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A tool for manufacturers to find opportunity in the circular economy – www.circulareconomytoolkit.org

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Abstract Living on a finite planet and operating in a linear take-make-dispose system is placing pressure on our resources and is burdening businesses through increased material costs and scarcity of materials. In a more 'circular' economy, materials are continuously reused to minimise resource depletion. Although academic research has focused on key areas such as remanufacturing and eco-design, no practical tools have been identified for manufacturers interested in the circular economy. How can manufacturers identify opportunities to create products and services that align with circular economy principles.

Building on literature, surveys from the automotive industry and case examples, a tool was developed to assist companies in their move to a circular economy. The tool shows benefits, guidelines and examples for each opportunity, as well as key challenges. Workshops were held with manufacturers across industries to test the tool. These workshops resulted in forty opportunities identified.

To make the work widely accessible, the CircularEconomyToolkit.org website was created. In the first month it was launched, the site received 3,338 visits across 76 countries, giving insight into the wider demographics of people interested in the circular economy. Universities and government agencies have been using the tool and workshops. This research took insights from the automotive sector. Future research will investigate the use and development of the toolkit in different sectors.

Key words: *business model innovation, sustainable business models, sustainability, closed loop, life cycle management.*

1. Background

In the past century, the development of industry and technology has accelerated economic growth and improved welfare. Access to low cost resources has led to material scarcity bringing supply chain risk to organisations through increasing and volatile material prices (McKinsey & Company, 2001). Living on a planet with finite resources means the linear take-make-dispose economy is unsustainable. With strains on the planet such as increased consumption, resource utilisation, increasing population and pollution (Ljungberg, 2005), the need for our global resource management needs to be addressed. Predictions are that by 2050 resource usage globally will have tripled compared to 2011 (UNEP, 2011). With 60% of all materials not recycled, reused or composted in the EU, ample improvement is still required in our resource usage (Eurostat EC, 2011).

In a more ‘circular economy’ – a term which has its origins in the 70s (Stahel & Reday-Mulvey 1976) but was popularised by the Ellen MacArthur Foundation (2013) - all materials are continuously used and reused to mitigate our resource consumption and product design needs to address this from the outset. Companies wanting to improve their environmental performance and engage with the circular economy have many options to improve. However, given the potential opportunities available, knowing where to start can be a challenge. The research question is: *How can manufacturers identify opportunities to create products and services that align with circular economy principles?*

2. Literature

To achieve a better understanding of the work already completed on the topic of manufacturers working towards the circular economy, the literature review has been broken down in to the following categories: The circular economy, drivers for the circular economy, opportunities for manufacturers within the circular economy and business tools to identify opportunity in the circular economy.

2.1 The circular economy

The circular economy has its conceptual roots in industrial ecology, which emphasises the benefits of recycling waste materials and by-products (Jacobsen, 2006). A circular economy can benefit society and the economy as a whole, through reducing the overall environmental effect and more importantly, preventing the continued and unsustainable mining and usage of virgin materials (Andersen, 2007). Already in 1970, Kneese et al. (1970) considered the balancing of materials on a finite planet and the effects to the environment and economy, whereas Stahel & Reday-Mulvey (1976) wrote about the impact a future economy which works in ‘loops’ would have on job creation, competitiveness, resource saving and waste prevention. Pearce and Turner (1990; in Andersen, 2007) first used the term circular economy by considering the linkages of economic functions and the environment.

The concept of the circular economy is closely linked with eco-efficiency and cradle-to-cradle thinking. Eco-efficiency is about getting more from less, in other words, more product or service value with reduced waste, resource use and toxicity (Shamiyeh, 2010, p. 253). Cradle-to-cradle considers the entire lifecycle of a product through production, use and disposal, the aim being to create materials that can constantly be used and reused through “upcycling” materials to retain or improve their quality and environmental value and prevent “downcycling”, where materials are recycled at a lesser quality (Braungart et al., 2006). Furthermore, Braungart et al., (2006) classify materials as biological or technical: Biological materials will ultimately form part of a natural cycle, whereas technical materials should be managed to allow “upcycling”, ensuring indefinite use in a technological closed loop system.
The Ellen MacArthur Foundation (2013) was established in 2010 to educate and drive the circular economy principles by partnering with businesses, academia and

non-profits. In 2011, the latest Chinese 5 year development plan included a chapter entitled “Vigorously develop circular economy”, showing their commitment (British Chamber of Commerce in China, 2011). This shows an increasing interest in the circular economy by businesses, governments, charities and academia across the globe.

