Investigation of commercial remanufacturing business models and complementary product design for a Mobile Broadband handset

Final Report
1 Executive Summary

This Feasibility Study investigates the methods and potential financial and environmental benefits of remanufacturing Exoteq’s second generation Mobile Broadband handset Meos within a planned two-tier lease business model. In addition, this study indicates the financial investments required to implement a remanufacturing system for the Meos handset.

The Design for Remanufacture process in this project was treated as a holistic design strategy. It incorporated elements such as: scoping study, business model ideation and development, conventional product design ideation and development, Design for Disassembly, Design for ‘Re’ and lifetime usage scenarios. The scoping study was a key document that was referred to throughout the project.

There is little reference data about Design for Remanufacture processes. This project aimed to put what theory there is into practice and this often required new process development. Challenges that were encountered during this process included establishing incentives for multiple stakeholders, generating feasible multiple-lifecycles and assessing these financially and environmentally.

To reduce the challenges of exploiting design concepts, Design for Remanufacture (much like conventional design) requires project needs and the required support from appropriate stakeholders to be established at the beginning of the process. This ensures that any investment in design will be meaningful and useful.

The processes carried out during this project resulted in numerous business model and product design concepts built around Exoteq’s leasing model, which protects Exoteq’s financial investment in the product and gives added customer service. The ‘DIY’ concept, inspired by the growing ‘Modding’ movement, allows technologically aware users to adapt the handset to perform functions not originally conceived or intended by the designer; components can be purchased online and unwanted components posted back for remanufacture. The ‘Post’ concept, which incorporates Active Disassembly to allow mechanical component separation, collects unwanted handsets using a credit card deposit and delivery-guarantee through the postal system. The ‘Modula’ concept allows users to choose different module configurations to customise the functions, aesthetic and ergonomics of the handset; unwanted modules are then collected for remanufacture at point-of-sale.

The Design for Remanufacture process can create added revenue streams but it is likely to require some additional investment in the design phase compared to the conventional product design process. It is difficult to develop generic information about this additional investment and return but as an example, this Meos G2 project has required approximately one third additional design investment, which if commercialised could result in increased profits of over 200%.

However, in order to realise the financial and environmental benefits of this investment in Design for Remanufacture for the second generation of Meos, Exoteq now need to identify and secure funding for the lease model.
2 Introduction

Remanufacturing can significantly reduce environmental impacts whilst generating profits. Consequently, remanufacturing presents an opportunity to break the unnecessary link between economic prosperity and environmental degradation.

2.1 Project Objectives

This feasibility study investigates the potential investments and returns of remanufacturing Exoteq’s second generation Mobile Broadband handset.

2.2 Exoteq & Meos

Founded in 2005, Exoteq are developing Meos, the world’s first Mobile Broadband handset. Exoteq is an international group with extensive experience in high-tech communication, entertainment and consumer electronic products.

Exoteq regard remanufacture as an ideal opportunity to comply with legislation whilst at the same time generating extra profits.

2.2.1 Meos Generation 1

Meos Generation 1 (Meos G1), seen in Figure 1, enables access to a high speed mobile internet connection within a citywide or nationwide wireless network. Features include a large high resolution screen for watching videos and browsing the Internet, a patented touchpad interface and a powerful ARM9 multimedia processor. Meos can also be used as a wireless broadband modem for desktop PCs or laptops via a mini USB connection.

Meos’ business model is built around a two-tier lease model whereby Exoteq lease Meos to Internet Service Providers (ISPs) who would in turn lease the product to the end users. In the best-case scenario, Exoteq estimate the end-user to use the handset for between 18 and 24 months.

2.2.2 Meos Generation 2

For the second generation of Meos (Meos G2), Exoteq wish to achieve a feasible and profitable business model with reduced environmental impacts. This Feasibility Study investigates the potential for remanufacture to achieve this.

2.2.3 Markets

Meos has two levels of customer through the two-tier lease model. A remanufactured Meos G2 will therefore need to satisfy the needs and be marketed to both of these levels:
1. ISP’s (marketed to by Exoteq)
2. End users (marketed to by ISP’s)

Interestingly, the two-tier lease model means that ISP’s do not need to buy handsets from Exoteq before leasing them to their customers. Therefore a significant advantage of the lease model is that ISP’s can increase their customer base through the product without the need for a large capital investment.

2.3 Location of Benefits

2.3.1 Financial
Primary financial benefits will accrue in England, where Exoteq are based.

2.3.2 Environmental
Meos’ production lifecycle occurs in different areas of the world, making environmental savings less simple than financial benefits to analyse. For example, waste reductions from End-of-Life (EoL) products will occur in England and other global markets and although manufacture will take place in Hong Kong the resultant production of gases contributing to climate change (namely CO₂) is a global issue.

These environmental impacts and any actions to significantly reduce them are governed by decisions made in England by Exoteq as a result of research and investments carried out in England. It is therefore reasonable to attribute environmental savings to England.

3 Design for Remanufacture

3.1 Introduction to Design for Remanufacture
Design for Remanufacture optimises the processes of remanufacturing to make business models more profitable, more feasible and therefore more likely to occur.

However, Design for Remanufacture is not just about the detailed product design. Particularly when designing with a company that has not previously been engaged in remanufacture, Design for Remanufacture requires the concurrent design of the business model and detailed product design.

3.2 The Design for Remanufacturing Process
There were numerous processes involved in Design for Remanufacture of Meos G2; the main activities are described below, along with their rationale.

3.2.1 Scoping Study
The Scoping Study identifies and investigates the issues and concerns to be dealt with during the project (see Table 1). In this way, it helps understand the brief, project planning and reduce project risks.
### Table 1. Scoping Study process focus and rationale

<table>
<thead>
<tr>
<th>Process Focus</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client (drivers, obstacles, history, incentives, internal and external stakeholders, pertinent supply chain issues, business strategy)</td>
<td>Understand the brief and how to overcome potential obstacles to innovation</td>
</tr>
<tr>
<td>Current Market (drivers, obstacles, history, incentives, stakeholders)</td>
<td>Understand the market and how to overcome potential obstacles to innovation</td>
</tr>
<tr>
<td>Potential Markets (new markets, recycling, reuse, repair, reconditioning, remanufacturing)</td>
<td>Identify new opportunities</td>
</tr>
<tr>
<td>Best Practice (activities, drivers, successes, obstacles)</td>
<td>Build on best practice</td>
</tr>
<tr>
<td>Legislative Factors (relevant legislation re. geography and activity, compliance requirements, reality of non-compliance, drivers, future legislation)</td>
<td>Understand the reality of relevant legislation to better understand client incentives</td>
</tr>
<tr>
<td>Potential Benefits (environmental and economic)</td>
<td>Focus activities on the major impacts</td>
</tr>
<tr>
<td>Collation</td>
<td>Effectively communicate the research</td>
</tr>
</tbody>
</table>

### Meos G2: Scoping Study Outputs

For the Meos G2 project, this phase resulted in a 65 page Scoping Study (Figure 2), which has been referred to throughout the subsequent project phases.

The Scoping Study identified key strategies specific to an electronic product such as Meos and the electronic product industry sector:

- **Design for Upgrade** - rapid technological obsolescence in this sector makes this a key design strategy; disassembly is an essential aspect of this.
- **Design for Disassembly** - allows cost-effective separation and access to electronic components.
- **Design for Re** - it is unlikely EoL scenarios can always be completely controlled due to changing economic, social and legislative factors. This means that although remanufacture may be the goal, in reality other elements ‘re’ strategies may be used to deal with the EoL handsets e.g. recycling, reconditioning. It is therefore prudent to optimise all these scenarios, for example to optimise recycling; this can be achieved by specifying recycling compatible materials for joined polymers, inks and coatings.
- **Reuse markets** - establishing reuse markets can help commercial reuse scenarios for components.
3.2.2 Concept Generation: Business Models and Product Design

This phase includes concept generation for both business model and product design concepts (Table 2). By generating new business model scenarios, new opportunities and methods can be identified and these can lead to new design solutions, and vice versa.

**Table 2. Concept generation process focus and rationale**

<table>
<thead>
<tr>
<th>Process Focus</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review of requirements</td>
<td>Ensures understanding &amp; focus</td>
</tr>
<tr>
<td>Business Model (BM) ideation</td>
<td>Generates BM ideas</td>
</tr>
<tr>
<td>Product Design</td>
<td>Generates design ideas that can result in new BMs</td>
</tr>
</tbody>
</table>

**Meos G2: Concept Outputs**

Review of the Scoping Study, brainstorming, discussion and sketching resulted in business model and product concept ideas for remanufacturing Meos G2 (illustrated in Figure 3).

3.2.3 Concept Selection: Business Models

After concepts have been generated, they need to be rated and selected according to the criteria identified at the start of the project. These are likely to include profit generation potential and in the case of Meos G2, environmental criteria (see Table 3).

Rating at this stage needs to be done quickly; simple guides and ‘rules of thumb’ are invaluable.

**Table 3. Business Model concept selection process and rationale**

<table>
<thead>
<tr>
<th>Activity Focus</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review of requirements</td>
<td>Ensures understanding &amp; focus</td>
</tr>
<tr>
<td>Evaluate BMs and select based on requirements (Quick LCA and Quick Profit Assessment)</td>
<td>Ensures BMs meet requirements and rates concepts</td>
</tr>
</tbody>
</table>
Meos G2: Quick-Decision Sustainability Tool

In order to help make focussed decisions quickly, Wax RDC have developed a simple tool that can rate concepts depending on their economic feasibility, customer satisfaction and environmental performance (see Figure 4). The tool’s criteria have been adapted according to the Scoping Study findings.

This resulted in 3 business models to take into the development phase.

