CENTRE FOR REMANUFACTURING & REUSE

Thought leadership

A description of the design for end-of-life process

A report prepared for the CRR by

Contents

1 Introduction

Global environmental challenges are making it necessary for all organisations to reduce the environmental impacts of their products, whilst maintaining profit margins. Landfill and recycling, currently the most common EoL (End-of-Life) practices are short-term solutions that overlook the potential for long-term gains. Additionally, legislative factors, such as the WEEE (Waste Electronic and Electrical Equipment) directive are changing the nature of production by making the producer bear the cost of treating EoL products.

Consideration of the residual value of products at EoL, in combination with LCT (Lifecycle Thinking), can provide opportunities for business development, generate increased profits, reduce environmental impacts and increase employment.

Designers and engineers are rarely trained in the consideration of EoL strategies. This guidance will provide designers and engineers with accessible information on EoL treatments. It should be noted however, that the document has been written for readers with a basic understanding of the issues of sustainability and lifecycle thinking.

1.1 Objectives

The objectives of this document are to:

- Describe the possible treatments for EoL products
- Describe the process of deciding the appropriate EoL treatment for a product
- Illustrate design strategies to optimize the EoL treatment of a product

1.2 Who will use this document?

This guidance will be useful to all employees working for organisations involved in the design and manufacture of products, but particularly designers and engineers. This guidance will offer most benefit to users with little or no training (either formal or through professional experience) in the consideration of EoL. It will be relevant to designers and engineers within the following types of organisation:

- Manufacturers with established product ranges and business models, not already designed to optimise EoL
- Design consultancies and manufacturers with little or no experience in the consideration of EoL

- Organisations without CSR departments to advise on EoL strategies. This will be particularly applicable to SMEs

This guidance is primarily intended for users in the following roles:

- Design (in-house or consultant)
- Design management
- Engineering/manufacturing

The guidance may be also directly or indirectly useful to those in areas of product development e.g. marketing, planning and business development.

2 Introducing the different treatments for EoL products

There are numerous strategies for the treatment of EoL products. A list of the potential options for the treatment of EoL products is shown below, in order of the perceived quality that is imbued during the EoL process.

- Remanufacturing
- Repurposing/refurbishing
- Reuse
- Repair
- Recycling
- Composting
- Incineration
- Landfill

This section describes these EoL treatments and gives an overview of the potential benefits and disadvantages of each. The strategies for maximising the net benefits (financial, environmental and social) obtained through each EoL treatment are also discussed.

2.1 Remanufacturing

Definition: The process of returning 'a used product to at least its original performance with a warranty that is equivalent or better than that of the newly manufactured product'.

Source: BS 8887-2:2009.

2.1.1 The product types that may be suitable for remanufacturing

The product types that may be suitable for remanufacturing will generally:

- Have low technological obsolescence
- Have a high inherent material value and production cost

- Be sold in a market tolerant of as-new products
- Be feasible to collect at EoL
- Contain a durable core* which can be reused many times
- Have the potential for disassembly down to component level

*the term ‘Core’ is commonly used to describe the component or product that will be retained through the remanufacturing process.

Source: “Remanufacturing and Product Design”, The Centre for Sustainable Design, 2007.

2.1.2 The main benefits and disadvantages of remanufacturing

Benefits	Disadvantages
Ability to charge an as-new price, whilst benefiting from reduced production costs and reduced environmental impacts	Only suited to products with specific characteristics
New business models based on Product Service Systems (PSS)	Product must be disassembled down to component level
Increased skilled employment	Significant time and financial investment to set up the system

2.1.3 The main challenges to remanufacturing and strategies for optimisation

Challenge	Optimisation strategy
Customer perceptions of quality	Offer appropriate guarantees
Levels of Core return	Build Core return into the business model (via lease or financial incentives)
Unknown Core quality	Incorporate wear markers into the product

2.2 Reconditioning/Refurbishing

Definition: The process of returning 'a used product to a satisfactory working condition by rebuilding or repairing major components that are close to failure, even where there are no reported or apparent faults in those components'

Source: BS 8887-2:2009.