2.2 Drivers for the circular economy

A move to a circular economy may help companies reduce cost, environmental damage, and risk, and improve competitiveness. Andersen (2007) described some of the drivers as: increased material costs; excess resource extraction leading to resource depletion; harmful residual flows beyond the capacity of biological systems and reducing the regenerative capacity of our systems. Benefits for corporations working towards a circular economy include: greater competitiveness, profitability, satisfying environmental legislation and improved image (Ijomah, et al., 2007), reduced cost of landfill and energy requirements (Kumar & Putnam, 2006), closer working relations to the customer and increased control of the product throughout its lifecycles (Sundin, et al., 2000) and mitigating the dependence on scarce materials (Peck & Bakker, 2012).

2.3 Opportunities for manufacturers within the circular economy

Creating products from raw material extraction, through production, usage and the end of life path taken, consumes resources across the product life cycle (Sarkis, 1995). The research undertaken in this paper is focused on the product and materials itself within a circular economy, not the production efficiencies for the product manufacture. To create the tool framework every lifecycle stage of the product and material flows needs to be considered. Jansen & Krause (1995) describe the lifecycles of production, use and recycling, where recycling is the broad term for enabling repeated use once the product has reached the end of its life with the consumer. In this section, opportunities for the circular economy across the product life cycle are discussed based on the literature and company examples.

Design

Design is the first step in creating sustainable products with a minimal or even positive impact on the environment. Different design methods defined by Dewberry & Goggin (1996) include: *green design,* which has a single-issue focus (e.g. recycled packaging), *eco-design*, which adopts a life-cycle approach to tackle the greatest impacts across the product’s life cycle, and *sustainable design* which takes a holistic approach, including concerns for ethics, services, dematerialisation, empowerment, sharing, as well as eco-design.

Reduced and optimised material use

Products can be redesigned to reduce the materials required to create the same functioning product. *Dematerialisation* is about using as little materials as possible and may indicate complete removal of materials all together and may refer to reductions in product or the packaging (Kuta, et al., 1995). Reducing materials use has the benefits of saving cost and carbon emissions for the manufacturer (Kuta et al., 1995). This is in line with the waste hierarchy where the first step is "prevention" of materials (DEFRA UK, 2013). An example of reducing materials can be found in the automotive industry where the use of high-strength materials allows reductions in material volumes whilst retaining material strength. For example, Ford (2013) uses high strength steel in their cars which reduces material usage whilst also improving fuel consumption for the user. A packaging example for reduced materials is Apple (2013) who redesigned the shape of its iPhone box in 2007 and reduced packaging by 28% and was able to transport 60% more phones whilst maintaining protection.

Optimise material use

The following factors may be taken into account to reduce the environmental impact associated with material use: the use of eco-efficient materials, recycled materials and renewable sources, and shortening supply chains and choosing non-toxic and non-scarce materials (Allione, et al., 2012).

Eco-efficient materials are characterised by minimised embodied energy (direct and indirect energy used to make and transport the materials) and CO_2 emissions to produce and deliver the materials (Allione, et al., 2012). *Recycled materials* contribute to closing the materials loop because used materials are reused again. Polartec (2013) for example manufacture fleeces from 100% recycled materials. *Renewable sources* (e.g. wood, cardboard, sugarcane) are reabsorbed by the natural environment through composting by anaerobic digestion or energy recovery, where there is no net impact on the environment (Allione, et al., 2012). Puma (2013) for example created biodegradable range of shoes and bags. *Short Supply Chain*s are about using locally available materials for production (Allione, et al., 2012). This can be achieved through avoiding long transportation and poor efficiency means of transport, which can reduce transportation costs and emissions, whilst supporting the local economy. Audi for example aim to locally source 90% of all car parts for their Mexico plant (Automotive News, 2013). Depending on the materials and substances, a material could be *toxic* for human health throughout its life cycle phase or at the end of its life. If a material does not release harmful substances during the pre-production, production and usage phases, it may be defined as bio-compatible (Allione, et al., 2012). Nike (2013) for example is aiming to reduce toxic substances through substitution, improved production processes and working closely with their suppliers. When designing a product, *scarce materials* should be considered as these present supply risks to the manufacturer and prevent continued production. A survey conducted by Peck & Bakker (2012) showed that 80% of companies had difficulties with raw material supplies from 2007 – 2012. Toyota for example is reacting to scarcity of neodymium by developing neodymium-free induction motors for its electric cars (Economist, 2011).