3.2.4 Development: Business Models

The selected business models now need to be developed to build a greater understanding of their potential to meet requirements (Table 4). Specific aspects that need to be developed include:

- incentives
- core collection
- distribution
- sorting
- disassembly
- remediation
- assembly
- reuse markets
- retail & marketing

This phase also identifies the design implications for the product design.

Table 4. Business Model development process and rationale

<table>
<thead>
<tr>
<th>Activity Focus</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop selected BMs</td>
<td>Develops BMs to make them feasible</td>
</tr>
<tr>
<td>Establish BMs’ design requirements</td>
<td>Identifies design needs</td>
</tr>
<tr>
<td>Associate BMs and product design concepts</td>
<td>Utilises design ideas already generated</td>
</tr>
</tbody>
</table>

Meos G2: Business Model Development Tool

A tool can be useful in visually communicating the business model ideation and development. Wax RDC have developed a simple tool based on sale/distribution/use activities and remanufacturing processes (see Figure 5). Wax RDC used the tool with Exoteq to generate, develop and clarify feasible business model scenarios for Meos G2.
Having developed and clarified the 3 business models, it was then possible to associate aspects of the design ideas previously generated with each business model.

### 3.2.5 Development: Product Design

In addition to the conventional product design process, Design for Remanufacture is likely to entail designing to optimise particular remanufacturing processes. Those pertinent to the electronics industry in particular are listed in Table 5.

<table>
<thead>
<tr>
<th>Activity Focus</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review requirements</td>
<td>Ensures understanding &amp; focus</td>
</tr>
<tr>
<td>Design for Core Collection</td>
<td>Optimises process</td>
</tr>
<tr>
<td>Design for Disassembly (and Assembly)</td>
<td>Optimises process</td>
</tr>
<tr>
<td>Design for Remediation</td>
<td>Optimises process</td>
</tr>
<tr>
<td>Design for Upgrade</td>
<td>Optimises process</td>
</tr>
</tbody>
</table>
Meos G2: Product Design

Developing the concepts into feasible product designs involved further research, design and development including Computer Aided Design (CAD), model-making and rapid prototyping (see Figure 6).

3.2.6 Justification & Selection

To help decision-making, a more robust evaluation of designs than conducted previously in the process, is required. This will involve an evaluation of feasibility and assessment of potential profits, and may also include an environmental assessment. An overview of the process is shown in Table 6.

Table 6. Selection process and rationale

<table>
<thead>
<tr>
<th>Activity Focus</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit lifecycle assessment (not including data sourcing and collation)</td>
<td>Establishes financial benefits</td>
</tr>
<tr>
<td>Streamlined lifecycle assessment (not including data sourcing and collation)</td>
<td>Establishes environmental benefits</td>
</tr>
<tr>
<td>Collation</td>
<td>Enables results to be communicated effectively</td>
</tr>
<tr>
<td>Design Selection</td>
<td>Identifies a design with which to progress to commercialisation</td>
</tr>
</tbody>
</table>

Meos G2: Concept Evaluation

To establish the benefits of each business model/design, Wax identified responsibility and actions over the entire lifecycle of the product. Then, having identified the information required, Wax collected this data and collated it into a spreadsheet (see Figure 7).

The multiple-lives and lifecycles of a remanufactured product must be taken into account in the evaluation. Based on the information found during the Scoping Study and available environmental
assessment data, Wax simulated a reasonable lifecycle scenario over a 10 year period. The scenario included the potential production, usage, EoL and remanufacturing actions that would be taken according to each business model. To create a baseline for comparison of the Meos G2 concepts, Meos G1 was analysed based on the same 10 year scenario.

This resulted in figures for the financial benefits and environmental benefits over a 10 year period for each business model/design concept. The results of these evaluations can be seen in Section 6.

### 3.2.7 Business Development

In order to progress with selected business models and designs, it may be useful to identify external funding streams that will support commercial exploitation (see Table 7). This can be particularly useful for designs which deal with issues of strategic national importance, such as reducing environmental impacts.

**Table 7.** Business development process and rationale

<table>
<thead>
<tr>
<th>Activity Focus</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify funding opportunities</td>
<td><em>Identifies methods of commercialising designs</em></td>
</tr>
</tbody>
</table>

**Meos G2: Business Development**

Identifying potential sources of funding for Meos G2's lease model is a key activity for the business model development, with up-front funding required to finance manufacture and distribution. To do this, Wax RDC is using web-based search engines, current knowledge and contacts such as the Centre for Remanufacturing and Reuse (CRR) to identify funding streams for commercialisation of this work.
4 Design for Remanufacture Concepts

Exoteq are a new technology company, driven by innovation. However, Exoteq have made it clear throughout this process that the outcome of this project should be a ‘real world’ practical proposal for their second generation handset. So as well as being innovative the final concept has to be realistic, suitable for remanufacture and be positioned within a profitable remanufacturing business model.

Many of the ideas produced by the concept generation process were too ‘blue sky’ to be included in the concepts for development. One initial concept included using electronic paper as the screen for the handset. At EoL this screen could be switched to display the Core collection centre’s address and the handset could then be simply placed in the post, without the need for any extra packaging. Using a button in the user interface to trigger the automatic disassembly of the handset is another idea that surfaced many times during the concept generation process. Many of these concepts were rejected because the technology required to realise them was in a nascent stage of development. However, these ideas will hopefully resurface in the design of future Exoteq handsets. Although many novel ideas did not make it through the selection process, they definitely had a positive influence on the development of the chosen concepts.

The developed concepts, selected by the concept evaluation process are named Post, Modula and DIY. The Post concept is based on exploiting the existing postal infrastructure to transport handsets around the remanufacturing system. In the Modula concept users can choose different module configurations to customise the technology within their handset, as well as its look, feel and ergonomics. The DIY concept, gives users total freedom to change the functionality of their handset to suit their individual needs.

These three concepts allow the user varying degrees of engagement with the technology of the handset and with the remanufacturing process itself:

**DIY:** The DIY concept allows the user significant ownership of the remanufacturing process, whilst still protecting certain valuable components. DIY users would test their own faulty handsets, disassemble them and order new components where necessary. They can then fit these new components, reassemble and re-test the handset.

**Post:** Users of Post would be the least engaged in remanufacturing, compared to the other concepts. Post users order a new handset and it is sent to them the next day, the used one is then returned. The whole process is completely controlled by Exoteq. If necessary the handset is upgraded during the remanufacturing process, without the user being aware of it.

**Modula:** The user decides which modules to upgrade and changes the modules to customise the handset to their requirements.

4.1 Concept 1- DIY

The DIY concept empowers customers to understand and upgrade their own handset. Customers can test their faulty handsets, order replacement components either in-store or online and install them in the handset’s user accessible area. The use of Active Disassembly (AD) allows the most essential and valuable components to be protected from accidental damage through user interference.

DIY generates increased profits through upgrade and reduced cost of remanufacture. It results in increased longevity, giving positive environmental benefits.
**End Users:** Targeted end users are customers who are interested in technology and enjoy modifying and upgrading equipment such as computers to suit their needs. This handset reintroduces the once common concept of users repairing electronic products. This aims to reconnect users with the product; encourage the user to extend the product’s useful life; and counter the view that modern electronic goods are ‘throw away’ items.

### 4.1.1 Product Design - Inspirations

DIY’s main inspiration has been the home inkjet printer. Many of these printers have sealed units containing complex electro-mechanical parts, as well as a user accessible area to allow the replacement of ink cartridges. The printer manufacturers purposefully make the complex mechanism difficult to access by fitting Torx head screws and concealing fastenings. However, there is easy access to the printer cartridges and changing them is made as simple as possible.

Most mobile phones have a user serviceable area that enables access to the battery and SIM card. The DIY concept can be considered an extension of this idea. Many mobile phones also have fascias that can be changed to customise the look, and in some cases the feel, of the product.

Another inspiration for the DIY concept is the growing ‘Modding’ movement amongst technology users. ‘Modding’ is the term given to a piece of hardware or software that is modified by the user to perform a function not originally conceived or intended by the designer. ‘Modding’ is prevalent in the open-source software community; it is also a well-established phenomenon in the automobile and computer hardware sectors. The Holga camera is a good example of the ‘Modding’ of a consumer electronics product. This very basic camera from the 1980s has been modified by many different users to give it relevance today.
4.1.2 Product Design - Features

DIY's product design advantages for remanufacturing are:

- Single mechanical button
- Wide format touch screen
- Interchangeable textured and coloured back cover
- User serviceable area with removable components simply slot into the back cover.
- All plastics used are the same type
- Dual action snap fit Active Disassembly fastening
- Sealed 'core' unit housing the PCB and LCD

4.1.3 Product Design - Advantages for Remanufacturing

DIY’s product design advantages for remanufacturing are:
Increased process efficiency - Active Disassembly: The design of the mouldings enables a dual action AD fastening. The sealed ‘core’ unit and the back cover assembly will dissemble with a single stimulus. User-controlled variations in the configurations of handsets returning for remanufacture will not affect the disassembly process. Handsets can therefore be disassembled completely without manual pre-processing.

Increased process efficiency - Testing by user: Users can run basic tests on the handset by connecting it to their home computer via USB. This identifies the components that are faulty and the user can attempt a repair or request a new component from Exoteq. This reduces the time it takes for Exoteq to identify faults with the handsets on arrival at the remanufacturing facility.

Ensured component integrity - User serviceable area: The design allows easy access to the user serviceable parts whilst keeping the sensitive and valuable parts protected from user interference. This ensures that the PCB and LCD are protected during use, therefore assuring a consistently high quality Core is returning for remanufacture.

Simplified tracking - RFID: RFID tags on each of the main components allow the components to be tracked throughout the remanufacturing system. This is linked to the serial number on each component, entered onto the online system by the user before returning their handset for remanufacture.

