Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

STRIVE
Report Series No.110

RE-Evaluate
Re-use of Electrical and Electronic Equipment (Evaluation and Mainstreaming)

STRIVE

Environmental Protection Agency Programme

2007-2013

SSTI Strategy for Science, Technology and Innovation

Comhshaol, Pobal agus Rialtas Áitiúil
Environment, Community and Local Government

Environmental Protection Agency

The Environmental Protection Agency (EPA) is a statutory body responsible for protecting the environment in Ireland. We regulate and police activities that might otherwise cause pollution. We ensure there is solid information on environmental trends so that necessary actions are taken. Our priorities are protecting the Irish environment and ensuring that development is sustainable.

The EPA is an independent public body established in July 1993 under the Environmental Protection Agency Act, 1992. Its sponsor in Government is the Department of the Environment, Community and Local Government.

OUR RESPONSIBILITIES

LICENSING

We license the following to ensure that their emissions do not endanger human health or harm the environment:

- waste facilities (e.g., landfills, incinerators, waste transfer stations);
- large scale industrial activities (e.g., pharmaceutical manufacturing, cement manufacturing, power plants);
- intensive agriculture;
- the contained use and controlled release of Genetically Modified Organisms (GMOs);
- large petrol storage facilities;
- waste water discharges;
- dumping at sea.

NATIONAL ENVIRONMENTAL ENFORCEMENT

- Conducting over 1200 audits and inspections of EPA licensed facilities every year.
- Overseeing local authorities' environmental protection responsibilities in the areas of - air, noise, waste, waste-water and water quality.
- Working with local authorities and the Gardaí to stamp out illegal waste activity by co-ordinating a national enforcement network, targeting offenders, conducting investigations and overseeing remediation.
- Prosecuting those who flout environmental law and damage the environment as a result of their actions.

MONITORING, ANALYSING AND REPORTING ON THE ENVIRONMENT

- Monitoring air quality and the quality of rivers, lakes, tidal waters and ground waters; measuring water levels and river flows.
- Independent reporting to inform decision making by national and local government.

REGULATING IRELAND'S GREENHOUSE GAS EMISSIONS

- Quantifying Ireland's emissions of greenhouse gases in the context of our Kyoto commitments
- Implementing the Emissions Trading Directive, involving over 100 companies who are major generators of carbon dioxide in Ireland.

ENVIRONMENTAL RESEARCH AND DEVELOPMENT

- Co-ordinating research on environmental issues (including air and water quality, climate change, biodiversity, environmental technologies).

STRATEGIC ENVIRONMENTAL ASSESSMENT

- Assessing the impact of plans and programmes on the Irish environment (such as waste management and development plans).

ENVIRONMENTAL PLANNING, EDUCATION AND GUIDANCE

- Providing guidance to the public and to industry on various environmental topics (including licence applications, waste prevention and environmental regulations).
- Generating greater environmental awareness (through environmental television programmes and primary and secondary schools' resource packs).

PROACTIVE WASTE MANAGEMENT

- Promoting waste prevention and minimisation projects through the co-ordination of the National Waste Prevention Programme, including input into the implementation of Producer Responsibility Initiatives.
- Enforcing Regulations such as Waste Electrical and Electronic Equipment (WEEE) and Restriction of Hazardous Substances (RoHS) and substances that deplete the ozone layer.
- Developing a National Hazardous Waste Management Plan to prevent and manage hazardous waste.

MANAGEMENT AND STRUCTURE OF THE EPA

The organisation is managed by a full time Board, consisting of a Director General and four Directors.

The work of the EPA is carried out across four offices:

- Office of Climate, Licensing and Resource Use
- Office of Environmental Enforcement
- Office of Environmental Assessment
- Office of Communications and Corporate Services

The EPA is assisted by an Advisory Committee of twelve members who meet several times a year to discuss issues of concern and offer advice to the Board.

EPA STRIVE Programme 2007-2013

RE-Evaluate
Re-use of Electrical and Electronic Equipment (Evaluation and Mainstreaming)

(2008-WRM-MS-4-S10)

STRIVE Report

End of Project Report available for download on http://erc.epa.ie/safer/reports

Prepared for the Environmental Protection Agency

by

Department of Electronic and Computer Engineering, University of Limerick

Authors:

Maurice O'Connell and Colin Fitzpatrick

ENVIRONMENTAL PROTECTION AGENCY

An Ghníomhaireacht um Chaomhnú Comhshaoil
PO Box 3000, Johnstown Castle, Co.Wexford, Ireland

Telephone: +353 53 916 0600 Fax: +353 53 916 0699
Email: info@epa.ie Website: www.epa.ie

ACKNOWLEDGEMENTS

This report is published as part of the Science, Technology, Research and Innovation for the Environment (STRIVE) Programme 2007–2013. The programme is financed by the Irish Government under the National Development Plan 2007–2013. It is administered on behalf of the Department of the Environment, Community and Local Government (DoECLG) by the Environmental Protection Agency which has the statutory function of co-ordinating and promoting environmental research.

The authors would like to thank the project Steering Committee who gave generously of their time and expertise during the study: Ms Sandra Kavanagh (EPA); Darren Byrne (DoECLG); Ruediger Kuehr (United Nations University). The authors would also like to thank all those who assisted us in the research, especially Rehab Recycle and Clondalkin Community Recycling Initiative. We would also like to thank all case study partners for their valuable input, including Elaine Coleman (Bryson) and Marc Willem (Komosie).

The Re-Evaluate project is an official StEP project, i.e. a project which is supported by members of the Solving the E-waste Problem (StEP) Initiative. StEP projects shall make their interim results and final results available to all interested StEP members. Any results which are to be published are reviewed by all StEP members and thus reflect the expertise of a multistakeholder initiative, representing academia, industry, governmental experts as well as non-governmental organisations from around the globe. StEP works towards a solution to the e-waste problem through its science-based but applied recommendations and StEP projects should support this aim. For more information on the StEP Initiative and its members, please see: www.step-initiative.org

The EPA STRIVE Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in relation to environmental protection. These reports are intended as contributions to the necessary debate on the protection of the environment.

EPA STRIVE PROGRAMME 2007-2013

ISBN**:** 978-1-84095-504-0

Price: Free **Online version**

Details of Project Partners

Maurice O'Connell
Department of Electronic & Computer Engineering,
University of Limerick
Castletroy
Limerick
Tel.: +353 (0)61 213102
Email: Maurice.w.oconnell@ul.ie

Colin Fitzpatrick
Department of Electronic & Computer Engineering,
University of Limerick
Castletroy
Limerick
Tel.: +353 (0)61 213561
Email: Colin.Fitzpatrick@ul.ie

Martin Reddy
Rehab Recycle
Unit 77
Broomhill Road
Tallaght
Dublin 24
Tel.: 1800 661 551
Email: Martin.Reddy@rehabrecycle.ie

Una Lavelle
Clondalkin Community Recycling Initiative
Unit 14/2 Crag Terrace
Clondalkin Industrial Estate
Clondalkin
Dublin 22
Tel.: +353 (0)1 4578321
Email: Unaccri@eircom.net

Jose Ospina
The Wooden House
Rossnagoose
Skibbereen
Co. Cork
Tel.: (+353)28 21890
Email: ospina@eircom.net

Table of Contents

Executive Summary

In this report, reuse of electrical and electronic equipment (EEE) is considered as a potential building block towards achieving more sustainable consumption. In addition to environmental considerations, the concept of a sustainability analysis is expanded to consider the economic and social dimensions of reuse.

Legislative changes proposed within the recast of Directive 2012/19/EE of the European Parliament and of the Council of 4 July 2012 on Waste Electrical and Electronic Equipment (WEEE) will oblige EU member states to prioritise reuse at the earliest stages of WEEE take-back, separate WEEE for reuse and enable access for refurbishment centres. Revised collection reporting will enable reuse to count towards collection targets both within the business-to-business (B2B) and business-to-consumer (B2C) markets, possibly enabling refurbishers to contribute to WEEE targets. As a result of the recast, the Department of the Environment Community and Local Government (DoECLG)'s *Waste Management Policy* published in July 2012 included proposals for a 'National Reuse Policy' for WEEE.

In the case of information and communication technology (ICT), a large body of literature supports the case for extending the usage phase of certain ICT equipment through reuse. The social and economic implications of personal computer (PC) reuse have also been analysed. Socially, second-hand markets enable access to IT, improving education and enabling business expansion. Economically, reuse generates employment and revenue.

For white goods (washing machines, dishwashers, tumble dryers and refrigeration units), the current research developed a quantitative model to determine when it is beneficial to reuse an appliance compared to the purchase of a new appliance; this took account of the energy rating of the appliance, original usage intensity, secondary usage intensity, the electricity generation portfolio and the efficiency of the electricity supply. The model implements a streamlined analysis of the cumulative energy demand (CED) indicator from non-renewable fossil sources, focusing on the two most significant phases of the life cycle: the manufacture and usage phases. This model allows the examination of multiple consumer-profile scenarios with different energy-rated appliances to determine whether a suitable amortisation period is achieved to merit the purchase of a second-hand appliance compared to the purchase of a new appliance. This provides considerable certainty that a recommendation for reuse of all 'A'- and 'B'-rated appliances is sustainable.

Development of a reuse sector provides an opportunity to make a significant contribution to social and economic growth by creating employment and ensuring real sustainable economic growth whilst at the same time minimising environmental pollution. An analysis of Rehab Recycle demonstrated that preparing a tonne of B2B ICT equipment for reuse employed 11 times more people than recycling an equivalent amount of material, and generated 15 times more revenue than recycling the equivalent quantity in the same period. Other international data estimates that 1,000 tonnes of electronics creates 15 jobs if recycled and 200 jobs if repaired. Anticipated demand for refurbished EEE is also a significant factor. A Flash Eurobarometer survey gauged Irish consumers' willingness to buy second-hand electronics which showed very positive sentiment towards reuse, similar to the attitudes found in the UK and Belgium where established reuse systems are in place.

Successful reuse enterprises in Ireland and abroad identified 'access to equipment' as the key enabling factor for reuse. A survey conducted by StEP (Solving the E-waste Problem Initiative) indicates that the legal framework conditions today do not optimally support reuse organisations in accessing sufficient volumes of EEE for preparation for reuse. Reuse trials conducted by Rehab and the Clondalkin Community Recycling Initiative (CCRI) for B2C white goods demonstrated the potential for reuse that may exist within their current recovery streams (retailers, distributors, kerbside collection). Early indications anticipate retailers and distributors as good sources for white goods, with Kerbside collections potentially facilitating the spare

parts inventory market. Case studies from Bryson also showed significant reuse potential for white goods at civic amenity (CA) sites.

Reuse is an activity that must be regulated in order to develop in a sustainable fashion, to prevent sham reuse and promote consumer confidence. Only organisations operating to sufficiently high standards should be considered eligible to undertake refurbishment and reuse activities and be given access to WEEE. This current research proposes a dedicated reuse body/organisation to ensure that only refurbishers recognised as operating to the designated standards will be in a position to access supply and to have their activities reported as official reuse.

Technological developments within the EEE space, such as the inclusion of radio frequency identification (RFID) transponders to enable automated item-level identification and growing capabilities within the 'internet of things' can potentially streamline the end-of-life (EOL) process, enabling the refurbisher to identify WEEE with possible potential for reuse instantaneously at the point of entry.

1 Introduction

A sustainable future for electrical and electronic equipment (EEE) is uncertain with rapid acceleration in technological advancements and resource consumption. Classical market economy models have led to a throwaway society that is based on economies of scale, planned obsolescence and a growing demand for new products (Mont, 2008). Sustainable consumption has been identified as one of the most important challenges facing the twenty-first century (Azzone and Noci, 1998; Madu et al., 2002; Wils, 1998) and unsustainable consumption of EEE has manifested itself as a global electronic waste problem (Widmer et al., 2005). Waste electrical and electronic equipment (WEEE) or e-waste[1] for short is defined by the StEP Initiative as all types of EEE that have or could enter the waste stream. Globally, e-waste is growing at a rapid rate with varied predictions on the actual amount generated (Ongondo et al., 2011). Estimates fluctuate between 30 and 50 million tonnes of e-waste generated worldwide on an annual basis (Guan et al., 2007; Ongondo et al., 2011; StEP, 2011a) with information and communications technology (ICT) and large domestic appliances (more commonly known as 'white goods'), dominating the waste fractions by weight. This is creating a new plethora of sustainability challenges and innovative opportunities. Governments around the world have been tackling the issue for years with a variety of environmental policies surrounding EEE (Atasu and Wassenhove; 2011; Tojo, 2004). The European Union (EU) WEEE Directive (Directive 2002/96/EC), the Japanese Home Appliance Recycling Law (1998) and the Electronic Waste Recycling Act (2003) in California are all examples of the increasing legislative frameworks enacted globally to tackle the huge number of electronic-waste sustainability challenges.

The question of whether to prioritise reuse before recycling is growing in significance within society and the academic literature (Kuehr et al., 2003; Geyer and Blass, 2010; Williams et al., 2008a; Darby and Obara, 2005). Reuse is mandated within the waste hierarchy as the optimal waste-management process apart from waste prevention. Yet the environmental benefits of extending the life span of an appliance compared to purchasing a more energy-efficient appliance are constantly in question. Recycling potentially enables more energy-efficient appliances to replace existing ones. But when do the potential benefits of a more energy-efficient appliance actually outweigh the benefits of reuse? To enable an unambiguous and holistic view, a sustainability analysis is necessary to consider all the dimensions of reuse, including the environmental, social and economic implications.

In this report, reuse is considered as a potential building block towards achieving more sustainable consumption of EEE. The initial focus in Section 2 examines the unprecedented problems that unfolded due to e-waste generation globally and policies and directives that have transpired to mitigate these issues. With a growing trend towards supporting reuse emerging from legislation, Section 3 evaluates the sustainability potential of developing an Irish reuse programme. Examining the environmental, social and economic aspects of WEEE reuse for Ireland will enable clear and informed policy to be pursued in this domain at a national level. Section 4 discuss the findings from a study conducted by StEP, with support from the University of Limerick (UL), which analyses the best practices in reuse and focuses on the specific barriers and success factors experienced by the refurbishment industry globally. It also looks at standards and quality labels. Findings from case studies and WEEE reuse analysis conducted in Ireland are described in Section 5. Re-evaluate conducted an analysis of two social enterprises, Rehab Recycle and the Clondalkin Community Recycling Initiative (CCRI), to explore what role the social economy can play in WEEE reuse. These analyses have also helped to identify the potential for reuse that exists within certain product categories and from which sources. Section 6 proposes changes that are necessary to enable reuse to become uninhibited

1 WEEE generally means all electronic waste within Europe while e-waste is a more global term for information technology (IT) waste.

and mature within Ireland's waste-management system, including a proposed transition towards a reuse-oriented WEEE management system. Section 7 discusses some potential advances for the future of e-waste management, including the development in auto-identification and the emerging 'internet of things' and their potential implications for more efficient WEEE management. Conclusions derived from the research and recommendations for uninhibited reuse are given in Section 8.

2 The Global E-Waste Landscape

The bulk of WEEE generated to date comes from countries within the Organisation for Economic Co-operation and Development (OECD) (Widmer et al., 2005; StEP, 2011a). These markets are constantly expanding because of further technical advancements, increased market penetration and shortening product lifetimes (Ongondo et al., 2011). This is accelerating the rate of replacement of EEE, leading to a significant increase in the amount of WEEE arising annually (Babu et al., 2007). WEEE from electronic devices is non-homogeneous and forms a complex mixture of materials and components, often containing hundreds of different substances, many of which are potentially highly toxic, such as chlorinated and brominated substances, poisonous metals, photoactive and biologically active materials, acids, plastics and plastic additives (He et al., 2006). However, WEEE also contains high residual value metals (value of metals at end of life [EOL]) such as antimony, copper, gold, hafnium, indium, iron, lead, nickel, palladium, rare earth metals, silver, tantalum, tin, and zinc in combination with valuable reusable plastic materials, including polycarbonates, polyethylene, polyesters, polypropylene and phenolformaldehyde (Dimitrakakisa et al., 2009). Material recovery from these secondary resources is dynamically linked to the fluctuating material prices due to resource scarcity, which has a direct influence on recycling practices (Wang et al., 2012).

2.1 Resource Scarcity

As demand for rare earth elements (REE), precious metals and minerals increases, driven by relentless growth in the emerging economies of Asia and South America and increasing utilisation and frequency of replacement of EEE, competition for resources fundamental for EEE manufacturing is growing. The extraction of precious metals and minerals through the mining process is relatively difficult requiring sophisticated separation methods such as ion exchange, fractional crystallisation and liquid-liquid extraction (Fray, 2000). Mining is capital intensive and has a high environment impact requiring high-energy consumption, significant land use and water extraction, with the environmental and social implications of growing concern (Price Waterhouse Coopers, 2012). As demand for these resources increases, particularly within the so-called clean technologies (electric vehicles and wind turbines), the supply of many minerals and metals is struggling to keep up with rapid increases in consumption (Alonso et al., 2012). Furthermore, producing countries have imposed trade restrictions on the exportation of metals and minerals with high innovative value, which has been stated as a measure to protect their own demand (Jepson, 2012). China currently produces over 90% of the world's REE with an estimated 23% of the proven reserve (Information Office of the State Council, 2012) and has recently imposed trade barriers for some metals, resulting in global concern and price hikes (PBL Netherlands Environmental Assessment Agency, 2011). Rare earth elements are available in other parts of the world but it has become economically, environmentally and socially unacceptable to mine them. Dependence on one supplier (i.e. China), tightening restrictions on exports and higher prices, have reopened searches for alternative mining sources of REE in Australia, Brazil, Canada, South Africa, USA and elsewhere (Chen, 2011).

Europe depends heavily on the foreign supply of REE and is particularly vulnerable to all of the above (Hague Centre for Strategic Studies, 2010). The EU has drawn up a list of 14 key raw materials (antimony, beryllium, cobalt, fluorspar, gallium, germanium, graphite, indium, magnesium, niobium, platinum group, rare metals [e.g. neodymium, dysprosium], tantalum and tungsten), which are needed to maintain its economy and lifestyle (European Commission, 2010). The list highlights a group of key rare/scarce materials where global production is concentrated in a few countries. The restricted supply base combined with the relatively low political stability ratings for some major producing countries significantly increase risk to supply.

Both policy-makers and industry are concerned about supply risk, the need to diversify supply from the Earth's resources and also the environmental implications of burgeoning consumption (Price Waterhouse Coopers,

2012). Resource efficiency is therefore becoming a central issue on the policy agenda, leading towards finding solutions for more sustainable consumption and production, improving products and changing consumption patterns. With WEEE containing many of these precious metals and REEs, utilising this resource presents itself as an obvious candidate for an alternative source from primary production but there are numerous technical and systematic issues to be tackled before it can come on stream (Öko-Institute.V, 2011).

2.2 Recycling of Waste Electrical and Electronic Equipment

WEEE represents a challenging recycling problem because of a vast array of waste products with varying amounts of material content. End-processing involves combinations of chemical, thermal and metallurgical processes to upgrade materials and reduce impurities. In the early stages of PC manufacturing, each unit contained up to 4 grams of gold and 1 tonne of WEEE contained up to 0.2 tonnes of copper, which made recycling an extremely attractive and lucrative industry (Babu et al., 2007). This has decreased to about 1 gram of gold in modern PCs, requiring recyclers to process even larger amounts of WEEE and to develop more innovative recycling methods for recovering other marginal high value materials to remain profitable. Recycling of WEEE requires different processes depending on its content. Larger household appliances (also known as white goods) are less complicated, with relatively low value material and requiring minimal manual separation and shredding, whilst smaller more complex consumer appliances require technological investment for innovative infrastructures to maximise the recovery of valuable precious metals and minerals whilst separating toxic materials in order to minimise the environmental impact. Currently across Europe only between 25% and 40% of electronic equipment placed on the market enters recycling and, of this, only a tiny amount of the original rare and precious materials emerge from the recycling chain (Huisman et al., 2008; UNEP, 2009). This occurs as these processes are currently optimised for the recovery of plastics, gold, steel, aluminium and copper. Many of the critical raw materials have their value destroyed through inappropriate treatments such as shredding in developed countries (Chancerel et al., 2009; Meskers et al., 2009) or informal leaching in developing countries (Keller, 2006; Rochat et al., 2008). Essentially, the relevant components are not making it through to the correct final treatment processes in sufficient quantities to be economically relevant, with several of the identified critical raw materials having overall recycling rates of <1% (UNEP, 2011). For recycling of WEEE to be a sustainable and efficient operation, it must be undertaken in large quantities requiring large-scale capital investment, which in some cases has led to the transboundary movement of WEEE.

2.3 Impact of Informal Recycling Activities in Developing Countries

A significant quantity of WEEE has arisen in non-OECD countries. Much of this originates from transboundary trading from OECD countries, in spite of legislation and treaties aimed at preventing e-waste exportation for disposal to non-OECD countries (WEEE Directive and the Basel Convention, discussed in detail in Section 2.4). In order to circumvent legislation, WEEE can be easily mislabelled and exported (often under the guise of second-hand EEE) to developing countries, where money can be made out of e-waste instead of paying for appropriate recycling in the EC (Osibanjo, 2007). It is estimated that about 50 to 80% of e-waste from developed countries is exported to developing regions such as China and Africa (Öko-Institute e.V, 2011; Huisman et al., 2008). This has created an entire new economic sector in developing countries around informal reuse and recycling, notably in India, China and Africa. Trading, repairing and recovering material from WEEE has become an income-generating opportunity for the local people, driven by the demand for second-hand electronic products and secondary resources (Feng et al., 2008). Reuse is prioritised purely due to economic gain. In Nigeria and Ghana there are highly efficient well-organised repair and refurbishment networks focusing on used equipment from domestic supplies and imports. Yet these industries are indirectly linked to the e-waste sector once the products become scrap (Öko-Institut e.V, 2011). Relatively high market value metals such as gold, copper and silver contained in WEEE also make informal recycling a lucrative business. Unfortunately, extensive manual dismantling without any health and safety requirements and the crude recycling methods

used are cost efficient because of the use of non-skilled manual labour and the disregard for any hazards to the local environment or personal health. Primitive methods currently being implemented in developing countries include:

1 Physical dismantling, using hammers, chisels, screw drivers and bare hands to separate different materials (Xing et al., 2009);

2 Employing coal-fired grills for removing components from printed circuit boards (Chi et al., 2011);

3 Stripping\treating circuit boards with acid and cyanide to recover gold and other precious metals (Wong et al., 2007);

4 Open burning cable piles to recover copper (Luo et al., 2009);

5 Dumping unwanted waste in rivers and banks (Sepúlveda et al., 2010a).

These recycling methods employed are not only causing severe risk to health but to the local environment, polluting the air, water, soil and endangering the health of people living near e-waste recycling operations. A Chinese informal/unofficial recycling village near Lianjiang river recorded lead levels in their drinking water 2,400 times the World Health Organisation's recommendations (UNEP, 2005). In Guiyu, China adverse birth effects due to chemicals and environmental contaminant exposure from informal e-waste recycling were observed from 2001 to 2008. Analysis showed that Guiyu had roughly four times higher risk of stillborn births compared with Xiamen, a control site used for study. Future long-term disabilities attributed to informal recycling include chronic lung disease, loss of hearing, loss of eyesight and reduced reproductive capabilities.

The EOL social and economic benefits for developing countries have also to be considered alongside the environmental problems (Williams et al., 2008a). Joint research conducted by the EMPA, UNEP, the EU, the Öko-Institute and the Secretariat of the Basel Convention, examined the current state of WEEE in Africa (Secretariat of the Basel Convention, 2010). In-depth socio-economic studies were carried out in Nigeria and Ghana to investigate refurbishment and recycling operations. In both Accra (Ghana) and Lagos (Nigeria), this refurbishing sector generates income for more than 30,000 people with salaries between US$2.20 and US$22 per day, which is above the internationally defined poverty line of US$1.25 per day. Alaba International Market in Lagos, Nigeria is the largest market for used and new electric and electronic goods in Africa, with about 6,000 repair and sale businesses, and an estimated 21,600 people working as employees and apprentices (Figs 2.1 and 2.2). Total annual income generated from these activities is estimated at US$50.8 million, contributing significantly to the local economy (Öko-Institute, 2011). A study conducted in Peru showed that 87–88% of imported used computers had a price higher than the ideal recycle value of constituent materials, therefore indicating computers were being imported for reuse as opposed to recycling (Kahhat and Williams, 2009). This indicates that a large proportion of imported used EEE are suitable for reuse but potentially EOL structures are not adequate when it inevitably becomes WEEE.

