Interreg
EUROPEAN UNION
North-West Europe
TRANSFORM-CE
European Regional Development Fund

Case study report - Circulogic

Good practice of circular economy business models

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As part of the TRANSFORM-CE project, several case studies are done to benchmark existing circular economy business models. This document covers the results of the case study into garage2green and EcoWOW, circular products and services developed by Circulogic, based in the UK. A total of 20 case studies will be completed, with five cases per country (The Netherlands, Germany, Belgium and the United Kingdom).

Date 29 April 2021

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Deliverable WPT3 D2.1 Benchmarking existing circular economy (CE) business models

This research has been conducted as part of the TRANSFORM-CE project. More information about the project can be found on: **www.nweurope.eu/transform-ce**. TRANSFORM-CE is supported by the Interreg North West Europe programme as part of the European Regional Development Fund (ERDF).

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1. Introduction and method

1.1 Goal of case study

TRANSFORM-CE is an international research project which researches amongst others (successful applications of) circular business models, barriers, enablers and needs for circularity, and offers in-depth support for the uptake of recycled feedstock by businesses. A core part of the project is to provide advice to businesses on their way to transition towards a circular economy (CE).

In order to help businesses with developing circular business models (CBM's), it is first important to benchmark existing CBM's of companies. This is done by conducting case study projects with 20 selected businesses throughout North-West Europe. The aim is to provide participating businesses with an in-depth analysis of their current situation and business model, to identify opportunities and provide recommendations for facilitating the transition towards a CBM for these and other companies. The case studies also present a unique opportunity to study barriers, enablers and needs for circularity (and recycling) in more detail.

1.2 Company background

A short overview of Circulogic is given in table 1.

Table 1: *Overview of company*

Topic	Information
Company name	Circulogic
Website	https://circulogic.uk/ / http://garage2green.com/ / https://www.ecowow.co.uk
Country	
Size of company (0-10, 10-200, 200-500, 500+ employees)	0-10
Mission/vision	'Our aim is to help organisations and sectors implement sustainable supply chains, and to provide Strategy, Procurement and Efficiency advice to those responsible for collecting and managing waste resources.'
Product category	Products manufactured from used golf club shafts and 3D printed recycled plastic components, including golf targets and litter pickers (at prototype stage).
Production/operational process	3D printing, machining (sewing), assembly
Used materials	Recycled post-consumer golf club shafts (fibreglass composite), plastic filament (rABS) and synthetic fabric (rPET polyester).

1.3 Case study process

The case studies are being carried out between September 2020 and December 2021. The case study process is structured in four steps[1], with an iterative approach at the end of each step. The first step (circularity of the business model) aims at creating a general overview of the company, the context and its (circular) business model, to capture how the company creates and delivers value. The second step (circularity in the value chain) involves a circularity assessment of the company and its activities in the value chain. The third step (circularity of operational activities) is focussed on the circularity of the company's operational activities. The last step involves a wrap-up of the results and concludes with the case company's strengths with regards to circularity, an overview of the barriers and enablers for circularity, and opportunities for further enabling circularity. The final result is a case study description, covering the previously established information.

An overview of the case study analysis process is shown in figure 1 on the next page. In order to obtain the results, each of the three steps is divided into four sub steps: 1) desk research and preparation; 2) interview; 3) reporting results; 4) iteration of results. More information about the process and the steps needed for receiving the results can be found in a separate document ('case study methodology') explaining the case study process in more detail. Three interviews are conducted for this case study, with one interview per step and the interviewed persons each having a different function and responsibility within the company. Table 2 gives an overview of the interviewed persons for Circulogic.

Table 2: *Overview of interviewed people*

	Interviewed person	**Function**
Interview 1: Circularity of business model	Geoff Sampson	Director
Interview 2: Circularity in the value chain	Geoff Sampson	Director
Interview 3: Circularity of operational activities	Geoff Sampson	Director

[1] We make grateful use of insights and methods derived from previous research, in particular the case study method of R2π (2017, 2019), the work of Circulab (2020) and the Ellen MacArthur Foundation (2017, 2019).

