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Are WEEE in Control?

Rethinking Strategies for Managing Waste Electrical and Electronic Equipment

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1. Introduction

Electrical and electronic equipment (EEE) that has come to its end-of-life (EoL) either by ceasing to function or ceasing to be of any value to its owners is commonly referred to as e-waste (Widmer et al., 2005). In the European Union (EU), these wastes are referred to as waste electrical and electronic equipment (WEEE). This chapter discusses two key themes critical to understanding and tackling the challenge posed by WEEE, namely: (i) four key issues that make WEEE a priority waste stream; and (ii) WEEE management practices in various countries and regions. Drawing on a comprehensive literature review and four case studies, we critically analyse and discuss the factors that influence the generation, collection and disposal of WEEE, specifically addressing the spatial and temporal interactions of these factors before an alternative approach to conceptualising and managing WEEE is proposed.

2. Importance of WEEE

Four key global issues make WEEE a priority waste stream, specifically: global quantities of WEEE; resource impacts; potential health and environmental impacts; and ethical concerns.

2.1 Global quantities of WEEE

The rate of discarded EEE is growing at an alarming rate, especially in OECD countries where markets are inundated with huge quantities of new electronic goods. As one of the fastest growing waste streams around the world (Dalrymple et al., 2007; Darby & Obara, 2005; Davis & Herat, 2008), a phenomenal growth in the amounts of discarded WEEE has been observed in various regions of the world (Ketai He, 2008; Nnorom & Osibanjo, 2008), attracting the attention of various governments, environmental organisations (Greenpeace, n.d.) and the scientific community. Increasingly short product lifecycles and rapidly advancing technology have led to huge volumes of relatively new electronic goods being discarded (Goosey, 2004). Although there is a paucity of reliable data, estimates place the amount of WEEE generated globally between 20-50 million tonnes annually (Greenpeace, n.d.; Ketai et al., 2008) although a recent estimate suggests ~40 million tonnes of WEEE are generated annually (Schluep et al., 2009). However, we believe this figure is highly unlikely (see Ongondo et al., 2011a) and almost certainly too low. Such large quantities of WEEE

have focused attention not only on how WEEE is handled but also on why so much of it is generated and ways in which it can be prevented.

2.2 Resource impacts

WEEE has an enormous resource impact (Meskers & Hagelüken, 2009). Access to and availability of a number of raw materials key to the production of EEE is increasingly becoming important with world reserves of metals such as gold and palladium in fast decline and becoming more expensive (See EurActiv, 2009; Meskers & Hagelüken, 2009). Consisting of a mixture of various materials, WEEE can be regarded as a resource of valuable metals, such as copper, aluminium and gold. When these materials are not recovered, raw materials have to be extracted and processed afresh to make new products, resulting in significant loss of resources (Cui & Forssberg, 2003). Insufficient EEE is collected, part of which is exported to developing countries where it is largely not entering official recycling systems (Meskers & Hagelüken, 2009). When WEEE is not recycled, raw materials have to be processed to make new products resulting in a significant loss of resources (Bains et al., 2006; Bohr, 2007). In addition to the resources that are lost when WEEE is discarded without some form of materials recovery, a phenomenon known as stockpiling traps resources and prevents them from re-entering the materials/resource stream. Stockpiling, a practice especially common in the USA and various other countries, refers to the storing/hoarding of EoL EEE by consumers despite such devices being of little or no use to them (Li et al., 2006; Lombard & Widmer, 2005; Wagner, 2009).

2.3 Potential health and environmental impacts

When WEEE is disposed of or recycled without any controls, there are potentially negative impacts on human health. Containing more than 1000 different substances, many of which are highly toxic (such as lead, mercury, arsenic and cadmium), there are potentially serious health impacts if WEEE is not disposed of properly (Widmer et al. 2005). The open burning of plastics, widespread general dumping, exposure to toxic solders and other malpractices associated with improper dismantling and treatment of WEEE as observed in various developing countries, can result in serious health consequences (Mureithi & Waema, 2008; Natural Edge Project, 2006; Puckett et al., 2003; Widmer et al., 2005). Hence, serious concerns have been raised with regard to the export of WEEE from developed countries for treatment in Asian countries such as China and India, where the waste treatment operations utilized have in some cases lead to adverse health and environmental consequences. The heavy metals found in WEEE (such as lead) can contaminate drinking water by leaching into groundwater from sources such as landfills (Fishbein, 2002). It is estimated that about 70% of the heavy metals in US landfills come from WEEE (Puckett et al., 2003). The extraction of raw materials, and the goods made from them, may also entail environmental damage through mining, manufacturing, transport and energy use (Bains et al., 2006). Although effective recycling has a much lower environmental footprint than primary production, it is reported that the amount of WEEE recycled today is still low (Meskers & Hagelüken, 2009).

2.4 Ethical concerns

Two issues highlight the ethical concerns associated with WEEE. The first is the reported incidences of child labour in informal WEEE industries/handling, especially in some parts of Asia (Puckett et al., 2003; Shinkuma & Huong, 2009) and Africa. Secondly, the illegal

shipments of WEEE from affluent countries to poorer developing countries that lack the facilities to properly treat such wastes is becoming more prevalent (Nnorom & Osibanjo, 2008; Puckett et al., 2003). The evidence suggests a close link between ethical malpractices in the handling of WEEE and the potential environmental and health impacts; it has been observed that WEEE collected from illegal shipments is often handled informally with very little regard to safety standards. Hence, prevention of illegal WEEE shipments could alleviate (but not necessarily eradicate) negative environmental and health impacts.

3. Brief overview of WEEE management strategies in selected countries

Various strategies and practices have been adopted by a few countries and regions to handle, regulate and prevent WEEE as a response to the above challenges posed by this waste stream. Most of these have been enacted via legislation specific to WEEE. These are briefly summarised below for selected countries.

3.1 Europe

In response to the large amounts of WEEE disposed within its borders every year, (~6.5 million tonnes), the EU enacted the so called WEEE Directive (Directive 2002/96/EC) which its Member States (MS) were to transpose as legislation in their respective countries. The extended producer responsibility (EPR)-based Directive obliges manufacturers to finance the takeback of WEEE classified in 10 categories from consumers and ensure their safe disposal. The legislation promotes individual producer responsibility (IPR), reuse, recycling and other forms of recovery in order to reduce the disposal of WEEE. In addition, it sets various annual targets for the collection, reuse and recycling of WEEE. Currently, MS are required to annually separately collect at least 4kg of household WEEE per person. Despite these efforts, the European Commission (EC) reports that only one-third of generated WEEE is collected and treated according to the stipulated procedures with prevalent exports to developing countries (Commission of the European Communities [CEC], 2008; Dalrymple et al., 2007; European Union, 2003).