2.2.1 The product types that may be suitable for reconditioning/refurbishing

The product types that may be suitable will generally:

- Have low technological obsolescence
- Have a high inherent material value
- Be sold in a market tolerant of second-life products
- Be feasible to collect at EoL
- Have the potential for disassembly down to sub-assembly level

2.2.2 The main benefits and disadvantages of reconditioning/ refurbishing

Benefits	Disadvantages
Reduced production costs and environmental impacts as only parts which require attention are remediated	Limited warranty and lack of standardised terminology leads to concerns over quality
New business models based on Product Service Systems	Market size is small compared to the market for new products
Increased skilled employment	Aesthetics of product may not be as-new

2.2.3 The main challenges to reconditioning/refurbishing and strategies for optimisation

Challenge	Optimisation strategy
Perceptions of quality	Give appropriate guarantees
Levels of Core return	Build core return into the business model (via lease or financial incentives)
Some faults may remain undetected after testing	Increase durability and reduce complexity of disassembly and testing

2.3 Reuse

Definition: The process by which ‘a product or its components are put back into use for the same purpose at EoL’

Source: BS 8887-2:2009.

2.3.1 The product types that may be suitable for reuse

The product types that may be suitable for reuse will generally:

- Have low technological and aesthetic obsolescence
- Be sold in a market tolerant of second-life products
- Be feasible to collect at EoL for resale

2.3.2 The main benefits and disadvantages of reuse

Benefits	Disadvantages
Little or no remediation required	Only appropriate for products with very low technological and aesthetic obsolescence
Minimal production costs and reduced environmental impacts	Concerns over quality and fitness for purpose
New business models based on PSS	Some faults may remain undetected during testing

2.3.3 The main challenges to reuse and strategies for optimisation

Challenge	Optimisation strategy
Technological and aesthetic obsolescence	Design product for easy upgrade and repair
Limited markets	Market to less technologically advanced global regions
Some faults may remain undetected after testing	Increase durability and reduce complexity of disassembly and testing

2.4 Repurposing

Definition: The process of 'utilising a product or its components in a role that it was not originally designed to perform.'

Source: BS 8887-2:2009.

2.4.1 The product types that may be suitable for repurposing

The product types that may be suitable for repurposing will generally:

- Have modular functionality (so that functions unnecessary in the new purpose can be easily disabled)
- Have multiple functions
- Support standard interfaces (e.g. USB for computing)
- Be controlled by a software based operating system (e.g. Symbian operating system for mobile phones)

2.4.2 The main benefits and disadvantages of repurposing

Benefits	Disadvantages
Can provide a novel market for outdated technologies and aesthetics	Difficulty of identifying appropriate markets
May require little or no remediation	Concerns over quality and fitness for purpose
Reduced environmental impacts of production	Legislation may be different in new product sector

2.4.3 The main challenges to repurposing and strategies for optimisation

Challenge	Optimisation strategy
Likely need for cross-sector partnerships in establishing new product	Create partnerships through industry bodies and networking hubs
Predicting possible second life uses during original design	Design product for easy upgrade and repair
Some faults may remain undetected after testing	Increase durability and reduce complexity of disassembly and testing

2.5 Repair

Definition: The process of returning 'a faulty or broken product or component back to a usable state'

Source: BS 8887-2:2009.

2.5.1 The product types that may be suitable for repair

The product types that may be suitable for repair will generally:

- Have a high inherent value (either financial or sentimental)
- Have high initial cost
- Be difficult or impossible to replace
- Contain components that can be replaced (via non-destructive means)

2.5.2 The main benefits and disadvantages of repair

Benefits	Disadvantages
Strong but small market for repair of products that cannot be easily replaced	No large scale systems in place for repair therefore costs may be high.
Increased local skilled jobs	Concerns over quality and fitness for purpose
Reduced environmental impacts of production	Product likely to command a low resale value

2.5.3 Challenges to repair and strategies for optimisation

Challenge	Optimisation strategy
Relatively small market for repaired products	Design business model with incentives for repair. Rebrand 'repair'.
High costs of one-off repair	Design product for easy upgrade, disassembly and repair by non-specialists.
Some faults may remain undetected after testing	Increase durability and reduce complexity of disassembly and testing

2.6 Recycling

Definition: The processing ‘of waste materials for their original purpose or for other purposes, excluding energy recovery’

Source: BS 8887-2:2009.