Life extension - Updatable technology and styling: Components can be changed easily by users; therefore the handsets can always contain the most current technology. The back cover of the handset will be available in a variety of different colours and textures. Users can adapt their handsets according to their changing needs and technological requirements. These things combined will extend each handset’s useful life. Consequently, the core units returning for remanufacture will be slower to change; this means more investment can be made in handset specific automated disassembly equipment, reducing costs for Exoteq.

Better EoL information - User Interface: Information for users about the EoL process for the product can be accessed from within the handsets interface. If this cannot be accessed, due to a fault, the information is also contained in the user guide supplied with the handset. This will decrease the possibility of customers not knowing what to do with a handset at EoL, therefore increasing Core collection.

Better customer service - Simple returns procedure: Users can connect the handset to their home computer to automatically upload information (including the results of any tests carried out) to the returns website. Customers with functioning handsets would be directed through to the Exoteq remanufacturing website to fill in the returns forms through their handsets, others would be given the current Exoteq remanufacturing URL. This provides a useful service to the user, whilst providing Exoteq with valuable information about the condition of handsets returning for remanufacture.

Simplified assembly, disassembly and reassembly - Low complexity: The design uses a simple snap-fit construction; it uses no screws and has no mechanical buttons. This reduces significantly the complexity of the assembly, disassembly and subsequent reassembly of the handsets.

4.1.4 Business Model Inspirations

The business model for DIY has been inspired by existing practices. Mobile phone manufacturers, such as Nokia, produce replacement fascias and keypads for their products. When the phone’s fascia becomes scratched and worn users can simply replace the fascia to rejuvenate the product. Nokia markets this feature of their products as providing customers freedom of choice and it also highlights the potential of the product to change with fashions.
Desktop PC component manufacturers are encouraging ‘Modding’ of their equipment by producing computers with transparent cases so that the adapted components are clearly visible to others. Online companies such as Overclockers have taken advantage of the growing ‘Modding’ movement by selling components for the modification of computers as well as providing user guides for replacing and modifying systems.

4.1.5 Business Model - User Interaction

The remanufacturing business model has been built to work with the end users’ needs and behaviour, and thereby increase the likelihood of Core collection. Figure 8 illustrates the basic steps of the end users’ interaction with remanufacturing:

Purchase of new or remanufactured handset lease (1). Customers can choose each component individually for a completely customised handset or choose from a range of standard component configurations.

Handset becomes faulty/out of date. Users log on to the Exoteq remanufacturing website where, after registration, they can download the testing software (if needed).

Order replacement component (2). If the tests show that the issue is a fault with one of the components within the user serviceable area then users can order new components online. If there is a fault within the core unit then the unit must be returned to Exoteq for repair. In the case of an upgrade no testing before ordering is required.

Remove used component and fit new one (3&4). The component will arrive in a few days after the order is placed. The cover is removed, the old component pulled out and the new one slotted in. The testing program is run again to check that the handset now functions properly.

Return of faulty component (5). The used component is then packaged up in the reusable packaging, which the new component arrived in, and sent back to Exoteq.

Faulty components sorted & remediated (6). Using the information provided by the user on the Exoteq remanufacturing website, in combination with the test results submitted automatically by the software, the component can be sorted, disassembled and remediated.

Figure 8. DIY – user interaction with business model
4.1.6 Business Model - System

4.1.7 Business Model - Advantages for Remanufacturing

The business model of DIY has the following advantages for remanufacturing:
**Extension of life - Upgradeability.** As the key technology components can be replaced easily by users, Exoteq can release upgrades by simply making new components available. This platform approach to the design of components allows fast technological upgrade, whilst the core unit remains the same. This means less environmental impact as the core unit will have a much longer useful life.

**Simplified remanufacturing process - Testing/repair by users.** Users run tests to identify the components that are faulty; the user can then attempt a repair or request a new component from Exoteq. Component testing, disassembly, repair and replacement are all undertaken by the user. This means that the remanufacturing operations can be simplified, reducing investment and running costs for Exoteq.

**Incentive for Core return - Deposit.** Users receive new components for their handset before sending their old ones back to Exoteq. During the registration for the returns service, card details are required. If Exoteq do not receive the old components back within a specified time after sending the new components they will charge the user the full retail price of the new components sent. This provides the user with a real incentive for Core return, increasing Core collection, whilst at the same time offering a valuable service.

**Informed new product development - Failure rate information.** As part of the online returns process the users fill in an online returns form, they must input results from any tests undertaken and fill out a questionnaire about how the handset has been used. This detailed information about individual components and their failure rates can then be used to inform new product development (NPD). Components with unacceptably high failure rates can be redesigned completely.

**Reduction of transport - Component replacement.** In most cases components, rather than complete handsets, will be transported. Therefore the total amount of material being transported around the remanufacturing system will be minimised, reducing cost for Exoteq.

**Better service offering - Flexible (tailor-made) lease options.** Customers can choose between three lease options. A lease for the handset only, they would then have to pay for any components they need to replace (discounted on the return of any used components). The second is a lease which enables them to replace a fixed number of components for free each year. In the final option the customer can replace an unlimited amount of components for free during the life of the lease.

### 4.2 Concept 2 - Post

Post delivers absolute convenience to the customer, letting them order a replacement handset or upgrade from anywhere, at any time. Within a day, customers can receive an upgraded or replacement handset in the post and they can conveniently return their used handset using the pre-paid envelope, ensuring customer satisfaction and optimum Core collection.

Post allows for a substantial profit increase through emphasis on customer service combined with a simple and streamlined business model. Environmental impacts are radically reduced by reusing electronic components through significant AD and the inclusion of innovative ADBC technology (Active Disassembly using Bio Composites).

**End users.** Targeted users are modern consumers with busy lifestyles. They either do not have the time or inclination to actively engage with the remanufacturing process. The remanufacturing process is effectively hidden from the user. Consumers can continue using their electronic products in the same way they always have, enjoying the latest technology as it evolves, whilst at the same time becoming environmentally friendly, without necessarily being aware of it.
4.2.1 Product Design - Inspirations

Post is inspired by current products and business practices. For example, Xerox lease their photocopiers to businesses and can therefore take back and replace the copiers as and when required. The customer can rely on always having a serviced, working product. Whether it is a new or used machine becomes less important than the service the copier offers. Xerox design standard parts and sub-assemblies for their copiers to fit into this lease business model.

Another inspiration for this concept has been the Apple iPod. An iPod is completely sealed and users cannot even access the battery to change it. Without specialist tools it is almost impossible to open a iPod to affect a repair, ensuring the products are returned to Apple for all repairs.
4.2.2 Product Design - Features

- Sealed unit
- Single mechanical button
- Compact and robust design
- All plastics used are the same type
- Simple snap fit, Active disassembly fastening
- Reusable paperfoam post clip to protect the screen in transit
- Revolutionary recyclable ADBC PCB

4.2.3 Product Design - Advantages for Remanufacturing

Post's product design advantages for remanufacturing are:
Ensured component integrity - Sealed unit. Users have no access to any internal components. This ensures that the Core has not been damaged or tampered with during use and therefore a consistently high quality of Core is returned for remanufacture. Logically this also allows more of the returned components to be reused.

Increased recyclability - ADBC PCB. The sealed unit allows the use of an ADBC PCB. ADBC pasta boards break down under controlled conditions when exposed to moisture. The tight fitting mouldings encapsulate the PCB to protect it from any such exposure.

Efficient logistics - Compact size. The compact size of the handset concept means easier handling during transport and remanufacture. Reducing the need for storage is an important success factor for remanufacturing; the smaller size means less investment is needed in costly storage space throughout the remanufacturing process.

Reduced transport costs - Light weighting. The lightweight mouldings and compact electronics mean transport will be less expensive. If the remanufacturing plant is sited in China these cost savings could be considerable.

Reduced damage during transport - Robust design. Robust mouldings, combined with reduced mechanical parts, mean that the handset will not get easily damaged during transit. The PaperFoam transport clip ensures that the handsets screen will survive the journey through the post.

Simplified assembly, disassembly and reassembly - Low complexity. Simple snap-fit AD fasteners are used for quick assembly, disassembly and reassembly, making the remanufacturing process more efficient. Reduced time of disassembly and reassembly is one of the critical requirements for a successful and profitable remanufacturing process.

Simplified tracking - RFID. An RFID tag on the PCB allows the handset to be tracked throughout the remanufacturing system. This is linked to the serial number of the handset, which the user enters onto the online system when returning their handset for remanufacture.

Better customer information - User interface. Information for users about the EoL process for the product can be accessed from within the handsets interface. If this cannot be accessed, due to a fault, the information is also contained in the user guide supplied with the handset. This will decrease the possibility of customers not knowing what to do with their handsets at EoL, thereby increasing Core collection.

Improved customer service - Simple returns procedure. The user can connect the handset to their home computer to automatically upload information (including the results of any tests carried out) to the returns website. Customers with functioning handsets would be directed through to the Exoteq Remanufacturing website to fill in the returns forms through their handsets, others would be given the current Exoteq Reman URL. This provides a useful service to the user, whilst providing Exoteq with valuable information about the condition of handsets returning for remanufacture.

Extension of life – Upgradeability. Exoteq will upgrade and change the technology within the handsets during remanufacture. This means less environmental impact as the core unit will be have a much longer useful life. It also means that the handsets always contain the most current technology.

4.2.4 Business Model - Inspirations

The business model of Post is inspired by existing business models. For example, Rexo Ltd handle warranty services for major PC component manufacturers such as Samsung. When a customer has
a fault with a Samsung hard drive they can opt to pay for the new one on a credit card. Rexo will dispatch this new hard drive to the user within three working days from the request being placed. When Rexo receive the used hard drive back the customer receives a refund for the whole cost of the drive. This therefore ensures that the user is without their PC for only a limited time.