3.2 Asia

Rapid economic growth in Asia has led to an increase in the quantities of WEEE generated in the region. Most of the WEEE generated from other parts of the world end up in Asian countries, especially in China (receives ~90%). There is no commonly agreed political strategy for managing WEEE in the region. However, various countries have or are in the process of ratifying WEEE specific legislation. To cope with the alarmingly large quantities of EoL products it receives and the attendant spontaneous illegal/informal and in some cases (potentially) harmful handling and treatment of WEEE within the country, China has recently legislated measures to cope with WEEE. Stockpiling of WEEE also occurs since people rarely dispose of their used EEE due to the perception that goods retain a residual value which might have future uses (Ketani et al., 2008; Li et al., 2006; Terazono, Murakami, et al., 2006; Y. Wang et al., 2009; Xinhua News Agency, 2010). Japan has legislation designed to tackle their 5 largest sources of WEEE: Televisions (TV); refrigerators; washing machines; clothes dryers; and air conditioning units. Specific recovery targets for reuse and recycling are stipulated by the legislation referred to as the home appliance recycling law (HARL). In addition, the law requires consumers to pay a recycling fee at the time of disposal (Aizawa et al., 2008; Zhang & Kimura, 2006).

3.3 Africa

African countries still lag behind when it comes to enacting legislation to deal with WEEE. This is despite well documented evidence showing that certain African countries have been the recipients of WEEE illegally exported from various affluent nations. It has been observed that informal collection, dismantling and recycling of WEEE is beginning to take shape in several countries such as Nigeria, Ghana and Kenya. However, the absence of infrastructure and appropriate collection and recycling services for WEEE is still a major challenge in addition to scarcity of data on amounts of WEEE generated. In South Africa, there is both informal and formal WEEE recycling with noticeable levels of recycling taking place (BAN, 2005; Dittke et al., 2008; Lombard & Widmer, 2005; Nnorom & Osibanjo, 2008; Rochat & Laissaoui, 2008).

3.4 North America

Both the USA and Canada lack WEEE specific federal legislation. However, a number of states in the USA have established some form of EPR regulations and takeback programmes to deal with WEEE including Maine, the first state to mandate producer responsibility. WEEE in the USA is mainly managed via municipal waste management services. As previously mentioned, a lot of WEEE is stockpiled rather than returned for reuse/recycling with ~24 million EoL computers and TVs destined for storage each year. In Canada, a national scheme for the collection of mobile phones, smart phones and similar devices exists although quantities of returned phones are still low (Canadian Wireless Telecommunications Association, 2009; Kahhat et al., 2008; Wagner, 2009).

3.5 Latin-South America

It is reported that penetration of EEE in a number of Latin-South American countries is reaching commensurate levels in industrialised countries. Formal recycling in some countries is still at its infancy although many others lack any such facilities. There is lack of political structure and logistical infrastructure to adequately handle WEEE. However, Brazil is currently the frontrunner in attempts to formulate policy on WEEE with Costa Rica the only country with specific WEEE legislation as of 2008. In Argentina, similar to countries in other developing economies, stockpiling of obsolete and broken products is common (Horne & Gertsakis, 2006; Silva et al., 2008).

3.6 Australia

Most of the WEEE generated in Australia is sent to landfills. In 2008, ~180 million WEEE items were destined for landfills. Until recently, the country lacked a national policy for dealing with WEEE. The end of 2009 saw the establishment of the National Waste Policy, a 10-year vision for resource recovery and waste management including a voluntary industry-led (but Government-supported) scheme for recycling TVs and computers. The scheme was scheduled to start operations in 2011, allowing householders to freely dispose of their EoL products. (Davis & Herat, 2008; Garrett, 2009; TEC, 2008).

Table 1 summarises WEEE generation and management practices in selected countries. For a thorough discussion on WEEE management practices in various countries see Ongondo et al. (2011a).

It is clear from the preceding discussions that strategies to effectively deal with WEEE have still not been perfected. Despite the efforts by various countries to deal with the challenge of

Country	Generation (tonnes/year)	Reported discarded items	Collection & treatment routes
Germany	1.1 million (2005)	Domestic WEEE	Designated collection points, retailers takeback
UK	940K (2003)	Domestic WEEE	Designated collection points, retailers takeback
Switzerland	66,042 (2003)	Diverse range of WEEE	National takeback programmes
China	2.21 million (2007)	Computers, printers, refrigerators, mobile phones, TVs	Mostly informal collection and recycling
India	439K (2007)	Computers, printers, refrigerators, mobile phones, TVs	Informal and formal
Japan	860K (2005)	TVs, air conditioners, washing machines, refrigerators	Collection via retailers
Nigeria	12.5K (2001-06)	Mobile phones chargers & batteries	Informal
Kenya	7,350 (2007)	Computers, printers, refrigerators, mobile phones, TVs	Informal
South Africa	59.6K (2007)	Computers, printers, refrigerators, mobile phones, TVs	Informal and formal
Argentina	100K	Excludes white goods, TVs and some consumer electronics	Small number of takeback schemes, municipal waste services
Brazil	679K	Mobile and fixed phones, TVs, PCs, radios, washing machines, refrigerators and freezers	Municipalities, recyclable waste collectors
USA	2.25 million (2007)	TVs, mobile phones, computer products	Municipal waste services; a number of voluntary schemes
Canada	86K (2002)	Consumer equipment, kitchen and household appliances	A number of voluntary schemes
Australia	-	Computers, TVs, mobile phones and fluorescent lamps	Proposed national recycling scheme from 2011; voluntary takeback

Table 1. WEEE generation and management in selected countries (compiled from Ongondo et al., 2011a)

WEEE, a lot still needs to be done to promote, in the first instance, prevention of WEEE, as well as reuse, recycling and safe treatment options (see Ongondo et al., 2011a). This situation calls for a global rethink in how WEEE is managed. A number of alternative approaches to managing WEEE have been proposed including the recast of the WEEE Directive which

would require a stricter collection target of 65% of the average weight of products placed in the respective markets of EU countries in the two preceding years (European Union, 2008). Huisman & Stevels (2006) proposed a shift away from weight-based approaches to takeback and recycling targets (such as the WEEE Directive household collection target). In their view, targeting specific important materials with high environmental and economic values makes much more sense. For instance, although ~50% of a mobile phone is composed of plastics, the recovery of the embedded precious metals such as gold, copper and palladium should be prioritised and hence reflected in policy/legislation recovery targets.

In an effort to contribute to the debate on how the management of WEEE can be rethought, we propose an alternative but complementary approach to conceptualising and managing WEEE with regard to consumers' decisions about their EoL products. The strategy, discussed below, is complementary to existing WEEE policies and regulations and would be more useful at the operational level of managing WEEE. Hence, it could find application in a waste practitioner's policies and strategies for managing WEEE.

4. Rethinking strategies for managing WEEE

At the heart of this proposed approach to managing WEEE is a critical understanding of the interaction of the factors that affect the generation, collection and disposal of WEEE in space and time. Knowledge about these interactions can help policy makers in their decision making regarding takeback and disposal for specific products as opposed to applying a one-size-fits-all approach to managing all WEEE. This essentially means using different models to manage WEEE depending on the context (the nature of the interactions). The ultimate aim of understanding these interactions is to facilitate a closed-loop system for resources/raw materials use as opposed to a linear flow of resources (see Figure 1). This calls for the design of strategies and systems to manage WEEE that would maximise the recovery of resources with minimal ethical malpractices, health and environmental impacts. A review of the literature reveals a number of factors that determine whether and how a product becomes WEEE, if, how and when it is collected and its eventual disposal or lack of it. However, these factors are mostly discussed in isolation of each other. What is lacking is an analysis and discussion on the interaction of the factors, i.e. to what extent do they interact to affect decisions (from consumers, policy makers and other stakeholders' point of view) about EoL appliances? Secondly, what is the nature of those interactions? Are they similar in space and time? Which factors are more important than others and why? Similarly, little has been discussed about the effect of the factors on each other. For instance, does recyclability of a product dictate its takeback or do takeback options affect recycling options?