2.6.1 The product types that may be suitable for recycling

The product types that may be suitable for recycling will generally:

- Contain components not suitable for more profitable reuse strategies
- Contain components made from materials that are recyclable and that can be collected at EoL for recycling
- Be constructed from a single or few separable materials
- Have the potential for disassembly down to component level
- Contain high value materials (and in large enough quantity to enable cost effective extraction)

2.6.2 The main benefits and disadvantages of recycling

Benefits	Disadvantages
OEMs' recovery obligations relatively easy to meet through recycling	May not meet increasing producer responsibility obligations
Positive branding opportunities due to widespread knowledge of recycling	Quantity of recyclate is often higher than demand
Diverts material from landfill and reduces production of virgin materials	Mass recycling of mixed waste can lead to contamination and quality variations

2.6.3 The main challenges to recycling and strategies for optimisation

Challenge	Optimisation strategy
Correct collection and separation of recyclable materials	Design for easy disassembly and/or sorting by householders and apply appropriate labelling
Contamination of materials	Specify single material types or compatible materials (when recycled together)
Low market value for recyclates	Specify recycled materials to create demand for recyclates

2.7 Composting

Definition: The process of converting organic matter (via controlled aerobic decomposition) to create a soil additive which improves soil structure and provides nutrients for plants. This may be undertaken domestically or at a municipal site.

2.7.1 The product types that may be suitable for composting

The product types that may be suitable for composting will generally be wholly made from:

- Organic or certified compostable materials
- Materials which will compost in 3 years or less (for domestic composting)
- No synthetic adhesives and material coatings that could potentially contaminate compost

2.7.2 The main benefits and disadvantages of composting

Benefits	Disadvantages
Domestic composting avoids financial cost of waste disposal & transport impacts at EoL	Compostable materials require specific environmental conditions to decompose (air, water, bacteria)
Sale of compost can offset a portion of collection costs (municipal composting)	Difficult to prevent contamination with non-compostable materials
Use of plant-based compostable biopolymers reduces reliance on crude oil	Relative environmental benefits compared to non-compostable materials are not yet clear

2.7.3 The main challenges to composting and strategies for optimisation

Challenge	Optimisation strategy
Preventing non-compostable materials from entering composting stream	Correctly label product and packaging. Design for easy separation of non-compostable material from product
Lack of composting facilities accredited to PAS 100	Design products for both composting and recycling
Preventing compostable materials being sent to landfill	Consider appropriateness of specifying a compostable component, given the likely EoL treatment of the product.

2.8 Incineration (with energy recovery)

Definition: The process of combustion of organic waste materials to generate electric power (or combined heat and power)

2.8.1 The product types that may be suitable for incineration

The product types that may be suitable for incineration will generally:

- Be products for which no other higher value EoL option is currently feasible and for which landfill is undesirable
- Have primarily organic (containing carbon) components with little heavy metal content

2.8.2 The main benefits and disadvantages of incineration

Benefits	Disadvantages
Heat and power generation can subsidise the treatment of waste	Toxic ash produced is hazardous to human health
Relatively low land use	Removes the major driver for the development of clean technologies
Reduces the volume of the original waste by up to 95%	Expert and local community concerns about the environmental impact of incineration

2.8.3 The main challenges to incineration and strategies for optimisation

Challenge	Optimisation strategy
Emissions and hazardous waste materials	Specify organic materials with little or no heavy metal content
Quantity of waste material	Create markets for recyclate and lightweight your products
Opposition to incineration	Specify recycled, compostable and recyclable materials

2.9 Landfill

Definition: The process of disposing of waste by burial

2.9.1 The product types that may be suitable for landfill

The product types that may be suitable for landfill will generally:

- Contain inert, non-toxic materials
- Not contain electronics (WEEE) or other regulated components/materials
- Be products for which no other EoL treatment is currently feasible