Figure 2.1. ICT refurbishing facility in Lagos, Nigeria (Öko-Institute, 2011).

Figure 2.2. Alaba international market, Lagos, Nigeria (Öko-Institute, 2011).

New preliminary research on future e-waste generation is forecasting that by 2018 or sooner the developing world will be disposing of more PCs than the developed world (Yu et al., 2010). To date, the main approach to mitigating the environmental impacts of informal recycling has been to reduce the amount of e-waste being exported outside the OECD countries. With increasing amounts of e-waste being generated domestically in developing countries, efforts are been made to set up activities for dealing with e-waste effectively without taking away their livelihoods. The key sustainability challenge for developing countries is to prevent informal WEEE recycling activities that can endanger human health and the environment without hampering the socio-economically valuable trade of used EEE of good quality.`

Wang et al. (2012) address the sustainability challenge for WEEE faced within the developed and developing worlds and propose a philosophy for the 'best of two worlds'. They note that optimal detoxification and recovery techniques to liberate target materials require manual disassembly pre-processing stages before smelting compared to mechanical pre-processing and optimised shredding. In the case of gold recovery from computers in a state-of-the-art smelting facility, manual disassembly of the mother boards, contacts, circuit boards, disks and power supply yields 97% recovery compared with mechanical treating, which yields 70% (Wang et al., 2012). This approach, however, is not viable in developed countries due to high labour costs and is not feasible in developing countries due to high capital investment required for setting up infrastructural requirements (smelter = €500Million) (Wang et al., 2012). Current informal recycling using acid leaching yields just 25% recovery with 180 times higher metal emissions to water and three times higher oxide emissions into the atmosphere (Wang et al., 2012). Therefore, a macro strategy for resource conservation and material efficiency was proposed where manual dismantling of WEEE is conducted within developing countries where labour costs are low, and so retaining local employment whilst generating finer material optimised for recovery. These fine fractions are forwarded to existing state-of-the-art facilities currently in the developed world for maximum material recovery, benefiting both economies environmentally, economically and socially.

2.4 Directives and Policies

Even in developed countries, recycling and disposal of e-waste may involve significant risk to workers and communities. Therefore, great care must be taken to avoid unsafe exposure in recycling operations and leaching of materials such as heavy metals from landfills and incinerator ashes must be avoided. Within the EU, directives have been enacted supporting alternatives to landfill (Waste Framework Directive 2008/98/EC) and promoting the collection and recycling of WEEE (WEEE Directive 2002/96/EC). Further emphasis has been placed on improving the environmental performance of energy-related products (Energy-related Products [ErP] Directive 2009/125/EC), restriction of the use of certain hazardous substances in EEE (Restriction of Hazardous Substances [RoHS] Directive 2011/65/EU) and restricting transboundary movement of these products once they become waste (Basel Convention/ Waste Shipment Regulation WSR 1013/2006). The directives are based on the extended producer responsibility (EPR) principle, in which a producer's responsibility, physical and/or financial, for a product is extended to the post-consumer stage of a product's life cycle (OECD, 2009a). This ensures that manufacturers are responsible for the various parts of the entire life cycle of the product, specifically take-back, recycling and final disposal of the product (Lindhqvist, 2000). The goals of the EPR-based programmes are to:

- Incentivise system and product design improvements;
- Heighten the utilisation of products and material through effective collection and environmentally sound treatment of collected products;
- Further utilise products and materials through reuse and recycling.

2.5 Waste Electrical and Electronic Equipment Directive

2.5.1 WEEE Directive

The European Parliament and the Council of the European Union issued Directive 2002/96/EC on WEEE on 27 January 2003. The WEEE Directive seeks to improve the way waste products are designed and managed through the prevention of such products from

entering municipal waste collection systems through reuse, recycling and recovery. It encourages and sets criteria for the collection, treatment, recycling and recovery of WEEE. Both household and non-household EEE are covered. The Directive is based on the principal of producer responsibility and tries to connect all the actors involved in the life cycle of these products, such as producers, distributors, consumers and treatment facilities. The Directive applies to those manufacturing, selling, distributing, recycling and treating EEE in the EU. The WEEE Directive requires producers to set up systems for the collection of electronic waste from households and requires each member state to collect 4 kg per person per year of WEEE by 1 January, 2006. This target has been shown to under-estimate the amount of WEEE arising in member states. In 2008 Ireland recovered approximately 9 kg per inhabitant, similar to Belgium (8.1 kg) Finland (9.8 kg) and Luxemburg (8.5 kg) but, elsewhere in Europe, recovery figures reported ranged from as low as 0.8 kg in Romania but as high as 14.8 kg in Sweden (Eurostat, 2012). The range of figures indicates that the current weight-based target does not give a clear representation of the waste that is actually arising in each representative member state.

The WEEE Directive imposes responsibility on producers for the environmental impact of their products throughout the life cycle. Producers' responsibility include both the upstream and downstream impacts, including design and selection of materials, production impact, use phase and disposal impacts. Article 4 of the WEEE Directive 2002/96/EC notes that: 'Member states shall encourage the design and production of EEE which takes into account and facilitates dismantling and recovery, in particular the reuse and recycling of WEEE, their components and materials.'

This is intended to have the effect of internalising the externalities of WEEE and shifts the responsibility firmly onto those who benefit most from the product. Table 2.1 lists these 10 categories that have been identified within the WEEE Directive as belonging to EEE.

Since the Irish government's implementation of the WEEE Directive 2002/96/EC in August 2005, all producers and distributors (retailers) of EEE must comply with the WEEE regulations. The 2005 regulations have recently been revoked in place of the 2011 European Communities WEEE Regulations (S.I. No. 355 of 2011), which now gives effect to the provisions of European Parliament and Council Directive 2002/96/EC as amended by European Parliament and Council Directive 2003/108/EC and by Article 5 of Directive 2008/112/EC of the European Parliament and of the Council.

Producers of EEE must register with the WEEE Register Society which acts as a national registration body for producers and foreign suppliers to the Irish market. The WEEE Register Society gathers information by means

Table 2.1. Waste electrical and electronic equipment (WEE) categories.

WEEE categories	Examples
1 Large household appliances (white goods)	Refrigeration units, washing machine, dryers, oven, etc.
2 Small household appliances	Vacuum cleaners, electric razor, hair dryer, etc.
3 IT and telecommunications equipment (ICT)	Computers, mobile phones, screens (CRT & flat panel), etc.
4 Consumer equipment	Hi-fi systems, home theatre systems, audio amplifiers, etc.
5 Lighting equipment	All fluorescent lamps, LED, torches, bicycle lamps, etc.
6 Electrical and electronic tools	Hammer drill, drill, saws, sewing machines, etc.
7 Toys, leisure and sports equipment	Electric trains, car-racing sets, video game consoles, etc.
8 Medical devices	Radiotherapy equipment, cardiology, dialysis, etc.
9 Monitoring and control instruments	Smoke detector, Heating regulators, Thermostats, etc.
10 Automatic dispensers	Automatic dispensers for hot drinks, solid products, etc.

of the 'WEEE Blackbox' which is used to establish and manage producers' financial liabilities associated with the management of a proportion of their WEEE arising in Ireland.

Producers can join a compliance scheme to help meet their collection, recycling and reporting requirements. A compliance scheme is defined by the WEEE Register Society of Ireland as 'a non-profit organisation that manages the collection, treatment and recycling of WEEE, batteries and accumulators from authorised collection points on behalf of their members' (WEEE Register Society, 2012). Currently there are two registered compliance schemes in Ireland: the European Recycling Platform (ERP) and WEEE Ireland. Compliance schemes require producers to join the scheme in order to apply for funds from the WEEE Blackbox to carry out WEEE compliance on behalf of the producer. Compliance schemes for WEEE help producers and retailers deal with regulations set forward in the WEEE Directive and assist businesses in developing cost-competitive solutions for discharging their WEEE obligations. WEEE is split into two categories: B2C and B2B, which are handled separately. Business to consumer (B2C) producers can either self-comply or join an approved producer compliance scheme and pay relevant fees. Business to business (B2B) producers must submit an EPA plan and sign up with a waste contractor/reprocessor for recovery & recycling of WEEE, as there is no equivalent B2B producer approved compliance scheme.

Retailers/distributors are prohibited from distributing EEE from a producer who is not in possession of a valid certificate of registration from the WEEE Registration Society. Retailers who distribute EEE supplied by a producer must display environmental management costs (EMCs). Retailers have a monetary role, displaying the WEEE charge and sending the money to WEEE Blackbox. Retailers must register as an EEE distributor with a local authority or an approved compliance scheme for their take-back obligations. Currently, they are only required to take back WEEE that they have sold, or on a like-for-like basis free of charge.

Each local authority must accept household WEEE free of charge at its civil amenity (CA) facilities. Generally, councils outsource their responsibilities to WEEE recyclers, therefore acting as a depot for WEEE. Treatment facilities/reprocessors need permits to deal with the treatment of WEEE while only authorised treatment facilities may issue WEEE evidence.

Since the implementation of the WEEE Directive, it is estimated that only one-third of WEEE in the EU is collected and appropriately treated (EU Commission, 2008). The collection target of 4 kg per person per year does not properly reflect the amount of WEEE arising in individual member states. As noted above, Ireland has consistently exceeded the 4 kg per capita collection target required by EU legislation, with its per-capita collection rate in 2009 standing at 9 kg. Currently reuse of whole appliances does not count towards WEEE targets. In December 2008, the European Commission therefore proposed to revise the Directive on Electrical and Electronic Equipment in order to tackle the fast increasing waste stream of such products and to increase the amount of e-waste that is appropriately treated.

2.5.2 Recast of WEEE Directive

The recently published recast of the WEEE Directive (2012/19/EU) aims to clarify its scope and definitions and improve its compatibility with other EU directives such as the Waste Framework Directive. The main areas of focus included changes within the requirements for design, reuse, collection, recovery and treatment. Within the revised Article 4, the recast will enforce eco-design requirement under the Energy-related Products (ErP) Directive 2009/125/EC (more commonly known as the Ecodesign Directive). In addition, there is an increased focus on reuse, in line with the Waste Framework Directive. Article 4 of the WEEE Directive states that: 'Producers do not prevent, through specific design features or manufacturing processes, WEEE from being reused'. In addition, Article 6 specifically requests that member states facilitate access to collected waste for third parties so they may pick appropriate products for reuse: 'In order to maximise preparing for reuse, member states shall promote that, prior to any further transfer, collection schemes or facilities, as appropriate, provide for the separation at the collection points of WEEE that is to be prepared for reuse from other separately collected WEEE, in particular by granting access for personnel from reuse centres'.

From a collection perspective, Article 7 of the recast requires a minimum collection rate of 45% of material to be placed on the market initially but increased to

65% within four years and 85% after seven years. New obligations are also placed on distributors of small WEEE requiring free-of-charge drop-offs for end users with no obligations to buy EEE of an equivalent type. Recovery targets of up to 85% are set, with an emphasis placed on reuse and recycling. These targets do not apply directly to individual companies but on the member state, who will be scrutinised by the European Commission. Member states can impose stricter collection regimes if warranted. Additional standards will be developed by the European Standardisation Organisation for the Treatment, including Recovery, Recycling and Preparing for Reuse of WEEE, no later than 14 February 2013 (Article 8).

2.6 Energy-related Products Directive/ Ecodesign Directive

The ErP Directive (2009/125/EC) was recast and entered into force on 20 November 2009. The updated Ecodesign Directive provides a coherent and integrated framework which allows for setting compulsory ecodesign requirements for all energy-related products. Ecodesign implies taking into account all the environmental impacts of a product right from the earliest stage of design. The ErP Directive obliges manufacturers of energy-using products to reduce energy consumption and other environmental impacts at the design stage. Currently 12 ecodesign measures have been introduced for standby (the electric power consumed by electronic and electrical appliances while they are switched off), street and office lighting, simple set top boxes, domestic lighting, external power supplies, electric motors, circulators, domestic refrigeration, televisions, domestic dishwashers, domestic washing machines and fans. For instance, the ecodesign measure on standby requires that domestic EEE such as washing machines, televisions or personal computers do not consume more than 1 W in off mode as of 2010, and not more than 0.5 W as of 2013. However, such ecodesign requirements shall not lower the functionality of a product, its safety, or have a negative impact on its affordability or consumer's health. A major goal of the Directive is to improve the energy efficiency of energy-using products and thereby contribute to efforts to reach European targets for climate protection (20% energy-saving target by 2020). The Directive, however, does not only cover the energy use of products but rather aims to reduce the overall negative environmental impact of the products under consideration. The effectiveness of the Ecodesign Directive and its implementing measures are continually reviewed. To ensure that products have complied with EU directives a 'CE' marking is issued to prove compliance. Products which do not comply with EU directives will not qualify for the CE marking, and therefore cannot be sold in the EU.

2.7 Basel Convention and Waste Shipment Directive

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal is a UN international treaty introduced to restrict the movement of hazardous waste between countries, specifically transfers of hazardous waste between developed and undeveloped countries. The convention, which was opened for signature on 22 March 1989, and entered into force on 5 May 1992, has been ratified by 173 countries. Afghanistan, Haiti, and the United States are the only countries to have signed the convention but not yet ratified it. The Basel Convention aims to protect human health and the environment against the adverse effects resulting from the generation, management, transboundary movements and disposal of hazardous and other wastes. E-waste is seen as priority waste stream and is covered in Annex VIII and Annex IX of the convention. Under the convention, parties are obliged to ensure that such wastes are managed and disposed of in an environmentally sound manner. The convention covers toxic, poisonous, explosive, corrosive, flammable, eco-toxic and infectious wastes. Parties are also expected to minimise the quantities that are transported, to treat and dispose of wastes as close as possible to their place of generation and to prevent or minimise the generation of wastes at source.

The OECD introduced regulation (92)39/Final to monitor the transboundary movement of wastes destined for recovery operations between member states (OECD, 2009). The regulation deviated from the convention seeking to control resources secured from wastes and minimise hazardous waste shipments (OECD, 2009), offering more detailed guidelines which allow countries who are not signatories of the convention to continue to trade waste with OECD member countries. The European Waste Shipment Regulation (1013/2006) transposes the Basel Convention and OECD decision into European law, making it legally binding in all EU

member states, which is referred to in the WEEE recast (Article 10). In order to prove a shipment does not contain waste, evidence must be provided that a shipment contains fully functional equipment, destined for direct reuse, that appropriate protection against damage has been implemented and, if defective, proof that the equipment is sent back for repair with the intention of reuse. Guidelines are being finalised on the distinction between WEEE and second-hand EEE as part of ongoing work on e-waste under the Basel Convention.

2.8 Waste Framework Directive

The revised Waste Framework Directive (2008/98/EC) came into force in December 2009 and had to be transposed by each member state by December 2010. The Directive seeks to promote the alternatives to landfill by (amongst other things) strengthening the role of the waste hierarchy as a priority order in waste prevention and management legislation and policy. The Directive introduced the 'polluter pays principle' and the 'extended producer responsibility'. Extended producer responsibility granted member states discretionary powers to introduce new producer responsibility measures to increase levels of recycling, reuse and waste prevention. As noted above, the waste hierarchy is a key structure for demonstrating the different impacts and indicating the best waste-management options and strategies for business development in the waste stream. It set out the order in which options for waste management should be considered based on environmental impact. The waste hierarchy aims to encourage the management of waste materials in order to reduce the amount of waste materials produced, and to recover maximum value from the wastes that are produced. Fig. 2.3 illustrates the pyramid theory designed to give order of precedence for dealing with the multiples of waste produced. The waste hierarchy refers to the 3Rs of 'reduce', 'reuse' and 'recycle', which classify waste-management strategies according to their desirability.

Waste prevention and waste minimisation are the favoured options in the waste-management hierarchy. Minimisation is not centred on technological advances but can be viewed as a method of managing existing resources and technology in order to maximise the efficiency of available resource use. Minimising waste generation has the potential to reduce costs or increase profits by maximising the use of resources and by reducing the amount and cost of waste to be disposed. Reuse extends the lifespan of a device and although devices still need to be recycled eventually, by allowing others to purchase used electronics, recycling can be postponed and value gained from device use. It also conserves the embodied energy and water. The amended EU Waste Framework Directive introduced definitions for 'reuse' and 'preparing for reuse'. 'Reuse' means any operation by which products or components *that are not waste* are used again for the *same* purpose for which they are conceived. 'Preparing for reuse' means checking, cleaning or repairing recovery operations, by which products or components of products *that have become waste* are prepared so that they can be reused without any other pre-processing. The five-step hierarchy must now be strictly adhered to in all member state policy and legislation, with options positioned higher up in the hierarchy being prioritised ahead of those positioned beneath them.

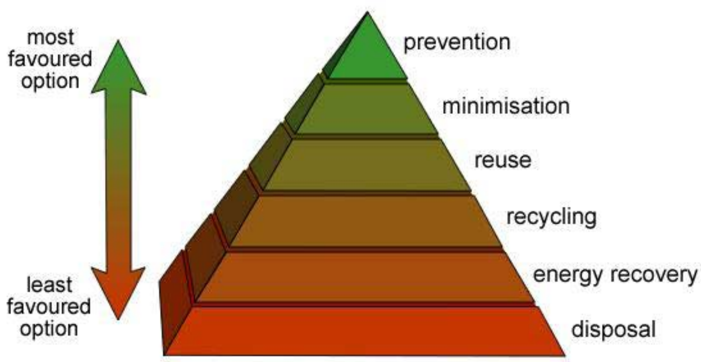

Figure 2.3. Waste management – waste hierarchy (Waste-online, 2004).

2.9 Discussion

Inadequate infrastructures surrounding e-waste within developed and developing countries lead to unsustainable levels of resource consumption and, in some, irreversible environmental contamination and human-health impacts. Directives and policies have paved a new approach towards a sustainable future for e-waste, where reuse is seen as a pivotal element. The recast of the WEEE Directive aligned with the Waste Framework Directive and the Ecodesign Directive will oblige member states to prioritise reuse at the earliest stages of WEEE take-back, separate WEEE for reuse and enable access for refurbishment centres. The implementation of the eco-design Directive, mandating the prevention of design features that inhibit reuse, and imposing responsibility on producers to provide dismantling information free of charge, provide a foundation for the integration of reuse. Moreover, by prohibiting certain hazardous substances, the RoHS Directive ensures reuse can happen more safely and effectively. With increased emphasis being placed on reuse, Section 3 evaluates the sustainability potential of a reuse programme in Ireland, examining the environmental, economic and social implications.

3 Evaluating the Sustainability Potential of a Refurbishment Programme in Ireland

3.1 Introduction

In this section reuse is analysed from a sustainability perspective. In addition to environmental considerations, the concept of a sustainability analysis is expanded to consider the economic and social dimensions of reuse. An integrative quantitative model is developed that permits a comparative analysis of reuse and non-reuse scenarios from an environmental perspective. It also provides a social and economic perspective. Socially, qualitative aspects of EEE reuse such as the job-creation potential and the impact on prosperity for low-income families are considered. Furthermore, to help understand the economic sustainability of reuse enterprises, comparisons are conducted between different WEEE refurbishers across Europe to ascertain the specific success factors and barriers which they have experienced.

3.2 Literature on Reuse

The overwhelming majority of literature in the reuse area is focused on the environmental questions associated with it. Several authors (Daniel et al., 2009; Kimuraa et al., 1998; Jofre and Morioka, 2005) note that reuse and remanufacturing have a significant contribution to play in the EOL management of WEEE. One question constantly arises, however: how do the environmental and socioeconomic benefits of extending the life span of an appliance rate when compared to recycling the appliance and recovering secondary raw materials? The case for maximising reuse focuses on a number of factors. When conducted in the appropriate circumstances it can conserve embodied energy and water (Williams et al., 2004). It is the most efficient use of scarce materials which are often lost in recycling (Sepúlveda et al., 2010b; Hagelüken and Meskers, 2008). It reduces the amount of transportation required in putting the product back on the market (Achillas et al., 2011). It provides jobs for disadvantaged people as opposed to health problems (Hines, 2008) and it reduces the amount of pressure on underdeveloped recycling infrastructures (Lau, 2008).

In the case of ICT a large body of literature has been published which supports the case for extending the usage phase life-cycle of certain ICT equipment through reuse (Williams and Sasaki, 2003; Sahni et al., 2010; Griese, 2004; Kuehr et al., 2003; Hickey and Fitzpatrick, 2007; Williams et al., 2008b). A number of life-cycle assessment (LCA) studies have been carried out in an attempt to quantify the energy consumed in production (Choi and Shin, 2004; Tekwawa et al., 1997). The high energy consumption resulting from the manufacture of PC microchips is a major factor for supporting lifetime extension, to recoup the invested energy consumed in the production process (Williams et al., 2002; Kuehr et al., 2003).The social and economic implications of PC reuse have also been analysed (Williams et al., 2008a). Socially, second-hand markets enable access to IT set-up, improving education and enabling the up-scaling of business practices. Economically, reuse generates employment and revenue.

The case in the literature for reuse of white goods has not been made as comprehensively. In the current research, white goods (washing machines, dishwashers, tumble dryers and refrigeration units) are seen as an important area for investigation due to the large volume produced annually and their relatively significant life-cycle impact. White goods contrast significantly with IT due to their bulky size, reduced level of integration and high operational energy usage. Extending their life through remanufacturing can save energy and raw materials during the production process but could be less energy efficient over the entire life cycle (Boustani and Sahni, 2010). Lindahl et al. (2006) deduced that the amount of energy needed to produce a new refrigerator is 50 times greater than the energy needed for refurbishment and 30 times for a washing machine. Kim et al. (2006) identify that replacing old models of refrigerators is beneficial to society from an environmental perspective but may be uneconomical from a consumer's vantage point.

A study conducted by the Öko-Institute in 2005 examined whether washing machines and tumble dryers with

different years of construction – ranging from 1985 to 2004 – should be replaced by new washing machines or should be kept in use (Rüdenauer and Gensch, 2005b). The study considered the environmental and economic implications of an accelerated replacement of appliances. It was concluded that when focusing on the CED analysis that the optimal substitution times for washing machines in 1985, 1990 and 1995 were approximately two, three and five years respectively. From an economic perspective, the payback period is greater, with a six-year amortisation for a 19-year-old washing machine. Devoldere et al. (2009) develop this theme further by looking at both environmental and economic aspects and analysing the trade-off between the total cost of ownership (TCO) of different energy grades of washing machines. Their results show that in certain scenarios the economic and environmental objectives of reuse centres can be violated by extending the product lifetime. The reuse of cheaper, less efficient products can potentially result in both a higher total cost and a higher total environmental impact than the purchase of a new appliance. The TCO is an important element of this study. Consumers perceive lower-cost refurbished machines to be a cheaper alternative. Therefore, in principle, only washing machines with an equal or lesser TCO than a newer machine should be resold.

Similar to the Öko-institute study, Devoldere et al. (2009) do not account for the projected changes in electricity generation and their related impacts on use phase during the period in which it will be reused. This is particularly important in an EU context given the ambitious renewable energy targets that many member states are pursuing.

As energy consumption in the use phase is such a dominant factor in deciding if reuse is suitable, it is necessary to consider some relevant developments in efficiency trends. Energy consumption in the usage phase, to a large extent, is controlled by the actions of the consumer (Richter, 2011) and is the most significant factor when determining the benefits of reuse. Richter (2010) notes that the consumer decision-making process is influenced by the increasing costs of energy and water. Eco-labels were identified as a way of encouraging consumers to adopt more sustainable consumption patterns through the purchase of products that are more resource and energy efficient (Bansal et al., 2001). This was adopted in Europe by means of the 'Household Appliances: Energy Consumption Labelling Directive' (92/75/EEC), which was later extended to all energy-related products (2010/30/EU), excluding transport. Further Directives such as the Ecodesign Directive (2005/32/EC) and the recast of Ecodesign Directive (2009/125/EC) for establishing a framework for the setting of ecodesign requirements for energy-related products were also implemented to improve the market penetration rate of the more energy-efficient appliances.