To illustrate the proposed alternative approach to conceptualising and managing WEEE, using case studies, the following section first discusses factors that influence the generation, collection and disposal of WEEE. Secondly, it groups and discusses those factors into similar variable groups. Finally, it critically discusses the interaction of some of the identified factors in relation to their influence on product EoL decisions.

4.1 Factors affecting the generation, collection and disposal of WEEE:

Examples from the UK

In the following sections, four case studies highlighting the key factors that influence the generation, collection and disposal of WEEE are presented (subsequently known as W-KFs).

Although all the case studies are from the UK, the literature review reveals that the identified factors are individually generic to various other countries.

4.1.1 Case study 1: UK household WEEE collection network

The aim of this study, carried out in 2010, was to assess and evaluate the UK household WEEE collection network. The study utilised both primary and secondary data. The latter was sourced from online databases of the environment agency (EA) as well as Valpak, UK’s only distributor takeback scheme (DTS). The aim of the DTS is to assist EEE retailers meet their compliance obligations as stipulated by the UK WEEE Regulations (Ongondo et al., 2011a). Primary data was collected from a broad national survey of UK’s designated collection facilities (DCF) for WEEE. A total of 393 DCFs were invited to participate in the questionnaire of which 168 completed the survey. The results show that in the UK, there is both an enabling infrastructure for the collection of WEEE as well as a matching service provision.

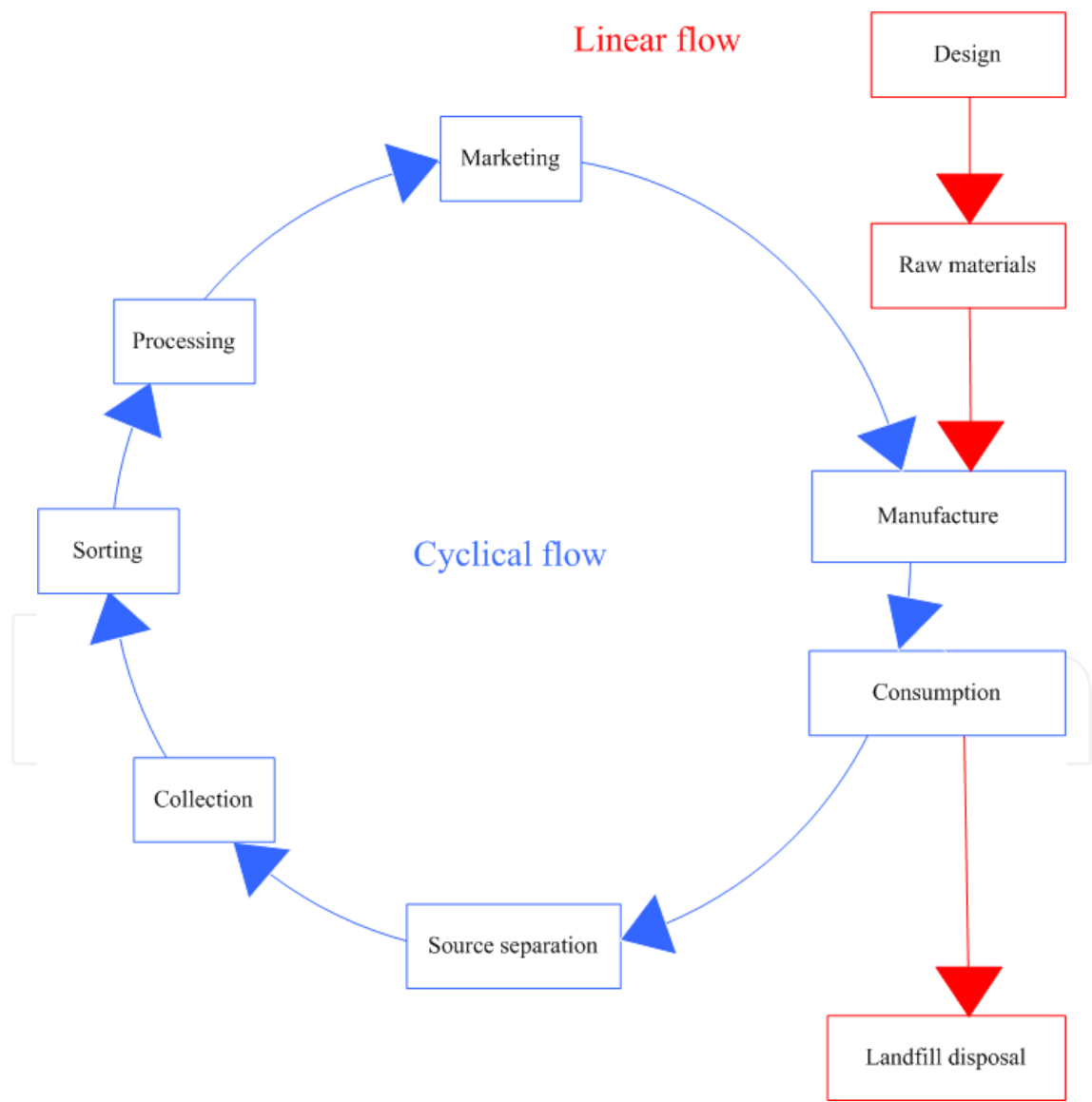


Fig. 1. Linear and cyclical resource flows (ZeroWIN, 2010)

The study revealed that in most urban areas in the UK there were adequate facilities for consumers to deposit their unwanted EEE. In general, the network is capable of collecting WEEE from 5 different streams (see Ongondo et al. 2011a) as stipulated by the UK WEEE Regulations. However, 26% of the DCFs did not have the capacity to collect all WEEE types. In addition, ~40% of the DCFs lacked sufficient storage space for collected WEEE (large appliances taking up a lot of space) whilst almost a quarter reported lack of awareness by the public to correctly separate WEEE at the DCFs.

Summary of the W-KFs identified from Case Study 1:

- Specific legal framework for handling WEEE;
- Infrastructure for collecting WEEE;
- Service for collecting and disposing of WEEE;
- Product size (problem with storing large appliances); and
- Public awareness about disposal service.

4.1.2 Case study 2: Mobile phone collection in the UK

An online survey to assess and evaluate the operations of UK voluntary mobile phone takeback services was carried out in Autumn-Winter 2008. Over 100 voluntary schemes operated by various organisations were identified. These promote their activities in various ways including newspapers, online and in-store. They also offer various incentives to encourage consumers to return their unwanted handsets to the takeback services for either reuse or recycling. The most common incentives are free collection of and monetary payments for returned devices. The takeback services offer various levels of convenience to enable the consumer to return their handsets in a hassle-free process. These include (in some cases) an easy to use online returns service, courier pick-up in cases involving 15+ phones as well as provision of appropriate envelopes/bags for returning unwanted phones. Most services use the available postal services infrastructure to collect phones from consumers. Central to the business model of these voluntary services are the residual reuse and recycling values of mobile phones.