BackStage Services Ltd offer a similar service to Rexo’s, to high-street retailers such as Comet. When a product becomes faulty BackStage send an envelope to the user for them to return the product for repair. The envelope contains a Jiffy Bag, into which the product is sealed. That Jiffy Bag is then sealed by the user in a Royal Mail Next-day Delivery plastic envelope. This plastic bag is insured and delivered by Royal Mail; BackStage are then billed according to the number delivered by the Postal Service.

4.2.5 Business Model - User Interaction

Figure 9 shows how the Post business model has been designed to suit the target users’ needs and behaviour, whilst subconsciously aiding remanufacturing:

**Purchase of new or remanufactured handset lease (1).** One handset type is available with the latest technology inbuilt.

**Handset becomes faulty or user is made aware of an upgrade (2).** Users are sent an upgrade alert by Exoteq. In the case of a fault the user logs on to the Exoteq Reman website and orders a replacement handset, a credit card number is taken.

**User receives new handset and packages the old one (3&4).** A replacement handset is despatched from Exoteq Reman by post. The used handset is packaged using the same packaging (post clip, jiffy bag) that the new handset arrived in.

**Used handset posted back to Exoteq (5).** The handset is sent by post to a third party logistics centre, from there it is grouped with others and sent on to the remanufacturing plant.

**Faulty/used handset remanufactured (6).** The handsets are sorted, disassembled and remediated.
4.2.7 Business Model - Advantages for Remanufacturing

The Post business model has the following advantages for remanufacturing:
**Incentive for Core return - Deposit.** Users receive a new handset before sending their old one back to Exoteq. If Exoteq do not receive the old handset back within a specified time after sending the replacement handset Exoteq will charge the user's account. This provides the user with a real incentive for Core return, increasing Core collection, whilst at the same time giving the user a valuable service.

**Reduced investment - Postal system.** Existing postal networks are utilised to transport the handsets to the Core collection facility. They may potentially be posted all the way back to the remanufacturing plant in China. Therefore, Exoteq do not need to invest in an expensive transport network, making their remanufacturing operations simpler and cheaper.

**Simplified infrastructure - Third-party Core collection.** Handsets arrive at the warehouse by post and the RFID tags are read. The handsets are then sorted accordingly and placed in crates for shipping. This could be contracted out to a third party logistics firm, simplifying Exoteq’s remanufacturing operations.

**Improved customer service - Seamless handset exchange.** Exoteq will provide a service so that users can upload their settings and calendar entries, files and contacts to a secure server. Users can then download them to their new handset when it arrives. This gives the user a better customer experience and increases their willingness to engage with the remanufacturing system.

**Material reuse and reduction - Postal packaging.** The handset for return is placed in the same packaging that the new handset arrived in. The bubble wrap bag and PaperFoam ‘clip’ are both reused. This minimises the cost of Core return for Exoteq whilst at the same time reducing the environmental impact of the system.

**Incentive for Core return - Convenience.** The user does not need to go to the store to exchange their handset. Users simply fill in an online form to receive a new handset in the post the next day. They then return the handset in the same packaging. This means they are more likely to engage with the remanufacturing system and this will increase Core return.

**Incentive for Core return - Lease.** The handsets are leased by the network providers to the users; the contract obliges the user to return the handset (in store or by post) to Exoteq at EoL.

**Simplified information gathering - Online returns system.** Details of the condition of the handset must be entered online when users apply for an upgrade or exchange; this gives Exoteq valuable information about the handset and how it has been treated. This enables Exoteq to pre-sort the handsets according to condition when they arrive at the remanufacturing facility without first unpacking and testing them.

**Positive user experience - Upgrade Alerts.** Users of the handsets can opt to be alerted about upgrades via a message direct to their handsets. This would ensure a continuous supply of handsets returning for remanufacture. This ease of upgrade will mean frequent sales and increased profit for Exoteq.

**4.3 Concept 3 - Modula**

The Modula concept is comprised of a ‘core’ unit and detachable modules. These modules can be simply exchanged with new modules to alter the functionality and styling of the handset. The modular system therefore allows easy technological, aesthetic and ergonomic customisation of the device. The Modula concept also gives users the freedom to customise and upgrade to the latest technology and styles in-store, without the hassle or costs of changing their entire handset.
The quick and easy replacement of modules facilitates in-store Core collection. Handsets and component modules are leased and returned in-store at the time of upgrade, ensuring a high percentage of Core returns for remanufacture and subsequent resale.

**End users.** Modula’s intended users are those interested in using the latest technology but without the time or inclination to disassemble or configure the individual components themselves.

The ability to easily upgrade the handset via the replacement of modules will ensure that the technology within each handset always remains current. Consequently, the core unit will have a much longer useful commercial life and therefore also reduce its environmental impact.

### 4.3.1 Product Design – Inspirations

Modula is inspired by existing and emerging business and user practices. For example, many electronics manufacturers have realised the benefits of building modularity into their products. Modular blenders, power tools and cameras are now commonplace. Many modern cameras can easily be adapted to suit the requirements of the user. This is achieved by attaching zoom lenses, flash, extra memory and battery packs to the standard ‘core’ unit.

Hi-fi systems, built up of many separate components, often from different manufacturers, are popular amongst audiophiles. This compatibility between different brands means that users can pick and choose the best component parts with which to build their systems. Users can choose from a much wider variety of components to get the functionality and quality of sound that they require.
4.3.3 Product Design - Advantages for Remanufacturing

Modula’s product design has the following advantages for remanufacturing:

*Increased potential market - Modularity.* Diverse global markets have adopted many different wireless standards (such as Flash-OFDM or WiMAX). The wireless standard used by the handset can be changed by inserting a different wireless module, therefore Exoteq can create one
core unit and add different wireless modules to configure the handset to suit every market. This will significantly reduce Exoteq’s R&D costs and simplify production/remanufacture.

**Increased process efficiency - Active Disassembly.** The design of the mouldings facilitates the use of a dual-action AD fastening. The sealed ‘core’ unit and each module will dissemble with a single stimulus. Variations in the configurations of modules in the handsets returning for remanufacture will not affect the disassembly process. Handsets can therefore be disassembled without manual preparation.

**Extension of life - Upgradeability.** Wireless technology is expected to develop quickly, Exoteq can release handset upgrades by releasing new modules to keep apace with these changes. This platform approach to the design of modules allows easy technological upgrade, whilst the core unit remains the same. This significantly reduces the environmental impact as the core unit will have a much longer useful life.

**Ensured component integrity - Sealed ‘core’ unit and modules.** Both the core unit and each module are sealed. The design allows the modules to be easily replaced whilst keeping all the components protected from user interference, this ensures a consistently high quality Core is returning for remanufacture.

**Simplified tracking - RFID.** An RFID tag on the core unit and on each module allows them to be tracked throughout the remanufacturing system. This is linked to the serial number on each part, entered onto the online system when the parts are scanned in-store and returned for remanufacture.

**Improved service offering - Customisation.** Users can choose between many different modules. For example Modules give extended battery life, upgraded wireless, video capability, Bluetooth communication or extra storage space. Each of these modules is available in different shapes and textures. Users can customise not only the technology but also the look, feel and ergonomics of the handset.

**Better customer information - User Interface.** Information for users about the EoL process for the device (and attached modules) can be accessed from within the handset's interface. If this cannot be accessed, due to a fault, the information is also contained in the user guide supplied with the handset. This will decrease the possibility of customers not knowing what to do with their handsets at EoL, therefore increasing Core collection.

**Simplified assembly, disassembly and reassembly - Low complexity.** Simple snap-fit AD fasteners are used for quick assembly, disassembly and reassembly, making the remanufacturing process more efficient. Reduced time of disassembly and reassembly is one of the critical requirements for a successful and profitable remanufacturing process.

### 4.3.4 Business Model Design - Inspirations

Modula's business model and product is a new model in the mobile phone sector but others in the sector have established similar re-use schemes. For example, Vodafone runs a worldwide programme to promote the reuse and recycling of old handsets and accessories. This collection of used handsets is handled in store by Vodafone staff. This ensures Vodafone retain control over the handling of these used mobile phones and it also encourages customers to visit Vodafone stores. The collection bins are also a good opportunity for Vodafone to advertise its green credentials.

### 4.3.5 Business Model Design - User Interaction

The Modula business model has been designed to suit the target users’ needs and through the new product, enable new behaviour. Figure 10 shows how the business model allows the user to aid remanufacturing:
**Purchase of new or remanufactured handset (1).** Customers can choose each module individually for a completely customised handset or choose from a range of handsets with standard module configurations.

**Handset becomes faulty/ technology is out of date (2).**

**User returns to store to choose new module (3).** User can choose from any of the modules compatible with their handset.

**Module is replaced in store (4 & 5).** The user removes the used module and fits the new one. The store personnel will be trained to help with this and recommend appropriate modules.

**Faulty/ used module is remanufactured (6).** Used modules are sent by the store (via reverse logistics) back to Exoteq, where the modules will be sorted, disassembled and remediated.

*Figure 10. Modula – user interaction with business model*
4.3.6 Business Model Design – Structure

4.3.7 Business Model – Advantages for Remanufacturing

The business model of Modula will have the following advantages for remanufacturing:
Reduction of transport – Modular replacement. In most cases modules, rather than complete handsets, will be transported. Therefore the total amount of material being transported around the remanufacturing system will be minimised, reducing cost for Exoteq.

Incentive for core return – Lease. The handset will be leased to end users. Exoteq will always retain ownership of the handset. At the end of the lease contract the handset must be returned to Exoteq. This provides a big incentive for Core return, increasing Core collection.

Increased control over Core collection – Module replacement. The fast, simple replacement of modules enables in-store Core collection. This increases the likelihood of Core returning to Exoteq.