The Sustainable Energy Authority of Ireland (SEAI, 2008) *Energy in the Residential Sector* report examined the market-penetration rate of 'A'-rated appliances, for the top four domestic appliances – dishwashers, washing machines, refrigerators and freezers – in Ireland from 1995 to 2005. At the outset, penetration rates of 'A'-rated appliances were below 10%, but with the introduction of the energy labelling for household appliances, a direct impact on the penetration rates of 'A'-rated appliances was attained by 2005, with 70% penetration for fridges and freezers and over 90% penetration for washing machines and dishwashers (Fig. 3.1).

This previous literature focuses on the improved energy efficiency of new appliances and as such an examination of the projected future trends of the energy efficiency is essential. Truttmann and Rechberger (2006) analysed the electricity consumption of eight household appliances from 1990 to 2005 and predicted future energy consumption demand for these appliances from 2005 to 2020. The results showed that from 1990 to 2005 high gains were made in the efficiency improvements of all appliances. These improvements correspond to the market penetration rate of 'A'-rated appliances. Due to technological limitations, the differential energy efficiency improvement of newer white goods will be considerably lower relative to the current 'A'-rated appliances on the market. These predicted trends indicate lesser gains in energy-efficiency improvements over time. Lower marginal gains from replacing appliances in the future are inevitable once systems have achieved an 'A' grade certification in efficiency. Over time, these diminishing returns remove the justification for early product replacement or dramatically increase the length of amortisation once appliances have reached a sufficiently high rating.

In summary, the case for promoting ICT reuse is already heavily substantiated within literature. The literature concerning reuse of large household appliances points to a need to consider the energy in the use phase, and a life-cycle perspective needs to be taken to ensure a minimum life-cycle impact.

3.3 Environmental Assessment

This analysis introduces two dimensions to the environmental assessment that have not been considered in previous studies. Firstly it looks at how national energy policy influences the reuse/recycling decision and secondly it makes the comparison on the basis of the new replacement product being the least expensive on the market as opposed to the most efficient, which has been the case before.

3.3.1 Energy policy

As discussed in the literature review, the impact of extending the use phase of an appliance through reuse is an important issue from an environmental perspective. On the one hand, reuse extends the product's useful life and prevents a certain amount of the burden associated with the manufacturing phase, EOL treatment and resource loss. On the other hand, energy consumption differentials between the appliance being reused and similar appliances currently available for purchase need to be considered.

An LCA of individual large household appliances allows the full range of environmental impacts attributable to these products to be ascertained (Helias and Haes, 2008). Previous LCA studies for white goods have shown the usage phase and manufacturing phases dominate the life-cycle impact with approximately 70% to 95% attributed to the usage phase and between 10% and 15% associated with the manufacturing phase (Rüdenauer and Gensch, 2005b; Rüdenauer and Gensch, 2005a; Rüdenauer and Gensch, 2004; Boustani and Sahni, 2010).

Due to this dominance of the energy consumed in the use phase in determining environmental impact, it is imperative to consider the electricity generation portfolio in the country in which it will be reused, and how it is projected to change during the relevant period. This is very important as it is due to the burning of fossil fuels in electricity generation that use-phase energy and environmental impact are so closely coupled. As this study is focused on the Irish situation some comment on Irish electricity generation is appropriate. As with other EU members, Ireland's strive towards a higher penetration of renewable energy has been driven by a necessity to achieve overall reductions of greenhouse gas emissions with the promotion of energy from renewable sources. Additionally, Ireland's resilience against fluctuations in foreign fossil fuel markets has continued to weaken since the mid-1990s, hitting an

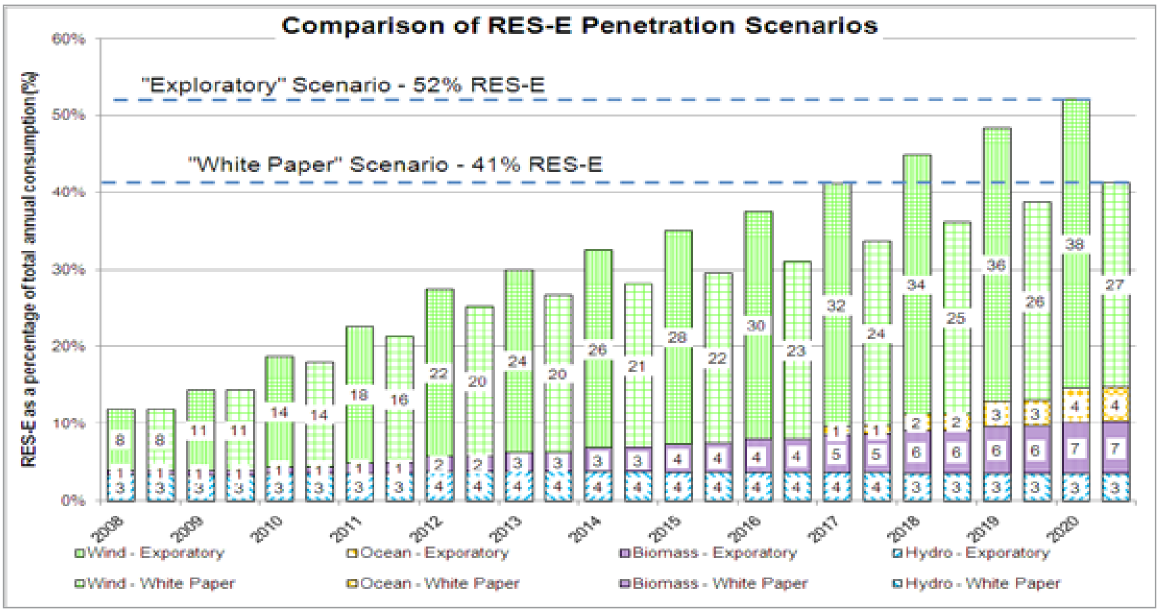

Figure 3.1. Comparison of RES-E penetration scenarios as described in SEAI's *Energy Forecast for Ireland to 2020* (Finn et al., 2011).

all-time low in 2007 with imported fuels accounting for 91% of annual consumption (OECD, 2009b). These factors have shaped government policy to maximise exploitation of Ireland's indigenous renewable energy from wind, wave, tidal, and biomass sources. As a result, Ireland's electricity generation from renewable sources (RES-E) has increased from 2% in 1995 to approximately 14.4% in 2009 (SEAI, 2010) and is set to increase to upwards of 40% by 2020 (DCENR, 2009) (Fig. 3.1).

This change in electricity generation over the period in which reuse takes place has the effect of lengthening the amortisation period and will be discussed further in Section 3.3.3.

3.3.2 Cheapest available technology

The typical means of undertaking a reuse analysis is to examine the amortisation period of replacing an EOL appliance with the manufacturing burden of a newer more efficient device. Previous studies have compared the reuse product to the best available technology whereas in this study the comparison is to the cheapest available technology which is a much more realistic scenario based on the usual target market of reuse appliances.

A survey conducted by the authors of six large white-goods retailers in Ireland examined the energy rating of the least expensive models on the market. The survey showed that for dishwashers, washing machines, refrigerators and freezers, the cheapest appliances available are 'A' rated. However, for dryers, the cheapest appliance available is 'C' rated. These are the efficiency ratings of the new appliances that will be used in the model.

3.3.3 Reuse model

A quantitative model was developed to determine when it is beneficial to reuse an appliance compared to a new appliance. The model implements a streamlined analysis of the CED from non-renewable fossil sources, focusing on the two most significant phases of the life cycle: the manufacture and usage phases (Fig. 3.2). The CED indicator has a close correlation with other indicators, such as Ecoindicator 99, Ecological Footprint, Eco Scarcity and Cumulative Energy Extraction and is recommended as a screening indicator for environmental performance (using linear regression analysis the Ecoindicator 99 correlation with CED is R^2=.81 [Huijbregtsm et al., 2010]). Figure 3.2 is the theoretical representation of a reuse decision model illustrating the amortisation period (pay-back period),

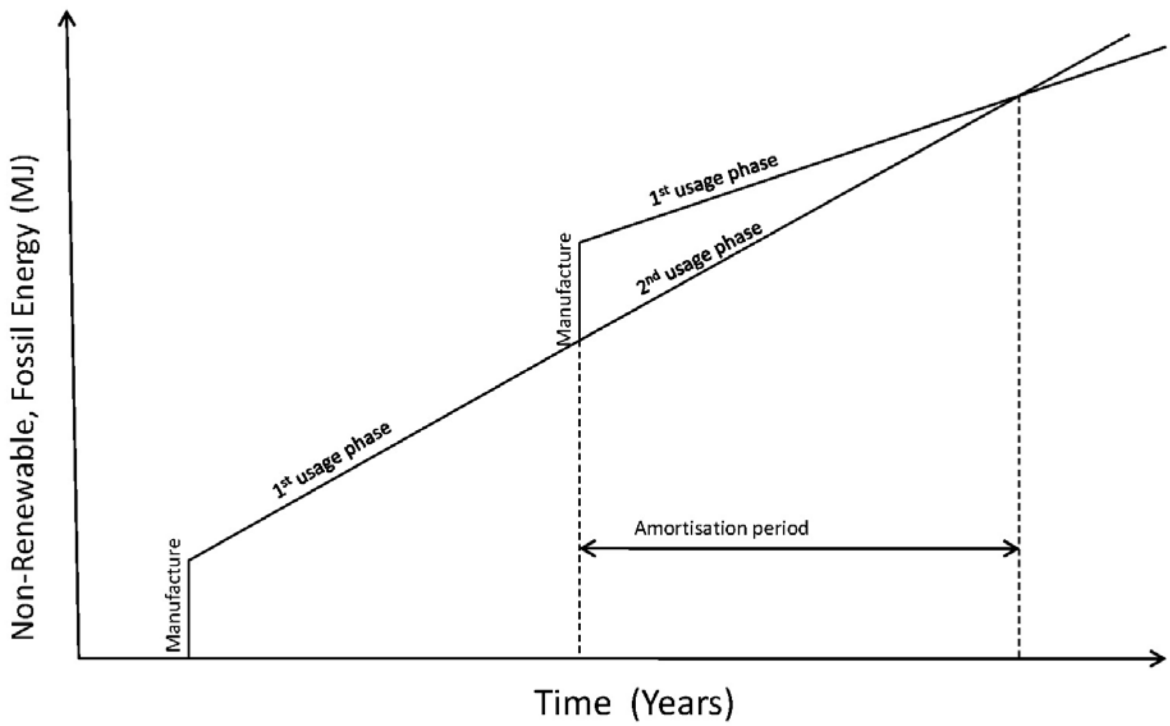

Figure 3.2. Energy amortisation in reuse scenarios.

for replacing a less energy-efficient appliance with a more energy-efficient appliance. A linear relationship is used to demonstrate the function of the model but, in practice, depending on the variables considered, this will not be the case. This will become more apparent in the next section.

Models of this nature will inevitably have a high level of uncertainty due to assumptions about the user profiling and future energy generation. For this reason, the analysis is conducted on 27 possible scenarios to examine the sensitivity of the results based on three different types of usage intensity (first and secondary) and three different ownership periods.

Using this model, multiple consumer-profile scenarios can be examined with different energy-rated appliances to determine whether a suitable amortisation period is achieved to merit the purchase of a second-hand appliance compared to the purchase of a new appliance. Determining a suitable environmentally and economically feasible amortisation period is both a key decision factor for and a limitation of the model. If the amortisation period is sufficiently long to be considered a reasonable duration for use of an appliance then the model recommends that it be reused. If the amortisation period is too short then the recommendation is for recycling. Determining what constitutes a suitable amortisation period is therefore somewhat arbitrary and a reasonable baseline must be predefined.

The model is broken into two phases. The initial manufacture and usage phase is determined for the original user and the second phase focuses on the second user's decision – whether to purchase a refurbished appliance, or purchase a new more energy-efficient appliance based on a suitable amortisation period. The slope of both usage phases is determined by:

1 The energy rating of the appliance (grade: A, B, C, D, E, F);
2 Original user-usage intensity (first ownership period and usage);
3 Second user-usage intensity (second ownership usage);
4 The electricity generation portfolio (annual energy in renewable energy penetration);
5 The efficiency of the electricity supply (source to point of use).

The user profile scenarios have two independent variables and one dependent variable. The two independent variables are the number of usage cycles per year and the ownership period. The dependent variable is the energy grade of the appliance. An economic analysis can also be conducted using the same model, substituting the Y axis 'Energy (MJ)' with 'Cost (€)', enabling the financial dimension of reuse to be examined compared to the acquisition of a new appliance. As noted above, case studies were conducted for a washing machine, dishwasher, tumble dryer and fridge-freezer to demonstrate the model in operation. In all cases a minimum amortisation period of six years was chosen as a baseline guide, to promote reuse before recycling. This is seen by the research team as a minimum requirement for ensuring the sustainable longevity of reused appliance. Previous studies conducted by the Öko-Institute determined five years' amortisation as a justifiable period for replacing a less efficient appliance with a new appliance (Rudenauer, 2007).

3.3.3.1 *Case study: washing machine*

A case study of a washing machine is now presented, using Ireland's changing energy profile as an example. The scenarios assume three types of consumers: high intensity (HI), average intensity (AI) and low intensity (LI) and also with three different periods of ownership: long, average and short. The current and future electricity-generation projections and the efficiency of electricity transmission are sourced from SEAI (2010).

The water consumption for white goods correlates to the amount of energy usage so is not considered as part of the model. Furthermore, Ireland currently does not have water charges, so this is not accounted for in the economic analysis. For the analysis, different grades of refurbished washing machine are compared to an equivalent 'A'-rated washing machine. Emphasis is placed on the energy label of cheapest new appliance on the Irish market, as this is seen by the research team as a more realistic target market for refurbished appliances.

The washing machine performance was measured according to European harmonised standard EN 60456 and Directive 92/75/EEC with regard to energy labelling of household washing machines (Tables 3.1 and 3.2). The energy-efficiency scale for washing machines is calculated based on a cotton cycle at 60 °C (140 F)

with a maximum declared load of typically 6 kg. The energy-efficiency index is in kW·h per kilogram of washing, assuming a cold-water supply at 15 °C. Using a constant operating temperature, fixed initial water temperature and a maximum weighted load per cycle as a limitation of the model, focusing on the worst case scenario (maximum energy used per load). Anticipated lower temperature cycles due to advancement in detergent capabilities would increase the amortisation period under the different scenarios. Similarly, the maximum declared load is maintained at 6 kg per cycle, any reduction in the load size will reduce the cycle energy consumption, shifting out the amortisation period. The manufacturing energy used is 3508 MJ (Rüdenauer and Gensch, 2005b), with the energy required in refurbishment considered negligible (Bole, 2006). The transport of products under all scenarios are also considered to be negligible (Quariguasi et al., 2010).

The analysis is conducted for a period centring around 2011 (the assumed time of the reuse decision for all scenarios). Three ownership periods for the original owner were analysed: long life (LL: 14 years), average life (AL: 10 years) and short life (SL: 6 years). Ten years is considered to be the average disposal period for washing machines (CECED, 2003). The upper (14-year ownership) and lower (6-year ownership) boundaries were also examined to ascertain how this influenced the amortisation period, as there is anecdotal evidence from recyclers that a significant number of quite recent machines enter the recycling stream.

Based on the energy efficiency index (EEI) the standard number of washing cycles per year is given as 220 cycles (EU Commission Regulation No 1015/2010), which is taken as the MI for the model. A sensitivity analysis is incorporated focusing on the upper and lower boundaries of the washing cycles per year with 392 cycles being the worst-case scenario (Bole, 2006) and 170 being the best-case scenario (Stamminger et al., 2008). For the economic analysis a purchasing cost and usage cost analysis comparison is conducted between different grades of refurbished washing machines compared to an equivalent 'A'-rated washing machine. The purchasing cost of a new machine is set at €300 and a refurbished appliance is set at €100. The cost per kW·h of electricity is fixed at 20 cents (SEAI, 2009).

The rate of decrease in efficiency of the appliance over time due to limescale and mechanical erosion was not accounted for in the model. Devoldere et al. (2009) analysed the deterioration for a washing machine over time and determined that the water consumption remains almost constant throughout the usage. The mechanical erosion within the belt and pulley system was estimated at 5 to 10% over the usage cycle, with limescale-affected heated elements accounting for an increase energy usage of 5 to 15% per millimetre of limescale over the usage cycle. This is indicatively dependent on the appliance maintenance employed and the limescale-prevention techniques selected over the usage phase. In cases where there is increased energy consumption due to deterioration, this will marginally shorten the amortisation period.

Figure 3.3 gives a sample calculation to compare the 'B'-rated washing machine with a ten-year use and an annual usage of 392 cycles for both the first and secondary user to an equivalent 'A'-rated machine. Two cases are shown:

1 Streamlined CED analysis not considering energy policy;

2 Streamlined CED analysis incorporating changes in electricity supply.

The decision point is centred on 2011, for determining the environmental amortisation (payback period) for replacing the 'B'-rated appliance with an 'A'-rated appliance, which is the energy grade of the cheapest available washing machine on the market. Initially, the analysis is conducted not considering Ireland's projected changes within the national energy policy (grey scale). The grey line illustrates the projected energy usage of the 'B'-rated washing from the year of manufacture (2000) up to 2020. The dashed grey line illustrates the projected energy usage of an 'A'-rated washing machine from the year of manufacture (2011), including the previous energy consumption of the 'B'-rated washing machine to that point and continued up to 2020 just incorporating the energy consumption of the 'A'-rated washing machine. The crossover point is the amortisation period. This previous analysis is then compared against an analysis incorporating the projected changes in electricity supply, based on SEAI data (black scale).

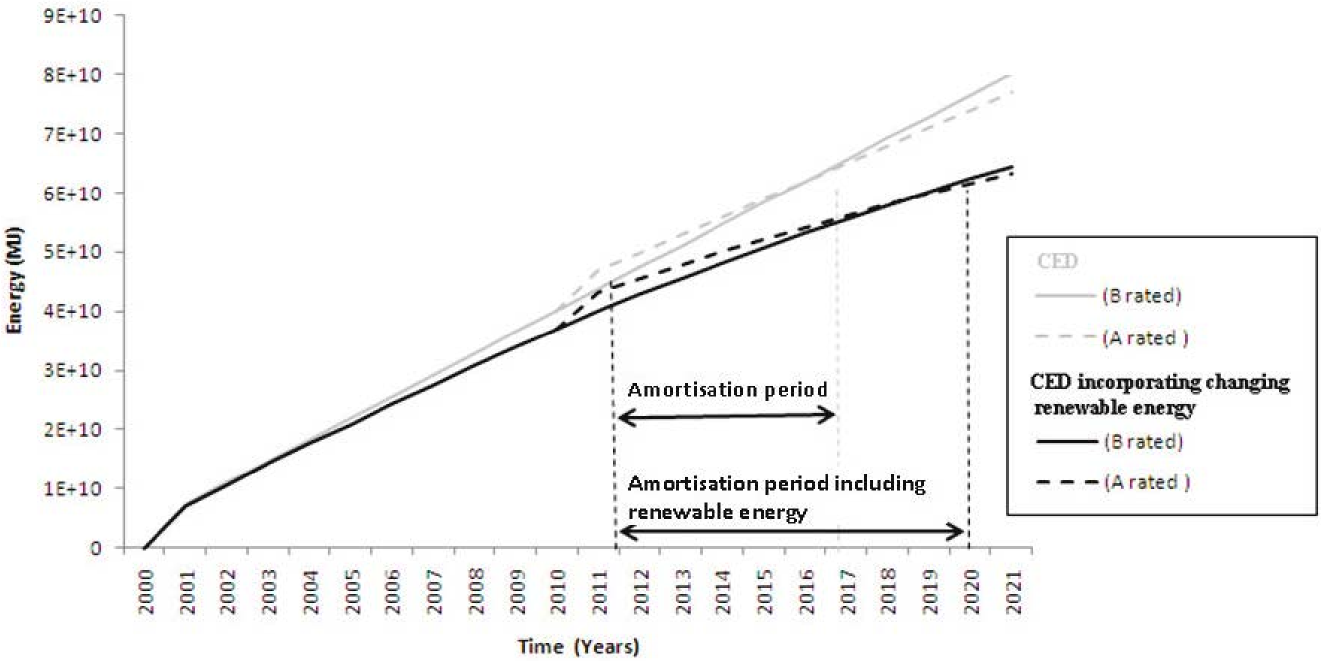

Figure 3.3. Streamlined cumulative energy demand (CED) analysis of a 'B'-rated washing machine compared to the purchase of an 'A'-rated washing machine.

From Fig. 3.3 it can be seen that the impact of washing machines is significantly altered over their lifetime when the changes in use-phase energy are considered. The streamlined CED model not incorporating the energy policy registers a larger impact over the life cycle, accelerating and possibly misrepresenting the amortisation for determining whether it is better to purchase a new 'A' rate machine compared to the continuation of use of a 'B'-rated machine. The streamlined CED model incorporating the changing renewable energy policy significantly increases the environmental payback time for purchasing a new machine. For this scenario the amortisation period is shifted from six years to nine years where the environmental gains for purchasing a new 'A'-rated machine compared to reusing a 'B' machine are only seen after nine years.

3.3.3.2 Results

The results for the environmental and economic analysis for all 27 scenarios are shown in Tables 3.1 and 3.2, with the amortisation period represented in years. The acquisition time and the usage phase intensity of the first user are combined with the usage phase intensity of the secondary user, to determine the amortisation period of a new 'A'-rated washing machines compared against a lower energy-rated washing machines.

Table 3.1. Environmental amortisation represented in years (HI: high intensity [392 annual cycles], MI: medium intensity (220 annual cycles), LI: low intensity [170 annual cycle]).

				Energy ratings					
First usage		**Second usage**		**A(<0.19 kWh)**	**B(<0.23 kWh)**	**C(<0.27 kWh)**	**D(<0.31 kWh)**	**E(<0.35 kWh)**	**F(<0.39 kWh)**
14-year ownership	Intensity		Intensity						
	HI	A(<0.19 kWh)	HI	Void	8	3	2	1	0
		A(<0.19 kWh)	MI	Void	>11	7	4	3	2
		A(<0.19 kWh)	LI	Void	>11	9	5	4	3
	MI	A(<0.19 kWh)	HI	Void	8	3	2	1	1
		A(<0.19 kWh)	MI	Void	>11	7	4	3	2
		A(<0.19 kWh)	LI	Void	>11	9	5	4	3
	LI	A(<0.19 kWh)	HI	Void	8	3	2	1	1
		A(<0.19 kWh)	MI	Void	>11	7	4	3	2
		A(<0.19 kWh)	LI	Void	>11	9	3	4	3
10-year ownership									
	HI	A(<0.19 kWh)	HI	Void	8	3	2	1	0
		A(<0.19 kWh)	MI	Void	>11	7	4	3	2
		A(<0.19 kWh)	LI	Void	>11	9	5	4	3
	MI	A(<0.19 kWh)	HI	Void	8	3	2	1	1
		A(<0.19 kWh)	MI	Void	10	4	3	3	2
		A(<0.19 kWh)	LI	Void	>11	8	5	4	3
	LI	A(<0.19 kWh)	HI	Void	8	3	2	1	1
		A(<0.19 kWh)	MI	Void	>11	7	4	3	2
		A(<0.19 kWh)	LI	Void	>11	9	5	4	3
6-year ownership									
	HI	A(<0.19 kWh)	HI	Void	8	3	2	1	0
		A(<0.19 kWh)	MI	Void	>11	7	4	3	2
		A(<0.19 kWh)	LI	Void	>11	9	5	4	3
	MI	A(<0.19 kWh)	HI	Void	8	3	2	1	1
		A(<0.19 kWh)	MI	Void	10	4	3	3	2
		A(<0.19 kWh)	LI	Void	>11	9	5	4	3
	LI	A(<0.19 kWh)	HI	Void	8	3	2	1	0
		A(<0.19 kWh)	MI	Void	>11	7	4	3	2
		A(<0.19 kWh)	LI	Void	>11	9	5	4	3

Table 3.2. Economic amortisation represented in years (HI: high intensity [392 annual cycles], MI: medium intensity [220 annual cycles], LI: low Intensity [170 annual cycle]).