Product use

In product design, the environmental impact in the usage lifecycle needs to be considered (e.g. Bocken and Allwood, 2012). The product designer should balance the replacement frequency against the product efficiency and should find ways to communicate potential usage savings to the consumer if upfront costs are high (e.g. in the case of LED lights to replace tungsten light bulbs). In principle, an extended lifetime of a product leads to a reduction of the environmental impact of our consumption pattern. However, if the product is consuming resources such as energy or water in the use phase, it can be more beneficial to replace it with newer, more efficient alternatives - product life time, replacement and usage need to be balanced (van Nes & Cramer, 2006).

Maintenance and repair

Maintenance is an activity undertaken in the usage phase of a product to improve availability of the product. It is the most effective way of retaining or restoring equipment back to the normal working conditions (Ajukumar & Gandhi, 2013). The maintenance support service offered by a company can include field technical support, spare parts distribution and customer care (Saccania, et al., 2007). Companies such as Dell (2013) offer repair services by providing step-by-step diagnostics, parts, upgrades, downloads and manuals to give the customer support to resolve their computer issues.

Reuse

Reuse extends the product life by second-hand use, so that fewer products overall have to be produced (Truttmann & Rechberger, 2006). Reuse of a component or product should consider the resource consumption of the product throughout its lifetime. Replacement of older electronics products for example, can reduce the overall lifetime emissions of the products, despite the energy and resources used to create the new product (Truttmann & Rechberger, 2006). Car dealerships, excavating dealers and websites such as Ebay offer resale of second hand goods.

Refurbish/ remanufacture

Remanufacturing is the process of restoring the product or part functionality to “as-new” quality, whereas reconditioning is the process of restoring the product or part to “like-new”, but the process will not be as thorough as remanufacturing (Ijomah, et al., 2007). For example, reconditioning could simply be improving the aesthetics of a product. Giroflex (2013) a Swiss furniture manufacturer has designed chairs with the cradle-to-cradle philosophy including the option to disassemble, replace parts and remanufacture the chairs when returned.

Recycling

At the end of the useful life of a product, it can either be disposed of via landfill, energy may be recovered, or the product can be recycled so the materials can be reused. For non-biodegradable products, recycling is essential to keep materials circulating in the system. The recycling process can first involve disassembly if there are materials, which are harmful or high value; the material can be shredded and sorted into common material types and then used as feedstock at the start of the production process (Bor, 1994). According to Braungart et al. (2006) we live in a world where most products have a "cradle to grave" manufacturing model. Many materials that are recycled are 'downcycled' or transformed into lower quality materials. If materials were 'upcycled' through initial design changes and managing recovery of materials, it would ultimately lead to a sustainable usage of materials. Cars are designed to allow quick removal of car fluids, disabling of airbags and seat tensioners; labelling of products and materials can ease the sorting process (e.g. BMW, 2013).

Reverse logistics

Reverse logistics is required for the supply of feedstock for reuse, redistribution, remanufacturing and refurbishment and product-service systems. Kumar & Putnam (2006) define three ways in which collection can be managed: (i) the customer gives the product to the retailer, who passes it to the manufacturer, (ii) the product is sent directly back to the manufacturer or (iii) the customer gives the product to a third party collector, who then passes it to the manufacturer. To encourage the return of products, different incentives can be used to encourage return of products, such as an *exchange* ('new' product or part is provided once the old is returned), *rebate* (money is given to the customer upon return of product) or *deposit* (money is paid at time of purchase and reimbursed when the product or part is returned) (Fleischmann, 2001).

Related areas: Industrial symbiosis and product service systems

Business model innovation and collaboration may be viewed as key components to the move to a more sustainable economy (Bocken et al., 2013). Industrial symbiosis is a key example of industrial collaboration, whereas a product service system is a major example of business model innovation.