Better service offering - Flexible (tailor-made) lease options. Customers can choose between three lease options. A lease for the handset only, they would then have to pay for any new modules they wanted to fit (discounted on return of used modules). The second is a lease which enables them to replace a fixed number of modules for free each year. In the final option the customer can replace an unlimited amount of modules for free during the life of the lease.

Simplified information gathering - Online returns system. Users enter details of what is wrong with the handset online when they apply for an exchange, this gives Exoteq valuable information about the handset and how it’s been treated. This enables Exoteq to pre-sort the handsets according to condition when they arrive at the remanufacturing facility without first unpacking and testing them.

5 Evaluation & Recommendation of Business Models

Following the development of the Design for Remanufacture concepts, they were presented to Exoteq and evaluated. This section briefly evaluates the desirability of each concept, leading onto recommendations for further development of the business models.

5.1 Evaluation of business models

5.1.1 DIY

Exoteq believe DIY to be an interesting concept, which could foster customer interaction and brand loyalty, however the potential market for the concept is perceived as small. In addition, the increased longevity of handsets is likely to make establishing effective incentives for Core return difficult.

5.1.2 Post

Exoteq are excited by the possibilities offered by the Post business model, which exploits the existing postal infrastructure for simple Core collection. Due to Exoteq’s small size, the company views the possibility to sub-contract Core collection to a third party logistics firm as attractive.

Although the use of the postal system for returns is an alluring possibility, Exoteq would want end users to be able to return their products for repair or replacement at the store where they were leased. This is likely to require elements of the infrastructure to be doubled-up.

The Post scenario, with its particularly low environmental impact, also offers the opportunity for targeted marketing at ‘green’ consumers through various mechanisms. One example would be to develop a website that attracts green customers.
5.1.3 Modula

Exoteq are very interested in the potential of the Modula concept, which is likely to result in enhanced profits, new global markets and a unique new range of modular products. New markets at a reduced cost are opened up by modularity. Inserting different wireless modules is a simple way to change the wireless networks accessed by the handset. Exoteq therefore create one core unit and add different wireless modules to configure the handset to suit every global market.

In addition, Exoteq see modularity as the answer to many of their technology dilemmas (whether to implement WiMAX, flash etc).

However, Exoteq are concerned that the Modula concept does not provide ISP's with any tangible benefits when compared to other manufacturers products (other than extra footfall in their stores and green marketing opportunities).

5.2 Recommendations for Business Plan Development

The concept evaluations provide the starting point for the next steps in the business plan development. What emerges from the concept evaluation is an interest in aspects of each concept. This suggests that a synthesis of aspects picked from multiple business model concepts may be appropriate. For example, the Modula concept could adopt Post's model for Core collection, likewise there is no reason why the Post concept could not be used with the Modula ‘in-store’ Core collection business model.

Specific aspects that require further development are discussed in the following sections.

5.2.1 Financial Recommendations

Exoteq are concerned that the potential increased profits attributed to the sales of replacement modules/components may not be as high as predicted because the handsets will be supplied within a lease model (which would likely include a certain amount of upgrades and remediation). To resolve this concern, the Terms & Conditions of the lease model need to be further developed, and further customer research carried out as to what the customer expects.

5.2.2 Contractual Relationship Recommendations

Exoteq are also concerned about the contractual relationship between retailers and Exoteq. For example, if all the returns are handled by Exoteq, who pays for these services? To resolve these issues, ISPs now need to be further researched and Terms & Conditions developed.

5.2.3 Customer Confidence Recommendations

Difficulties in effectively wiping data from flash memory make data security issues a considerable obstacle to the reuse of flash memory in the handset. To resolve this issue, flash memory may be eliminated from reuse and disposed of by conventional means, or for a potentially more profitable and environmentally friendly method, methods of effectively destroying data need to be established. Contacts have been made with an organisation involved in data security, which may allow this issue to be solved.

5.2.4 Core Collection Recommendations

End users may have a legal right to be able to return products for repair or replacement to the location where they were obtained. In order to develop any postal Core collection techniques, legal obligations need to be better researched, and methods of possibly combining the postal with conventional returns methods developed.
5.2.5 Location of Remanufacturing Recommendations

All of the business models have been developed based on the remanufacturing facility being placed alongside the manufacturing plant. This reduces capital investment in remanufacture, and reduces the risks associated with reaching the break-even point in terms of volume of phones returned and re-sold.

In the future, for certain minor remediation requirements, satellite remanufacturing facilities located close to Exoteq’s main markets may further reduce costs, timescales and environmental impacts associated with transportation, whilst bringing work to local regions. This is a refinement to the business model that may be integrated at a later stage.

5.2.6 Marketing Recommendations

Exoteq like the idea of extending the useful lives of their handset and believe that if customers engage with the lease/remanufacturing system they are more likely to be loyal to the brand and continue their relationship with the ISP (i.e. stay with their current contract for longer).

However, Exoteq believe the concepts’ tangible benefits to the ISP’s (i.e. extra footfall in ISPs’ stores and green marketing opportunities) need to be quantified, and other benefits established. Without this the ISPs may have little incentive to lease Exoteq’s handsets. To resolve this concern, the benefits of the final design need to be quantified by customer perception research for both end users and ISPs. ISP stakeholders can also be involved, and further development aligned to their needs.

Markets. For some buyers such as business to business (B2B), business to government (B2G) and business to consumers (B2C), 1st life (new) will be a big issue but for others a cheaper price and green credentials could be selling point, especially if they are associated with reduced costs and possibly a quantified carbon footprint reduction. The potential reduced costs of leasing may create big opportunities for B2B and B2C among those who would buy a large quantity of mobile phones e.g. companies, universities etc. This may create opportunities for funding the lease model.

Marketing Focus. Marketing of Meos G2 can focus on many areas but the innovative nature of the Meos product enables marketing to concentrate on the exciting new functional benefits of the product. In addition, through the leasing model, users are provided with the ‘service’ of a handset rather than just being sold the handset. This guarantees the service of a working handset no matter what the circumstance and therefore reduces the risk associated with ownership. Where environmental benefits can be robustly justified they may also be used.

Marketing Mechanisms: Techniques for marketing product advantages are well established but any marketing and communication of environmental benefits will require mechanisms to be put in place to ensure ‘green washing’ is avoided. These mechanisms could potentially involve training of Exoteq’s sales department and/or sales people at ISP retail outlets.

ISP Customer contact: In marketing to ISPs the benefits of leasing i.e. cash flow can be used as an attractive sales proposition.

5.2.7 Funding the business model

Funding of the leasing model is a fundamental issue for exploiting the lease and remanufacturing business model. In order to develop this Exoteq need:

- UK remanufacturing partners
- Funding

...
6 Investment & Returns of Design for Remanufacture

The Design for Remanufacture process can create additional revenue streams, however it is likely to require some added investment in the design phase. It is difficult to accurately quantify the additional investment required to build and optimise the processes of remanufacturing because design development time and cost will differ depending on the client, product and objectives.

This Remanufacturing Feasibility study for Meos G2 provides an indication for the added time and costs of Design for Remanufacture in the consumer electronics industry. The investments carried out in each stage of Design for Remanufacture are separated into sections: Design, Financial Assessment and Environmental Assessment. There may be challenges in implementing these processes, and these are also indicated in the following sections.

6.1 Investment: Design

Design for Remanufacture may be seen as a holistic design activity, initiated by a strategic decision at the start of the project (or earlier).

6.1.1 Process Investments

The conventional design practices of research, design ideation and design development must still be carried out in a Design for Remanufacture process. Elements that are likely to be needed in addition to the conventional design process are those of business model ideation, development and the use of specific design strategies such as Design for Disassembly, Remediation and Upgrade. An indicative assessment of processes, time and cost is shown in Table 8.

Based on the design timings for the Meos G2 remanufacturing feasibility study, Table 8 shows that Design for Remanufacture adds approximately one third to the conventional design investment in terms of time and financial cost.

To justify both this added cost a more detailed Financial Assessment and streamlined LCA can be conducted. These can be seen in the section 6.4.

6.1.2 Challenges

Basic challenges that may increase the time and cost of Design for Remanufacture may occur if designers lack knowledge/experience in:

- Ideation: Business model components and development methods/needs
- Remanufacturing: Procedures
- Design: Design for Remanufacture processes e.g. material compatibility for recycling, and Design for Disassembly

Designers can clearly take advice to acquire these skills, however time, cost and few training opportunities may hinder this.
Table 8. **Indicative** costings and timings for Design for Remanufacture relative to conventional design practice.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Activity Focus</th>
<th>Conventional design</th>
<th>Design for Remanufacture</th>
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### 6.2 Investment: Financial Assessment

A financial assessment of the remanufacturing business model and design concept identifies the potential rewards and is therefore a useful aid in design development and consideration of whether to take a concept through to commercialisation.