2.9.2 The main benefits and disadvantages of landfill

Benefits	Disadvantages
Existing infrastructure	Valuable resources (such as copper and aluminium) are not reused/recycled
Convenience	Potential water pollution and soil contamination
Possibility of future gas harvesting and landfill mining	Increasing costs of landfill taxes

2.9.3 The main challenges to landfill and strategies for optimisation

Challenge	Optimisation strategy
Lack of space	Design to encourage other EoL strategies
Quantity of waste material	Create markets for recyclate and lightweight your products
Valuable resources (such as copper and aluminium) are not recycled	Correctly label product and packaging. Design for disassembly, reuse and recycling

3 How to design products and associated business models optimised for EoL

Apart from when used to comply with environmental legislation, design for EoL is often considered as outside the remit of conventional design. However, there are significant financial, environmental and social benefits obtained through the consideration of EoL during the design of products and associated business models.

Although producers can have influence over the outcome, through appropriate design of the product and supporting business model, it is the end-user (an individual or business), not the producer who actually determines the EoL treatment a product is subject to. It is therefore the designer's and product development engineer's role to:

- Gain knowledge of EoL treatments in order to decide which is the most appropriate for their product
- Influence the EoL decisions made by end-users through appropriate product and business model design
- Ensure that the product they design is optimised for the chosen EoL treatment (and to a lesser extent the other possible EoL treatments that the product may be subject to)

This section describes the process of designing for EoL. To simplify the process it has been split into three sequential phases:

- Project set up
- Design
- Presentation.

However, the processes within each phase, and the order in which they are undertaken, will differ depending on the:

- Organisation
- Organisation's priorities
- Organisation's product(s)
- Time available for consideration of EoL within design activities

3.1 Project set up

To enable designers and engineers to engage in design for EoL, it must be written into their design brief. For this to occur in a commercial organisation a business case must be made and stakeholder buy-in achieved. These activities all happen within the project set up phase.

3.1.1 Understand EoL treatments and terminologies

The design team must gain a broad knowledge of the various EoL treatments. Additionally, it must identify the processes a product will be subject to, during each treatment.

During the design project it is important that the whole team is using a standard set of EoL terminologies. Therefore, the terminologies to be used within the project must be defined during the project set up. A definition of each EoL treatment is given in section 2 of this document.

Recommended tasks:

- Researching the various EoL treatments (and the processes within them)
- Investigating the potential benefits, disadvantages and design implications of each EoL treatment
- Preparing a document listing the standard set of EoL terminologies to be used by the project team

3.1.2 Understand the organisation and its needs

An in-house design team should already have a good understanding of their organisation. An external design consultancy will have to conduct a short research phase to gather the required information. Some of the details about the organisation that should be researched are:

- Current and prospective products
- Current and prospective markets
- Management structure
- Geographic locations of its operations and markets
- Business drivers, objectives and (future) legal obligations
- Structure and systems
- CSR policies

- Current EoL strategies
- Competitors and partners

An organisation will have many needs. Many of these needs can be met by considering and implementing an appropriate EoL strategy. A selection of these needs is listed below:

The need to exploit financial opportunities (and manage constraints)

- Serving new markets and exploiting new opportunities (e.g. eco products)
- Reducing the impact of increases in energy and resource prices (by increasing resource efficiency)
- Forging closer relationships with existing customers (via service systems)

The need to satisfy and publicise CSR

- Benefiting from carbon trading
- Meeting internal targets for carbon/waste reduction
- Creating opportunities for green marketing

The need to ensure Legislative compliance

- WEEE, ELV, RoHS etc

The need to adapt to changing operating conditions

- Scarcity of resources
- Reducing impact of the increasing landfill taxes

As well as identifying the needs of the organisation the needs of its stakeholders and markets must also be examined.

Recommended tasks:

- Conducting background research on the organisation
- Analysing current products and business models
- Identifying the organisations drivers and objectives
- Competitor analysis
- Identifying the needs of the organisation, its stakeholders and markets

3.1.3 Conduct a scoping study to identify opportunities for changing the organisation's EoL strategies (and applicable EoL treatments)

Before writing a formal brief, it is useful to conduct a scoping study to investigate the opportunities for changing EoL strategy within the organisation. Additionally, this study will identify applicable EoL treatments that the organisation can implement to exploit these opportunities. This approach is particularly useful when an organisation is actively considering EoL for the first time. The study will usually involve a short financial and environmental analysis to compare all possible EoL strategies, using indicative tools. The result of the study will be a list of appropriate/feasible EoL treatments to take forward into the design project as well as detailed research on the processes involved within each of those EoL treatments.