Industrial symbiosis is the physical exchange of materials or energy between organisations: waste from one organisation becomes the resource for another organisation. The expression "symbiosis" builds on the notion of biological symbiotic relationships in nature, in which at least two otherwise unrelated species exchange materials, energy, or information in a mutually beneficial manner – similarly, industrial symbiosis consists of resource exchanges among geographically near entities (Chertow, 2000). Collaboration and the synergistic possibilities offered by geographic proximity are key components of industrial symbiosis, of which Kalundborg in Denmark is perhaps the most cited example (Jacobsen, 2006). Cooperation between companies can lead to "win-win" situations where there is competitive advantage for both companies, or “win-win-win” business models where there also is a ‘consumer-win’ through improved business model features (Bocken & Allwood, 2012).

A *Product-Service System (PSS)* is a combination of products and services in a system that provides functionality for consumers and reduces environmental impact (Goedkoop, et al., 1999). To develop a PSS, the design aspect must consider a life cycle perspective and a series of interconnected product and service life cycles, which has a greater potential for eco-efficiency gains (Manzini & Vezzoli, 2002). Several companies are moving to a more service based offering, such as car clubs (Chase, 2012).

2.4 Tools to assess and discover opportunity in the circular economy and gaps

A number of tools have been developed for environmental design and management (see Baumann et al., 2002; Bocken et al., 2011) which can be summarised as measurement (e.g. life cycle assessment, material flow analysis), guidelines/ checklists (‘Ten golden rules’; Luttrop & Lagerstedt, 2006), evaluative (Environmentally Responsible Product Assessment Matrix; Graedel, 1997), comparative / trade-off tools (e.g. Eco-compass by Fussler and James, 1996;) and idea generation tools (Bocken et al., 2011). Furthermore, the concept of the circular economy is grounded in the literature (e.g. Stahel & Reday-Mulvey, 1976; Braungart et al., 2006). The literature review has found a significant amount of fragmented research across several aspects of the circular economy, however there is a gap in consolidating this information to provide an overview to businesses of the potential opportunities. These opportunities could improve both a manufacturer’s ‘green’ credentials and provide a financial benefit such as material saving, resource saving, increased sales, improved customer relations and compliance with regulation.

Organisations such as the Ellen MacArthur Foundation (EMF, 2013) and The Waste & Resource Action Programme (WRAP, 2013) provide free resources for companies on the circular economy. They provide examples of different opportunities, but not necessarily a format, such as a workshop to facilitate a session and find their own opportunities. The approach taken by organisations that promote the Circular Economy, specialised consultancies and local government agencies is at a broader, higher level to educate, or to work directly with selected companies. There is no information widely available to companies to the authors’ knowledge that can help manufacturers find opportunity across all areas of the Circular Economy. These high level materials online do not give autonomy to the user, preventing any action to be taken by themselves and a specialised consultancy comes at a price.

This research addresses the following question: *How can manufacturers identify opportunities to create products and services that align with circular economy principles?* A tool is developed to assist manufacturers in the identification of opportunities.

3. Methodology

The research method is highlighted in Figure 1. Literature and practice review (of existing company who have sought opportunity in the circular economy) led to an initial tool framework. Through surveys additional insights for the tool development were gained on the services offered to the customer, the most important considerations for businesses, and environmental design management tools used that may support the move to a circular economy. The surveys were focused on the automotive industry because this industry has already adopted some circular economy principles such as PSS, remanufacturing and reuse, perhaps because of specific environmental legislation and consumer preference. Workshops were run to test the effectiveness of the tool. Website analytics were used to analyse behaviour of tool users.