#### 6.2.1 Process Investments

To conduct a financial assessment, it is necessary to establish likely usage and EoL scenarios over a given time span. This can help to identify the costs of distribution, remediation and the profits that may be accrued (illustrated in Table 9).
Table 9. *Indicative* costings and timings for each concept to conduct a financial assessment of remanufacturing business model for multiple product lifecycles.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Activity Focus</th>
<th>Days</th>
<th>Cost (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Establish needs of financial assessment</td>
<td>0.1</td>
<td>35.00</td>
</tr>
<tr>
<td>2</td>
<td>Establish time period of assessment e.g. 10 years</td>
<td>0.1</td>
<td>35.00</td>
</tr>
<tr>
<td>3</td>
<td>Identify lifecycle of use scenario</td>
<td>0.2</td>
<td>70.00</td>
</tr>
<tr>
<td>4</td>
<td>Establish number of re-lifecycles and scenarios for each</td>
<td>0.4</td>
<td>140.00</td>
</tr>
<tr>
<td>5</td>
<td>Sourcing financial data</td>
<td>0.5</td>
<td>175.00</td>
</tr>
<tr>
<td>6</td>
<td>Generate spreadsheet</td>
<td>0.3</td>
<td>105.00</td>
</tr>
<tr>
<td>7</td>
<td>Enter data and collate results</td>
<td>0.2</td>
<td>70.00</td>
</tr>
<tr>
<td>8</td>
<td>Communicate results</td>
<td>0.1</td>
<td>35.00</td>
</tr>
</tbody>
</table>

**TOTAL PER CONCEPT** 1.90 665.00

6.2.2 Challenges

There are several challenges in calculating financial benefits over multiple lifecycles:

- Scenarios: Establishing realistic yet comparable multiple-lifecycle scenarios
- Scenario: Minimising the assumptions made during the development of usage, EoL reasons and remediation needs.
- Data: Sourcing financial cost data for lifecycle aspects can be time-consuming and is likely to require assumptions
- Calculation: Generating an appropriate spreadsheet to produce the data can be time-consuming

To reduce these challenges it is necessary to establish project needs and gain the buy-in from appropriate stakeholders at the beginning of the process. This ensures that results calculated and presented will be meaningful and useful.

6.3 Investment: Streamlined Life Cycle Assessment

A streamlined Life Cycle Assessment (LCA) can provide evidence that a concept meets certain environmental specifications and this may be useful for actions such as product development and marketing. The streamlined LCA considers a focused set of Life Cycle processes and is a way to reduce the time and cost of conducting a full LCA, whilst still achieving meaningful results.

6.3.1 Process Investments

The investment in carrying out a streamlined LCA (indicated in Table 10) can vary hugely depending on the experience of the designer and type of streamlined LCA required.
Table 10. *Indicative* cost/time per concept of remanufacturing business model for multiple product lifecycles, carried out by a designer with knowledge of conducting a streamlined LCA (this does not include dataset sourcing/purchase).

<table>
<thead>
<tr>
<th>Stage</th>
<th>Activity Focus</th>
<th>Days</th>
<th>Cost (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Establish needs of streamlined LCA</td>
<td>0.1</td>
<td>35.00</td>
</tr>
<tr>
<td>2</td>
<td>Identify suitable streamlined LCA method</td>
<td>0.1</td>
<td>35.00</td>
</tr>
<tr>
<td>3</td>
<td>Establish time period of assessment e.g. 10 yrs</td>
<td>0.1</td>
<td>35.00</td>
</tr>
<tr>
<td>4</td>
<td>Identify lifecycle of use scenario</td>
<td>0.5</td>
<td>175.00</td>
</tr>
<tr>
<td>5</td>
<td>Establish number of re-lifecycles</td>
<td>0.2</td>
<td>70.00</td>
</tr>
<tr>
<td>6</td>
<td>Identify lifecycles of re-use scenarios</td>
<td>0.5</td>
<td>175.00</td>
</tr>
<tr>
<td>7</td>
<td>Collate data into spreadsheet</td>
<td>0.5</td>
<td>175.00</td>
</tr>
<tr>
<td>8</td>
<td>Establish specific datasets required</td>
<td>0.1</td>
<td>35.00</td>
</tr>
<tr>
<td>9</td>
<td>Gather data</td>
<td>0.5</td>
<td>175.00</td>
</tr>
<tr>
<td>10</td>
<td>Enter data into spreadsheet</td>
<td>0.5</td>
<td>175.00</td>
</tr>
<tr>
<td>11</td>
<td>Collate results &amp; communicate</td>
<td>0.5</td>
<td>175.00</td>
</tr>
<tr>
<td></td>
<td><strong>TOTAL PER CONCEPT</strong></td>
<td></td>
<td><strong>1,260.00</strong></td>
</tr>
</tbody>
</table>

6.3.2 **Challenges**

Despite the simplified nature of the streamlined LCA compared to a full LCA, numerous and considerable challenges remain. Depending on the project, these may be:

- Scenarios: Building lifetime usage scenarios can be time-consuming and the level of assumption can make results debatable.
- Assumptions: Designs are unlikely to be fully resolved, necessitating assumptions and guesstimates of elements such as material, weight and distribution.
- Data: The purchase cost of data sets will vary dependent on their complexity. A data set may cost from £10 to over £5,000.

To reduce the challenges of conducting a streamlined LCA, as with financial assessment, it is necessary to establish the project needs, communication requirements and gain buy-in from appropriate stakeholders at the beginning of the process. This can increase the likelihood of results being accepted.

6.4 **Returns**

As described, the potential returns on the investment in Design for Remanufacture can be seen through Financial and Environmental Assessments over the remanufacturing lifecycle.

In addition to financial benefits, remanufacturing is reputed to result in significant environmental savings such as reduced Greenhouse Gas emissions, diversion of materials from landfill and reduced virgin material use. The environmental assessment of the Meos G2 remanufacturing concepts, indicates their potential environmental savings.
The following sections show average yearly results based on each concept's 10 year business model. They have been calculated using a simple Financial Assessment and the 'Eco-Design of Energy-Using Products' Environmental Assessment Tool.

6.4.1 Calculation Method

In order to carry out the Financial and Environmental Assessments the following methods and assumptions were used:

**Scope.** The assessments are based on production, distribution and disposal of the handset itself and do not include packaging. The concepts are not designed to change user behaviour and so the use phase was not assessed, although it is accepted that the energy used in this lifecycle phase is an area of major environmental impact.

**Business Model Length.** Each concept has been assessed over a 10 year business model. Meos G1 is assumed to have a maximum life of 2 years so the costs and environmental impacts of Meos G1 have been multiplied by 5 to create a baseline for comparison. Yearly savings are based on the average yearly saving over the 10 year business model.

**Scenario Behaviour.** The lifetime scenario for each concept was based on assumed likely behaviour for the given concept. A list of these can be seen in Appendix I.

6.4.2 Costs Savings (£ p.a.)

Cost savings (Figure 11) from the Design for Remanufacture product designs range from approximately £40-60 million per year, depending on the concept.

These cost savings are largely due to the reuse of components and therefore reduced production needs.

In addition, remanufacturing processes would be optimised by reduced disassembly time, recycling compatible polymers and inks etc, however it is difficult to establish these economic savings at this early development stage.

**Location of Benefits:** These cost savings would accrue in England, where Exoteq are based.

![Figure 11. Concept cost savings relative to Meos G1](image)
6.4.3 Increased Sales (£ p.a.)

The financial assessment for the Exoteq Meos G2 business models (Figure 12) shows a potential increase in sales of up to £3 million per year with the Modula concept. This increase comes mainly from the increased convenience of replacing components such as batteries.

DIY actually would result in lower sales income – primarily because there is little turnover in handsets.

**Location of Benefits:** Revenue from sales will accrue in England, where Exoteq are based.

6.4.4 Reduction in Greenhouse Gas Equivalents (CO₂E)

Reductions in greenhouse gas (GHG) equivalents range from approximately 2,000-3,000 tonnes per year, depending on the concept (Figure 13).

These reductions come from the reduced production enabled by remanufacture of components.

**Location of Benefits:** Reduction in GHG emissions will occur at sites of material extraction, production (China) and globally during distribution. The decisions that guide these emissions would be made by England-based Exoteq, and so it is reasonable to attribute these savings to England.
6.4.5 Virgin raw materials saved (tonnes p.a.)

Virgin raw material savings range from approximately 75-85 tonnes per year, depending on the concept (Figure 14).

**Location of Benefits:** The vast majority of these savings will be achieved in China and Asia.

![Figure 14. Virgin raw material use reductions relative to Meos G1](image)

6.4.6 Reduction in hazardous waste (tonnes p.a.)

Reduction in hazardous wastes ranges from approximately 85-185 tonnes per year, depending on the concept (Figure 15).

**Location of Benefits:** Reduction in hazardous wastes will occur in England and in other global regions where the handset is used and disposed of.

![Figure 15. Reduction in hazardous waste relative to Meos G1](image)
6.4.7 Materials diverted from landfill (tonnes p.a.)

Material diversion from landfill ranges from approximately 220-285 tonnes per year, depending on the concept (Figure 16).

**Location of Benefits:** Landfill savings will occur in England and in other global regions where the handset is used and disposed of.

![Figure 16. Materials diverted from landfill relative to Meos G1](image)

6.4.8 Water Conservation (tonnes p.a.)

Water conservation ranges from approximately 10,000 - 15,000 tonnes per year, depending on the concept (Figure 17).

**Location of Benefits:** The vast majority of these water savings will be achieved at the production site in China.

![Figure 17. Reductions in water use relative to Meos G1](image)
6.5 Investments v. Returns

For approximately one third increased investment to allow Design for Remanufacture (as opposed to conventional design), the potential profits from commercialisation could be doubled.

6.5.1 Increased Investment and Returns

Financial calculations, the potential increased costs and returns for the conventional design of three Meos G2 concepts are indicated in Table 11:

Table 11. Indicative investment and returns increase for Design for Remanufacture of 3 Meos G2 concepts.

<table>
<thead>
<tr>
<th>Potential Investment-Returns Increase*</th>
<th>% Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential Capital Investment (£)</td>
<td>31%</td>
</tr>
<tr>
<td>Potential Yearly Profit (£)</td>
<td>271%</td>
</tr>
<tr>
<td>Potential GHG savings (tonnes CO2 eq)</td>
<td>44%</td>
</tr>
</tbody>
</table>

*Approximate figures are based on the Design for Remanufacture processes and 5 generations sales of 1,000,000 Meos G2 units, over a 10 year business model. A brief explanation of these findings may be seen in Appendix II.