Recommended tasks:

- Identifying the organisations current EoL strategy through research
- Identifying opportunities to improve EoL strategy through analysis of current strategies
- Determining the appropriate EoL strategies to adopt, in order to exploit opportunities for change
- Analysis of indicative financial and environmental assessments
- Conducting research to understand the processes involved in the EoL treatments relevant to the design project

3.1.4 Identify stakeholders and gain their support

It is necessary to cooperate with a number of different stakeholders to change an organisation's EoL strategy. It is essential that there is support for rethinking EoL strategies within the organisation. Additionally, gaining support from stakeholders

external to the organisation may also be necessary. To gain stakeholder support it is first necessary to determine who the relevant stakeholders are, then what their needs are, and finally how those needs can be met.

Recommended tasks:

- Identifying relevant stakeholders (internal and external)
- Investigating the needs of stakeholders
- Identifying how to meet those needs
- Presenting to stakeholders to gain support

It will be helpful to create a table similar to that shown below to organise the information about relevant stakeholders (only a selection is shown below):

Relevant stakeholder	Role in EoL strategy	Needs	Strategies to meet those needs
Finance Department	Funding	Rough financial costings and ROI (Return on Investment) data	Prepare costings and RoI
Marketing Department	Communicating CSR benefits and exploiting positive marketing opportunities	Indicative CSR benefits	CSR benefits and simple environmental assessment data
Retailers	Sale/leasing model. Returns and Core Collection	Simple system of return and core collection	Involve retailers in business model development

3.1.5 Discuss potential projects and set the brief

Ideas for potential projects should be brainstormed, discussed and developed. Discussion during this phase should be driven by the opportunities for changing EoL strategies and applicable EoL treatments identified in the scoping study (4.1.3). At this stage a draft project plan should be written and should include the time-frame, tasks, deliverables and indicative costings.

A brief should then be written and include guidance to the designer such as:

- Scope of the project (whether it covers a product, a range of products or all of the organisations products)
- Priorities for improvement
- Level of detail required
- Expected deliverables

3.1.6 Secure project funding and resources

Funding sources for the project must be identified and secured. The project may be funded internally, by assigning existing employees and funds to the project. However, the organisation may lack the experienced staff, capacity or finance to fund the project (and the organisation may also not see EoL as a strategic priority). In this case external funding will have to be sought and should it be necessary, appropriate partnerships secured to obtain collaborative funding.

Recommended tasks:

- Estimate the level of funding and resources required for the project
- Researching and identifying appropriate funding sources (should internal funding/resources not be available)
- If appropriate identifying partnerships to obtain collaborative funding
- Securing appropriate stakeholder support for the application
- Submitting applications for external funding

3.2 Design (product and business model development)

The basic design for EoL methodology is to understand the brief, conduct appropriate research, generate concepts and develop them into detailed designs. Indicative financial and environmental benefits should be calculated to guide concept selection. During the design phase, concepts and progress reports will be presented to different stakeholders including marketing, operations and business development.

The processes undertaken in the design of new products and the redesign of existing products will be different. The freedom to make changes is often limited when redesigning existing products for EoL as there are numerous constraints such as existing tooling, infrastructure, business models, markets etc. Conversely, when designing new products for EoL, too much time can be consumed investigating all the possible scenarios and options. One strategy to combat this is to select a product similar to the one being designed (a previous generation, a competitor's product, or a product with similar attributes) and

business model to obtain an indication of areas for improvement. The following process will help ensure the best design resolution is achieved, whether you are designing a new product, or redesigning an existing one:

3.2.1 Establish the current EoL treatment for each product component

- **Inventory of EoL treatments** – Create an inventory of all components in the product. Establish the current EoL treatment for each component and identify the stakeholders involved.

