, which participated in the present study. While three case study partners operate one major facility, one case study partner coordinates a regional network of social enterprises including 16 certified re-use and repair centres. Moreover, each of the four case study organizations focuses on a different supply channel: one sources most equipment directly from individual users, another collects mainly from retailers (products returned by customers to retailers when they buy a new product), and two receive most part of used products from public collection sites.

3.1.4.2. Offer. As for the offer, the main differences between the two Social Enterprise types consider service offerings.

- Offer of Social Enterprises focusing on ICT:
  Social Enterprises that focus on ICT products receive the used equipment as donations. They offer the same services to supplying customers as Close the Digital Divide organizations: collection, secure data destruction and certified compliant preparation for re-use or recycling and disposal. After preparation for re-use they sell a big share of the products to eligible recipients, i.e. educational or health institutions or other not-for-profit organizations. They offer technical support and maintenance warranty services to these customers. The Social Enterprises usually charge a fee, if the customers wish to extend the services beyond the warranty period. Some of the Social Enterprises also offer user trainings and capacity building support. They often also offer a take-back service for the distributed products when they have reached their end-of-life. This service fulfils an important function; it secures safe recycling and disposal of the products.
- Offer of Social Enterprises focusing on large household appliances:
  The social enterprises case study partners, which offer large household appliances, often also process small household appliances and consumer electronics (0–60% of total supply). Washing machines account for 10–40%, electric cooking appliances for 10–15%, freezing appliances for 0–25% and dish washer for 0–20% of total supply. In terms of services, Social Enterprises, which process large household appliances, offer collection and certification for compliant preparation for re-use or recycling to suppliers. To receiving customers, they offer technical support, maintenance and repair services.

3.1.4.3. Customers. There are also different customer segments for the two product lines:

Customers of Social Enterprises focusing on ICT:
Desktop and notebook computers are distributed to both eligible recipients (10–100%), mostly educational institutions, and to low income individual users (0–55%). One of the case study partners supplies mainly to distributors and retailers (90%) who sell new and used ICT products.
Customers of Social Enterprises focusing LHA:
Social Enterprises for large household appliances distribute almost exclusively to individual users through own or externally managed charity retail shops.

Except for one, all of the Social Enterprises, which participated in the present study, whether they focused on ICT or on LHA, sold exclusively to local markets, i.e. they did not export any equipment for re-use. One case study partner, who is specialized in ICT products, sells refurbished equipment to distributors; it is possible, that these distributors export some equipment outside the country of collection.

3.1.4.4. Finance. The financial structure looks similar for the two Social Enterprise types:

- Financial structure of Social Enterprises focusing on ICT:
  The annual income for the Social Enterprise case studies processing ICT equipment amounts to 500,000–38,500,000 USD. For these Social Enterprises, income is generated either through sale of products (0–80%), through sale of sorted material for recycling (0–30%) or through private or public funding (0–100%).
- Financial structure of Social Enterprises focusing on LHA:
  As for the case studies concentrating on LHA, total annual income varies between 450,000 and 4,300,000 USD. Main income streams are as follows: sale of products (15–80%), collection-, refurbishment- and repair-services (0–80%), private or public funding (5–20%) and sale of e-waste and sorted materials to recyclers (0–20%).

3.1.5. Comparison of different models

Tables 6 and 7 summarize the identified re-use operating models and compare them along the dimensions of the analytical framework. The great variety in the case study set and the peculiarities of the single organizations analysed make it difficult to derive generally valid results, especially when it comes to quantitative data. Therefore, the quantitative information is indicated as ranges in the tables. The ranges show the difference between the lowest and the highest value in the group of case studies for the respective operating model. It is important to be aware of the limited generalizability when interpreting the data. However, they do provide a basis to understand the typical logics behind the four models and the aspects that differentiate them from each other.

4. Conclusions

This study identified four generic re-use operating models for ICT products and large household appliances:

1. The Networking Equipment Recovery Model
2. The IT Asset Management Model
3. The Close the Digital Divide Model
4. The Social Enterprise Model

On a first-level, the models differentiate from each other based on their financial orientation; whereas the two first types are for-profit oriented, the Close the Digital Divide and the Social Enterprise Model pursue both a non-profit purpose. They aim to provide marginalized people with access to ICT products and to the Internet or to affordable household appliances and to create employment and education opportunities.