				Energy ratings					
First usage		**Second usage**		**A(<0.19 kWh)**	**B(<0.23 kWh)**	**C(<0.27 kWh)**	**D(<0.31 kWh)**	**E(<0.35 kWh)**	**F(<0.39 kWh)**
14-year ownership	Intensity		Intensity						
	HI	A(<0.19 kWh)	HI	Void	>11	6	4	3	2
		A(<0.19 kWh)	MI	Void	>11	>11	7	5	4
		A(<0.19 kWh)	LI	Void	>11	>11	9	7	5
	MI	A(<0.19 kWh)	HI	Void	>11	6	4	3	2
		A(<0.19 kWh)	MI	Void	>11	>11	7	5	4
		A(<0.19 kWh)	LI	Void	>11	>11	9	7	5
	LI	A(<0.19 kWh)	HI	Void	>11	6	4	3	2
		A(<0.19 kWh)	MI	Void	>11	>11	7	5	4
		A(<0.19 kWh)	LI	Void	>11	>11	9	7	5
10-year ownership									
	HI	A(<0.19 kWh)	HI	Void	>11	6	4	3	2
		A(<0.19 kWh)	MI	Void	>11	>11	7	5	4
		A(<0.19 kWh)	LI	Void	>11	>11	9	7	5
	MI	A(<0.19 kWh)	HI	Void	>11	6	4	3	2
		A(<0.19 kWh)	MI	Void	>11	>11	7	5	4
		A(<0.19 kWh)	LI	Void	>11	>11	9	7	5
	LI	A(<0.19 kWh)	HI	Void	>11	6	4	3	2
		A(<0.19 kWh)	MI	Void	>11	>11	7	5	4
		A(<0.19 kWh)	LI	Void	>11	>11	9	7	5
6-year ownership									
	HI	A(<0.19 kWh)	HI	Void	>11	6	4	3	2
		A(<0.19 kWh)	MI	Void	>11	>11	7	5	4
		A(<0.19 kWh)	LI	Void	>11	>11	9	7	5
	MI	A(<0.19 kWh)	HI	Void	>11	6	4	3	2
		A(<0.19 kWh)	MI	Void	>11	>11	7	5	4
		A(<0.19 kWh)	LI	Void	>11	>11	9	7	5
	LI	A(<0.19 kWh)	HI	Void	>11	6	4	3	2
		A(<0.19 kWh)	MI	Void	>11	>11	7	5	4
		A(<0.19 kWh)	LI	Void	>11	>11	9	7	5

For the 27 different user profile scenarios, in the case of 'A'- and 'B'-rated machines, reuse is deemed the preferred EOL strategy with a minimum of eight years' environmental and economic amortisation, independent of the secondary consumer's usage profile. This is represented as the unshaded section in the tables. For 'C'-rated refurbished washing machines, in certain scenarios, the environmental amortisation range between seven and nine years for medium and low intensity users with the economic amortisation for both intensities greater than eleven years for all scenarios. For high-intensity usage, the environmental benefit is half that of the economic benefit with a three-year environmental amortisation compared to six years'

economic amortisation. For both 'D'- and 'E'-rated refurbished washing machines, there are no scenarios with a minimum environmental amortisation period of six years, independent of the secondary consumers' usage profile. In certain scenario (MI and LI) there are potential economic gains, but these are mitigated by the shortened environmental benefit.

Comparable 'A'-rated energy using profiles for the cheapest available dishwashers and fridge freezers indicate similar environmental and economic amortisation periods. This provides considerable certainty that a recommendation for reuse of all 'A'- and 'B'-rated appliances will be sustainable. For 'C'-rated refurbished washing machines, in certain scenarios, the environmental and economic amortisation period is greater than the prescribed six years. This is dependent on the secondary consumer having a low-intensity usage, indicating that 'C'-rated machines should only be reused for single-occupancy dwellings. For both 'D'- and 'E'-rated refurbished washing machines, there are no scenarios with a minimum environmental and economic amortisation period of six years, independent of the secondary consumers' usage profile. Due to the relatively lower energy ratings of the cheapest available tumble driers ('C' rated), it is recommended that only tumble driers equal or above the energy label of the cheapest available machine would be environmentally and economically suitable for reuse. Apart from tumble driers a rough guideline for sustainable reuse would recommend the reuse of any appliance one energy grade lower than the cheapest available appliance on the market.

3.4 Social Assessment

When considering the social implications of white-goods reuse, the criteria indicating improvement in the social domain include metrics such as levels of employment, improved standard of living and reduced social exclusion, to name a few (UK Department of Health Social Services and Public Safety, 2001). Job creation resulting from reuse industries and long-term employment creation for those currently unemployed merits investigation. The following sections provide further discussion on these social indicators. A comparison is also made with successful reuse models from other operational EEE-refurbishment categories in Ireland.

3.4.1 Increasing quality of life by providing refurbished WEEE to low-income households

The global recession has significantly impacted on the standard of living worldwide. The current economic crisis has proved severely detrimental to the financial well-being of many people and this is particularly evident in the area of household finances whereby the numbers of defaults are becoming increasingly high (International Monetary Fund, 2012). Taking Ireland as an example, in 2009 almost 25% of households were in arrears on one or more of the following items: utility bills, rent or mortgage payments, hire purchase agreements or other loans/bills (CSO, 2009). This compares with a rate of approximately 10% in 2008. Enforced deprivation, which refers to the inability to afford basic specific goods or services has also increased significantly over a three-year period from 13.8% in 2008 to 17% in 2009 to over 22.5% in 2010 (CSO, 2010). This deprivation index takes into account access to resources other than income which are generally taken to be the norm in a particular society. In Ireland, 11 basic items are used to construct the deprivation index:

- Without heating at some stage in the last year;
- Unable to afford a morning, afternoon or evening out in the last fortnight;
- Unable to afford two pairs of strong shoes;
- Unable to afford a roast once a week;
- Unable to afford a meal with meat, chicken or fish every second day;
- Unable to afford new (not second-hand) clothes;
- Unable to afford a warm waterproof coat;
- Unable to afford to keep the home adequately warm;
- Unable to afford to replace any worn out furniture;
- Unable to afford to have family or friends for a drink or meal once a month;
- Unable to afford to buy presents for family or friends at least once a year.

Increased levels of deprivation in Ireland in turn affect people's ability to purchase basic necessities such as white goods. In 2009, 0.6% of individuals were unable to afford a washing machine, 6.5% of individuals were unable to afford a clothes dryer and 8.6% were unable

to afford a dishwasher. These figures indicate that consumers within the enforced deprivation bracket prioritise the purchase of washing machines compared to clothes driers and dishwashers, but still struggle to meet the purchasing requirements. In comparison to 2010, 18.5% of individuals were unable to afford to replace any worn-out furniture (CSO, 2010), which provides an indication for other commodities including white goods. Providing low-cost white goods could potentially lessen the strain on low-income households. An important consideration is to ensure that the TCO is reduced by providing refurbished appliances. Short-term economic gains due to price reduction could be quickly negated by the long-term costs due to higher energy consumption.

3.4.2 Job-creation potential of reuse and recycling

A report published by Cascadia Consulting Group found that the field of 'recycling and economic development' had a lack of quantitative data on employment (Cascadia, 2009). However, what little data is available indicates that reuse is more labour intensive than recycling and thus creates more employment for an equivalent amount of material processed. Looking more generally at reuse and recycling, the US EPA estimated that 10,000 tonnes of materials create 1 job at the incinerator, 6 jobs at landfills, 36 jobs at recycling centres, and 28–296 jobs for the reuse industry (US EPA, 2002). It concluded that recycling and reuse represent a significant facet of the US economy that contributes to job creation and economic development (UNIDO Microsoft, 2009).

Employment figures provided by Bryson, the Northern Irish white-good refurbishment enterprise (described in more detail in Section 3.5.1), showed that from April 2010 to March 2011 14 full-time staff and 2 trainees (subsidised by Northern Ireland's Department of Education and Learning) were employed in processing 6,395 machines of which 4,605 were reused. This roughly correlates to 1 job per 280 machines reused. Data sourced from Bryson is auditable and is reported to an authoritative compliance scheme (the European Recycling Platform [ERP]) on bi-monthly basis.

As part of this study, the employment statistics for one Irish organisation that conducts IT refurbishment as well as some pre-treatment for recycling has also generated some valuable data. Rehab Recycle, a charitable organisation conducting ICT refurbishment and WEEE recycling in Ireland found that the job creation differential between B2B PC reuse and e-waste processing was a factor of ten times more employment generated per tonne than the recycling of an equivalent amount of e-waste in their facility from June 2009 to May 2010. These figures are used only to provide an indication of the potential employment opportunities within the EEE-refurbishment industry.

3.5 Economic Sustainability

Any environmental and social dividends from reuse can only be realised in the context of an economically sustainable system. This would include such factors as a secure supply of suitable equipment, a competitive cost base and sufficient revenues from sales and other sources in order for the business to survive. In an attempt to examine whether a white-goods reuse programme could possibly operate in a competitive manner with new appliances, this study has examined examples of comparable businesses operating in the EU as well as interpreting statistics on consumer demand and making comparisons with a successful B2B IT refurbishment operation in Ireland.

3.5.1 Reuse of White Goods in the EU

Reuse of white goods is common practice in many EU countries where it is predominately carried out by social enterprises. Bryson in Northern Ireland and De Kringwinkel in Belgium are examples of social enterprises conducting white-goods refurbishment on different scales. Northern Ireland and Belgium correlate to Ireland due to similar population, close correlation in demand for second-hand electronic appliances (Eurobarometer, 2011) and comparable WEEE recovery rates (Eurostat, 2012). As part of this study both of these organisations were visited and qualitative interviews were conducted with two senior managers. The semi-structured interviews focused on operational logistics, collection and refurbishment techniques, workforce skill set and the specific success factors and constraints experienced within the industry.

Bryson employs a skilled workforce for the technical aspects of refurbishment operations and an unskilled workforce for collection and delivery services. De Kringwinkel employs a largely unskilled workforce, providing employment and training opportunities for

those distanced from the labour market. Within the UK and Belgium, reuse of WEEE counts towards recycling targets as part of the WEEE Directive (2002/96/EC), which both organisations have identified as a contributing factor to their success.

One of the key success factors for Bryson is the means by which it sources and segregates white goods with potential for reuse. Bryson locates white goods predominantly from CA sites but also from retailers within Belfast in cooperation with the ERP compliance scheme. Bryson has developed a highly successful three-tier cherry-picking system, for white goods evaluation and refurbishment. These steps include:

1 Segregating of white goods from other WEEE at the CA sites by CA staff;
2 Inspection of white goods on site, and the recovery of any machines that have the possible potential for reuse;
3 Technical assessment of the machines at the Bryson facility to determine whether refurbishment is technically feasible.

Bryson works closely with the CA sites from which it has arranged collections. On-site staff are trained and informed of the storage requirement for white goods with possible potential for reuse. From April 2010 to March 2011, Bryson processed 6,395 machines of which 4,605 (3,333 CA, 1,272 retailer) appliances were refurbished. In 2010 the UK achieved 6.8% reuse for LHA and 2% for SHA.

One of the key success factors for De Kringwinkel is also the collection system. De Kringwinkel has 33 reuse centres, 100 outlets and 8 WEEE refurbishment centres. WEEE is collected from three sources: household collections (~70%), reuse centres (~15%) and municipalities (~15%). All WEEE collected is processed at the 8 refurbishment centres and resold through its outlets. In 2005 a reuse rate of 11% for refrigerators and 20% for large household appliances was achieved from its input sources. In 2010 Belgium achieved 5% reuse of all LHA and 22% for SHA. De Kringwinkel has attributed the following three aspects to its commercial success:

- The branding system for the shops, 'De Kringwinkel' is a recognised brand throughout Belgium. It aims to distinguish these shops by guaranteeing them a common logo, organisation and presentation;
- An initiative called 'Revisie', a quality label for electronic appliances: 73% of the WEEE-reuse centres that have been accredited use the 'Revisie' label, whereby the aim is to offer safe and reliable second-hand electric appliances;
- The incorporation of the European Foundation for Quality (EFQM) model is designed for helping organisations in their drive towards being more competitive. Regardless of sector, size, structure or maturity, organisations need to establish appropriate management systems in order to be successful; 55% of the reuse network has currently employed this model.

One of the major constraints experienced by both organisations is the unpredictability in supply of the right mix of appliances. In order to be cost effective, there is a minimum amount of throughput necessary to maintain viability. Access to sufficient volumes of used equipment at good quality is imperative for the survival of the industries. This is supported by Kissling (2011) in a worldwide study of refurbishers across many product groups.

Clearly, these examples show that a successful white-goods refurbishment sector can operate even in countries with similar characteristics to Ireland. However, the criticality of a sustainable supply of material is paramount and the difference in interpretation of the WEEE Directive to include reuse towards WEEE targets in the UK and Belgium and its non-inclusion in Irish legislation may be a very significant factor.

3.5.2 Successful Reuse Models in Ireland

When contemplating white-goods reuse, indicators are necessary to show that is can be a viable and sustainable business. Successful reuse models for ICT already exist in Ireland, for example Rehab Recycle. Rehab Recycle is an accredited Microsoft's Authorised Refurbisher (MAR),[2] providing high-quality low-cost PCs and software to schools and charities. Since the initiative was started in 2006, Rehab has placed 27,000 pieces of refurbished IT equipment back in use.

2 The MAR programme is a commercial offering for large refurbishers that provides a reduced royalty licence for refurbished PCs with a previous Windows operating system software licence.

The organisation conducts both refurbishment and recycling of WEEE and from June 2009 to May 2010 analysis has shown that reuse of B2B IT generated 15 times more revenue than general e-waste pre-processing per tonne. This figure was calculated using Rehab Recycle financial statements in Tallaght from June 2009 to May 2010, focusing on the profit and loss analysis of the reuse and recycling practices.

3.5.3 Consumer Demand

A survey conducted by Flash Eurobarometer gauged EU citizens' perceptions, attitudes and practices concerning resource efficiency, waste management and recycling (Eurobarometer, 2011). A sample size of one thousand sources aged 15 and older were used for each country within the EU 27. European Union citizens' willingness to buy second-hand products and reasons for not buying second-hand products were two categories within the survey. Consumer's willingness to buy furniture, electronic equipment and textiles were compared and the reasons negative respondents gave for not buying second-hand products. On average 56%, 45% and 36% of EU citizens showed a willingness to buy second-hand furniture, electronic equipment and textiles. The socio-demographic considerations demonstrated the positive responses through reuse from younger respondents and full-time students compared with those over 54 years, respondents with low education and who were unemployed showed the least likelihood to say they would buy second-hand goods. Gender purchasing differences were also considered. In the case of purchasing second-hand electronics, men were more likely to do so than women (49% vs. 41%).

The highest ranking reasons given by respondents for not being willing to buy second-hand products was quality/usability of the product and safety concerns. 'Less appealing looking' and 'Afraid of what others might think' rated lower on the scale.

In relation to Ireland, Irish people's willingness to buy second-hand electronics is 42% compared to 28% for second-hand textiles and 57% for second-hand furniture. Three-quarters of respondents in Ireland said that health and safety concerns prevented them from buying second-hand products. Looking at markets close to Ireland, results have shown that the acceptance of the Irish population and their willingness to buy second-hand electronics (42%) is quite close to the UK (46%) and is significantly higher than Belgium (31%), both countries with established reuse activity. This highlights the potential for a viable refurbishment market in Ireland, where standards are in place to ensure quality and safety.

3.6 Discussion

This analysis has demonstrated that WEEE reuse adopted as part of national policy can potentially benefit all levels of society in a sustainable manner. From an environmental perspective, the quantitative model outlined in Section 3.3 demonstrated the importance of considering user-consumption profiles and the changing energy generation portfolio in determining the best EOL strategy, whether it should be reuse or recycling. The results show that, for all 'B'-rated washing machines, there is both an environmental and economic incentive to purchase a refurbished washing machine, regardless of the secondary consumer usage profile. However, for 'C'-rated machines, this is not the case. For an amortisation period of six years (or greater in this case), the environmental and economic benefits are seen only for low-intensity users. For 'D'- and 'E'-rated refurbished washing machines, there are no environmental and economic benefits for purchasing the refurbished machine. Given the very high penetration rates of 'A'-rated machines in recent years, re-using this stock of machines is an environmentally preferable option. Even during the period when the older stock of machines is being returned, these results demonstrate that it should not delay a reuse strategy.

The social and economic sustainability has also been considered. Reuse of white goods, if conducted through social enterprises, will create more employment than an equivalent amount of recycling for those most vulnerable to unemployment – for example, youths, disabled people and unskilled workers. It is critical that social safety nets effectively reach these groups and support them in their transition to work, encourage attainment of higher wages – and work to avoid long-term detachment from the labour market. The social enterprises examined include Rehab, De Kingwinkel and Bryson and each has demonstrated its ability to engage with reuse in an economically sustainable fashion. Based on this, a special role for the social

economy in reuse policies should be considered in Ireland. Furthermore, the potential to increase prosperity and bridge the social divide, by providing low-cost high-quality white goods to low-income families is a significant factor, specifically under Ireland's current economic crisis and the increased potential of households to become at risk of poverty.

The economic case for white goods reuse is strong, but economies of scale is a factor, with constant supply of the right material a necessity to insure an adequate level of through-put for maintaining viability. This is the most significant barrier identified and current waste-management practices must be examined in order to prevent them from frustrating reuse activities.

4 Best Practices in Reuse

4.1 Barriers and Success factors for Reuse

In a study conducted by StEP (StEP, 2011b), with support from the UL, a list of generic success factors and barriers for EEE reuse operating models were identified and ranked with regards to their importance. These were based on 28 case-study interviews conducted on a diverse set of reuse organisations that live up to good reuse practices and belong to the leading actors in their respective segments. Four reuse models were identified as part of the research: two for-profit models: (i) the Networking Equipment Recovery model and (ii) the IT Asset Management model and two not-for-profit models: (iii) the Close the Digital Divide model (iv) the Social Enterprise model (Kissling et al., 2012a). Based on a comparison of the specific success factors and barriers, a list of generic success factors and barriers relevant for each reuse operation was identified (Kissling et al., 2012b). Figure 4.1 illustrates the generic barriers for conducting reuse, identified by the 28 case study interviews in order of importance. Fifteen factors were identified and weighted in order of perceived importance (Rank 1 has a weighting of 15, Rank 2 a weighting of 14, Rank 3 a weighting of 13, etc.).

The fifteen factors identified can be categorised into four groups in order of priority:

Access to equipment: The survey results indicate that current legal framework conditions do not optimally support reuse organisations to access sufficient volumes of EEE for preparation for reuse. The lack of legislations that incentivise and enforce reuse is seen as the most significant barrier (Rank 1). Survey results demonstrate that the sourcing of sufficient volumes of used good-quality equipment is a key challenge for every organisation that engages in reuse of EEE (Rank 2). Except for Ranks 3 and 4, the first seven barriers in the priority ranking can all be directly related to accessing EEE with reuse potential.

Informal and illegal reuse practices: Bad reuse practices, that is, ‘sham reuse’, is considered as a significant barrier for reuse of EEE, creating a negative impact on organisations conducting their business to known best practice (Rank 3). Informal actors also distort competition in the reuse sector, which is seen as one of the most impactful barriers for compliant reuse organisations (Rank 4); informal actors save on costs, which accrue from implementation of effective social and environmental regulations, and compete with

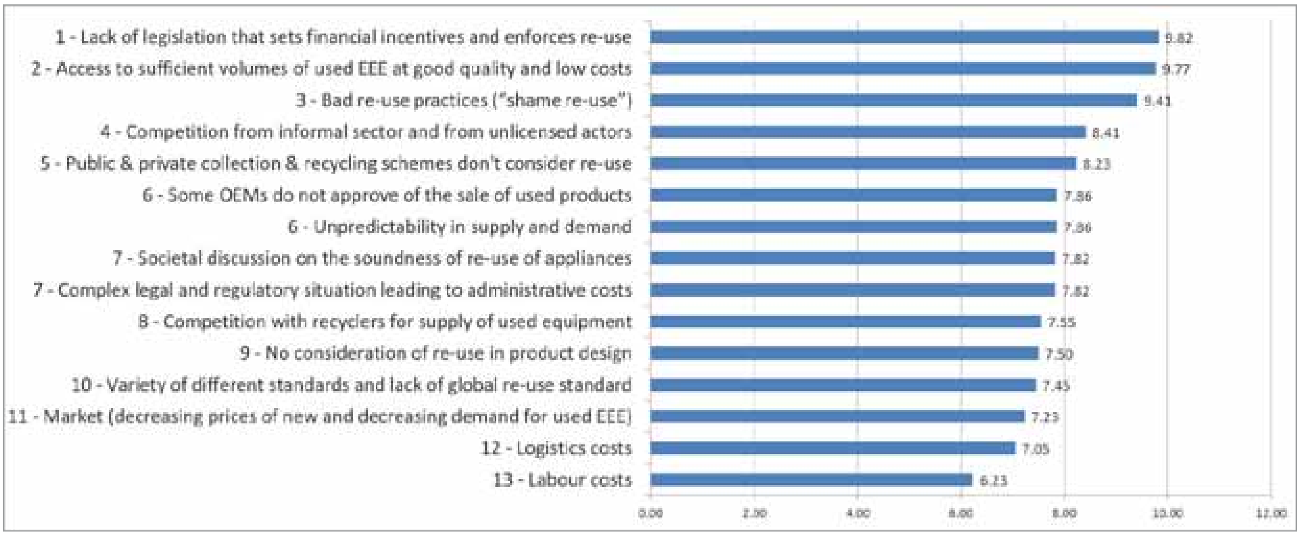

Figure 4.1. Generic barriers in order of importance (Kissling, 2011).

compliant reuse organisations for both access to used equipment and redistribution of EEE prepared for reuse.

Regulations, standards and product design: Variance and complexity in regulations leads to increased administrative costs (Rank 7), such as the implementation of the WEEE Directive. The existence of a variety of different standards (ISO90001 [certified repair centres for ICT and imaging inspection systems], MAR, PAS141, WEEELabex) and the lack of a globally recognised reuse standard make it difficult to refer to common definitions of good reuse practices and to enhance transparency and quality control in the reuse sector. However, this barrier was not considered a pressing priority in the survey (Rank 10). Also, the incomplete consideration of reuse in product design is not ranked among the most important barriers for reuse (Rank 9), but none the less is still considered a barrier.

Cost: Market prices, logistics costs and labour costs are ranked 11–13. Competition with recyclers is also considered a factor (Rank 8). Cost is a fundamental aspect to the viability of a EEE reuse enterprise, but the other factors previously discussed are reported as having more bearing before cost can be considered.

Figure 4.2 illustrates the generic success factors for conducting EEE reuse identified by the 28 case-study interviews in order of importance. Thirteen factors were identified and weighted in order of perceived importance (Rank 1 has a weighting of 13, Rank 2 a weighting of 12, Rank 3 a weighting of 11, etc.).

The thirteen factors identified can be categorised into four groups in order of priority:

Product and process quality: The quality and reliability of products distributed for reuse is ranked by far as the most important success factor (Rank 1) followed by quality control during preparation for reuse (Rank 2). Access to high-quality used equipment (high specification corporate ICT system refreshes) (Rank 3) and the ability to provide secure destruction of user data (Rank 4) rank highly. Strict control of product and process quality and reliable guarantee of data and brand security enable reuse organisations to differentiate themselves from the informal sector and non-compliant actors, which are perceived as critical barriers. Moreover, proven quality of preparation for reuse processes and products offered for reuse serves as a means to dissolve the negative public perception of the reuse sector (StEP, 2011b).

Stakeholder relationship: Stakeholder relationship management was ranked as relatively important for the success of reuse operations (Rank 5). The ability to offer a one-stop-solution for EOL WEEE management, including collection, preparation for reuse and recycling is considered less important (Rank 8), indicating it is preferable to specialise within a certain area.

Documentation and reporting: The ability to secure a proper recycling solution for the products that have been distributed for reuse (Rank 7) is especially important, when products are distributed in countries where recycling infrastructure is not developed yet to satisfactory standards.