3.2.2 Establish the impacts of current EoL treatment for each product component and identify areas for improvement

- **Identify impacts –** Lifecycle thinking (LCT) should be used to identify and understand the impacts (financial, environmental and social) associated with the current EoL treatments. The impacts of the product and associated business model, over its whole lifecycle must be considered. Also the time spans over which the impacts occur should be established.

- **Assess the effects on the organisation –** Consider the impacts identified by the LCT and establish the effect they will have on the organisation and its objectives (e.g. reducing costs, increasing income, reducing environmental impacts).

- **Prioritise areas for improvement -** Identify impacts in the inventory list that have the largest negative effect (financial, environmental etc) on the organisation and its objectives.

3.2.3 Design strategies

Design strategies such as user research, brainstorming, and system modelling can be used to optimise the product for the processes it will undergo during EoL treatment. It may be useful to identify and consult with organisations that have already implemented the relevant EoL treatment(s) to aid system development.

Many design strategies are useful in the design for EoL process. A selection of design for EoL strategies and potential design modifications to implement those strategies is shown below:

Communication (to inform users and facilitate EoL treatments)

- Place material identification information on all components

- Communicate the intended method of core return and user incentives
- Place graphical information about intended EoL treatment on the product and packaging
- Produce open-source design specifications for the product

Design for disassembly

- Minimise number of components
- Specify reversible fastenings
- Consider ergonomic factors e.g. finger size
- Incorporate Active Disassembly

It is useful to structure the design for EoL process. A practical way of achieving this is to:

- Break down the chosen EoL treatment into individual processes
- Use design strategies to produce a number of designs to optimise each individual process
- Collect and compare the all designs to find similarities and conflicts
- Combine the designs to create design concepts

Design for efficient logistics

- Lightweighting
- Protective packaging
- Produce tessellating/stackable packaging
- Specify localised production and EoL treatment (closed loop)
- Incorporate tracking devices (RFID etc) into components

Design for durability and longevity

- Provide extra protection for fragile and valuable components
- Specify durable finishes (Scratch/scuff resistant casing)

Design for easy cleaning and testing

- Design for multi-stage disassembly and cleaning

Design for modularity and component reuse

- Understand the next generation of the product (functions and features it requires)

Product Service Systems

- Build product into a service system that ensures it is returned for EoL processing

Material specification

- Specify materials and components with an appropriate durability (based on business model)
- Avoid specification of harmful materials that may be exposed during disassembly or reprocessing
- Specify recyclable materials and recycled content
- Reduce the number of different materials used in the product

User-centred design

- Understand user behaviour using questionnaires and observations
- Predict user behaviour to design product, business model and specify materials accordingly

Consult with re-processors (remanufacturers, recyclers etc)

- Consult and co-design with re-processors at the beginning of the design process

It is important when making design modifications to consider which EoL treatments will be affected by the modification. Examples of design modifications, and the relevant EoL treatments they will affect are shown below:

Design Techniques	EoL treatment affected					
	Remanufacturing	Reconditioning	Reuse	Repurposing	Repair	Recycling
Improving product labelling	●	●	●	●	●	●
Specifying recyclable materials	●	●		●	●	●
Specifying recycled content						●
Reducing no. of different mat'ls used						●
Design for disassembly	●	●	●	●	●	●

Lightweighting*	●	●	●	●		
Designing components for durability	●	●	●	●	●	
Design for easy cleaning and testing	●	●	●	●	●	
Offering incentives for Core return (business model design)	●	●	●	●	●	
Reducing number of components	●	●		●		
Localised production and EoL treatment (closed loop)	●	●	●	●	●	●
Design for modularity	●	●		●	●	

*Lightweighting must be dealt with carefully to ensure it does not have adverse impacts e.g. reducing the material used within a product may reduce its robustness for multiple cycles of use.

3.3 Presentation

Along with the standard design outcomes, presented via visualisations and concept boards (specifications, scenarios, features etc), there are additional elements, resulting from the design for EoL activities, which must be communicated. These are explained in the following sections:

3.3.1 Communication of business model and EoL system design

The business model and EoL system design need to be communicated clearly to gain stakeholder support. Graphical representations of system concepts (via flow charts for example) and EoL scenarios will aid understanding. To help audiences understand the EoL system concepts and to relate to them, fictional (yet realistic) user scenarios can be created.