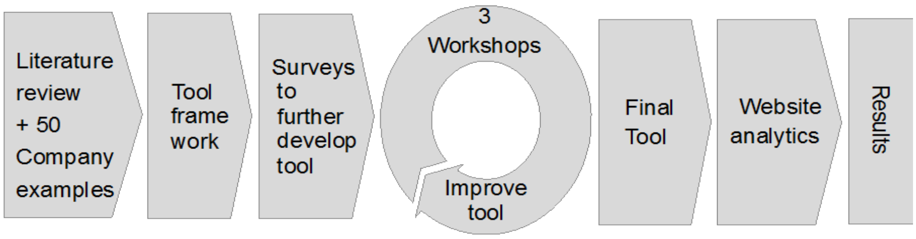

Figure 1. Research method. Developed from Bocken et al. (2011)

For companies there is an element of risk to making changes. As Short et al. (2012) found, there is "*risk involved in making any changes - whether an individual implementing Eco design unofficially, or the proposing of or implementation of sustainability at a corporate level*". To reduce risk, a tried and tested approach is required which shows the potential challenges and considerations required to find opportunities in the Circular Economy for manufacturers. Furthermore, the materials should be made publically available to help the ultimate goal of mitigating climate change and environmental impact. Following on from this, the tool should:

- Categorise opportunities, show distinct improvement areas and be backed academically
- Provide a tool structure including: benefits, considerations, design best practice and company examples
- Provide an approach for manufacturers to identify opportunities within their business.
- Be human-centric, workshop-based, neutrally facilitated, lightly controlled, modular, scalable and visual (Kerr et al., 2013)
- Be allowed for public viewing and give autonomy to the manufacturers to find opportunities themselves.

Surveys

Given the number of opportunity areas, it would not be possible to survey them all. Distinct opportunity areas must therefore be selected for the data collection. Survey areas were chosen in areas, which were expected to be least familiar to manufacturers (based on the lack of literature in these areas). These survey areas built on the life strategies defined by Rose (2000) and product service systems (Table 1).

	Circular Economy Opportunity Areas								
	Reduce material usage	Optimise material usage	Industrial Symbiosis	Usage	Maintain/Repair	Reuse	Remanufacture/Refurbish	PSS	Product Recycling
Introduction									
Benefits									
Considerations					Survey 2				
Product Design									
Environmental Design Management Tools	Survey 1								

Table 1. Survey areas. Source: based on Rose (2000). Note. Survey areas indicated in grey.

Survey 1 covering all opportunity areas in Table 1 was an environmental design management tool survey to establish which environmental management tools are used most frequently. Questions were based on design guidelines and environmental management tools found from the literature review. An electronic survey was sent to participants. Surveys were sent to UK design managers at automotive manufacturers. Ten surveys were sent, and seven responses were received.

Survey 2 was a life cycle management survey to find successes and challenges in providing the service and added value and service offered to the customer. These considerations by manufacturers were important for the tool design to gain understanding of the challenges faced by the businesses and rank common answers. Parts of the lifecycle to be surveyed included: Maintain/ repair, reuse/ redistribute, refurbish/ remanufacture, PSS and product recycling. These themes were observed from the literature review. Face-to-face structured interviews were used to allow discussion whilst staying focused on the questions and answers. The interviews were conducted with managers in automotive dealerships, garages and vehicle recycling centers at the Amsterdam ReMaTec 2013 conference for remanufacturers and refurbishers. A total of 30 surveys were completed; ten surveys were conducted for refurbish/ remanufacture, and five for each of the remaining four circular economy opportunity areas (Survey 2, Table 1). The response rate for the interview surveys was 79%.

Tool

An initial tool framework was developed from the literature review and survey results. For each circular economy opportunity identified, the following were developed:

- 'Introduction'
- 'Benefits' of the initiative, to the company, consumer and environment
- 'Considerations' of aspects which require attention before a decision is made
- 'Case studies' to show how other manufacturers are successfully running initiatives

The tool has been designed from the outset to be appropriate for a website. The web tool allows the user to see an introduction for each section and allows for further information to be investigated if desired.

Workshops

To test the usefulness of the tool, it was trialled in three workshops with manufacturers. A feedback form was provided to the attendees to give constructive feedback for improvement. A workshop format was trialled so that:

- Tool contents and workshop format could be tested
- Content of the workshop and tool could be uniformly controlled by the facilitator
- Any issues with the tool or workshop format could be quickly and accurately identified
- Communication between the workshop attendees could be observed
- Feedback from the sessions could be obtained

For each workshop, the following was prepared: *Estimated lifecycle carbon emissions*, from material extraction to product disposal, and a *competitor analysis*, showing other companies offering services which support the circular economy, such as remanufacturing, resale and lease.