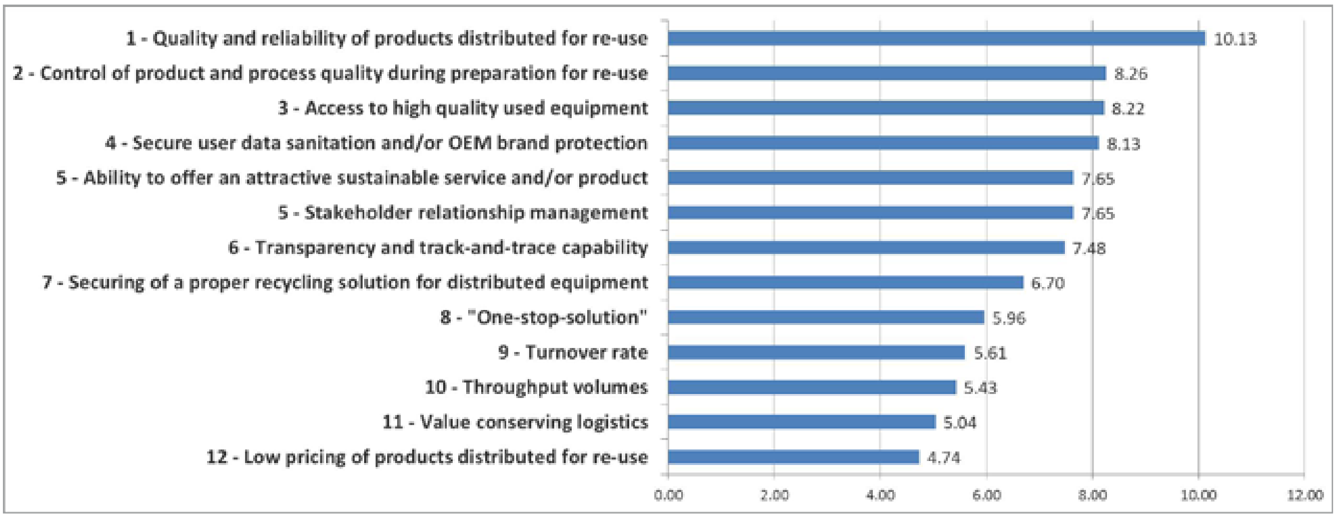

Figure 4.2. Generic success factors in order of importance (Kissling, 2011).

Costs and revenues: Turnover (Rank 9), throughput (Rank 10), value conserving logistics (Rank 11) and low price (ranked 12) are ranked lower, as higher-ranked factors have to be achieved before success can be attained in terms of costs and revenues.

4.2 Reuse Standard

From the barriers and success factors, regulation in terms of legislation for access to WEEE and standards in terms of quality and safety weigh heavily. Reuse is seen as an activity that must be regulated in order to develop in a sustainable fashion. The recast of the WEEE Directive provides the foundation for regulation and access to WEEE for reuse. However, it is essential that 'sham reuse' is eradicated. This can only be done by setting standards that reuse organisations must achieve before they can become part of the reuse system. Only organisations operating to sufficiently high standards should be considered eligible to undertake refurbishment and reuse activities and be given access to WEEE. A recently published standard (31 March 2011) for reuse has being developed by the British Standards Institution (BSI-PAS141), PAS 141: Reuse of Used and Waste Electrical and Electronic Equipment (UEEE and WEEE) Process management Specification (BSI-PAS141, 2011).

4.2.1 PAS 141

The recently published standard for reuse developed by British Standards Institution, PAS 141, provides a framework for those involved in reuse to help minimise the impact of EEE on the environment and to assure consumers that refurbished products are fit for purpose both in terms of safety and function. PAS 141 was developed from the WEEE Advisory Body's specification for the reuse of WEEE and UEEE. The PAS 141 standard enabled a specification to be rapidly developed in order to fulfil an immediate need in industry. It covers the preparation for reuse for equipment and components. It does not cover the recycling process, although it does include requirements for assigning WEEE and used electrical and electronic equipment (UEEE) for recycling. Processes used by organisations involved in the reuse of WEEE and UEEE need to be designed to identify and minimise the impact they have upon the natural environment. The aim of PAS 141 is to encourage the reuse of WEEE.

PAS 141 is broken into five sections: (i) handling, (ii) preparation for reuse, (iii) reuse, (iv) recycling and (v) operational management. Under handling the segregation, storage, protection and tracking of the material with potential for reuse are outlined. Equipment and components shall be segregated and stored in accordance within a documented segregation and storage process. Each piece of equipment processed with potential for reuse shall be uniquely identified and tracked throughout the reuse process with records maintained. When preparing for reuse a number of provisions are included:

- *Visual inspection:* A documented visual inspection is required;
- *Safety:* Insuring safety throughout, insuring compliance with the Low Voltage Directive (LVD) (2006/95/EC) the General Product Safety Directive (GPSD) (92/59/EEC) and other sector safety Directives;
- *Function:* The refurbished units must meet the ordinary use for which the item was originally placed on the market;
- *Data eradication and licensing*: For ICT, data eradication and licensed software are vital elements;
- *Disassembly*: Disassembly conducted in accordance with a documented disassembly process, where repair is recommended as a waste-preventative measure;
- *Original equipment manufacturer warranty*: Original equipment manufacturer (OEM) warranty is invalidated when work is conducted by a unauthorised OEM person, when parts replacement aren't OEM approved, where serial numbers are altered or damaged or when unapproved ancillary equipment causes damage;
- *Parts replacement:* The reuse organisation shall ensure that the use of replacement components does not impair product safety;
- *Retesting:* Retesting for safety after any changes to parts or software;

- *Cleaning:* For cleaning purposes, all user identification has to be removed whilst ensuring manufacturers brand and labels remain;
- *Classification:* Where equipment has been prepared and verified for reuse in accordance with this PAS 141 compliance, it shall be classified as reuse electrical and electronic equipment (REEE); otherwise, it remains WEEE. Any WEEE collected and not fit for reuse must be documented and assigned for recycling.

Reuse organisations are obliged to maintain records of the organisation(s) to which they transfer their waste. Operational regulations for health and safety, permits, licences and other legal requirements needed to operate must be adhered to. If previous requirements are met, a reuse label is issuable and the item can be sold as REEE. Documentation of the sale must be recorded, including product information for reporting purposes. A minimum warranty of 28 days is also mandated. Overall, PAS 141 provides a framework for those involved in reuse to help minimise the impact of EEE on the environment and to assure consumers that any REEE is fit for purpose, both in terms of safety and function.

4.3 Discussion

International best practices being conducted for reuse identified generic barriers and success factors experienced throughout their development. Access to the right equipment is the key issue – acting either as a barrier or contributing to their success where the right condition is in place. Standards within the sector are also vital for maintaining high quality in terms of safety and functionality. PAS 141 has been identified as a benchmark standard, which should be a minimum requirement for all enterprises conducting refurbishment. Developing and introducing standards and labels should instil confidence in consumer perceptions towards certified reuse products. A UK-based waste and resource action programme (WRAP), set up in 2000 to help recycling take off in the UK, developed a set of protocols based on industry experience on how to implement PAS 141 for a range of product categories, including digital cameras, fridges and freezers, ICT equipment, mobile phone equipment, televisions, vacuum cleaners and washing machines (WRAP, 2012). These protocols highlight the tests and procedures that should be conducted as a minimum to form a baseline for electrical product assessment and repair for reuse and can be used as a guideline to product assessment and testing.

5 Conducting Reuse: Business to Business and Business to Consumer

Any departure into reuse of B2C equipment will involve a significant amount of learning in order to undertake it in a sustainable fashion. This learning can come in numerous forms, including experience gained in B2B reuse, fact-finding visits to operations in other countries and also by trials or 'learning by doing'. External experiences provide valuable information about performing reuse from logistics, access to equipment, right up to the operational organisation.

5.1 Business to Business Reuse

Business to business reuse is primarily focused on ICT refurbishment with fully operational and established systems in place across Europe, including Ireland. The not-for-profit organisation, Rehab Recycle, is Ireland's largest ICT refurbisher dedicated to delivering high-quality, person-centred services that enable people to enhance the quality of their live. Rehab is an accredited MAR, the programme, as noted above, which was developed for large-scale refurbishers that average a minimum volume of 5,000 refurbished PCs monthly, enabling it to supply refurbished computers and servers preinstalled with genuine Microsoft software to businesses, consumers, and non-profit organisations. Since Rehab joined the programme in 2006, 27,000 refurbished ICT units have been placed back in use, and 138 people have been employed, 85 of whom have a disability. Rehab is PAS 141 accredited and was recently awarded (2012) a Green Corporate Citizen award, given to companies, organisations and individuals for their efforts in tackling climate change through sustainable initiatives. The case study for B2B ICT focuses on Rehab's operations to learn from their market experiences, documenting procurement policies, asset-assessment guidelines, operational flow and after-sales warranty and liability issues.

For B2C, the white-goods refurbishment market was analysed. Visits conducted to Bryson (Northern Ireland) and De Kringwinkel (Belgium) explored their refurbishment processes, focusing on access to material, sources of WEEE which showed significant potential for reuse, logistics involved, refurbishment set-up requirements and demand for refurbishment equipment (Sections 3.3 and 3.4 above). Combined with these experiences and Rehab B2B expertise an operational flow model was developed, accounting for the necessary requirements within Ireland's waste-management system. Re-evaluate partners CCRI and Rehab conducted B2C white goods trials to give an indication of where the reuse potential exists in Ireland and to enable both organisations to get a feel for the environment and to assess the build-up capacity, throughput and resources required to maintain viability. Similar to Rehab, CCRI is a social enterprise, providing employment for long-term unemployed people. Set-up to assist the South Dublin County Council (SDCC) tackle the problem of illegal dumping of old household appliances, CCRI operates a recycling and kerbside collection facility currently employing 10 people. To date, over 250 tonnes of WEEE have been collected and processed for recycling from 28,000 households. Currently CCRI and Rehab both conduct processing of WEEE for recycling and are examining the opportunities of expanding into the refurbishment of white goods.

5.1.1 B2B Reuse (RehabRecycle)

Rehab's existing operations cater for the EOL phase of business ICT. This phase commences when the B2B user conducts a system refresh for a variety of reasons, ranging from product malfunction through to hardware and software upgrade requirements for technical requirement. Rehab has developed an innovative procurement campaign called 'Promise It' to Rehab (RehabRecycle, 2012). 'Promise It' is about encouraging companies to pass on their out-of-date and unused computers and other electrical equipment as part of their corporate social responsibility (CSR) to Rehab, extending its life span and providing it to those who need it most. Customers include DELL, Allied Irish Bank, Microsoft, 02, Health Service Executive, Eircom, Meteor, Fáilte Ireland and An Post.

5.1.2 Rehab ICT operating model

Rehabs ICT returns predominantly consist of laptops, desktops, servers and LCD/CRT screens. An initial

visual and processing assessment is conducted on all equipment collected to ascertain whether refurbishment is advantageous based on cost and market demand. The processing power of the central processing unit (CPU) generally determines whether a market exists for the machine in question. Current in-house standards developed by Rehab only allow machines with Pentium 4 processors or higher to be refurbished. The ICT refurbishment requires a high level of sophistication and automation as shown Fig. 5.1. Complying with guidelines set out in PAS 141 Rehab Recycle Tallaght is capable of refurbishing 200 pieces of IT equipment per hour.

Reverse logistics: Rehab employs its own team for logistics, providing data destruction on site if necessary. An asset recovery waste (ARW) management system at point of source ensures minimal handling damage.

Asset monitoring: Rehab employs an ARW to enable assets to be monitored throughout the refurbishment process. Each ICT item in the batch is tagged with a barcode. The barcode itself specifies a job number and an item number. The job number is linked to the client's account number on the ARW system, enabling an audit trail to be conducted for each appliance throughout the refurbishment process. Once individual products are barcode tagged the following information is manually uploaded into the ARW database:

(a) ARW tag (barcode);

(b) Hardware type;

(c) Manufacturer;

(d) Model number;

(e) Grade type (visual A, B, C, D);

(f) Note (anything missing from product, apparent faults part damage etc.);

(g) Serial number (manufacturer serial number on the system);

(h) Asset tag (company asset tag number).

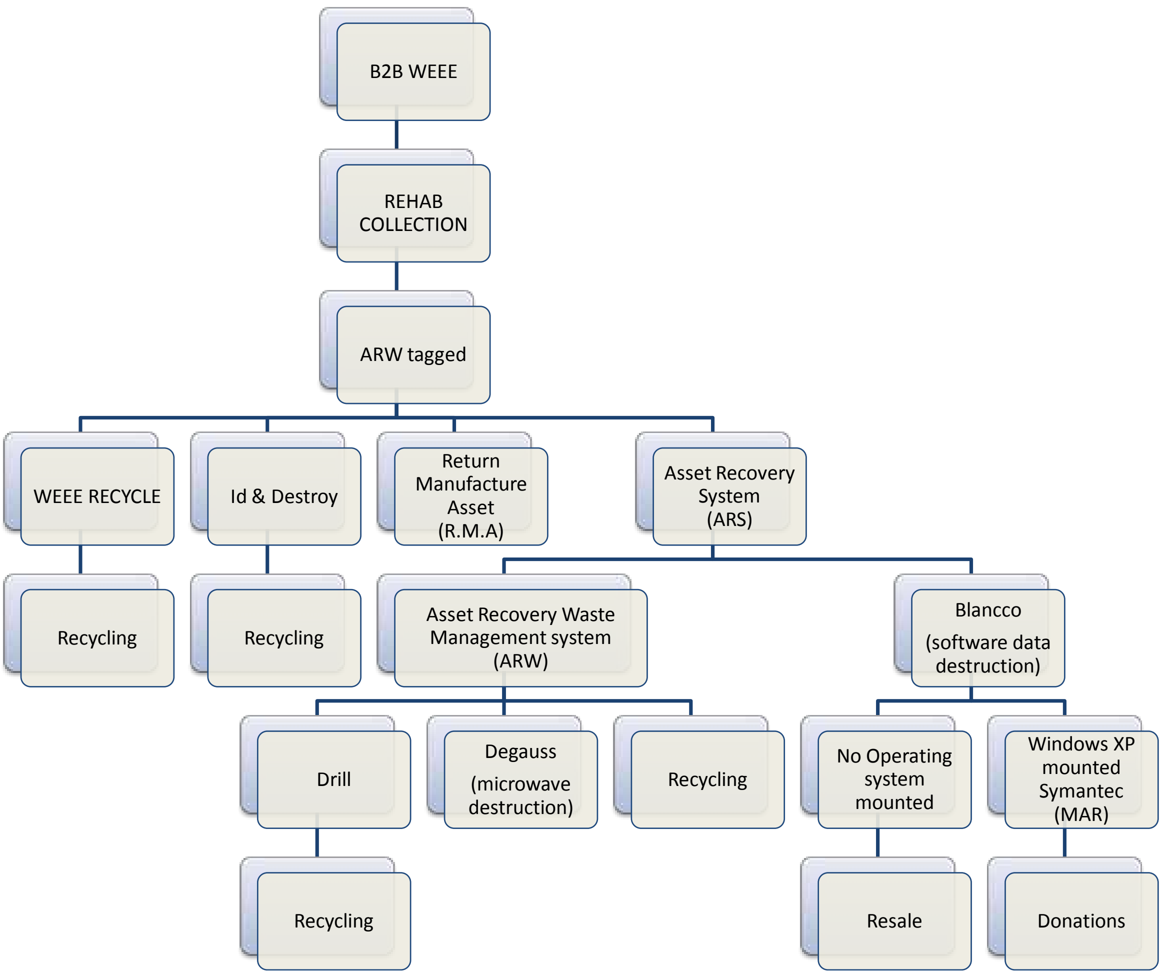

Figure 5.1. Operational flow diagram for ICT refurbishment for Rehab Recycle.

Data destruction: Rehab's ICT refurbishment incorporates data destruction with three different options available: blancco (software), drill (mechanical), degauss (electromagnetic.) Drill and degauss are two data-destructive methods that render the hard drive unusable. If either of these two options is chosen a replacement hard drive has to be sourced or the system is cannibalised for spare parts or material recovery. If blancco (software wipe certified to US military deactivation standard) is chosen, the hard drive is reusable.

Operating system: As noted above, Rehab is an MAR, so Microsoft XP is mounted onto the systems using Symantec, a programme capable of mounting numerous machines concurrently. Hard-drives have previously being wiped in the blancco progress. On average it takes 40 minutes to mount the operating system.

Resale/donation: Rehab Recycle employs a dedicated remarketing team, charged with the resale of assets recovered for reuse. Low or zero cost equipment is also made available for schools, charities, community groups and start-up enterprises.

An inherent part of refurbishment is insuring appropriate OEM (Quariguasi et al., 2010) brand protection, indemnifying the OEM from the refurbishment process. Refurbished items must be clearly labelled demonstrating the unit as refurbished by an external organisation. Liability and product recall are also pressing issues. All unprecedented eventualities must be covered to instil confidence within the refurbished appliance market and to cover the refurbisher.

Brand protection: Rehab removes any branding associated with previous owner. OEM branding remains combined with Rehab's Promise label of excellence, indicating the item was refurbished to Rehab externally verified standard of best practice.

Liability: Rehab is accredited to international standards ISO 14001; Environmental Standard, ISO 9001; Quality Standard and OHSAS 18000; Health and Safety Standard and fully compliant with PAS 141. Bi-annual independent surveillance audits are carried out in order to maintain their ISO and OHSAS performance accreditation. Rehab has private and public liability in the unlikely event of a refurbished product causing damage.

Warranty and recall: Rehab operates its own in-house warranty service through its remarketing team. Refurbished products have a six-month warranty, servable by Rehab. Sale items are registered to an individual consumer for product recall provisions to be implemented

5.1.3 *Rehab ICT refurbishment data*

Data was compiled for Rehab's refurbishment enterprise from 14/12/2009 to 10/12/2010 (Table 5.1). The majority of machines returned are three to four years old which depends on the supplier inventory refresh protocol. Reverse logistics are conducted, predominantly by Rehab, ensuring minimum damage in transit. A large amount of servers (649/663) were recorded with no potential for reuse, due to modern processing power requirements. The CRTs returned were predominately working, but had limited potential for reuse, due to a lack of demand. Alternatively, LCDs returned had a large potential for reuse at 87%. Hard drive potential for reuse is determined by the size of the hard drive and wipe technique employed (blannco, degauss, drill).

Table 5.1. Rehab ICT refurbishment, 2009–2010.

Appliance	Total acquired	Potential for reuse	% of total
Hard drives	1255	112	9
Base units	5052	3225	64
CRTs	945	234	25
Data cartridges	1428	17	1
Laptops	899	519	58
Printers	60	21	35
Servers	663	14	2
LCDs	254	221	87
TVs	3	0	0

5.1.4 Rehab ICT – Facility refurbishment

Rehab has invested significantly in its ICT reuse service, launching a new state-of-the-art facility dedicated to electrical reuse in Tallaght in 2012. The Tallaght site features a new data-destruction area; an improved asset-identification system; a secure area for storing assets with data, including enhanced security measures in place (CCTV security system). The new operation will be focused on the reuse of EEE and will have the capacity to process up to 10,000 tonnes of EEE a year, with a capability of refurbishing 200 pieces of IT equipment per hour (Fig. 5.2).

5.2 Business to Consumer White Goods

In comparison to ICT, white-goods refurbishment is a less technical process as there are no data concerns. Figure 5.3 depicts an operational flow diagram of how a B2C white-goods take-back model would operate based on the Irish B2C set-up and experiences gained from Rehab, Bryson and Kingerwingel.

Point of aggregation: Ideally, white goods with potential for reuse are separated and stored within a covered environment at points of aggregation (retailer, CA site, kerbside collection, open days). Providing education to employees on site, to enable an understanding of which items should be separated, increases reuse potential. A simple assessment matrix is necessary for isolating appliances with potential for reuse. This has been developed and implemented by Bryson with immediate success.

Reverse logistics: Reuse logistics should be conducted at point of source, ensuring adequate handling and enabling another level of inspection to be conducted by the authorised refurbisher. This minimises transportation costs and isolates whites goods with potential for reuse.

Asset monitoring: Each item must be tagged and accounted for during the refurbishment process. Similar to the ICT ARW system implemented by Rehab a number of key peripherals must be documented for the refurbishment process:

Figure 5.2. Rehab's refurbishment facility.

1 Unique tag (barcode);
2 Appliance type;
3 Manufacturer;
4 Model number;
5 Energy rating;
6 Visual inspection grade (1–5);
7 Note (anything missing from product, apparent faults, part damage etc.);
8 Serial number (manufacturer serial number on the system).

Visual and operational inspection: Once the assets have reached the refurbishment stage, it will have undergone two evaluation stages, before one final visual and operational inspection stage. Refurbishment is conducted where the final visual and operational assessment considers refurbishment viable. Otherwise, donor parts are considered or the unit is sent for recycling.

Refurbishment: Refurbishment should be conducted by a qualified service engineer to an externally verified standard (PAS 141), which includes electrical safety testing (PAT Testing).

Similar to the provisions implemented for ICT refurbishment, brand protection, liability cover and product warranty/ recall are fundamental aspects for refurbishment that need to be addressed. Consumers must be easily able to identify that the appliance they

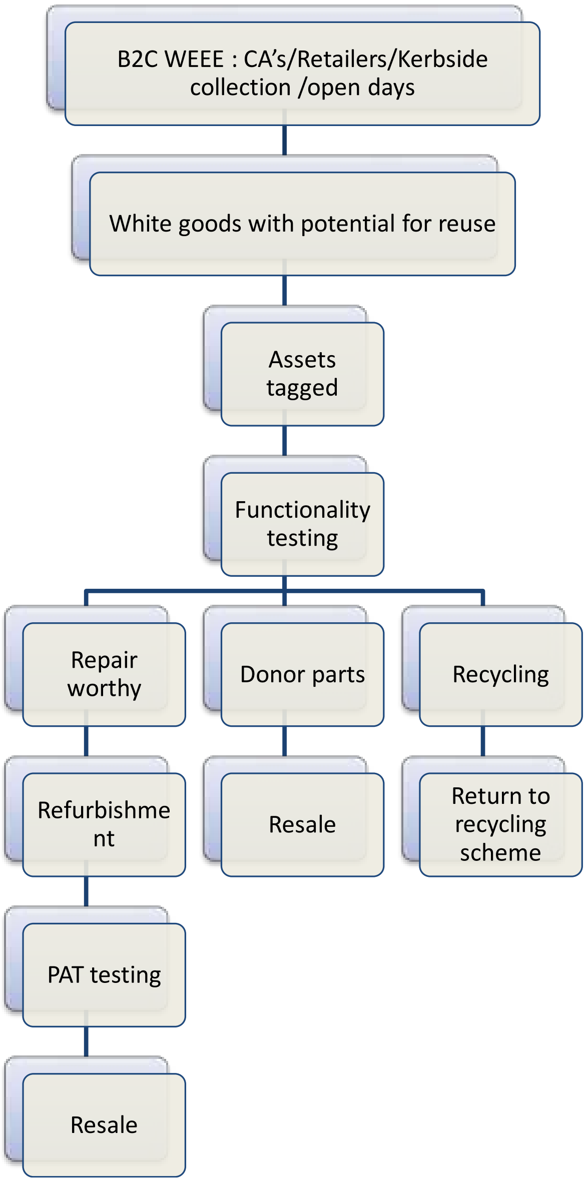

Figure 5.3. Operational flow-diagram for white-goods refurbishment.

are purchasing is second hand. The concept of a recognised quality label implemented by De Kringwinkel and Rehab would ensure consumer confidence that the appliance was refurbished to a recommended standard by a certified organisation. Similar liability, warranty and recall cover, as implemented by Rehab for ICT refurbishment, should be employed.

5.2.1 Business to consumer trials

Based on the knowledge gained from external expertise, CCRI and Rehab conducted white-goods trials to assess the potential avenues available to them, the logistics required and the facility upgrade requirements necessary to conduct reuse. CCRI analysed a local distributor and their kerbside collections over a four-month period. Visual and operation assessments were conducted by a service engineer. Over the course of the trials CCRI upgraded its facility to cater for small-scale refurbishment. Rehab analysed three retailer take-backs and conducted visual assessments of the appliances. Rehab also upgraded its facility in Tallaght for catering for white goods. A dedicated large-household-appliances section has been developed with the necessary requirement for conducting refurbishment, including a wet room area, water outlets and a weigh bridge (Fig. 5.4). Complying with guidelines set out in PAS 141, it is capable of repairing up to 20 large household appliances per hour.