Summary of the W-KFs identified from Case Study 2:

- Infrastructure for collecting WEEE (virtual [Internet] and physical);
- Service for collecting and disposing of WEEE;
- Product size (mobile phones are generally small and easy to transport);
- Product reusability and recyclability;
- Incentives to encourage takeback;
- Convenient takeback services; and
- Public awareness about collection service via promotion and advertising.

4.1.3 Case study 3: Consumer attitudes and behaviour toward use of mobile phones

This study involved a large scale online survey of 2287 students at 5 universities in South-East England carried out between November 2008 and August 2009. The aim of the research was to assess the behaviour of university students with regard to their use and disposal of mobile phones. The findings indicate that many students replace their phones at least once a year with male students replacing phones more often than females. The most common reasons advanced for changing mobile phones were replacement of broken phones (~58%) followed by upgrade phones offered by mobile phone network providers (~40%). Other reasons given were a desire to have a phone with a longer battery life (~18%) and fashion

trends (~16%). Despite most students' awareness of takeback services for mobile phones (69%), in total, most of the phones replaced by students (~60%) are not sent to reuse/recycling services but are stockpiled. This equates to almost 3.7 million phones stockpiled by students in UK higher education (comparatively, 29.3 and 28.1 million stockpiled respectively for Europe and USA) (see Ongondo & Williams, 2011a). The most cited reason for stockpiling phones was "keep as back-up phone" (~78%) followed by "I don't know what to do with the phone" (~30%). Monetary incentives were found to elicit the greatest influence on students' willingness to recycle their unwanted mobile phones, followed by convenience of the takeback system and its ease of use.

Summary of the W-KFs identified from Case Study 3:

- Use and disposal attitudes and behaviour;
- Influence of gender on use and disposal of a small EEE;
- Service for collecting and disposing of WEEE;
- Product size (mobile phones are generally small and easy to store);
- Product durability (lifespan);
- Product reusability and recyclability;
- Incentives to encourage takeback;
- Promotion by retailers;
- Fashion;
- Convenient and easy to use takeback services; and
- Awareness about takeback services.

4.1.4 Case study 4: WEEE arising from one-off large scale events

Similar to countries in the EU and the USA, the UK enacted a policy to switch to digital-only TV by 2012. The policy, referred to as the digital switchover policy (DSO), would see all TV regions in the UK switch off their terrestrial analogue TV signals in favour of solely digital ones. In relation to this, the aim of this case study was to assess the potential logistical, financial, ethical and environmental impacts of the DSO on UK's network for collection of household WEEE. The Hampshire County Council in the South-East of England was used as a case study. Two public surveys (postal and structured street interviews) of Hampshire residents were carried out (319 respondents) in 2009. It was found that majority of residents (~98%) were aware of the DSO although only a moderately lower number (~67%) were aware of when the event would actually take place. The findings also showed that people on low-incomes and the unemployed were more aware about the date of the event in comparison to those on higher incomes and in employment respectively. The results showed that the DSO had the potential to generate large quantities of TV and related equipment WEEE (see Ongondo et al., 2011b). Whereas residents indicated their intention to dispose of their unwanted TVs via the established networks, smaller TV-related items such as remote controls and aerials would not warrant a trip to the household waste recycling centres (HWRCs); these were most likely disposed in the general waste. Residents also indicated they would keep their video cassette recorders (VCRs) despite their technological limitations once the switchover took place (see Ongondo, et al., 2011b). In addition, more males than females were aware that the capabilities of their VCRs would be affected by the switchover.

Summary of the W-KFs identified from Case Study 4:

- Impact of policy and technological changes;
- Use and disposal attitudes and behaviour;

- Influence of gender on use of EEE (VCR limitation issue);
- Service for collecting and disposing of WEEE;
- Product size (smaller items disposed of in general waste; larger ones taken to recycling centres);
- Effect of economic status on awareness regarding important events affecting EEE; and
- Public awareness about takeback services.

4.2 Factor groups

The evidence summarised in Section 4.1 indicates that factors that affect the generation, collection and disposal of WEEE can be grouped into at least 3 broad categories:

- Consumer variables: *Attitudes, behaviour, perception, values, awareness levels, age, gender, employment status, storage space, etc.;*
- Takeback system variables: *Infrastructure, service provision, convenience and ease of use of takeback system, incentives/disincentives, promotion and advertising of takeback options (awareness); and*
- Product variables: *Product type, size, quality (condition), quantity, material composition, reusability and recyclability.*

In addition, a number of factors external to the consumers' immediate decision making scope may influence the generation, collection and disposal of WEEE. These include:

- Policy: *Regulations, legislation, guidelines;*
- Technological change: *Emergence of new technologies such as digital TVs;*
- Market forces: *Fashion, retailer promotions, etc.;*
- Costs: *Cheaper/affordable products, etc.;*
- Product EoL; and
- Social need/pressure: *Peer influence, etc.*

These factor groups are individually discussed in the succeeding sections followed by an analysis of how they interact with each other and the likely outcomes of those interactions.

4.2.1 Consumer variables

Consumer variables such as age, gender, culture, perceptions and attitudes affect both the generation and disposal of WEEE, although globally there are disparities between countries regarding the effect of these variables. Whereas in some parts of Asia and Africa EoL products are rarely thrown out, in some parts of Europe the opposite is true. In the former, perception of what is waste is very different from attitudes in Europe. Possibly, this is largely shaped by the differences in affluence in these regions. In Asia, South America and Africa, it is not uncommon for EoL products to find secondary uses. For instance, a broken refrigerator would find use as a cupboard. Hence, stockpiling of WEEE is generally common in Asia compared to Europe. Although the same phenomenon occurs in the USA, the reasons behind the practice are different. The key consumer variable in the USA is the availability of space to store unused and EoL EEE as well as the lack of (affordable) takeback services for the devices.

4.2.2 Takeback system variables

Takeback services are an integral part of the management of WEEE. However, the existence of such services is neither a guarantee that WEEE will be collected nor disposed of properly. In addition, the nature of the takeback services may influence the type and amounts of

WEEE collected. Important variables in takeback services include infrastructure, formal or informal operations, incentives/disincentives offered by the services, awareness about the services and the number and types of products collected. This means that takeback services range from the “fairly straightforward” (e.g. takeback of mobile phones) to complex systems such as the takeback of different WEEE within the EU. Due to the many variations in the interplay of these variables, the logistics of designing and implementing a takeback system for WEEE are complex.