7 Conclusions

This Feasibility Study has shown that Design for Remanufacture of the Meos G2 Mobile Broadband handset can lead to UK cost savings, increased sales and environmental savings including reductions in Greenhouse Gas equivalents. The study has investigated the worth and possibilities of Design for Remanufacture for the Meos G2 handset, and in parallel has reviewed the Design for Remanufacture processes of business model design and product design.

7.1 Worth of Design for Remanufacture

Remanufacturing would be a worthwhile activity for Exoteq to implement within their business. Design for remanufacture may require financial investment increased by one third, but annual profits for commercialised remanufacturing designs may be increased by over 200%. Therefore the relatively small added initial investment in Design for Remanufacture is worthwhile.

Although all the Meos G2 business model/product design concepts indicated potential increased UK profit and environmental savings attributable to the UK, Exoteq prefer the innovative Modula design concept (Figure 17). Modula’s business model may possibly be combined with aspects of the postal Core collection system.

Figure 17. The Modula design concept is preferred for its unique selling proposition and potential profits.
7.2 Design for Remanufacture Process:

The Design for Remanufacture process requires numerous design strategies, the selection of which may vary depending on the industry sector. This Feasibility Study has also identified several challenges and potential design process improvements that are described in this section.

7.2.1 Key Strategies in the Consumer Electronics Industry

The Design for Remanufacture of Meos G2 involved several key strategies which may be relevant to the consumer electronics industry as a whole.

**Business Model Design.** Establishing the business model in which the designs will operate can give a rationale to component recovery and reuse. This should fundamentally include Core collection incentives and methods and would usefully include establishing potential markets for reused products.

**Design for Disassembly.** Allows quick, easy and cheaper access to certain valuable electronic components.

**Design for Upgrade.** Allows certain electronic components to be reused, saving costs and reducing environmental impacts. It is likely that the designer is unable to control the electronic components’ design but they may specify components that can be replaced or with a long lifespan. This element may require additional expertise from electronics manufacturers.

**Design for Re.** Although remanufacturing may be the objective given the significant economic and environmental benefits, it is unlikely EoL scenarios can always be completely controlled due to changing economic, social and legislative factors. Therefore the design must account for all potential EoL eventualities i.e. products should also be designed for recycling, reconditioning and reuse).

7.2.2 Challenges & Potential Process Improvements

Numerous challenges and potential Design for Remanufacture process improvements have been identified during this Feasibility Study. These are:

**Innovation.** Given the low knowledge and sometimes negative perceptions of remanufacturing, it is necessary to concentrate on producing realistic designs. This project focussed on business model designs which would be palatable and feasible to Exoteq. This reduced the time available for creating innovative variations at the macro level, which could conceivably result in more radical financial and environmental benefits. Establishing a more open, ‘blue sky’ session at the start may generate radical ideas, which could potentially feed into the more obvious and realistic ideas generated later in the project.

**Electronic Components.** Most of the environmental impact (perhaps over 90%) comes from the electronic components within the handset. Reducing the environmental impacts of these components is therefore key to reducing environmental impacts. A good starting point for this is to establish the financial case by identifying and establishing electronic component re-use markets. This is likely to require substantial time investment and although it may be most useful to do this at the project start, it is likely to be more feasible later in the design development when the research can be more focussed.

**Streamlined LCA.** Even a streamlined LCA requires a considerable amount of time and investment. In order to ensure this is worthwhile, before any LCA work is done, the purpose of the streamlined LCA should be understood and a robust methodology with stakeholder agreement established. On the subject of project exploitation, the value of the streamlined LCA can be
increased by aligning its key results to potential funding streams e.g. those dealing with CO₂ emissions.

A streamlined LCA can be useful at the project start to identify areas of environmental priority however during design development, a faster method such as a checklist, is likely to be more useful.

**Client.** A detailed understanding of the client, their pressures, needs and knowledge must be established at the start of the project to ensure that needs are met and existing skills are exploited. Advance planning is also key to ensuring that the client's time can be utilised. In this Meos G2 project, more detailed planning and understanding would have helped to gain more structured time within Exoteq's busy schedule. This would have reduced the amount of design work required in many areas of the project.

**Marketing Incentives.** It is necessary to understand the market fully in order to establish the incentives for ISPs to ‘buy in’ to the remanufacturing system. For example, time was spent estimating the costs of complying with the Waste Electrical and Electronic Equipment (WEEE) directive. However it is the ISP not Exoteq who is responsible for the cost of compliance because of the sales model. Having this knowledge during the Design for Remanufacture process can ensure that concepts are selected and presented to emphasise the marketing incentives.

With regards to improving the Design for Remanufacture processes applied to this project, there may be advantages in doing further research into ‘re’ systems in countries of best-practice resource efficiency such as Japan. Process improvements may also be achieved by investigating markets with growing domestic production of phones e.g. India, China and Thailand where there may already be flourishing 2nd-life markets based on domestically produced 1st-life products and/or imported e-waste.

### 7.3 Meos G2: Next Steps for Remanufacture

There are several key issues for establishing remanufacturing for Meos G2. These are:

**Quantifying the benefits of the (remanufactured) handset.** Markets (both ISPs and end users) need to be further understood so that strategic marketing strategy decisions can be made, and this will establish what specific benefits need to be quantified. For example some markets such as B2B, B2G or even some B2C, may hold functionality and price to be the most important purchase considerations. In the immediate-term, communicating carbon reduction potential could be useful but this cannot be ‘greenwash’ and needs to be put in context of other environmental impacts, such as the carbon produced in the use phase.

**Markets.** In particular, market size needs to be established for the (remanufactured) handset; further methods of accessing those markets may also be established. If environmental benefits are to be communicated, avenues such as the Friends of the Earth product catalogue may be an avenue to explore. Understanding marketing strategy will require further research, perhaps including focus groups. However the realities of Exoteq’s financial and time pressures make this depth of research challenging.

**Detailed Remanufacturing Costs.** The total upfront costs of setting-up the remanufacturing system need to be established.

**Funding the lease model.** The lease model of Meos is fundamental to the remanufacturing business model, which can result in higher financial benefits and reduced costs. However it requires a large initial investment by Exoteq. In order to make the financial and environmental
benefits occur, further funding mechanisms for the lease model now need to be identified and sought.

7.4 New Remanufacturing Opportunities

The research established by this Feasibility Study has identified other opportunities that could be exploited by those who have invested in Design for Remanufacture.

7.4.1 Remanufacturing System

There may be an opportunity to develop a remanufacturing system or business model for mobile phones that could be sold into countries with growing domestic/imported phone e-waste. This could result in a Systems Integration business that:

- helps design systems and integrates partners for a fee
- builds remanufacturing kits for manufacturers e.g. ‘reman in a portacabin’ that could be bought and set-up in existing factories or elsewhere
- develops software that simulates the overall remanufacturing system process (reverse logistics, manufacturing planning, forward logistics, marketing and forecasting, etc); and specifically simulates the remanufacturing processes in the factory. This software could then be used as a tool for designers to Design for Remanufacture.

7.4.2 Remanufacturing Start-up Grants

In order to ensure that the financial and environmental benefits of remanufacturing remain in the UK, a Government sponsored grant scheme could support companies to investigate and engage in remanufacturing. This could work in a similar manner to POCKET funding.

7.4.3 Remanufacturing of Electronic Components

Following on from the streamlined LCA of Meos, it is clear that the environmental impact of electronic components such as the PCB, are the major production environmental impact. A project to investigate the commercial development of the ADBC PCB used in the Post concept is now being investigated.
8 Glossary of Terms and Abbreviations

2nd Life goods
Any goods that have been used and returned to the market after treatment. This treatment can be, amongst others, refurbishing, remanufacturing and reuse.

3G
3G (or 3-G) is short for third-generation mobile telephone technology. (i.e. WCDMA or CDMA2000).

3Play
Triple play is grouping together Internet access, TV and telephone service into one subscription on a broadband connection.

4G
4G (or 4-G) is short for fourth-generation the successor of 3G and is a wireless access technology.

ADSL
Asymmetric Digital Subscriber Line (ADSL) is a form of DSL, a data communications technology that enables faster data transmission over copper telephone lines than a conventional modem can provide.

CDMA
Code division multiple access (CDMA) is a form of multiplexing (not a modulation scheme) and a method of multiple access that does not divide up the channel by time (as in TDMA), or frequency (as in FDMA), but instead encodes data with a certain code associated with a channel and uses the constructive interference properties of the signal medium to perform the multiplexing. CDMA also refers to digital cellular telephony systems that make use of this multiple access scheme, such as those pioneered by Qualcomm, or W-CDMA.

Core
The product or component that will be remanufactured.

DSL
Digital Subscriber Line, or DSL, is a family of technologies that provide digital data transmission over the wires used in the "last mile" of a local telephone network.

EoL
End-of-life. This can occur for many reasons, some of which are redundancy, malfunction and style changes.

Linux
An open-source operating system for Personal Computers, mobile devices and servers.

Flash OFDM
Flash-OFDM is a system that is based on OFDM and specifies extra higher protocol layers. It has been developed and marketed by Flarion, now owned by Qualcomm Inc. Flash-OFDM has generated interest as a packet-switched cellular bearer, to compete with GSM and 3G.
GSM
The Global System for Mobile Communications (GSM) is the most popular standard for mobile phones in the world. GSM service is used by over 1.5 billion people across more than 210 countries and territories.

IM
Instant messaging is the act of instantly communicating between two or more people over a network such as the Internet. Instant messaging requires the use of a client program that hooks up an instant messaging service and differs from e-mail in that conversations are then able to happen in realtime.

IP
The Internet Protocol (IP) is a data-oriented protocol used for communicating data across a packet-switched internetwork.

IPTV
IPTV (Internet Protocol Television) describes a system where a digital television service is delivered to subscribing consumers using the Internet Protocol over a broadband connection. This service is often provided in conjunction with Video on Demand and may also include Internet services such as Web access and VOIP where it may be called Triple Play and is typically supplied by a broadband operator using the same infrastructure.