Second, these operating models differ in terms of their offerings and customer segments. The Networking Equipment Recovery model offers refurbishment and redeployment services on large networking equipment mainly for OEMs. The IT Asset Management model specializes in asset recovery services for desktop and notebook computers for miscellaneous large corporate users. Close the Digital Divide organizations also refurbish desktop and notebook computers, but they distribute them at low prices to eligible institutional recipients in developing countries. Social Enterprises, finally, prepare ICT or LHA (and consumer electronics) for resale either through charity outlets directly to individual users or to eligible institutional users such as schools or health organisations.

The identified models constitute generic ways to structure re-use operations along the four dimensions of the analytical

framework ("supply chain", "offer", "customers", "finance"). Different entities can utilize one or multiple combinations of these models.

The present division into the Networking Equipment Recovery model and the IT Asset Management model follows from the theoretical application of the analytical framework. The two models might overlap a lot in practice though.

This work aims to create a better understanding of the complex structure and dynamics of the re-use sector by creating a typology that can help in a more concise description of re-use activities and its outcomes. A more concise typology of this type is an important step in more thorough research into the differing environmental, social and economic benefits and outcomes of electronics re-use and can assist in the targeted support of these industries to achieve specific desired outcomes. Based on the clear distinction between the different organizations that undertake re-use such research should examine reasons for market failure and how to correct them in the case of for-profits and the use of instruments for the achievement of social goals through re-use should be an emphasis for non-profits.

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Appendix 1. Interview-guide

Project:	**Best practices in re-use operating models**
Document:	**Interview guide**
Content:	• ...
Interview:	• ...
Date of interview:	• ...
Interviewee:	• ...
Interviewer:	• ...

0.0	**Profile**	
0.1	Name	• ...
0.2	Homepage	• ...
0.3	Year of foundation	• ...
0.4	Location of headquarter	• ...
0.5	Location of subsidiaries	• ...
0.6	Organization type	• ...
0.7	Corporate mission	• ...
1.0	**Personnel**	
1.1	Total number of employees *in FTE (full time equivalent)*	• ...
1.2	Number of employees in operations	• ...
1.3	Expertise in operations	• ...
1.4	Regular education and training	• ...
2.0	**Products & services offered**	
2.1	Assortment	• ...
2.2	Product lines *in percentages of total products sold*	• ...
2.3	Minimal hardware requirements	• ...
2.4	Average age of used products	• ...
2.5	Average re-use lifespan	• ...
2.6	Operating system	• ...
2.7	Product warranty	• ...
2.8	Product labels/certificates	• ...
2.9	Services offered to supplying customers	• ...
2.10	Services offered to receiving customers	• ...
3.0	**Procurement**	
3.1	Suppliers	• ...
3.2	Quantity of product supply *in # of items per year*	• ...
3.3	Potential for re-use *in % of total annual product supply*	• ...
3.4	Price level of product supply *average price per item in USD*	• ...
4.0	**Processes**	
4.1	Processes performed in-house by *(name of case study partner)*	• ...
4.2	Processes performed by Partners	• ...
4.3	Function testing technology	• ...
4.4	Product safety testing technology	• ...
4.5	Information & documentation system (IDS) for recording, storage & administration of data	• ...
4.6	Information tracked	• ...
4.7	Quality Management System	• ...
5.0	**Marketing & Distribution**	
5.1	Total annual turnover *in total number of items sold per year*	• ...
5.2	Market segments	• ...
5.3	Distribution channels	• ...
5.4	Average product resale prices	• ...
5.5	Average product margin *in % of resale price*	• ...
5.6	Average service prices *processing fees per item*	• ...
6.0	**Finances**	
6.1	Total annual income	• ...
6.2	Revenue streams *in % of total revenues*	• ...
6.3	Cost pools *in % of total costs*	• ...
6.4	Profit margin *total revenues minus total costs in % of total revenues*	• ...
6.5	Average annual growth over the last 5 years	• ...
7.0	**Main success factors and barriers**	
7.1	Success factors	• ...
7.2	Barriers	• ...

Thank you for your valuable contribution!

Appendix B. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.resconrec.2012.04.003.

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