Perhaps the basis of any takeback system is an enabling infrastructure (see Timlett & Williams, 2011). As the evidence in Case Study 2 suggests, this does not have to be specific infrastructure established for takeback of WEEE since piggy-backing on existing infrastructure may be a viable option. Lack of infrastructure is a primary limiting factor to the takeback of WEEE, as highlighted in Sections 3.3 and 3.5. Equally important in a takeback system is the provision of a service to collect WEEE for reuse or recycling from consumers. As demonstrated in Australia, although there is infrastructure in place to collect WEEE, the deficiency of a matching reuse and recycling service and policy has resulted in vast amounts of WEEE deposited in landfills. An additional issue in WEEE takeback is competition among takeback services. In China, competition between informal and formal takeback and recycling of WEEE curtails the operations of the latter. In some cases, this has led to serious health and environmental consequences resulting from informal WEEE recycling activities (see Ongondo et al., 2011a).

A common thread in takeback systems is the influence of incentives on consumer willingness to return unwanted products. Although there is very strong evidence (see Ongondo & Williams, 2011a) suggesting incentives, especially monetary ones, positively influence consumers to return their WEEE, offer of incentives varies by region and by product. Monetary incentives are generally offered for products with a residual reuse value such as mobile phones (see Ongondo & Williams, 2011a; 2011b). On the contrary, in some countries such as Japan, despite the existence of takeback/recycling fees, many consumers still return their unwanted products using the official takeback schemes. This is conceivably related to the culture/attitudes of the people in that country since in the USA the suspicion is that recycling fees encourage stockpiling (see Ongondo et al., 2011a). In Case Study 4, it was established that one of the reasons given by UK consumers for throwing WEEE in the general waste is that the size of the WEEE does not warrant a trip to the HWRC. This raises an important issue about the levels of convenience and accessibility that takeback systems should offer balanced against the level of responsible behaviour that consumers should display.

4.2.3 Product variables

The influence of product variables on the generation, collection and disposal of WEEE cannot be underestimated. At the basic level, attributes such as size, type and quantity have a bearing on these 3 aspects of WEEE. Case Studies 1 and 4 illustrated that sizes and quantities of WEEE also have a bearing on how the waste is handled. For instance, the potentially large quantities of TV WEEE generated by the DSO would necessitate careful and strategic planning to ensure the takeback system would effectively handle the waste arising. As exemplified in Section 3 as well as Case Studies 2 and 3, product reusability dictates what happens to WEEE at its EoL. On average, devices with higher reusability value such as mobile phones and computers will rarely be thrown away compared to other WEEE with lower reusability value such as TV remote controls, toasters and hairdryers.

4.2.4 External factors

Policy decisions have the potential to trigger large scale generation of WEEE. For instance, the DSO policy in the UK and other countries will lead to the generation of substantial amounts of waste TVs and related equipment. Without adequate plans in place, such decisions may lead to a strain on existing infrastructure to cope with the sudden influx of WEEE. This was the case in 2001 in the UK when the Regulation on Ozone Depleting Substances was enacted. The ban on the export of refrigerators containing such substances led to the build up of thousands of refrigerators (so-called “fridge mountain”) at local councils’ civic amenity sites (Florence & Price, 2005). This highlights the importance of policy on management of WEEE and available infrastructure being in tandem. Policies such as the WEEE Directive can also lead to undesirable negative effects such as the illegal export of WEEE to countries without the capacity to properly handle such wastes (see CEC, 2008).

In the case of the DSO, changes in policy were necessitated by advances in technology. However, as a separate entity, changes in technology or new technology can in themselves lead to the generation of WEEE. Some of the effects can be gradual, for instance, the replacement of old technology, such as the adoption of digital TVs and the subsequent replacement of analogue ones, or exponential, for instance, the rapid uptake of mobile phones especially in developing countries with the subsequent replacement of land line telephones. An example of the latter case in Nigeria is discussed by Nnorom & Osibanjo (2008).

Social pressure (e.g. fashion), affordability and market forces such as advertising can exert influence on consumers to give up their perfectly functional EEE in favour of newer technology (see Ongondo & Williams, 2011a), a situation that can be referred to as “perceived obsolescence”. For certain products such as mobile phones, perceived obsolescence may be of benefit, for instance, the reuse of unwanted handsets in secondary markets such as export to developing countries or local second-hand markets. However, in order to assess the true worth of this apparent benefit, the costs of acquiring raw materials to manufacture new technology would need to be weighed against the benefit of reusing “old” technology. In some cases, the evidence suggests that perceived obsolescence is not always beneficial as in some countries such as the USA and Australia it has led to stockpiling and massive landfilling of WEEE respectively. On the other hand, it can be argued that second-hand products allow less economically endowed members of the society access to technology.

Naturally, all EEE have a specific lifespan after which they are expected to reach their EoL and become WEEE. An important point question raised by Ongondo & Williams (2011a) was whether manufacturers of EEE deliberately design their products to have short lifecycles (although technically they could last longer) in order to gain financially from the purchase of replacement products. The authors gave the example of a mobile phone; from a technical point of view, handsets have a lifespan of 10 years. On the contrary, the evidence suggested that most phones are replaced since they get damaged well before their 10th anniversary. However, the authors posited that the proposition that EEE manufacturers intentionally design products with short lifecycles was not conclusive since it was possible that consumer lifestyles could contribute to the shorter lifespans of the devices.

4.3 Interaction of factors influencing WEEE generation, collection and disposal

At the heart of this proposed alternative approach to handling WEEE is the interaction of factors that influence the generation, collection and disposal of WEEE. In this section, a few examples illustrating the nature of such interactions will be discussed.

A decision that policy makers and designers of takeback schemes may need to make is whether reuse/recycling options dictate takeback services or if the opposite is true, i.e. takeback services dictate what reuse/recycling options should be provided. In the former case, only WEEE that has capacity to be reused or recycled would be catered for via a takeback system. An example of this is mobile phone takeback programmes. Before mobile phones were invented, the infrastructure for their takeback already existed, for instance, courier and postal services. However, no takeback services existed until reuse/recycling options for mobile phones were “discovered”. When reuse/recycling options were created, matching services for the returns of the devices were started. This is true for both formal reuse/recycling operations such as those found in USA and Europe and informal ones such as those observed in Africa. For the latter case, where the existence of a takeback service shapes the reuse/recycling options, an example is the previously mentioned “fridge mountain” experience in the UK in 2001. A service for collecting bulky waste via local council civic amenity (CA) sites already existed that led to the system collecting a vast amount of EoL refrigerators which contained such banned substances. What were lacking in this case were complementary reuse/recycling options to deal with the “contaminated” WEEE. The end result was a huge pile-up of EoL refrigerators at CA sites (see Ongondo et al., 2011b). Similarly, it is reported that in Japan, takeback services for specific types of WEEE have influenced manufacturers to tailor their recycling operations to match the types of WEEE coming through the takeback system (Aizawa et al., 2008). Hence, these examples demonstrate that either of these factors can influence the other and no one approach is superior to the other.