As the tool has been designed to be a general tool for any manufacturer, the companies selected for the workshops required different product types and company sizes. Table 2 shows a summary of the companies who participated in the workshops.

Workshop	Product	Employees
1	Healthcare equipment	~ 50
2	Wood stoves	~ 200
3	Electrical generators	~ 40,000

Table 2. Companies selected for workshop

Web analytics

The website has been designed to gather feedback data to continuously improve the website in three ways:

1. *Google analytics* to understand usage of the website
2. *Website questionnaire* to understand usefulness of the different parts of the tool
3. *Product and service assessment tool answers* to provide insight of the types of companies looking at the websites and ways in which they rate themselves and identify opportunities.

4. Results

Various forms of the tool format (variations on representations of a product life cycle and value chain) were tested against company examples. As a result of this exercise, the final tool format was developed (Figure 2). For example, design, manufacture and distribution were combined under one opportunity area, because product design led initiatives often would not have been possible without the manufacturing equipment and potentially the distribution network (e.g. biodegradable sportswear). Product Service Systems affect all parts of the life cycle and therefore needed to be represented separately, yet in some way showing the connection to all parts of the framework. Finally, the encompassment of the 'Circular' concept was missing from the initial framework leading to the redesign in a circular format. The alterations and improvements to the initial framework led to the tool framework as can be seen in Figure 2.

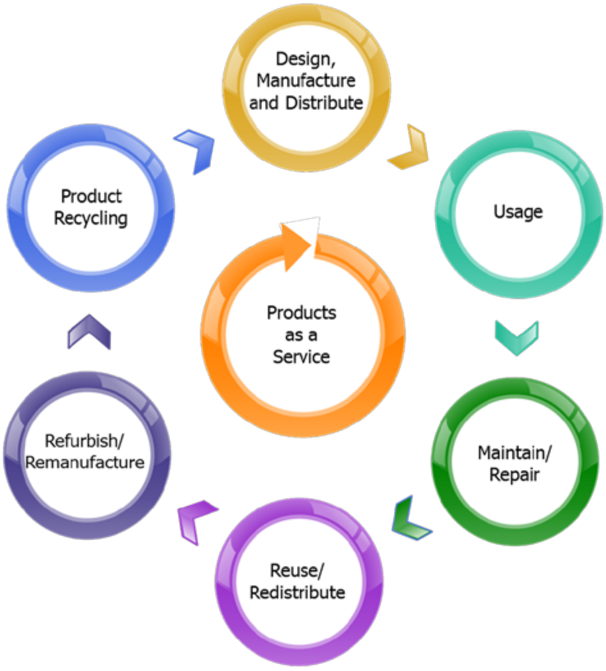

Figure 2. Tool framework on the website. Source: www.circulareconomytoolkit.org

The main steps in the tool framework include: Design, Manufacture and Distribute; Usage; Maintain/ Repair; Reuse/ Redistribute, Refurbish/ Remanufacture, Product recycling, and Products as a service. Figure 2 highlights the Design, Manufacture and Distribute phase. Each of these steps includes an Introduction, Benefits, Considerations for manufacturers, Product Design considerations, and Case Studies. The content is based on the literature, examples from practice and surveys. The full tool is freely available online.

During the workshops a total of forty business opportunities were identified across all the different opportunity areas, of which the most promising one would potentially save £3-4 M in materials and up to 10,000t of CO_2 per annum. A company self-assessment tool was developed on the website, based on which the most suitable circular economy opportunities would arise (Figure 3). Workshop attendees were asked to complete the self-assessment prior to the workshop starting. Testing the assessment tool against the workshop outputs showed that the tool identified 88% of the opportunity areas found during the workshops, which shows that the self-assessment tool mostly generates opportunities relevant to the tool users. More workshops and self-assessments will need to be conducted to test the fit of the tool.

The website was launched on Tuesday, 20th August 2013 with 4 press releases to UK-based sustainability news websites. Adding tracking code to the website allowed Google analytics to monitor the number of visits to the website. In the first month, the site received 3,338 visits across 76 countries. China contributed to 67% of the visits, followed by the UK (11%), the Netherlands (7%), Russia (2%) and the other remaining countries (13%). Refurbish/ remanufacturing and products as a service received the longest mean viewing time. Data will be skewed due to English speakers and local promotion of the website.