LCD
A liquid crystal display (LCD) is a thin, flat display device made up of any number of colour or monochrome pixels arrayed in front of a light source or reflector. It is prized by engineers because it uses very small amounts of electric power, and is therefore suitable for use in battery-powered electronic devices.

Mbps
A megabit per second (Mbps or Mbit/s) is a unit of data transmission equal to 1,000 kilobits per second or 1,000,000 bits per second. The bandwidth of consumer broadband internet services are often rated in Mbit/s.

MP3
MPEG Audio Layer 3, more commonly referred to as MP3, is a popular digital audio encoding and lossy compression format invented and standardized in 1991 by a team of engineers directed by the Fraunhofer Society in Germany. It was designed to greatly reduce the amount of data required to represent audio, yet still sound like a faithful reproduction of the original uncompressed audio to most listeners. In popular usage, MP3 also refers to files of sound or music recordings stored in the MP3 format on computers.

MPEG-4
MPEG-4, introduced in late 1998, is the designation for a group of audio and video coding standards and related technology agreed upon by the ISO/IEC Moving Picture Experts Group (MPEG). The primary uses for the MPEG-4 standard are web (streaming media) and CD distribution, conversational (videophone), and broadcast television.

ODM
An Original Design Manufacturer (ODM) is a company which designs and manufactures a product which ultimately will be branded by another firm for sale.
OEM
Original Equipment Manufacturer is a company which designs, manufactures and sells a product under their own brand.

OFDM
Orthogonal frequency-division multiplexing (OFDM), also sometimes called discrete multitone modulation (DMT), is a transmission technique based upon the idea of frequency-division multiplexing (FDM).

PDA
Personal digital assistants (also called PDAs) are handheld devices that were originally designed as personal organizers, but became much more versatile over the years. A basic PDA usually includes date book, address book, task list, memo pad, clock, and calculator software. Newer PDAs also have both colour screens and audio capabilities, enabling them to be used as mobile phones, web browsers or media players. Many PDAs can access the Internet, intranets or extranets via Wi-Fi, or Wireless Wide-Area Networks (WWANs).

QVGA
The Quarter Video Graphics Array (also known as Quarter VGA or QVGA) is a popular term for a computer display with 320x240 resolution. QVGA displays are most often seen in mobile phones and PDAs. Most often the displays are portrait mode (other mode is landscape) and are referred to as 240x320 as the displays are taller than they are wide.

RAM
Random-access memory (commonly known by its acronym RAM) refers to data storage formats and equipment that allow the stored data to be accessed in any order -- that is, at random, not just in sequence.

Recyclable
The reuse of products or parts or the use of reconditioned or remanufactured products or parts in another product. 'Re-use', 'reconditioning' or 'remanufacturing' are entitled to be called 'recycled,' and a product to which these terms can be applied can also be called 'recyclable'.

SD
Secure Digital (SD) is a 'flash memory' memory card format. It is used in portable device, including digital cameras and handheld computers. SD cards are based on the older Multi Media Card (MMC) format, but most (not all) are physically slightly thicker than MMC cards.

SIP
Session Initiation Protocol (SIP) is a protocol developed by the IETF MMUSIC Working Group and proposed standard for initiating, modifying, and terminating an interactive user session that involves multimedia elements such as video, voice, instant messaging, online games, and virtual reality. In November 2000, SIP was accepted as a 3GPP signalling protocol and permanent element of the IMS architecture. It is one of the leading signalling protocols for Voice over IP, along with H.323.

SMS
Short Message Service (SMS) is a service available on most digital mobile phones that permits the sending of short messages (also known as text messages, messages, or more colloquially SMSes,
texts or even txts) between mobile phones, other handheld devices and even landline telephones. Other uses of text messaging can be for ordering ringtones, wallpapers and entering competitions.

**TD-CDMA**

TDMA Time Division Multiple Access (TDMA) is a technology for shared medium (usually radio) networks. It allows several users to share the same frequency by dividing it into different time slots. The users transmit in rapid succession, one after the other, each using their own timeslot. This allows multiple users to share the same transmission medium (e.g. radio frequency) whilst using only the part of its bandwidth they require. Used in the GSM, PDC and iDEN digital cellular standards, among others.

**TFT**

TFT LCDs are a variant of liquid crystal display which use thin-film transistor technology to improve their image quality. TFT LCDs are one type of active matrix LCD, though this is usually synonymous with them.

**UMTS-TDD**

UMTS Time Division Duplexing, one of three 3G standards. UMTS TDD Mobile Broadband technology is a packet data implementation of the international 3GPP Universal Mobile Telecommunication System (UMTS) standard.

**USB**

Universal Serial Bus (USB) provides a serial bus standard for connecting devices, usually to computers such as PCs and the Apple Macintosh, but is also becoming commonplace on video game consoles such as Sony's PlayStation 2, Microsoft's Xbox 360, Nintendo's Revolution, and PDAs, and even devices like televisions and home stereo equipment.

**VGA**

Video Graphics Array (VGA) is a computer display standard with 640x480 resolution.

**VoIP**

Voice over Internet Protocol (also called VoIP, IP Telephony, Internet telephony, and Digital Phone) is the routing of voice conversations over the Internet or any other IP-based network. The voice data flows over a general-purpose packet-switched network, instead of traditional dedicated, circuit-switched voice transmission lines.

**VPN**

A Virtual Private Network, or VPN, is a private communications network usually used within a company, or by several different companies or organizations, to communicate over a public network.

**WAP**

Wireless Application Protocol (WAP), an extension of the MMS text messaging standard used to transmit multimedia content via text message.

**Wi-Fi**

Wi-Fi is a short range wireless technology brand owned by the Wi-Fi Alliance intended to improve the interoperability of wireless local area network products.
WiMAX

WiMAX is an acronym that stands for Worldwide Interoperability for Microwave Access, a certification mark for products that pass conformity and interoperability tests for the IEEE 802.16 standards. WiMAX is a standards-based wireless technology that provides high-throughput broadband connections over long distances. WiMAX can be used for a number of applications, including "last mile" broadband connections, hotspots and cellular backhaul, and high-speed enterprise connectivity for business.
Appendices

Appendix I - Scope and Assumptions of Financial and Environmental Assessments

Each concept has different usage depending on the target user group. The lifetime scenario for each concept was based on assumed likely behaviour allowed by the particular concept. This results in different handset or component replacement patterns, in turn resulting in financial and environmental implications for each concept.

In order to carry out the Financial and Environmental Assessments the following methods and assumptions were used:

Scope of Assessment. The assessments are based on Production, Distribution and Disposal of the handset itself. Previous environmental assessments have shown the environmental impact of the packaging to be insignificant and therefore for speed of environmental assessment, packaging has been excluded; packaging has however been included in the Financial Assessment with a Production cost of £1 per unit leased. The concepts are not designed to change user behaviour and so the Use phase was not assessed, although it is understood that the energy used in this lifecycle phase is an area of major environmental impact.

Business Model Length. Each concept has been assessed over a 10 year business model. Meos G1 is assumed to have a maximum life of 2 years so the costs and environmental impacts and  of Meos G1 have been multiplied by 5 to create a baseline for comparison. Yearly savings are based on averages over the 10 year business model.

Remanufacture of components. The following actions were assumed for each scenario:

- Casings - Each new product has a newly moulded casing
- Components – Only PCB and Wireless card components are remanufactured for assumed economic reasons

As far as possible, the following component use scenario over a 10 year business model has been applied:

- 2 PCBs (one new, one remanufactured)
- 3 Wireless Cards (one new, two remanufactured)
- 5 batteries (5 new)

Assumed Calculations for Remanufacturing. The precise financial and environmental impacts of specific remediation procedures are unknown. Assumptions and adjustments in calculation have been made: financial costs of remediation of PCB or Wireless Card was assumed to be 75% that of original production. The environmental costs of a remediated PCB or Wireless Card are assumed to be 50% that of original production.
9.2 Appendix II - Indicative Investment-Returns of Design for Remanufacture

**Conventional Design.** Referring back to Tables 8 and 9, the potential costs and returns for the conventional design of three Meos G2 concepts are indicated in Table 12:

**Table 12.** *Indicative* investment and returns for (theoretical) conventional design of 3 Meos G2 concepts.

<table>
<thead>
<tr>
<th>Costs: Conventional Design (Meos G2 Concepts)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase</td>
</tr>
<tr>
<td>Capital Investment (£)</td>
</tr>
<tr>
<td>Potential Returns (£ average per year over 10 yr BM)</td>
</tr>
<tr>
<td>Design</td>
</tr>
<tr>
<td>Financial Assessment (by Exoteq)</td>
</tr>
<tr>
<td>Environmental Assessment</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

*Approximate figures based on a conventional design process and 5 generations’ sales of 1,000,000 Meos G2 units, over a 10 year business model.

9.2.2 Design for Remanufacture

Referring back to Tables 8, 9 and 10, the potential costs and returns for the conventional design of three Meos G2 concepts are indicated in Table 13:

**Table 13.** *Indicative* investment and returns for Design for Remanufacture of 3 Meos G2 concepts.

<table>
<thead>
<tr>
<th>Costs: Design For Remanufacture (3 Meos G2 Concepts)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase</td>
</tr>
<tr>
<td>Potential Capital Investment (£)</td>
</tr>
<tr>
<td>Potential Returns (£ average per year over 10 yr BM)</td>
</tr>
<tr>
<td>Design</td>
</tr>
<tr>
<td>Financial Assessment (by Designer)</td>
</tr>
<tr>
<td>Environmental Assessment (by Designer)</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

*Approximate figures are based on the Design for Remanufacture processes and 5 generations sales of 1,000,000 Meos G2 units, over a 10 year business model.