3.3.2 Communication of quantitative assessment results

The results of any quantitative assessments conducted for the product and business model concepts can be used to highlight the tangible benefits to the organisation. Quantitative analysis techniques include simple LCA (Life Cycle Assessment) and RoI calculation.

LCA can be used to show the reduction in environmental impacts achieved by adopting the new product design and business model, in comparison to the baseline product. A RoI calculation is used to show how much financial benefit the organisation will receive by adopting the new product design and business model over a given period of time, in comparison to the baseline product.

The baseline product can be a previous generation of the product, a competitor's product, or a product that performs the same function. The baseline product should be decided at the beginning of the assessment and the same baseline should be used for both the environmental and financial assessments.

Where the product is reused (either whole or in part) the assessments should account for all the impacts and benefits associated with the multiple lifecycles of the product, over a given period of time. These impacts and benefits should then be compared against those of the baseline product over the same period of time. The period of time should be chosen to represent a set number of product users or lives, to aid understanding.

The assessment results should be communicated in an appropriate way for the audience i.e. abstract statements such as "2,345kg of CO_2-Eq emissions" can be confusing and therefore ineffective for non-specialist audiences.

3.3.3 Identifying practical next steps

In-house design teams will have established mechanisms for commercialising designs. Consultancies however may find it useful to work with their clients to seek further collaborators and funding streams to commercialise projects. Methods to implement the product design and business model must also be developed and communicated.

4 Conclusions

4.1 The design for EoL process

It is important to recognise that although producers can have influence over the process, it is the end-user (an individual or business), not the producer who actually determines the EoL treatment a product is subject to. It is therefore the designers' and product development engineers' role to increase their influence over the EoL decisions end-users make and design products optimised for their intended EoL treatment. The design for EoL process can facilitate both of these activities. This document has broken down the process of design for EoL into three stages: project setup, design and presentation. The key steps within each stage have been identified as:

Project setup

- Gaining knowledge of EoL treatments
- Standardising EoL terminologies across the design team and other stakeholders
- Identify opportunities for adopting alternative EoL strategies
- Securing project funding and resources

Design

- Establishing the current EoL treatment for each product component, its impacts and areas for improvement
- Selecting an appropriate EoL treatment for the product, based on the company priorities
- Breaking down the selected EoL treatment into individual processes and using design strategies to produce designs that optimise each individual process
- Combining those designs to create product and business model concepts

Presentation

- Communication of business model and EoL system design
- Communication of quantitative assessment results
- Identifying practical next steps

4.2 Recommendations/guidance

Increase EoL knowledge amongst designers and engineers

In order to effectively design for EoL designers and engineers must have knowledge of the processes involved in common EoL treatments. An EoL reference resource for designers and engineers is needed. This resource (within a book or website) could give a detailed explanation of the processes involved in each of the common EoL treatments, and the problems associated with them.

Relate design for EoL information to real examples

It is challenging to explain to designers the steps involved in the design for EoL process, without them being related to the design of an actual product. Understanding of the steps could be facilitated by relating them to the design of a real or fictional (yet realistic) product. This would be particularly useful to describe how elements of the product and business model design interact and complement each other.

Improve design for EoL tools

An EoL decision making tool would be using in choosing the most appropriate EoL treatment for an existing product . A simple tool/flowchart is needed (possibly building on CRR's draft tool) that asks a series of questions about a product or component to determine the EoL that is most suitable. This may be best resolved as an interactive, online tool.

Generate/provide case studies

A body of case studies of existing successful EoL strategies and systems is needed to facilitate research and increase knowledge transfer. A database of case studies should be created and made accessible to design teams engaged in design for EoL.

Provide design for EoL training

Training exercises and workshops for designers and engineers engaged in design for EoL could compliment any guidance produced.

View design for EoL as just one part of the design process

Whilst for the sake of clarity this document has focussed on design for EoL, this is just one strategy of maximising value that must be balanced with other product considerations and design techniques. The time given to design for EoL will depend on the company's priorities. Case studies, as mentioned above, can help to increase the importance given to design for EoL.