Figure 5.4. Rehab Recycle's dedicated white-goods refurbishment section, Tallaght.

Figure 5.5. Clondalkin Community Recycling Initiative take-back and refurbishment process.

5.2.2 Clondalkin Community Recycling Initiative

5.2.2.1 Distributor take-back

A local white-goods distributor was analysed by CCRI. Logistics were controlled by CCRI, ensuring minimal handling and a controlled transport environment. Visual and operation assessment of the white goods collected were conducted at their Clondalkin facility by a qualified service engineer (Fig. 5.5).

The results from the trial (Table 5.2) showed that 41% of washing machine returned had a potential for reuse after an operational assessment. Other appliances had a low sample size, but give similar indications for reuse potential. White goods returned from the distributor were of the same brand, enabling remaining appliances with no potential for reuse being suitable for donor parts.

Table 5.2. Clondalkin Community Recycling Initiative distributor take-back.

Appliance	Total acquired	Potential for reuse	% of total
Washing machine	29	12	41
Dryer	1	0	0
Dishwasher	8	2	25
Cooker	3	1	33

5.2.2.2 Kerbside collection

Kerbside collections analysis was conducted over a course of four-month period from October 2011–March 2012. Reverse logistics are conducted by CCRI, enabling access at point-of-source and facilitating minimal transportation damage (Fig. 5.6).

Figure 5.6. Kerbside collection undertaken by Clondalkin Community Recycling Initiative.

Over the course of trials 554 white goods were collected and assessed visually and operationally. The percentage of appliances with potential for reuse ranged from 10% to 0% after visual and operational assessments, which were closely matched (Table 5.3). Low-reuse potential is attributed to predominately older appliances and outdoor storage.

Table 5.3. Kerbside collections.

Oct–Dec. 2011			
Appliance	**Acquired**	**Potential for reuse**	**% age of total**
Washing machine	80	6	8
Dryer	63	2	3
Fridge/freezer	0	0	0
Dishwasher	53	3	6
Ovens	18	1	6
Cookers	63	0	0
Jan–March 2012			
Appliance	**Acquired**	**Potential for reuse**	**% age of total**
Washing machine	87	2	2
Dryer	65	3	5
Fridge/freezer	0	0	0
Dishwasher	41	4	10
Ovens	20	0	0
Cookers	64	2	3

5.2.3 Rehab

Rehab conducts WEEE collection for retailers as part of its recycling operation. White-goods analysis for three retailers was conducted while the equipment was staged at Rehab, before appliances where prepared for recycling.

5.2.3.1 Retailer 1

Rehab's Retailer 1 take-back comprised of 50 white-goods units, predominantly washing machine and fridge freezers (Fig. 5.7, Table 5.4).

Washing machines showed a large potential for reuse after visual inspection (62%), with the remaining machines having spare-parts potential because of similar branding. Fridge freezers had a 40% potential for reuse after visual inspection, with similar spare parts potential. Small samples of dishwashers (6 units) and dryers (1 unit) were recovered, with some reuse potential.

Table 5.4. Rehab Retailer 1 take-back.

Appliance	Total acquired	Potential for reuse	% of total
Washing machine	16	10	63
Dryer	1	1	100
Dishwasher	27	11	41
Cooker	6	2	33

Figure 5.7. Retailer 1 collection at Rehab Recycle, Tallaght.

Figure 5.8. Retailer 2 take-back at Rehab Recycle, Tallaght.

5.2.3.2 Retailer 2

Retailer 2 take-back comprised of 33 units predominantly washing machine (Fig. 5.8, Table 5.5).

Washing machines showed similar reuse potential to Retailer 1: 50% of washing machines showed potential for reuse, with the remaining machines having spare-parts potential due to similar branding. Fridge/freezer sample rate was low, with a 25% perceived potential for reuse after visual assessment. Dryer sample rate was also low, but had relatively high potential for reuse.

Table 5.5. Rehab retailer 2 take-back.

Appliance	Total acquired	Potential for reuse	% of total
Washing machine	20	10	50
Dryer	3	2	67
Fridge freezer	8	2	25
Cooker	2	0	0

5.2.3.3 Retailer 3

Retailer 3 take-back comprised of 38 units predominantly comprised of washing machines (Fig. 5.9).

Figure 5.9. Retailer 3 take-back at Rehab Recycle, Tallaght.

Washing machines' potential for reuse showed relatively lower results compared to the other retailers: 25% of washing machines showed potential for reuse (Table 5.6). Of the 24 washing machines acquired, there were five different brands, making donor parts more difficult to source. Seven dishwashers and three ovens were examined with 0% potential for reuse.

Table 5.6. Rehab retailer 3 take-back.

Appliance	Total acquired	Potential for reuse	% of total
Washing machine	24	6	25
Dryer	4	0	0
Dishwasher	7	0	0
Cooker	3	0	0

5.3 Discussion

Refurbishment of ICT products conducted by Rehab is fully operational and conducted to known industry best standards with PAS 141 certification. Data from the Rehab ICT refurbishment showed a strong reuse potential for the three main ICT areas: base units (64%), laptops (58%) and LCDs (87%). Figures represented a significant yearly flow of equipment through Rehab and demonstrated the strong platform developed for B2B IT refurbishment within Ireland. Furthermore, during the analysis period it was shown that from a Rehab perspective preparing a tonne of B2B ICT equipment for reuse employed 11 times more people than in recycling an equivalent amount of material. Reuse also generated 15 times more revenue than recycling of the equivalent quantity in the same period. One of the key success components is attributed to having control over the reverse logistics and minimising uncontrolled transportation damage. Customer processor speeds specification is the main reason why machines aren't fit for reuse.

For white goods, currently no formalised reuse is been conducted in Ireland. Visits to operational white-goods refurbishment enterprises abroad facilitated an understanding and observation of the refurbishment process. Access to the right equipment and appropriate storage at points of aggregation play a pivotal role in promoting reuse. Business to customer trials enabled CCRI and Rehab to evaluate potential avenues for refurbishable white goods and indicated how to integrate refurbishment into their operating models. The trials give indications of possible WEEE sources with potential for reuse. On average, apart from kerbside collections, 40% of washing machines and fridge freezers showed potential for reuse. The remaining machines were predominantly suitable for spare parts. Other white goods, including tumble dryers and dishwashers, had lower numbers of machines examined, but when machines were available similar reusability trends were observed. Kerbside collection appliances had the lowest reuse potential, after a visual and operational assessment. Early indications anticipate this source to cater for the spare-parts inventory market. No CA site trials were conducted during the Re-evaluate project. However, figures reported from Bryson indicate CA sites as a significant resource for refurbishable white goods. From April 2010 to March 2011, Bryson refurbished 3,333 appliances sourced from CA sites. Experience from Bryson has shown that a strong relationship with

those at the point of collection and suitable storage can prove valuable in identifying the most appropriate equipment for reuse and in preventing damage by mixing refurbishable appliances with equipment that is destined for recycling.

The trials showed clearly that there is potential for reuse within the B2C white-goods sectors in Ireland. Evidence from Belgium also suggests that small household appliances would be a good candidate for a reuse programme. B2B reuse is currently self-controlled, but anticipated changes with the recast of the WEEE Directive anticipate similar B2C recovery and reporting obligations. Therefore, reuse within B2B and B2C WEEE should be a regulated activity and participants should work to externally validated standards, such as PAS 141, for reporting purposes, ensuring accountability and traceability whilst providing reassurance to consumer confidence in relation to safety and quality. Developing a framework and protocols that effectively control this space and promoting sustainable reuse is essential. A dedicated body is necessary to insure only refurbishers recognised to be operating to the designated standards will be in a position to access supply and to have their activities reported as official reuse and count towards compliance obligations.

6 Transitioning to a Reuse-oriented Waste Electrical and Electronic Equipment Management System

Reuse of WEEE is a complicated and multi-faceted undertaking and should be considered in a holistic and sustainable fashion. In order to provide a singularity of purpose and to prevent duplication of effort or a fragmented approach, a dedicated reuse-oriented organisation is proposed to coordinate reuse-related activities in Ireland. The objective of such an umbrella reuse organisation is to develop conditions for the reuse of EEE to flourish and maximise the economic, social and environmental benefits of this industry for Ireland. Working on a not-for-profit basis it should aim to stimulate a sustainable level of refurbishment and remarketing that will:

- Create refurbishment jobs;
- Create retail jobs;
- Make low-cost equipment available to people on low-incomes;
- Reduce imports;
- Reduce raw material extraction;
- Reduce waste.

Establishing and running an operating framework is fundamental for enabling all stakeholders to have confidence that reuse is being undertaken in a sustainable and properly regulated fashion with a level playing field for everyone involved

6.1 A Dedicated Reuse Organisation

A dedicated reuse organisation would operate as a clearing house for all reuse activities in Ireland, including B2B and B2C reuse. It would provide the necessary oversight to instil confidence in producers, distributors, refurbishers, consumers, local authorities and government that reuse of EEE is being conducted in the most sustainable means possible. Acting on instruction from the DoECLG, this organisation would define the conditions under which authorised reuse may occur in Ireland, and membership will be a means of complying with the relevant EEE reuse regulations and will provide a means of documenting and reporting all reuse to related activities that take place in Ireland. Focused solely on reuse of WEEE, it would work to complement the existing producer-funded compliance schemes and reuse operators. It will operate as a hub for stakeholders to achieve reuse obligations as prescribed by the DoECLG and the agents that will undertake the refurbishment and re-marketing of EEE.

6.2 Business to Consumer and Business to Business Reuse

The reuse organisation would work in both the B2C and B2B domains, which will be described separately below. Traceability and liability are inherent obligations within both systems. Ensuring traceability and accountability are vital conditions for a reuse organisation. Asset-management tracking tools, such as ARW and Bespoke, provide the capability for documentation and unique identity monitoring for individual EEEs that stream from point of entry at a refurbishment facility. From a liability perspective, refurbishers will be required to have public and private liability insurance and be fully compliant with environmental and health and safety legislative requirements.

6.2.1 Business to Consumer

The B2C WEEE domain is dominated by two large compliance schemes which act as approved bodies for producers in fulfilling their obligations for the environmentally sound management of WEEE. Currently, these organisations arrange for the collection, pre-processing and recycling of all consumer WEEE in Ireland, none of which is currently prepared for reuse. A reuse organisation would work as a means for these compliance schemes to meet reuse obligations, determined by DoECLG, that may arise, providing services such as:

- Collection of WEEE with potential for reuse;
- Distribution of WEEE with potential for reuse to approved refurbishment centres;
- Approval of refurbishment centres;
- Reporting of reuse quantities.

WEEE with potential for reuse must be segregated at the point of collection and will come under the mandate of the reuse organisation and will proceed as shown in Fig. 6.1. This will happen at retailers, CA sites, special collection days and kerbside/household collections. International experience has shown that a strong relationship with those at the point of collection can prove very valuable in identifying the most appropriate equipment for reuse. It can also prevent damage caused by mixing it with equipment that is destined for recycling. The reuse organisation must develop a programme to educate and train those at the frontline of equipment return about the needs of a refurbishment centre. After collection it will be directed to a dedicated and certified refurbisher who undertakes to perform its operations to an externally validated standard such as PAS 141. Potential for reuse is considered as environmentally, economically, socially, technically and legally beneficial to reuse. Equipment that is deemed not to have potential for reuse upon inspection and testing will be returned to the current compliance scheme and processed and reported under the existing conditions.

6.2.2 Business to Business

The proposed reuse organisation should also operate for the B2B reuse market, providing a service to refurbishers offering services to business customers. In this instance, existing commercial arrangements such as asset recovery services and charitable donations will continue as normal but will have to be reported to the reuse organisation in order to be registered towards compliance with the relevant obligations. Only refurbishers recognised to be operating to the designated standards will be in a position to have their activities reported as official reuse and count towards compliance obligations.

6.3 Marketing

A vital part of any system that aims to achieve reuse is to generate and sustain markets for the products that have been refurbished. The micro-economic literature in this space all points to the ability to reliably signal quality as being crucial in instilling confidence in customers. Public awareness, branding and warranty

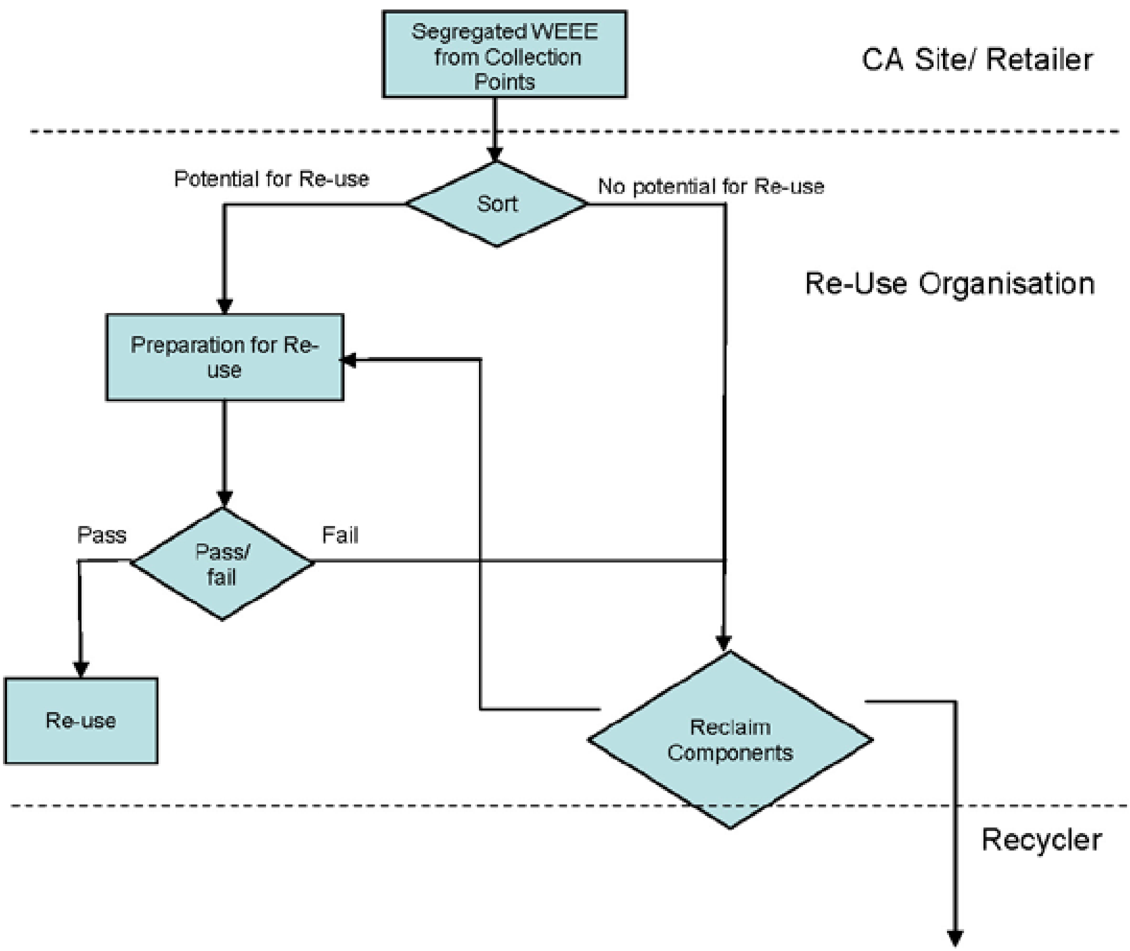

Figure 6.1: Overview of reuse process.

have to be developed to generate the right conditions for a market for reuse equipment to flourish.

6.3.1 Public awareness

A sustained public awareness campaign is an essential element as final markets for the reused products are essential for the ongoing success of the endeavours. This campaign should focus on job creation, value for money and the environmental benefits that reuse brings and should be undertaken through the national and local media as well as online advertising and social networks. Inclusion of mandated public-awareness targets should be considered.

6.3.2 Branding and labelling

A reuse organisation should have its own unique brand and labelling scheme, which enables certified and compliant refurbishers to attach clearly visible labels to reused product fit for resale. The unique brand and label will enable customers to identify that they are purchasing a second-hand appliance, which has be refurbished to a predefined standard (possibly PAS 141), has a warranty of a definite duration and has aided in the provision of employment for Ireland. The 'Revise' label used by De Kringwinkel is Belgium is an example of a recognised quality label for reused EEE across Belgium.

6.3.3 Warranty

Warranty is a fundamental aspect of EEE reuse for promoting consumer confidence. Under the PAS 141 standard, a minimum of 28 days warranty is directed. From case studies conducted, a standard six months warranty is common practice and should be the minimum requirement of a reuse organisation membership. The branding and labelling should make it explicitly clear who to contact in the case of warranty issues.

7 Potential Future of Waste Electrical and Electronic Equipment – Auto-identification and Cyber-infrastructures

The future of WEEE is poised for legislative and technological change. Auto-identification (Auto-ID) in conjunction with the internet of things could shape a new landscape for WEEE management. Auto-identification technologies such as radio frequency identification (RFIDTags.com.) are slowly being integrated into product design for beginning of life-process control, asset management and supply-chain logistics. RFID is the use of wireless noncontact systems that use radio frequency electromagnetic fields to transfer data from a tag attached to an object, for the purpose of auto-identification (Finkenzeller, 2003) Radio Frequency Identification and Near-Field Communication (RFID tags contain a read-write option which enables data to be stored on a RFID tag, or the embedded unique RFID tag code used as an identifier linked to a database. An RFID system combined with mobile computing and Web technologies provides a way for organisations to identify and manage their assets autonomously. One key benefit of RFID is that it removes the need for a line of sight back to a reader (bar-code technology requires a scanner to pass over each item). RFID enables pallets of products to pass through a stationary portal reader and the information to be automatically captured, requiring less human intervention in the data-capturing process (Thomas, 2003). Unlike bar-code technology, multiple RFID tags can be identified simultaneously and they often have a longer life span than bar codes as they can be produced in a variety of form factors depending on the operating environment (Dempsey et al., 2010). Major international corporations, including Wal-Mart, Cisco and Dell are realising the existing power and potential of RFID technology as an enabling platform for performing a plethora of tasks while using one piece of technology (Vance et al., 2009). Developing the RFID infrastructures beyond the beginning of life (BOL) phases, towards a more life-cycle management system approach, can have significant economic and environmental benefits at EOL. An RFID-enabled product lifecycle management (PLM0 architecture, supporting item-level identification) can potentially provide early identification of e-waste in the reverse supply chain, supporting value-conserving logistics and enabling decisive measures at the EOL, such as refurbishing, remanufacturing, and recycling to be undertaken more efficiently.

The potential of RFID technology for facilitating WEEE management has already been explored to some extent. Specifically, Binder et al.'s (2008) study of the current waste and resource management system in Switzerland shows that implementing RFID in WEEE management would increase the recycling rate and reduce the disposal rate. Saar et al. (2004) discuss the benefits that the identification technology of product codes can bring for the recycling of cell phones. The identification of the brand and model can be linked to a database which provides information on how to dismantle the product, information on the hard drive, random access memory (RAM), and circuit boards, the type of plastic in the case, and hazardous materials content or other product composition information. A range of authors (Thomas, 2009a; Kahhat et al., 2008; Kulkarni et al., 2005; Abdoli, 2009) present the benefits of using RFID in recycling and refurbishing enterprises to increase the recycling rate and help them choose the most appropriate EOL activity. The usage of RFID could also increase the collection rate if coupon values are provided to consumers who drop their used products into a recycling bin and the RFID reader reads the product's characteristics (Thomas, 2007). Delen et al. (2007) stress that RFID technology can improve supply-chain visibility by benefiting inventory management and asset utilisation since the information at different organisational levels (for example at the shelves, point of sale, etc.) can be distributed in real time. Also Zhou (2009) discusses the benefits of RFID technology on supply-chain processes, including more efficient control through increased information accuracy, better knowledge of customer behaviour, better tracking of quality problems, and better management of perishable items and returns.

However, using RFID technology for WEEE management poses different technological challenges (Dempsey et al., 2010; Thomas, 2009b), the most important are the hard-to-define read conditions and the high amount of metal present. Not-defined read

conditions mean that the position of the transponder cannot be guaranteed and thus the segregation of mixed WEEE is unclear. Moreover, the metal in the surrounding reduces the readability significantly, especially of ultra high frequency (UHF) transponders (Dobkin and Weigand, 2005; Derbek et al., 2007; Singh et al., 2009). Another limitation of RFID is the RFID read range (Thomas, 2003). These physical limitations indicate that to read an RFID tag on a product, the reader needs to be closer than 1 m and the amount of metal nearby needs to be limited (Thomas, 2003). Another technical challenge that hinders the use of RFID in WEEE management is that tags need to be read regardless of their orientation (Thomas, 2007). The aforementioned limitations have already been observed in pilot studies concerning reverse logistics for WEEE. For example, in the 'Multi Life Cycle Centre for electronic and electric equipment (MLCC)' project conducted in 2007, RFID was explored as a mechanism to optimise the flow of EEE product related information once it had entered the waste stream (Kopacek, 2007). Initially, problems arose in the MLCC project due to de-tuning of antennas from their operating resonant frequency most likely caused by radio frequency variations, losses due to metal proximity, harmonic effect and signal reflection. These issues had a detrimental influence on the tag/reader communication distance. Secondly, problems occurred in the labelling of containers. Passive RFID tags were unable to be read out when mounted on metal. Similar problems occurred in the tagging of WEEE due to the large percentage of metal components. With an overall read rate of 30% received, the study concluded that the introduction of RFID was not feasible for B2C WEEE management. Further studies investigating the tagging of EEE durables observed again the reflection, absorption and detuning effects caused by metal (Derbek et al., 2007; Singh et al., 2009).

Fortunately, in recent years there has been significant research and development in the field of RFID tags, and many of the issues experienced in the past have been resolved. Such an example concerns the emergence of metal mount tags (Odin-Technologies, 2008; RFIDTags.com., 2010). Initial developments altered the tag design incorporating a spacer to shield the tag antenna from the metal, creating bigger tags. New techniques focus on a specialised antenna design that utilises the metal interference and signal reflection. The metallic surface is used as a ground plane of the antenna or as an energy-improving reflector, for longer-read range than similar sized tags attached to non-metal objects (Rao et al., 2008). A range of IT asset-management tags have recently become available, specifically designed for use with EEE equipment. These tags reportedly provide a long-read range for their size and a suitable form factor for application to EEE products (Odin-Technologies, 2008). However, data sheet performance measurements collated within anechoic chambers, relate little to the real-world operating conditions of multiple tags within a densely populated waste environment. Anechoic chambers are designed to stop reflections of either sound or electromagnetic waves and prevent exterior sources of interference, which simulate free-space conditions.

Field trials were conducted by the UL to investigate the actual capability of RFID transponders to technically facilitate EOL product identification. Trials were conducted in Mungret CA site with the support of Limerick County Council, Indaver and the European Recycling Platform (ERP), specifically focusing on large household appliances and mixed WEEE. Taking typical product characteristics and the operating environment at CA sites into account, the tag size, tag type, tag frequency and reader type could all be pre-determined from analysis of the RFID manufacturer datasheets prior to actual testing. Ultra high frequency RFID technology was chosen over the other frequency types available, as UHF provides the most suitable read range (i.e. 3–5 m) for the operating environment. All the tags selected for trials were passive UHF EPC Gen2 RFID metal mount tags, which are specifically designed to withstand a variety of environmental and harsh waste operating conditions, as is the case with WEEE. Passive UHF RFID tags require no battery; instead, they operate by harvesting energy through electromagnetic waves provided by the RFID reader to induce a voltage, when the tag is within the reading range of the reader, and strong enough to activate the silicon chip on the tag. A leading industry standard hand-held reader (Motorola MC9090) was employed for the tests as handheld readers permit an increased level of flexibility compared to their fixed counterparts (Fig. 7.1). Metal mount tag types were perceived as the best choice for tagging appliances due to the heterogeneous mix of materials that constitute white goods and mixed WEEE.

Figure 7.1. Experimental set-up with fixed-reader configuration for mixed waste electrical and electronic equipment (WEEE).