The interplay of product variables and other consumer variables such as attitudes, perceptions, storage space and other geographical regional differences strongly dictate how WEEE is produced and how it is managed. To illustrate, consider the case of a refrigerator which from a product point of view is relatively bulky in size. In the UK, a refrigerator that has come to its EoL would most likely be disposed of via a HWRC or paid-for retailer takeback since the consumer would not have enough room to store it in their residence. In the USA, there is a high chance that the product could be stockpiled in a garage since, generally, space constraints would not be a hindrance. In Australia, it would probably be disposed of via landfill whereas in South Africa, the product could be stockpiled due to the perception that it retains a residual value despite the household space limitations. In the case of smaller WEEE, such as mobile phones and portable music players, their size (easy to store) and the residual values (monetary, sentimental, etc.) attached to them mean that at their EoL (which for mobile phones may incorporate upgrading or replacement by a more fashionable model) they would probably be stockpiled. Similarly, Case Study 1 highlighted that in the UK smaller items would most likely not warrant a trip to the HWRCs. The same is probably true of items such as toasters, hairdryers and irons. In this case, although the products are relatively small in size, their lack of appreciable residual value would probably see them end up in the general refuse. Due to the previously discussed (cultural) reasons, the same may not be true in certain poorer regions of Asia and Africa; such WEEE would most likely be hoarded. In the case of medium sized products with a high residual value such as computers, stockpiling of the products would most likely occur in the USA (due to availability of space), Africa, South America and many Asian countries (due to culture, perceptions and economic status) whereas in affluent Europe the products would most likely be donated to charities (e.g. in the UK) for reuse. Passing on the items to relatives and friends would also be a likely scenario in all these regions/countries.

5. Discussion

The fact that WEEE is the fastest growing waste stream in many countries and regions is incontrovertible. Similarly, the issues that make WEEE a global priority are beyond refute. Although various countries/regions have taken positive steps to deal with the challenges posed by WEEE, the desired outcomes – prevention and minimisation of WEEE; increased reuse, recycling, recovery of EoL EEE; deterrence of illegal exports; and minimisation of negative environmental and health risks are still not occurring at palpable levels.

Drawing together the findings from the literature review and the case studies as well as the discussion in Section 4 reveals a crucial point; the generation, collection and disposal of WEEE is a product of the interface of various factors whose nature of interactions varies over space and time. This supports the argument that factors affecting the generation, collection and disposal of WEEE should not be considered in isolation. The extent to which the factors interact and the nature of those interactions and how they affect decisions (from consumers, policy makers and other stakeholders' point of view) about EoL appliances vary by country, over time and by product type. On the issue of geographical variations in how WEEE is generated and handled, EoL products are rarely thrown out in developing nations of Asia and Africa in comparison to the more affluent societies. In the case of the former, cultural attitudes and limited incomes influence the consumers to stockpile their WEEE (consumer variables) whereas in the latter, a throw-away culture, better incomes (consumer variables) and availability of takeback services (takeback system variables) drive the consumers to dispose of their WEEE. The DSO (Case Study 4) in the UK highlighted the temporal nature of some factors that interact to affect EoL decisions. The DSO has the capacity to generate large amounts of TV WEEE thereby possibly necessitating, albeit temporarily, increased returns services of such WEEE. In this case, takeback system and product variables (TV sizes, types, etc.) assume an important role for a limited time. Similarly, the "fridge mountain" experience in the UK serves as an example of an event with temporal influence over the generation, collection and disposal of WEEE.

Due to the nature and interactions of the influencing factors, it is not possible to generically conclude which factors are more important than others since spatial, temporal, consumer, takeback services and product variabilities as well as other external dynamics dictate which factors are significant on a case by case basis. However, on a broad geographical basis, the findings by Ongondo et al. (2011a) serve as a reasonable (though not unequivocal) basis for conclusions about which factors are most important in influencing the generation, collection and disposal of WEEE in various regions. These factors are summarised in Table 2 under their respective factor/variable groups. Although the factors are generic to the respective regions, differences (in some cases significant) at the country level should be expected, for instance, the case of Japan versus poorer countries within Asia.

All these factors taken together clearly demonstrate the complexities involved in the management of WEEE.

6. Conclusion and recommendations

This chapter has discussed the global challenge of managing WEEE and illustrated why it should be regarded as a priority waste stream. Generally speaking, on a global and country level, where available, the desired outcomes of systems and strategies designed to manage WEEE have not been fully achieved; the quantities of WEEE generated remain high and the policies to successfully tackle the waste stream are either largely inexistent in many parts of

the world or ineffective. The current situation calls for a rethink on how WEEE is managed. Hence, an alternative strategy to rethink how WEEE is managed has been proposed and discussed.

Central to the proposed approach is a critical understanding of the factors that influence the generation, collection and disposal of WEEE and how these factors interact both spatially and temporally. We have identified so-called W-KFs that have been classified into four distinct groups; consumer, takeback system and product variables as well as external factors.

On a factor group level, it has been shown that consumer variables such as age, gender, culture, attitudes, etc. influence the use and disposal of EEE leading to various disposal outcomes. Consumers' perceived value of products such as mobile phones has led to stockpiling of large amounts of the devices. Likewise, in poorer regions of the world, it has been observed that WEEE is rarely thrown out due to the perception that the equipment has some residual value.

Infrastructure, both physical and virtual (e.g. the Internet), and service provision (both formal and informal) are key factors that influence the collection and disposal of WEEE. Lack of infrastructure is a primary limiting factor to the takeback of WEEE as typified in developing countries. On the other hand, the existence of infrastructure and related service provision for takeback is no guarantee that WEEE will be collected nor disposed of properly. This was illustrated in Case Study 4 where it was established that some householders in the UK would bin small items of WEEE despite the existence of a collection system. In addition, the nature of the takeback services in terms of awareness about the service, the level of convenience and ease of use it offers consumers as well as incentives offered to encourage returns of WEEE influences the type and amounts of WEEE collected. Due to the many variations in the interplay of these variables, the logistics of designing and implementing a takeback system for WEEE are complex.

Product variables such as size, quality, quantity and reusability dictate what happens to EEE at its EoL. In some cases, consumers considered some WEEE too small to warrant a trip to the established WEEE collection centres. On average, devices with higher reusability value such as mobile phones are either stockpiled at their EoL or sold for their monetary residual value (typically for reuse).

With regard to external factors, the review of WEEE generation and management practices in selected countries and regions showed that emergence of new technologies is an important factor that influences the generation of WEEE across geographical borders. The example given of the abandonment of fixed telephone equipment in Nigeria in favour of mobile phone devices is a testament to this.

Policy, or the lack of it, is a key driver affecting the generation, collection and treatment of WEEE. Policy includes regulations/legislation and related management principles such as EPR. The DSO policy in the UK and other countries is an example of a policy that leads to the generation of WEEE. In the EU, the EPR-based WEEE Directive and its enactment in MS exemplifies the effect of legislation on the collection of WEEE. Conversely, lack of legislation in many other countries has meant that WEEE is not collected and/or disposed of properly. However, it was also established that collection and treatment networks for WEEE can exist despite lack of legislation, for instance, the informal WEEE management practices in China, Kenya, etc. and the voluntary mobile phone collection networks in Australia and the USA. Factors that influence the generation, collection and disposal of WEEE do not operate in isolation but interact to influence end-of-use/EoL decisions and outcomes for EEE. More important than the individual factors themselves, the significance of how the factors interact in space and time to influence the generation, collection and disposal of WEEE have been

critically discussed. Recognising the nature of these interactions is crucial to the management of WEEE.