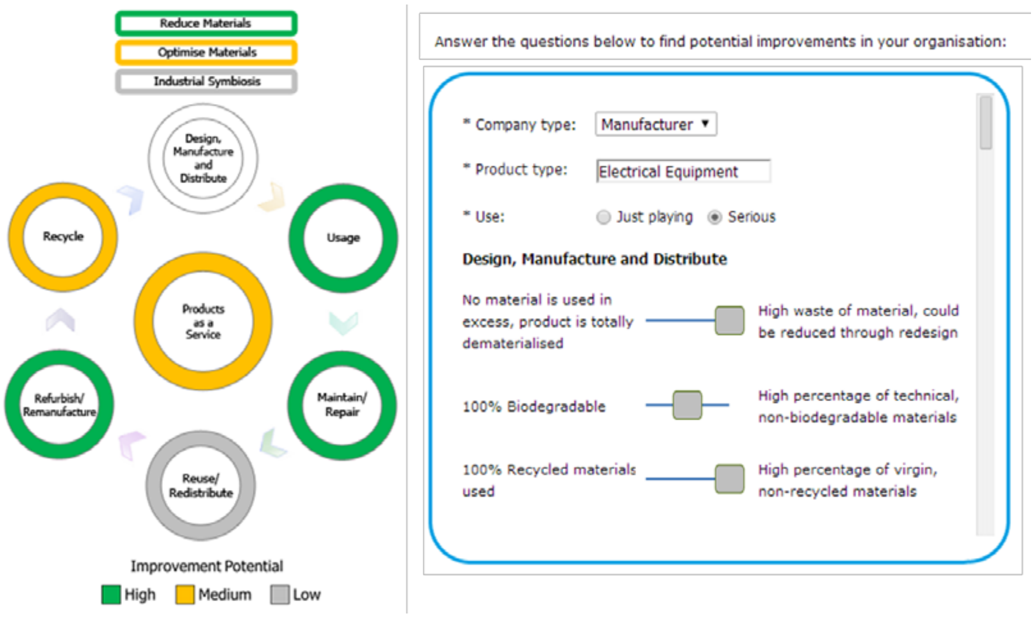

Figure 3. Website Self-Assessment Tool. Source: www.circulareconomytoolkit.org

5. Discussion

A Circular Economy Toolkit was developed to support companies in the transition to a circular economy, help them create value, reduce materials usage, design for a longer product life while being resource efficient, and identify opportunities for the product through its lifecycle. Although each of these individual areas has received individual attention in the literature, this research aimed to build on this academic work (e.g. cradle-to-cradle, remanufacturing, industrial symbiosis, sustainable business models) to develop an easy to use and accessible circular economy toolkit.

The research was limited by a small number of surveys in the automotive industry. However, the industry examples gathered to develop the tool, and workshop to test the tool spanned a wider area of industries. Only five areas of the toolkit were surveyed (Survey 2; Fig 1); investigating more areas would lead to more insights on opportunities and challenges for manufacturers. The Circular Economy opportunity areas structure (Fig. 2) is one format developed from the literature and cases. However, other formats such as WRAP's business model map (WRAP, 2013) may also be considered. Further workshops in other sectors (e.g.

consumable products such as food or cosmetics) could be facilitated to further develop the tool. Finally, this work is viewed as a first step in collating the disparate literature on areas such eco-design and remanufacturing in a tool for manufacturers to consider the 'circular economy'. The authors encourage future research to deepen the knowledge base in this area.

Future research could look into an in-depth analysis of each of these opportunity areas and continue to look for more and better opportunities to help companies move to a circular economy. Moreover, the linkages to other business model innovations, such as sufficiency based business models, concerned with mitigating consumption (see Bocken et al., 2013), could be considered.

6. Conclusions

Key concepts to find opportunities for manufacturers in the circular economy have been compiled from the literature and practice, which has resulted in a circular economy toolkit (Figure 2). The toolkit was tested with companies in a workshop format to trial the proposed method. The information gathered from the tool and workshops were then presented on the website, CircularEconomyToolkit.org. Future researchers are encouraged to further expand the knowledge base on how companies might move to a circular economy.

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