The results obtained indicate that RFID can technically aid EEE product identification in the B2C WEEE management domain, achieving higher read rates than in the past. For the white-goods WEEE category, 100% readability was accomplished. Complete identification is attributable to the bulk size, storage and stacking techniques employed for EOL white goods. Currently, integration of RFID within the white-goods sector appears to be at concept level with the development of the internet of things and smart appliances. Full-scale adoption and standardisation within the white-goods industry can facilitate EOL identification and enable more efficient systems to be developed for reuse and recycling. In the case of mixed WEEE, a 100% brand identification was not achieved in the field trials. Different tags on different products were read for each scanning sweep as a result of reshuffling. Mixed WEEE was placed into steel WEEE cages in a random fashion, leading to a vast number of possible product-placement combinations which could not be accounted for. When tags are densely surrounded by products in an almost enclosed environment, this seriously alters the antenna behaviour and thus reduces power coupled to the integrated circuit on the tag, which consequently reduces the probability of a positive read. Read rates achieved varied from 95% to 50% depending on the UHF metal mount tag employed and the relative positioning of the tags within the cage. Results demonstrate that only a sample of the products will be read upon their return due to random stacking techniques employed. The higher read rates achieved indicate that further investigation for incorporation of RFID tags in EEE for EOL management is warranted.

Taking for granted the integration of UHF RFID tags at BOL manufacture, a back-end system cyber-based architecture is still required to collate the information into usable data for EOL. Developing more integrated product life-cycle management systems that account for the EOL e-waste processes (refurbishing, remanufacturing, and recycling) can potentially minimise the life-cycle impact of the appliance while increasing visibility and efficiency within the system. A number of IT solutions are under development for implementing the requirements for PLM, including EPC global, Promise, WWAII Semantic. The objective of these architectures is to develop a new generation of product-information tracking and flow management systems, that will allow all actors that play a role during the life cycle of a product (managers, designers, service and maintenance operators, recyclers, etc.) to track, manage and control product information at any phase of its life cycle (design, manufacturing, MOL, EOL), at any time and any place in the world. Currently the EPC Architecture Framework, developed by EPC Global, is the industry accepted approach due to its standardised and robust network structure. The EPC Architecture Framework aims to link each physical object to the global Internet to enable visibility within supply chains. The focus of EPC Global framework is on item-level logistics. It is defined in terms of industry-driven data and interface standards that are intended to guarantee interoperability between solutions from different technology providers. The whole EPC network has been designed with a layered architecture, to provide maximum flexibility of reconfiguration to users, while minimising disruption when changes are made.

The greatest promise of the EPC Global Network is its ability to extend the benefits across trading-partner boundaries. By leveraging RFID and emerging standards around item-level identification such as the electronic product code (Sepúlvedaa et al., 2010), the EPC Global Network can address real-world challenges by enabling the automatic dissemination and discovery of real-time, accurate, and on-demand product information for all parties in the supply chain. Developing the EOL aspects of the PLM systems is vital for designing a waste-management system that better facilitates reuse and recycling through early item-level identification. Designing the reverse-logistics system, with item-level identification will ensure adequate channels are created as upstream as possible to protect WEEE from uncontrollable factors such as weather corrosion, facial damage, theft, exposed hazardous materials and illegal exporting.

8 Conclusions and Recommendations

Ireland's Second Framework for Sustainable Development outlines the need to achieve positive economic, environmental and social outputs while at the same time ensuring equality and an appropriate balance between the three pillars of sustainability (Department of Environment, Community and Local Government, 2012): 'This Framework will be most effective by deepening and widening sustainable development through focusing on key challenges, identifying the gaps and committing to the actions that are needed to mainstream and deliver sustainable development'.

The aim of the framework is to identify and adopt policies that can assist in shifting focus towards greener sustainable growth in line with the Europe 2020 Strategy towards becoming a smart, sustainable and inclusive economy. These three mutually reinforcing priorities aim to deliver high levels of employment, productivity and social cohesion. Reuse of EEE as a policy measure can implement these objectives by providing employment for long-term unemployed or physically impaired people, reducing the life-cycle impact of an appliance by conserving embodied energy and water and enabling social inclusion through access to low-cost appliances.

8.1 Reuse at Policy Level

Reuse of EEE is consistent within EU and Irish strategies, policies and directives towards a more sustainable future. The recast of the WEEE Directive aligned with the Waste Framework Directive will oblige member states to priorities reuse at the earliest stages of WEEE take-back, separate WEEE for reuse and enable access for refurbishment centres. Revised collection reporting will enable reuse to count towards collection targets both within the B2B and B2C markets combined with the implementation of the Eco-design Directive which mandates the prevention of design features inhibiting reuse and the responsibility of producers to provide dismantling information free of charge, should provide a foundation for the integration of reuse. As a result of the recast of WEEE Directive, the DoECLG's new Waste Policy discussion document in August 2012 has included proposals for a 'National Reuse Policy' for WEEE.

8.2 Sustainability of Reuse

A sustainability analysis demonstrated that WEEE reuse, when adapted as part of national policy, can potentially benefit all levels of society in a sustainable manner. From an environmental perspective, the case for ICT reuse was already heavily substantiated in literature. For white goods, the case in the literature for reuse has not been made as comprehensively. A quantitative model permitted a comparative analysis of reuse and non-reuse scenarios. The model demonstrates the importance of considering user-consumption profiles and the changing national electricity generation portfolio in determining the best end of life strategy; whether it should be reuse or recycling. Apart from tumble driers, due to the relatively lower energy ratings ('C' rated), a rough guideline for sustainable reuse of white goods would recommend the reuse of any appliance one energy grade lower than the cheapest available appliance on the market. Research is focused on ICT and white goods as an initial building block for developing reuse initiatives but leaves open the space for research into the sustainability of reuse for other WEEE categories.

8.3 Reuse Opportunities

Development of a reuse sector provides an opportunity to make a significant contribution to social and economic growth by creating employment, ensuring real sustainable economic growth whilst simultaneously minimising environmental pollution. Analysis of Rehab Recycle demonstrated that preparing a tonne of B2B ICT equipment for reuse employed 11 times more people than in recycling an equivalent amount of material, and generated 15 times more revenue than recycling of the equivalent quantity in the same period. Illinois Department of Commerce and Economic Opportunity estimate that 1,000 tonnes of electronics creates 15 jobs if recycled and 200 jobs if repaired. Anticipated demand for refurbished EEE is also a significant factor. As noted above, the Flash Eurobarometer survey gauged Irish consumers' willingness to buy second-hand electronics which showed positive sentiment towards reuse similar to

the UK and Belgium where established reuse systems are in place.

8.4 Sources of Waste Electrical and Electronic Equipment for Reuse

Reuse trials conducted by Rehab and CCRI for B2C white goods demonstrated the potential for reuse that may exist within their current recovery streams (retailers, distributors, kerbside collection). Early indications anticipate retailers and distributors as good sources for white goods, with kerbside collections potentially facilitating the spare parts inventory market. The Bryson case study in Northern Ireland also showed a significant reuse potential for white goods at CA sites, where necessary storage and staff training was carried out. Statistics from Belgium also support the inclusion of small household appliances.

8.5 Facilitating Reuse

Successful reuse enterprises in Ireland and abroad identified access to equipment as the key enabling factor for reuse. A survey conducted by StEP indicates that the legal framework conditions today do not optimally support reuse organisations in accessing sufficient volumes of EEE for preparation for reuse. Case studies conducted in Bryson also demonstrated the importance for segregation of WEEE with potential for reuse at point of aggregation, facilitating appropriate storage and providing education to onsite staff. Furthermore, reuse is seen as an activity that must be regulated in order to develop in a sustainable fashion, preventing sham reuse and promoting consumer confidence. Only organisations operating to sufficiently high standards should be considered eligible to undertake refurbishment and reuse activities and be given access to WEEE.

8.6 Reuse Body

A dedicated reuse organisation is necessary to insure that only refurbishers who are recognised to be operating to the designated standards will be in a position to access supply and to have their activities reported as official reuse. Establishing an operating framework through a reuse body will enable all stakeholders to have confidence that reuse is being undertaken in a sustainable and properly regulated fashion. A level playing field for everyone involved generates the right conditions for a market for reuse equipment to flourish.

8.7 Technological Develoments for Reuse

Technological developments within the EEE space with the inclusion of RFID transponders for enabling automated item level identification and the growing capabilities within the internet of things can potentially enable the development of an integrated product life-cycle management systems to account for the EOL e-waste processes (refurbishing, remanufacturing, and recycling), minimising the life-cycle impact of the appliance whilst increasing visibility and efficiency within the system. This would streamline the EOL process and allow refurbishers to identify WEEE with possible potential for reuse instantaneously at point of entry.

References

ABDOLI, S. 2009. RFID application in municipal solid waste management system. *International Journal of Environmental Research*, vol 3, pp 447–54.

ACHILLAS, C., VLACHOKOSTAS, C., MOUSSIOPOULOS, N., PERKOULIDIS, G., BANIAS, G. & MASTROPAVLOS, M. 2011. Electronic waste management cost: a scenario-based analysis for Greece. *Waste Management and Research*, vol 29, pp 963–72.

ALONSO, E., SHERMAN, A. M., WALLINGTON, T. J., EVERSON, M. P., FIELD, F. R., ROTH, R. & KIRCHAIN, R. E. 2012. Evaluating rare earth element availability: a case with revolutionary demand from clean technologies. *Environmental Science andTechnology*, vol 46, pp 3406–14.

ATASU, A. & WASSENHOVE, L. N. V. 2011. An operations perspective on product take-back legislation for e-waste: theory, practice, and research needs. *Production and Operations Management*, vol 21, May–June 2012, 407–22.

AZZONE, G. & NOCI, G. 1998. Identifying effective PMSs for the deployment of 'green' manufacturing strategies. *International Journal of Operations & Production Management,* vol 18, pp 308–35.

BABU, B., PARANDE, A. & BASHA, C. 2007. Electrical and electronic waste: a global environmental problem. *Waste* Management & Research, vol 25, pp 307–18.

BAN 2006. Basel Action Network. available at: http://www.ban.org/photogallery/china_guiyu/pages/dump_sampling_pic.html [accessed 02/03/2012].

BANSAL, P. K., BRAUN, J. E. & GROLL, E. A. 2001. Improving the energy efficiency of conventional tumbler clothes drying systems. *International Journal of Energy Research*, vol 25, pp 1315–32.

BINDER, C., R. QUIRICI, S. DOMNITCHEVA & STÄUBLI, B. 2008. Smart labels for waste and resource management: an integrated assessment. *Journal of Industrial Ecology Journal of Industrial Ecology*, vol 12, pp 207–28.

BOLE, R. 2006. Life-Cycle Optimization of Residential Clothes Washer Replacement. Report No. CSS06-03, University of Michigan.

BOUSTANI, A. & SAHNI, S. 2010. Appliance Remanufacturing and Life Cycle Energy and Economic Savings. In: IEEE (ed.) International symposium Sustainable Systems and Technology 17–19 May Washington.

BSI-PAS141 2011. 'Reuse of used and waste electrical and electronic equipment (UEEE and WEEE)'. Specification. March 2011, PAS 141:2011, Available at: http://shop.bsigroup.com/en/ProductDetail/?pid=000000000030245346.

CASCADIA 2009. Recycling and Economic Development: A Review of Existing Literature on Job Creation, Capital Investment, and Tax Revenues. Available at: http://your.kingcounty.gov/solidwaste/linkup/documents/recycling-economic-development-review.pdf

CECED 2003. CECED Report on Energy Consumption of Domestic Appliances in European Households. European Council of Domestic Equipment Manufacturers, www.ceced.org/

CECED 2009. *Guidance Manual for the Control of Transboundary movements of Recoverable wastes*, Paris: The Organisation for Economic Co-operation and Development.

CHANCEREL, P., MESKERS, C. E. M., HAGELÜKEN, C. & ROTTER, V. S. 2009. Assessment of precious metal flows during pre-processing of waste eectrical and electronic equipment. *Journal of Industrial Ecology,* vol 13**,** pp 791–80.

CHEN, Z. 2011. Global rare earth resources and scenarios of future rare earth industry. *Journal of Rare Earths,* vol 29, pp 1–6.

CHI, X., STREICHER-PORTE, M., WANG, M. Y. L. & REUTER, M. A. 2011. Informal electronic waste recycling: A sector review with special focus on China. *Journal of Waste Management,* vol 31, pp 731–42.

CHOI, B. C. & SHIN, H. S. 2004. Life cycle assessment of a personal computer and its effective recycling Rrate. *Journal of Life Cycle Assessment,* vol 11**,** pp 122–8.

CSO (Central Statistics Office Ireland) 2009 Survey on the income and living conditions in Ireland. Central Statistics Office Ireland (http://www.cso.ie/releasespublications/documents/silc/current/silc.pdf).

CSO 2010. Survey on Income and Living Conditions (SILC) Preliminary results Central statistics office ireland (http://www.cso.ie/en/media/csoie/releasespublications/documents/silc/2010/prelimsilc_2010.pdf).

DANIEL, V., GUIDE, R. & WASSENHOVE, L. N. V. 2009. The evolution of closed-loop supply chain research. *Journal of Operations Research,* vol 57, pp 10–18.

DARBY, L. & OBARA, L. 2005. Household recycling behaviour and attitudes towards the disposal of small electrical and electronic equipment. *Resources, Conservation and Recycling,* vol 44, pp 17–35.

DCENR (Department of Communications, Energy and Natural Resources) 2009. 'National Renewable Energy Action Plan IRELAND', Department of Communications, Energy and Natural Resources. Available at: http://www.dcenr.gov.ie/NR/rdonlyres/03DBA6CF-AD04-4ED3-B443-B9F63DF7FC07/0/IrelandNREAPv11Oct2010.pdf [accessed 09.09.2011].

DELEN, D., HARDGRAVE, B. C. & SHARDA, R. 2007. RFID for better supply-chain management through enhanced information visibility. *Journal of Production and Operations Management,* vol 16**,** pp 613–24.

DEMPSEY, M., ROSSEM, C. V., LIFSET, R., LINNELL, J., GREGORY, J., ATASU, A., PERRY, J., SVERKMAN, A., WASSENHOVE, L. N. V., THERKELSEN, M., SUNDBERG, V., MAYERS, C. K. & KALIMO, H. 2010. Individual Producer Responsibility: A Review of Practical Approaches to Implementing Individual Producer Responsibility for the WEEE Directive. *Working paper, INSEAD, Fontainebleau, France.* Available at: http://www.insead.edu/facultyresearch/research/doc.cfm?did=45054

DEPARTMENT OF ENVIRONMENT, COMMUNITY AND LOCAL GOVERNMENT, 2012. *Our Sustainable Future: A Framework for Sustainable Development for Ireland. Department of Environment, Community and Local Government*. Available at: http://www.environ.ie/en/Environment/SustainableDevelopment/PublicationsDocuments/FileDownLoad,30452,en.pdf [accessed 28 June 2013].

DERBEK, V., C. STEGER, R., WEISS, J., PREISHUBER-PFLÜGL & PISTAUER., M. 2007. A UHF RFID measurement and evaluation test system. *Elektrotechnik & Informationstechnik*, vol 124, pp 384–90.

DEVOLDERE, T., WILLEMS, B., DUFLOU, J. & DEWULF, W. 2009. The eco-efficiency of reuse centres critically explored – the washing machine case. *International Journal of Sustainable Manufacturing*, vol 1, pp 265–85.

DIMITRAKAKISA, E., JANZB, A., BILITEWSKIB, B. & GIDARAKOSA, E, 2009. Determination of heavy metals and halogens in plastics from electric and electronic waste. *Waste Management,* vol 29, pp 2700–06.

DOBKIN, D. M. & WEIGAND, S. M. 2005. Environmental effects on RFID tag antennas. *Microwave Symposium Digest, IEEE MTT-S Internationa.,* Long Beach, California, USA.

EU COMMISSION 2008. Recast of the WEEE Directive: Status of the recast process. Available at: http://ec.europa.eu/environment/waste/weee/index_en.htm

EUROBAROMETER 2011. Attitudes of Europeans towards resource efficiency: Analytical report. *Flash Eurobarometer (European Commission),* http://ec.europa.eu/public_opinion/flash/fl_316_en.pdf

EUROBAROMETER 2011. Attitudes of Europeans towards resource efficiency: Analytical report. *Flash Eurobarometer (European Commission).* Available at: http://ec.europa.eu/public_opinion/flash/fl_316_en.pdf

EUROPEAN COMMISSION 2010. Critical raw materials for the EU. Available at: http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/report-b_en.pdf

EUROSTAT 2012. Waste Electrical and Electronic Equipment (WEEE). Available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/waste/key_waste_streams/waste_electrical_electronic_equipment_weee

FENG, W., HUISMAN, J. & KOREVAAR, G. 2008. Economic conditions for developing large scale WEEE recycling infrastructure based on manual dismantling in China. Master Thesis, University of Technology, Leiden, Delf.

FINKENZELLER, K. 2003. RFID HandBook: Fundamentals and Applications in Contactless Smart Cards, Radio Frequency Identification and Near-Field Communication (3rd). Wiley.

FINN, P., FITZPATRICK, C., CONNOLLY, D., LEAHY, M. & RELIHAN, L. 2011. Facilitation of renewable electricity using price based appliance control in Ireland's electricity market. *Energy,* vol 36, pp 2956–60.

FRAY, D. J. 2000. Separating rare earth elements. *Science,* vol 289, pp 2295–96.

GEYER, R. & BLASS, V. D. 2010. The economics of cell phone reuse and recycling. *The International Journal of Advanced Manufacturing Technology*, vol 47, 515–25.

GRIESE, H.P., SCHISCHKE, H., NESS, K., REICHL, H. 2004. Reuse and lifetime extension strategies in the context of technology innovations, global markets, and environmental legislation [electronics]. *In:* IEEE (ed.) *Conference of Electronics and the Environment (10–13 May).*, pp 173–8, Phoenix, AZ USA.

GUAN, Y.-F., WANG, J.-Z., NI, H.-G., LUO, X.-J., MAI, B.-X. & ZENG, E. Y. 2007. Riverine Inputs of Polybrominated Diphenyl Ethers from the Pearl River Delta (China) to the Coastal Ocean. *Journal of Environmental Science and Technology,* vol 41, pp 6007–13.

HAGELÜKEN, C. & MESKERS, C. 2008. Mining our Computers – Opportunities and Challenges to Recover Scarce and Valuable Metals from End-of-Life Electronic Devices. *In:* IEEE (ed.) *Electronics Goes Green.* Stuttgart: Fraunhofer IRB.

HAGUE CENTRE FOR STRATEGIC STUDIES. 2010. Scarcity of Minerals: A strategic security issue. Available at: http://www.hcss.nl/reports/scarcity-of-minerals/14/

HE, W., LI, G., MA, X., WANG, H. & HUANG, J. 2006. WEEE recovery strategies and the WEEE treatment status in China. *Journal of Hazardous Materials,* vol 136, pp 502–12.

HELIAS, A. & HAES, U. 2008. Life cycle assessement and the use of broad indicators. *Journal of Industrial Ecology,* vol 10, pp 5–7.

HICKEY, S. & FITZPATRICK, C. 2007. Tackling adverse selection in secondary PC markets. *Journal of Advances in Life Cycle Engineering for Sustainable Manufacturing Business,* vol 4**,** pp 347–52.

HINES, F. 2008. Social enterprises and waste management: employment, engagement and eviornment for sustainable local comunities. *In:* Marsden,T. (ed.) *Sustainable Communities: New spaces for planning, participation and engagement,* Elsevier Ltd.

HUIJBREGTSM, M., HELLWEG, S. & HENSRIK, S. 2010. Cumulative energy demand as predictor for the environmental burden of commodity production. *Environmental Science and Technology,* vol 44**,** pp 2189–96.

HUISMAN, J., MAGALINI, F., KUEHR, R. & MAURER, C. 2008. 2008 Review of Directive 2002/96 on Waste Electrical and Electronic Equipment (WEEE). United Nations University. Available at: http://ec.europa.eu/environment/waste/weee/pdf/final_rep_unu.pdf

HUO, X., PENG, L., XU, X., ZHENG, L., QIU, B., QI, Z., ZHANG, B., HAN, D. & PIAO, Z. 2007. Elevated blood lead levels of children in Guiyu, an electronic waste recycling town in China. *Environ Health Perspect*, vol 115**,** 1113–17.

INFORMATION OFFICE OF THE STATE COUNCIL 2012. SITUATION AND POLICIES OF CHINA'S RARE EARTH INDUSTRY. 2012. *The People's Republic of China,June 2010, Beijing,First Edition 2012,* White Paper. Available at: http://www.chinadaily.com.cn/china/2012-06/20/content_15514823_8.htm

INSTITUTE.V., O. 2007. Environmental and economic evaluation of the accelerated replacement of domestic appliances Case study refrigerators and freezers. Available at: http://www.oeko.de/oekodoc/271/2007-016-en.pdf

INTERNATIONAL MONETARY FUND (IMF) 2012. Household Debt Holds Back Recoveries but Restructuring Can Help. IMF Survey online (http://www.imf.org/external/pubs/ft/survey/so/2012/RES041012B.htm).

JEPSON, N. 2012. A 21st century scramble: South Africa, China and the Rare Earth Metals Industry. Discussion Paper. Available at: http://scholar.sun.ac.za/handle/10019.1/21176

JOFRE, S. & MORIOKA, T. 2005. Waste management of electric and electronic equipment: comparative analysis of end-of-life strategies. *Journal of Material Cycles and Waste Management,* vol 7, pp 24–32.

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,* vol 52, pp 955–64.

KAHHAT, R. & WILLIAMS, E. 2009. Product or waste? Importation and end-of-life processing of computers in Peru. *Journal of Environmental Science and Technology,* vol 42, pp 6446–54.

KELLER, M. 2006. Assessment of Gold Recovery Processes in Bangalore, India and Evaluation of an Alternative Recycling Path for Printed Wiring Boards, a case study. M.Sc. thesis of EMPA and ETH Zurich.

KEOLEIAN, G. A. & HORIE, Y. A. 2006. Optimal household refrigerator replacement policy for life cycle energy, greenhouse gas emissions, and cost. *Journal of Energy Policy,* vol 34, pp 2310–23.

KIM, H.C, KEOLEIAN, G.A., HORIE, Y.A. 2006. Optimal household refrigerator replacement policy for life cycle energy, greenhouse gas emissions, and cost. *Energy Policy*, vol 34, pp 2310–23

KIMURAA, F., HATAA, T. & SUZUKIA, H. 1998. Product quality evaluation based on behaviour simulation of used products. *CIRP Annals – Manufacturing Technology,* 47**,** 119–22.

KISSLING, R. 2011. Best Practices in Reuse, success factors and Business for Reuse operating models. Available at: http://www.step-initiative.org/

KISSLING, R., FITZPATRICK, C., BOENIA, H., LUEPSCHENC, C., ANDREWD, S. & DICKENSONE, J. 2012a. Definition of generic reuse operating models for electrical and electronic equipment. *Resources, Conservation and Recycling,* vol 65**,** pp 85–99.

KISSLING, R., FITZPATRICK, C., LUEPSCHENC, C., ANDREWD, S. & DICKENSONE, J. 2012b. Success Factors and Barriers for EEE Reuse Organisations. *Electronics goes Green 2012, September 9–12, 2012,* Berlin, Germany.

KOPACEK, B. 2007. Reverse Logistics: Final Technical Report Task 5. *The Multi Life Cycle Centre for Electric and Electronic Equipment.*

KUEHR, R., VELASQUEZ, G. T. & WILLIAMS, E. 2003. Computers and the environment: understanding and managing their impacts. *Earth and Environmental Science*, vol 14**,** 1–15.

KUEHR, R. & WILLIAMS, E. 2003. *Computers and the Environment: Understanding and managing their impacts*. Vol. 14. Kluwer Academic Pub, KIM, H. C.

KULKARNI, A. G., PARLIKAD, A. K. N., MCFARLANE, D. C. & HARRISON, M. 2005. Networked RFID systems in product recovery management. *IEEE International Symposium on Electronics and the Environment,* New Orleans, LA USA May 16–19, pp 66–171.

LAU, C. 2008. Reasons for the slow development of reverse logistics in the electronic industry of China. *In:* Wolfgang Kersten (ed.) *Global Logistics Management: Sustainability, Quality, Risks.* Die Deutsche Bibliothek.