	Consumer variables	Product variables	Takeback system variables	External factors
Africa	Perceived residual value, limited incomes	Product reusability/secondary uses	Lack of takeback services, infrastructure and proper treatment facilities	Lack of legislation
Asia	Perceived residual value, limited incomes	Product reusability/secondary uses	Lack of takeback services, infrastructure and proper treatment facilities (with notable exception of Japan)	Lack of/weak legislation
Australia	Cultural norms (throw-away society), higher incomes	Product reusability (primarily in the case of mobile phones)	Lack of takeback services	Lack of/weak legislation, technological change
Europe*	Storage limits, cultural norms (throw-away society), higher incomes	Product reusability (primarily in the case of mobile phones), material composition	Established takeback services and infrastructure	Stringent legislation, technological change
Latin - South America	Perceived residual value, limited incomes	Product reusability/secondary uses	Lack of takeback services, infrastructure and proper treatment facilities	Lack of legislation
North America	Large storage spaces (limits collected amounts), cultural norms (throw-away society), higher incomes	Product reusability (primarily in the case of mobile phones)	Lack of/limited takeback services	Lack of/weak legislation, technological change
*Europe- mostly the EU and other affluent European countries.				

Table 2. Key factors influencing the generation, collection and disposal of WEEE in various regions (adapted from Ongondo et al., 2011a)

Despite the potential inherent challenges and limitations of this proposed approach to managing WEEE (such as a clear understanding of relevant factors, hence need for access to data), this alternative way of thinking offers a novel approach to contextualise the genesis of WEEE generation and how it is collected and disposed whilst offering insights on how to rethink strategies to best manage it. The approach fits into the idea of a closed-loop system for the management of WEEE since it promotes the design of systems and strategies to recover different types and volumes of WEEE (see Guide & Van Wassenhove, 2009). We propose that recognition of the factors that influence the generation, collection and disposal

of WEEE and their interactions is crucial in decision making when designing systems and strategies for the management of WEEE.

7. References

- Aizawa, H., Yoshida, H. & Sakai, S. (2008). Current results and future perspectives for Japanese recycling of home electrical appliances. *Resources, Conservation and Recycling*, 52 (12), pp. 1399-1410.
- Bains, N., Goosey, M., Holloway, L. & Shayler, M. (2006). *An Integrated Approach to Electronic Waste (WEEE) Recycling: Socio-economic Analysis Report*. Rohm and Haas Electronic Materials Ltd, UK.
- BAN (2005). *The Digital Dump: Exporting High-Tech Re-use and Abuse to Africa*. Basel Action Network (BAN). Available from <<http://www.ban.org/films/TheDigitalDump.html>> [Last accessed 20 March 2011].
- Bohr, P. (2007). *The Economics of Electronics Recycling: New Approaches to Extended Producer Responsibility*. PhD thesis, Technischen Universität, Berlin, Germany. Available from [Last accessed 10 February 2010].
- CEC (2008). *Commission staff working paper accompanying the proposal for a directive of the European Parliament and of the Council on waste electrical and electronic equipment (WEEE) (recast) - Summary of the impact assessment*, SEC 2934. Commission of the European Communities (CEC), Brussels, Belgium. Available from <<http://eur-lex.europa.eu/Notice.do?val=484253:cs&lang=en&list=506087:cs,505637:cs,504254:cs,504814:cs,499467:cs,499047:cs,488044:cs,484207:cs,484236:cs,484253:cs,&pos=10&page=1&nbl=48&pgs=10&hwords=>>> [Last accessed 12 January 2010].
- Cui, J. & Forssberg, E. (2003). Mechanical recycling of waste electric and electronic equipment: a review. *Journal of Hazardous Materials*, 99 (3), pp. 243-263.
- CWTA (2009). *Recycle My Cell*. Canadian Wireless Telecommunications Association (CWTA), Canada. Available from <<http://rcbc.bc.ca/>> [Last accessed 8 January 2010].
- Dalrymple, I., Wright, N., Kellner, R., Bains, N., Geraghty, K., Goosey, M. & Lightfoot, L. (2007). An integrated approach to electronic waste (WEEE) recycling. *Circuit World*, 33 (2), pp. 52-58.
- Darby, L. & Obara, L. (2005). Household recycling behaviour and attitudes towards the disposal of small electrical and electronic equipment. *Resources, Conservation and Recycling*, 44 (1), pp. 17-35.
- Davis, G. & Herat, S. (2008). Electronic waste: The local government perspective in Queensland, Australia. *Resources, Conservation and Recycling*, 52 (8-9), pp. 1031-1039.
- Dittke, S., Newson, G., Kane, C., Hieronymi, K. & Schluep, M. (2008). A Material Recovery Facility in Cape Town, South Africa, as a replicable concept for sustainable e-waste management and recycling in developing countries. In: *Global Symposium on Recycling, Waste Treatment and Clean Technology*, Cancun, Mexico, October 12-15. Available from <http://ewasteguide.info/2008_Schluep_REWAS> [Last accessed 17 August 2010].
- EurActiv (2009). EU starts screening raw materials "critical list" | EU - European Information on Sustainable Dev. [Internet]. Available from

- <<http://www.euractiv.com/en/sustainability/eu-starts-screening-raw-materials-critical-list/article-187791>> [Last accessed 12 January 2010].
- European Union (2008). Environment - Waste Electrical and Electronic Equipment [Internet]. Available from <http://ec.europa.eu/environment/waste/weee/index_en.htm> [Last accessed 3 February 2009].
- European Union (2003). EU WEEE Directive 2002/96/EC [Internet]. Available from <<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32002L0096:EN:HTML>> [Last accessed 4 May 2008].
- Fishbein, B.K. (2002). *Waste in the Wireless World: The Challenge of Cell Phones*. INFORM, ISBN 0-918780-78-0, USA.
- Florence, Z. & Price, T.J. (2005). Domestic-fridge recycling in Wales: mountains or mole hills? *Applied Energy*, 80 (2), pp. 125-140.
- Garrett, P. (2009). National first: new waste policy and new recycling schemes for TVs, computers and tyres - media release. Available from <<http://www.environment.gov.au/minister/garrett/2009/mr20091105a.html>> [Last accessed 10 January 2010].
- Goosey, M. (2004). End-of-life electronics legislation - an industry perspective. *Circuit World*, 30 (2), pp. 41-45.
- Greenpeace - The e-waste problem | Greenpeace International [Internet]. Available from <<http://www.greenpeace.org/international/campaigns/toxics/electronics/the-e-waste-problem#>> [Last accessed 5 May 2008].
- Guide, V.D.R. & Van Wassenhove, L.N. (2009). The Evolution of Closed-Loop Supply Chain Research. *Operations research*, 57 (1), pp. 10-18.
- Horne, R.E. & Gertsakis, J. (2006). *A Literature Review on the Environmental and Health Impacts of Waste Electrical and Electronic Equipment - 2. International Policy and Regulation [Ministry for the Environment]*. New Zealand, RMIT University (Centre for Design). Available from <<http://www.mfe.govt.nz/publications/waste/weee-literature-review-jun06/html/page3.html>> [Last accessed 14 September 2009].
- Huisman, J. & Stevels, A.L.N. (2006). Eco-efficiency of take-back and recycling, a comprehensive approach. *IEEE Transactions on Electronics Packaging Manufacturing*, 29 (2), pp. 83-90.
- Kahhat, R., Kim, J., Xu, M., Allenby, B., Williams, E. & Zhang, P. (2008). Exploring e-waste management systems in the United States. *Resources, Conservation and Recycling*, 52 (7), pp. 955-964.
- Ketai He (2008). Research on recovery logistics network of Waste Electronic and Electrical Equipment in China. In: *Industrial Electronics and Applications, 2008. ICIEA 2008. 3rd IEEE Conference on Industrial Electronics and Applications*, 1797-1802.
- Ketai, H., Li, L. & Wenying, D. (2008). Research on recovery logistics network of Waste Electronic and Electrical Equipment in China. In: *Industrial Electronics and Applications, 2008. ICIEA 2008. 3rd IEEE Conference on Industrial Electronics and Applications*, pp. 1797-1802.
- Li, J., Tian, B., Liu, T., Liu, H., Wen, X. & Honda, S. (2006). Status quo of e-waste management in mainland China. *Journal of Material Cycles and Waste Management*, 8 (1), pp. 13-20.