LINDAHL, M., SUNDIN, E. & ÖSTLIN, J. 2006. Environmental issues within the remanufacturing industry. *Journal of Advances in Life Cycle Engineering for Sustainable Manufacturing Businesses,* vol 14, pp 447–52.

LINDHQVIST, T. 2000. *Extended Producer Responsibility in Cleaner Production: Policy Principle to Promote Environmental Improvements of Product Systems. PhD Dissemination Lund University, Sweden.* Available at: http://www.lub.lu.se/luft/diss/tec355.pdf

LUO, Y., LUO, X.-J., LIN, Z., CHEN, S.-J., LIU, J. & MAI, B.-X. 2009. Polybrominated diphenyl ethers in road and farmland soils from an e-waste recycling region in Southern China: Concentrations, source profiles, and potential dispersion and deposition. *Science of The Total Environment,* vol 407, pp 1105–13.

MADU, C. N., KUEI, C. & MADU, I. E. 2002. A hierarchic metric approach for integration of green issues in manufacturing: a paper recycling application. *Journal of Environmental Management,* vol 64, pp 261–72.

MESKERS, C. E. M., HAGELÜKEN, C. & SALHOFER, S. 2009. Impact of Pre-processing Routes on Precious Metal Recovery from PCs. *In Proceedings of European Metallurgical Conference, 2009*, June 28–July 1, Innsbruck, Austria.

MONT, O. 2008. Innovative approaches to optimising design and use of durable consumer goods. *International Journal of Product Development,* vol 6, pp 227–50.

ODIN-TECHNOLOGIES 2008. IT Asset Tracking Benchmark Report. *Odin Technologies.*

ODYSSEE. *Energy Efficiency Indicators in Europe* [Online]. Available at: http://www.odyssee-indicators.org/ (Accessed 2010).

OECD 2009a. IEA World Energy Statistics and Balances. Available at: http://www.oecd-ilibrary.org/energy/data/iea-world-energy-statistics-and-balances_enestats-data-en

OECD 2009b. IEA World Energy Statistics and Balances.

ÖKO-INSTITUT E.V 2011. Study on Rare Earths and Their Recycling. Final Report for The Greens/EFA Group in the European Parliament. Available at: http://reinhardbuetikofer.eu/wp-content/uploads/2011/01/Rare-earths-study_Oeko-Institut_Jan-2011.pdf

ÖKO-INSTITUTE 2011. Informal e-waste management in Lagos, Nigeria – socio-economic impacts and feasibility of international recycling co-operations. *Final report of component 3 of the UNEP SBC E-waste Africa Project.*

ÖKO-INSTITUTE E.V 2011. Informal e-waste management in Lagos, Nigeria – socio-economic impacts and feasibility of international recycling co-operations. *Final report of component 3 of the UNEP SBC E-waste Africa Project.* Available at: http://www.oeko.de/oekodoc/1371/2011-008-en.pdf

ONGONDO, F. O., WILLIAMS, I. D. & CHERRETT, T. J. 2011. How are WEEE doing? A global review of the management of electrical and electronic wastes. *Waste Management,* vol 31, pp 714–30.

OSIBANJO, O. 2007. The challenge of electronic waste (e-waste) management in developing countries. *Waste Management & Research,* vol 25, pp 489–501.

PBL NETHERLANDS ENVIRONMENTAL ASSESSMENT AGENCY 2011. Scarcity in a Sea of Plenty? Global Resource Scarcities and Policies in the European Union and the Netherlands. Available at: http://www.pbl.nl/en/publications/2011/Scarcity-in-a-Sea-of-Plenty-Global-Resource-Scarcities-and-Policies-in-the-European-Union-and-the-Netherlands

PRICE WATER HOUSE COOPERS 2012. Minerals and metals scarcity in manufacturing: The ticking time bomb. Available at: http://www.pwc.com/resourcescarcity

QUARIGUASI, J., WALTHER, G., BLOEMHOF, J., NUNEN, J. A. E. E. V. & SPENGLER, T. 2010. From closed-loop to sustainable supply chains: the WEEE case. *International Journal of Production Research,* vol 48, pp 4463–81.

RAO, K., LAM, S. F. & NIKITIN., P. V. 2008. Wideband metal mount UHF RFID tag. *IEEE Antennas and Propagation Symposium,* 5–11 July, San Diego, CA.

REHABRECYCLE 2012. Promise it to rehab recycle. Available at: http://www.rehabrecycle.ie/Promise-It/What-is-Promise-it.aspx [accessed 04/04/2012].

RFIDTAGS.COM. 2010. Metal Mount RFID Tags. Available at: http://www.rfidtags.com/metal-mount-rfidtags [accessed 3 February 2011].

RICHTER, C. P. 2010. Automatic dishwashers: efficient machines or less efficient consumer habits? *International Journal of Consumer Studies*, vol 34, pp 228–34.

RICHTER, C. P. 2011. Usage of dishwashers: observation of consumer habits in the domestic environment. *International Journal of Consumer Studies,* vol 35, pp 180–6.

ROCHAT, D., RODRIGUES, W. & GANTENBEIN, A. 2008. india: Including the Existing Informal Sector in a Clean e-waste Channel. *Proceedings of the Waste Management Conference 2008*, Durban, South Africa.

RÜDENAUER, I. & GENSCH, C.-O. 2004. Energy demand of tumble driers with respect to differences in technology and ambient conditions. Öko-institut e.V.

RÜDENAUER, I. & GENSCH, C.-O. 2007. Environmental and economic evaluation of the accelerated replacement of domestic appliances Case study refrigerators and freezers. Öko-institut e.V.

RÜDENAUER, I. & GENSCH, C. O. 2005b. Eco-Efficiency Analysis of Washing machines Refinement of Task 4: Further use versus substitution of washing machines in stock. Öko-*institute e.V.,* Available at: http://www.oeko.de/das_institut/mitarbeiterinnen/dok/630.php?id=43&dokid=270&anzeige=det&ITitel1=&IAutor1=

SAAR, S., M. STUTZ & THOMAS., V. M. 2004. Towards intelligent recycling: a proposal to link bar codes to recycling information. *Resources, Conservation and Recycling,* vol 41, pp 15–22.

SAHNI, S., BOUSTANI, A., GUTOWSKI, T. G. & GRAVES, S. C. 2010. Reusing personal computer devices - good or bad for the environment? *In:* IEEE (ed.) *Sustainable Systems and Technology (ISSST).*

SEAI 2008. Energy in the Residential Sector. *Sustainable Energy Authorirty Ireland Report.* Available at: http://www.seai.ie/News_Events/Press_Releases/Energy_in_the_Residential_Sector_FNL.pdf.

SEAI 2009. Electricity & Gas Prices in Ireland 2nd Semester (July–December) 2009. Available at: http://www.seai.ie/Publications/Statistics_Publications/EPSSU_Publications/Electricity_and_Gas_Prices/Electricity_Gas_Prices_in_Ireland.pdf

SEAI 2010. Renewable Energy in Ireland. *Update on Sustainable Energy Authority of Ireland,.* Available at: http://www.seai.ie/Publications/Statistics_Publications/SEI_Renewable_Energy_2010_Update/RE_in_Ire_2010update.pdf

SECRETARIAT OF THE BASEL CONVENTION 2010. Where are WEEE in Africa? Findings from the Basel Convention E-waste Africa Programme. *EMPA, UNEP, European Union,* Öko-Institute*, Basel convention.* Available at: http://www.basel.int/Implementation/TechnicalAssistance/EWaste/EwasteAfricaProject/Publications/tabid/2553/Default.aspx

SEPÚLVEDA, A., SCHLUEP, M., RENAUD, F. G., STREICHER, M., KUEHR, R., HAGELÜKEN, C. & GERECK, A. C. 2010a. A review of the environmental fate and effects of hazardous substances released from electrical and electronic equipments during recycling: Examples from China and India. *Environmental Impact Assessment Review,* vol 30, pp 28–41.

SEPÚLVEDA, A., SCHLUEP, M., RENAUD, F. G., STREICHER, M., KUEHR, R., HAGELÜKEN, C. & GERECKE, A. C. 2010b. A review of the environmental fate and effects of hazardous substances released from electrical and electronic equipments during recycling: Examples from China and India. *Environmental Impact Assessment Review,* 30, 28–41.

SINGH, J., OLSEN, E., VORST, K. & TRIPP., K. 2009. RFID tag readability issues with palletised loads of consumer goods. *Packaging, Technology and Science* vol 22, pgs 431–41.

STAMMINGER, R., BROIL, G., PAKULA, C., JUNGBECKER, H., BRAUN, M., RÜDENAUER, I. & WENDKER, C. 2008. Synergy Potential of Smart Appliances D2.3 of WP 2 from the Smart-A project. Available at: http://www.smart-a.org/D2.3_Synergy_Potential_of_Smart_Appliances_4.00.pdf

STEP 2011a. Annual Report 2011. Available at: http://www.step-initiative.org/tl_files/step/_documents/StEP%20Annual%20Report%202011_lowres.pdf

STEP 2011b. *Best Practices in Reuse*. Success Factors and Barriers for Reuse Operating Models. Available at: http://www.weee-forum.org/system/files/documents/2011_sbestpractices_in_reuse_projectreport_final_empa.pdf

TEKWAWA, M., MIYAMOTO, S. & INABA, A. 1997. Life cycle assessment; an approach to environmentally friendly PCs,. *In:* IEEE (ed.) *Electronics and the Environment San Francisco, CA, USA MAY 5–7,* pp 125–30.

THOMAS, V. M. 2003. Product self-management: evolution in recycling and reuse. *Environmental Science and Technology* vol 37, pp 5297–302.

THOMAS, V. M. 2007. A Universal Code for Lifecycle Management of Products. *Proceedings of the 2007 IEEE International Symposium on Electronics & the Environment:,* MAY 7–10, Orlando, Florida, USA.

THOMAS, V. M. 2009. A universal code for environmental management of products. *Resources, Conservation and Recycling,* vol 53, pp 400–8.

TOJO, N. 2004. Extended Producer Responsibility as a Driver for Design Change – Utopia or Reality? IIIEE Dissertations, Lund University.

TRUTTMANN, N. & RECHBERGER, H. 2006. Contribution to resource conservation by reuse of electrical and electronic household appliances. *Resources, Conservation and Recycling,* vol 48, pp 249–62.

UK DEPARTMENT OF HEALTH SOCIAL SERVICES AND PUBLIC SAFTEY 2001. Socio-Economic Indicators: List of Indicators. Available at: http://www.dhsspsni.gov.uk/print/ki_2001_list.pdf.

UNEP (UNITED NATIONS ENVIRONMENT PROGRAMME) 2005. E-waste, the hidden side of IT equipment manufacturing and use. Available at: http://ewasteguide.info/biblio/e-waste-the-h

UNEP 2009. Recycling – from E-waste to Resources. United Nations Environment Programme (UNEP). Available at: http://www.unep.org/PDF/PressReleases/E-Waste_publication_screen_FINALVERSION-sml.pdf

UNEP 2011. Recycling Rates of Metals, A Status Report. Available at http://www.unep.org/resourcepanel/Portals/24102/PDFs/Metals_Recycling_Rates_110412-1.pdf

UNIDO MICROSOFT 2009. Reuse and reycling: growing green business. Available at: http://www.unido.org/fileadmin/user_media/Services/PSD/ICT/0_Green_busines.PDF [accessed 10.17.2011].

US EPA 2002. Resource Conservation Challenge: Campaigning Against Waste. *US EPA 530-F-02-033*.

VANCE, A., LOWRY, P. B. & OGDEN, J. A. 2009. Testing the potential of RFID to increase supply-chain agility and to mitigate the bullwhip effect. *International Journal of Applied Logistics (IJAL).* Forthcoming.

WANG, F., HUISMAN, J., MESKERS, C. E. M., SCHLUEP, M., STEVELS, A. & HAGELÜKEN, C. 2012. The Best-of-2-Worlds philosophy: Developing local dismantling and global infrastructure network for sustainable e-waste treatment in emerging economies. *Waste Management,* In press http://dx.doi.org/10.1016/j.wasman.2012.03.029

WASTE-ONLINE 2004. After it's been binned. Available at: http://dl.dropbox.com/u/21130258/resources/InformationSheets/WasteDisposal.htm, [accessed 25 April 2012]

WEEE REGISTER SOCIETY 2012. http://www.weeeregister.ie/

WIDMER, R., DEEPALI, S., BÖNI, H., OSWALD, H. & SCHNELLMANN, M. 2005. Global perspectives on e-waste. *Environmental impact assessment review,* vol 25, pp 436–58.

WILLIAMS, E., AYRES, R. & HELLER, M. 2002. The 1.7 Kilogram Microchip: energy and material use in the production of semiconductor Devices. *Journal of Environmental Science andTechnology,* vol 36, pp 5504–10.

WILLIAMS, E., KAHHAT, R., ALLENBY, B., KAVAZANJIAN, E., KIM, J. & XU, M. 2004. Energy intensity of computer manufacturing: hybrid assessment combining process and economic input−output methods. *Journal of Environmental Science and Technology,* vol 38, pp 6166–74.

WILLIAMS, E., KAHHAT, R., ALLENBY, B., KAVAZANJIAN, E., KIM, J. & XU, M. 2008a. Environmental, social, and economic implications of global reuse and recycling of personal computers. *Journal of Environmental Science and Technology,* vol 42, pp 6446–54.

WILLIAMS, E., KAHHAT, R., ALLENBY, B., KAVAZANJIAN, E., XU, M. & KIM, J. 2008b. Sustainability review of the international reverse chain for reuse and recycling of computers. *In:* IEEE (ed.) *Electronics and the Environment.*

WILLIAMS, E. & SASAKI, Y. 2003. Energy Analysis of End-of-life Options for Personal Computers: Resell, Upgrade, Recycle. *In:* IEEE (ed.) *International Symposium on Electronics and the Environment.*

WILS, A. 1998. End-use or extraction efficiency in natural resource utilisation: which is better? *System Dynamics Review,* vol 14, pp 163–88.

WONG, M. H., WU, S. C., DENG, W. J., YU, X. Z. & LUO, Q. 2007. Export of toxic chemicals – a review of the case of uncontrolled electronic-waste recycling. *Journal of Environmental Pollution,* vol 149, pp 131–40.

WRAP 2012. Waste and resource action programme. Available at: http://www.wrap.org.uk/reuse/

XING, G. H., CHAN, J. K. Y., LEUNG, A. O. W., WU, S. C. & WONG, M. H. 2009. Environmental impact and human exposure to PCBs in Guiyu, an electronic waste recycling site in China. *Journal of Environment International*, vol 35, pp 76–82.

YU, J., WILLIAMS, E., JU, M. & YANG, Y. 2010. Forecasting global generation of obsolete personal computers. *Journal of Environmental Science and Technology*, vol 44, pp 3232–7.

ZHOU, W. 2009. RFID and item-level information visibility. *European Journal of Operational Research,* vol 198, pp 252–8.

Acronyms

AI	Average intensity
AL	Average life
ALE	Application level events
B2B	Business to business (B2B)
B2C	Business to consumer (B2C)
BOL	Beginning of life
BSI	British Standards Institute
CA	Civic amenity
CBV	Core business vocabulary
CD	Compact disk
CECED	European Committee of Domestic Equipment Manufacturers
CED	Cumulative energy demand
CRT	Cathode ray tube
CSO	Central Statistics Office
CCRI	Clondalkin Community Recycling Initiative
DOECLG	Department of Environment Community and Local Government
EEE	Electrical and electronic equipment
EEI	Energy Efficiency Index
EOL	End of life
EPA	Environmental Protection Agency
EPR	Extended Producer Responsibility
ERP	European Recycling Platform
GDP	Gross domestic product
GPSD	General product safety directive
HI	High intensity
ICT	Information and communication technology
IPR	Individual producer responsibility
IT	Information technology
LCA	Life cycle assessment
LCD	Liquid crystal display
LDA	Large domestic appliances
LF	Low frequency

LI	Low intensity
LL	Long life
LVD	Low voltage directive
MAR	Microsoft Authorised Refurbisher
OECD	Organisation for Economic Cooperation and Development
OEM	Original equipment manufacturers
PC	Personal computer
PLIM	Product Lifecycle Information Management
PLM	Product Lifecycle Management
PRI	Producer Responsibility Initiatives
REE	Rare earth elements
REEE	Reuse electrical and electronic equipment
RES-E	Ireland's Electricity Generation from Renewable Sources
RFID	Radio frequency identification
SEAI	Sustainable Energy Authority of Ireland
SL	Short life
StEP	Solving the E-waste Problem
TCO	Total cost of ownership
UEEE	Used electronic and electrical equipment
UHF	Ultra high frequency
UNEP	United Nations Environmental Programme
VCR	Video cassette recording
WEEE	Waste electrical and electronic equipment

An Ghníomhaireacht um Chaomhnú Comhshaoil

Is í an Gníomhaireacht um Chaomhnú Comhshaoil (EPA) comhlachta reachtúil a chosnaíonn an comhshaol do mhuintir na tíre go léir. Rialaímid agus déanaimid maoirsiú ar ghníomhaíochtaí a d'fhéadfadh truailliú a chruthú murach sin. Cinntímid go bhfuil eolas cruinn ann ar threochtaí comhshaoil ionas go nglactar aon chéim is gá. Is iad na príomh-nithe a bhfuilimid gníomhach leo ná comhshaol na hÉireann a chosaint agus cinntiú go bhfuil forbairt inbhuanaithe.

Is comhlacht poiblí neamhspleách í an Ghníomhaireacht um Chaomhnú Comhshaoil (EPA) a bunaíodh i mí Iúil 1993 faoin Acht fán nGníomhaireacht um Chaomhnú Comhshaoil 1992. Ó thaobh an Rialtais, is í an Roinn Comhshaoil, Pobal agus Rialtais Áitiúil.

ÁR bhFREAGRACHTAÍ

CEADÚNÚ

Bíonn ceadúnais á n-eisiúint againn i gcomhair na nithe seo a leanas chun a chinntiú nach mbíonn astuithe uathu ag cur sláinte an phobail ná an comhshaol i mbaol:

- áiseanna dramhaíola (m.sh., líonadh talún, loisceoirí, stáisiúin aistrithe dramhaíola);
- gníomhaíochtaí tionsclaíocha ar scála mór (m.sh., déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta);
- diantalmhaíocht;
- úsáid faoi shrian agus scaoileadh smachtaithe Orgánach Géinathraithe (GMO);
- mór-áiseanna stórais peitreail;
- scardadh dramhuisce;
- dumpáil mara.

FEIDHMIÚ COMHSHAOIL NÁISIÚNTA

- Stiúradh os cionn 2,000 iniúchadh agus cigireacht de áiseanna a fuair ceadúnas ón nGníomhaireacht gach bliain
- Maoirsiú freagrachtaí cosanta comhshaoil údarás áitiúla thar sé earnáil - aer, fuaim, dramhaíl, dramhuisce agus caighdeán uisce
- Obair le húdaráis áitiúla agus leis na Gardaí chun stop a chur le gníomhaíocht mhídhleathach dramhaíola trí comhordú a dhéanamh ar líonra forfheidhmithe náisiúnta, díriú isteach ar chiontóirí, stiúradh fiosrúcháin agus maoirsiú leigheas na bhfadhbanna.
- An dlí a chur orthu siúd a bhriseann dlí comhshaoil agus a dhéanann dochar don chomhshaol mar thoradh ar a ngníomhaíochtaí.

MONATÓIREACHT, ANAILÍS AGUS TUAIRISCIÚ AR AN GCOMHSHAOL

- Monatóireacht ar chaighdeán aeir agus caighdeáin aibhneacha, locha, uiscí taoide agus uiscí talaimh; leibhéil agus sruth aibhneacha a thomhas.
- Tuairisciú neamhspleách chun cabhrú le rialtais náisiúnta agus áitiúla cinntí a dhéanamh.

RIALÚ ASTUITHE GÁIS CEAPTHA TEASA NA HÉIREANN

- Cainníochtú astuithe gáis ceaptha teasa na hÉireann i gcomhthéacs ár dtiomantas Kyoto.
- Cur i bhfeidhm na Treorach um Thrádáil Astuithe, a bhfuil baint aige le hos cionn 100 cuideachta atá ina mór-ghineadóirí dé-ocsaíd charbóin in Éirinn.

TAIGHDE AGUS FORBAIRT COMHSHAOIL

- Taighde ar shaincheisteanna comhshaoil a chomhordú (cosúil le caighdéan aeir agus uisce, athrú aeráide, bithéagsúlacht, teicneolaíochtaí comhshaoil).

MEASÚNÚ STRAITÉISEACH COMHSHAOIL

- Ag déanamh measúnú ar thionchar phleananna agus chláracha ar chomhshaol na hÉireann (cosúil le pleananna bainistíochta dramhaíola agus forbartha).

PLEANÁIL, OIDEACHAS AGUS TREOIR CHOMHSHAOIL

- Treoir a thabhairt don phobal agus do thionscal ar cheisteanna comhshaoil éagsúla (m.sh., iarratais ar cheadúnais, seachaint dramhaíola agus rialacháin chomhshaoil).
- Eolas níos fearr ar an gcomhshaol a scaipeadh (trí cláracha teilifíse comhshaoil agus pacáistí acmhainne do bhunscoileanna agus do mheánscoileanna).

BAINISTÍOCHT DRAMHAÍOLA FHORGHNÍOMHACH

- Cur chun cinn seachaint agus laghdú dramhaíola trí chomhordú An Chláir Náisiúnta um Chosc Dramhaíola, lena n-áirítear cur i bhfeidhm na dTionscnamh Freagrachta Táirgeoirí.
- Cur i bhfeidhm Rialachán ar nós na treoracha maidir le Trealamh Leictreach agus Leictreonach Caite agus le Srianadh Substaintí Guaiseacha agus substaintí a dhéanann ídiú ar an gcrios ózóin.
- Plean Náisiúnta Bainistíochta um Dramhaíl Ghuaiseach a fhorbairt chun dramhaíl ghuaiseach a sheachaint agus a bhainistiú.

STRUCHTÚR NA GNÍOMHAIREACHTA

Bunaíodh an Ghníomhaireacht i 1993 chun comhshaol na hÉireann a chosaint. Tá an eagraíocht á bhainistiú ag Bord lánaimseartha, ar a bhfuil Príomhstiúrthóir agus ceithre Stiúrthóir.

Tá obair na Gníomhaireachta ar siúl trí ceithre Oifig:

- An Oifig Aeráide, Ceadúnaithe agus Úsáide Acmhainní
- An Oifig um Fhorfheidhmiúchán Comhshaoil
- An Oifig um Measúnacht Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáide

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag ball air agus tagann siad le chéile cúpla uair in aghaidh na bliana le plé a dhéanamh ar cheisteanna ar ábhar imní iad agus le comhairle a thabhairt don Bhord.

Science, Technology, Research and Innovation for the Environment (STRIVE) 2007-2013

The Science, Technology, Research and Innovation for the Environment (STRIVE) programme covers the period 2007 to 2013.

The programme comprises three key measures: Sustainable Development, Cleaner Production and Environmental Technologies, and A Healthy Environment; together with two supporting measures: EPA Environmental Research Centre (ERC) and Capacity & Capability Building. The seven principal thematic areas for the programme are Climate Change; Waste, Resource Management and Chemicals; Water Quality and the Aquatic Environment; Air Quality, Atmospheric Deposition and Noise; Impacts on Biodiversity; Soils and Land-use; and Socio-economic Considerations. In addition, other emerging issues will be addressed as the need arises.

The funding for the programme (approximately €100 million) comes from the Environmental Research Sub-Programme of the National Development Plan (NDP), the Inter-Departmental Committee for the Strategy for Science, Technology and Innovation (IDC-SSTI); and EPA core funding and co-funding by economic sectors.

The EPA has a statutory role to co-ordinate environmental research in Ireland and is organising and administering the STRIVE programme on behalf of the Department of the Environment, Heritage and Local Government.

Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

ENVIRONMENTAL PROTECTION AGENCY
PO Box 3000, Johnstown Castle Estate, Co. Wexford, Ireland
t 053 916 0600 f 053 916 0699
LoCall 1890 33 55 99
e info@epa.ie w http://www.epa.ie

SSTI Strategy for Science, Technology and Innovation

Comhshaol, Pobal agus Rialtas Áitiúil
Environment, Community and Local Government