- Lombard, R. & Widmer, R. (2005). *e-Waste assessment in South Africa, a case study of the Gauteng province*. EMPA - Swiss Federal Laboratories for Materials Testing and Research, Switzerland. Available from <http://ewasteguide.info/Widmer_2005_Empa> [Last accessed 9 September 2009].
- Meskers, C.E.M. & Hagelüken, C. (2009). Closed loop WEEE recycling? Challenges and opportunities for a global recycling society. In: S. M. Howard ed. *EPD-TMS congress 2009*. Proceedings of sessions and symposia sponsored by the Extraction & Processing Division (EPD) of The Minerals, Metals & Materials Society (TMS). San Fransisco, California, USA. February 15-19, 1049-1054.
- Mureithi, M. & Waema, T. (2008). *E-waste Management in Kenya*. Kenya ICT Action Network (KICTANet), Kenya. Available from <http://ewasteguide.info/Waema_2008_KICTANet> [Last accessed 9 September 2009].
- NEP (2006). *E-Waste Curriculum Development Project. Phase 1: Literature Review*. The Natural Edge Project (NEP). Available from <<http://www.naturaledgeproject.net/default.aspx>> [Last accessed 5 May 2008].
- Nnorom, I.C. & Osibanjo, O. (2008). Electronic waste (e-waste): Material flows and management practices in Nigeria. *Waste Management*, 28 (8), pp. 1472-1479.
- Ongondo, F.O. & Williams, I.D. (2011a). Greening academia: Use and disposal of mobile phones among university students. *Waste Management*, In Press, Corrected Proof.
- Ongondo, F.O. & Williams, I.D. (2011b). Mobile phone collection, reuse and recycling in the UK. *Waste Management*, In Press, Corrected Proof.
- Ongondo, F.O., Williams, I.D. & Cherrett, T.J. (2011a). How are WEEE doing? A global review of the management of electrical and electronic wastes. *Waste Management*, 31 (4), pp. 714-730.
- Ongondo, F.O., Williams, I.D. & Keynes, S. (2011b). Estimating the impact of the “digital switchover” on disposal of WEEE at household waste recycling centres in England. *Waste Management*, 31 (4), pp. 743-753.
- Puckett, J., Byster, L., Westervelt, S., Gutierrez, R., Davis, S., Hussain, A. & Dutta, M. (2003). *Exporting Harm: The High-Tech Trashing of Asia*. Basel Action Network and Silicon Valley Toxics Coalition. Available from <<http://www.ban.org/E-waste/technotrashfinalcomp.pdf>> [Last accessed 5 May 2008].
- Rochat, D. & Laissaoui, S.E. (2008). *Technical report on the assessment of e-waste management in Morocco*. EMPA - Swiss Federal Laboratories for Materials Testing and Research, Switzerland. Available from <http://ewasteguide.info/Laissaoui_2008_CMPP> [Last accessed 9 September 2009].
- Schluep, M., Hagelüken, C., Kuehr, R., Magalini, F., Maurer, C., Meskers, C.E.M., Mueller, E. & Wang, F. (2009). *Recycling – from e-waste to resources*. United Nations Environment Programme & United Nations University, Germany. Available from <http://isp.unu.edu/news/2010/files/UNEP_eW2R_publication.pdf> [Last accessed 17 August 2010].
- Shinkuma, T. & Huong, N.T.M. (2009). The flow of E-waste material in the Asian region and a reconsideration of international trade policies on E-waste. *Environmental Impact Assessment Review*, 29 (1), pp. 25-31.

- Silva, U., Ott, D. & Boeni, H. (2008). E-Waste Recycling in Latin America: Overview, Challenges and Potential. In: *Global Symposium on Recycling, Waste Treatment and Clean Technology*, Cancun, Mexico, October 12-15. Available from [Last accessed 10 January 2010].
- TEC (2008). *Tipping Point: Australia's e-Waste Crisis*. Total Environment Centre (TEC), Australia. Available from <<http://www.tec.org.au/index.php>> [Last accessed 8 May 2009].
- Terazono, A., Murakami, S., Abe, N., Inanc, B., Moriguchi, Y., Sakai, S.-ichi, Kojima, M., Yoshida, A., Li, J., Yang, J., Wong, M.H., Jain, A., Kim, I.-S., Peralta, G.L., Lin, C.-C., Mungcharoen, T. & Williams, E. (2006). Current status and research on E-waste issues in Asia. *Journal of Material Cycles and Waste Management*, 8 (1), pp. 1-12.
- Timlett, R. & Williams, I.D. (2011). The ISB Model (Infrastructure, Service, Behaviour): A tool for waste practitioners. *Waste Management*, In Press, Corrected Proof.
- Wagner, T.P. (2009). Shared responsibility for managing electronic waste: A case study of Maine, USA. *Waste Management*, 29 (12), pp. 3014-3021.
- Wang, Yacan, Ru, Y., Veenstra, A., Wang, R. & Wang, Ye (2009). Recent developments in waste electrical and electronics equipment legislation in China. *The International Journal of Advanced Manufacturing Technology*, 47 (5-8), pp. 437-448.
- Widmer, R., Oswald-Krapf, H., Sinha-Khetriwal, D., Schnellmann, M. & Böni, H. (2005). Global perspectives on e-waste. *Environmental Impact Assessment Review*, 25 (5), pp. 436-458.
- Xinhua News Agency (2010). New rule to manage e-waste [Internet]. Available from <http://news.xinhuanet.com/english2010/china/2010-06/07/c_13336556.htm> [Last accessed 16 August 2010].
- ZeroWIN (2010). *ZeroWIN Project Deliverable 1.1 (Version 2)*, May 2010. This will be publicly available via www.zerowin.eu when approved by the European Commission.
- Zhang, B. & Kimura, F. (2006). Network Based Evaluation Framework for EEE to Comply with Environment Regulations. In: *Proceedings of the 2006 IEEE International Conference on Mechatronics and Automation*, pp. 797-802.

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