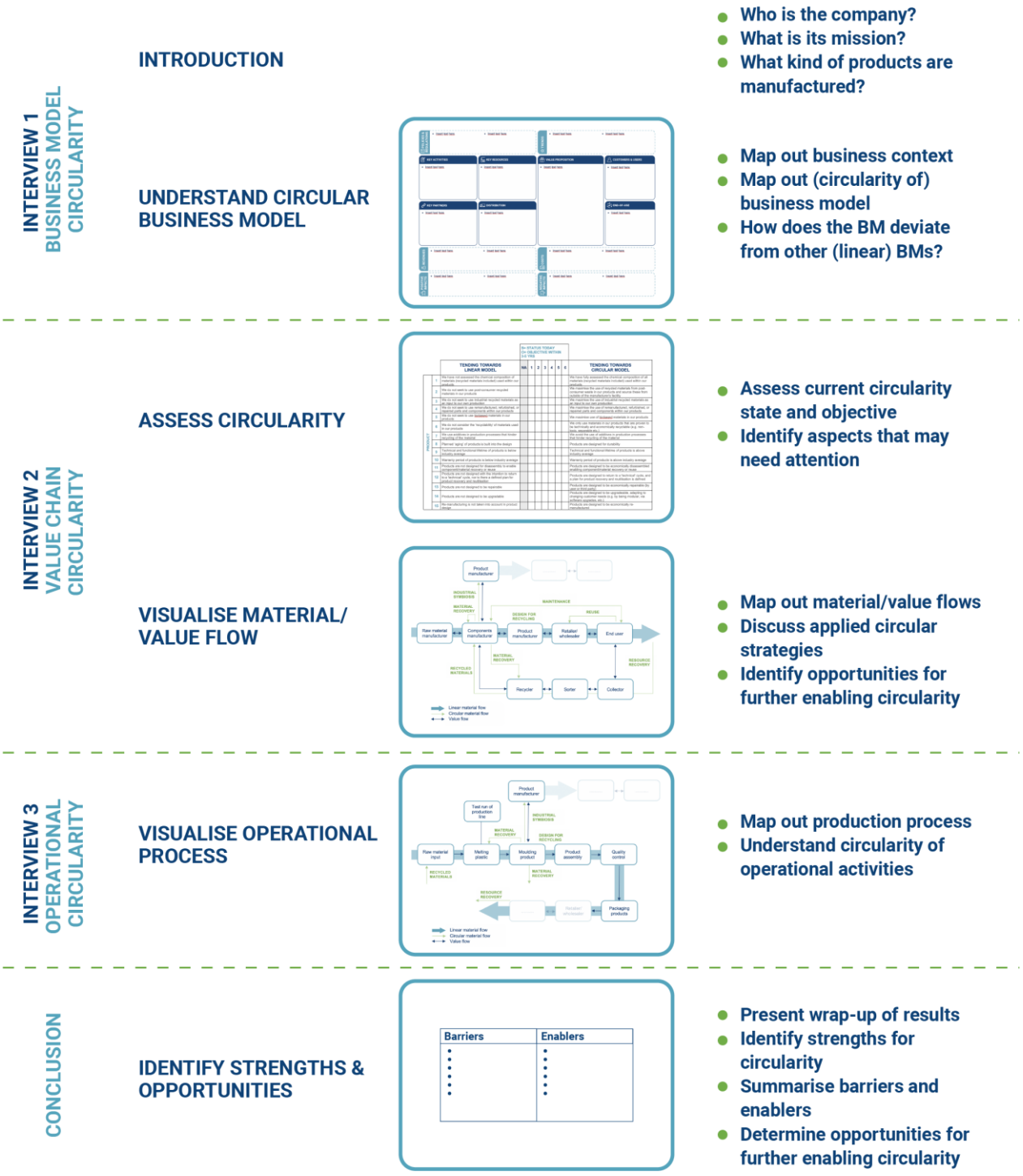

Figure 1: *Overview of case study process*

2. Circularity of business model

The first step aims at creating an overview of the company's business model and the context in which it operates, to capture how the company creates and delivers value (for circularity).

2.1 Circular business model canvas

The circularity of the business model is investigated by using a circular business model canvas (CBMC). This model is created for the purpose of this study and shows how the company creates, delivers, and captures value through its garage2green and EcoWow initatives highlighting circularity aspects of these elements of the business. The CBMC of Circulogic's garage2green and EcoWow initiatives is visible in Figure 2 and a description of each element is given below.

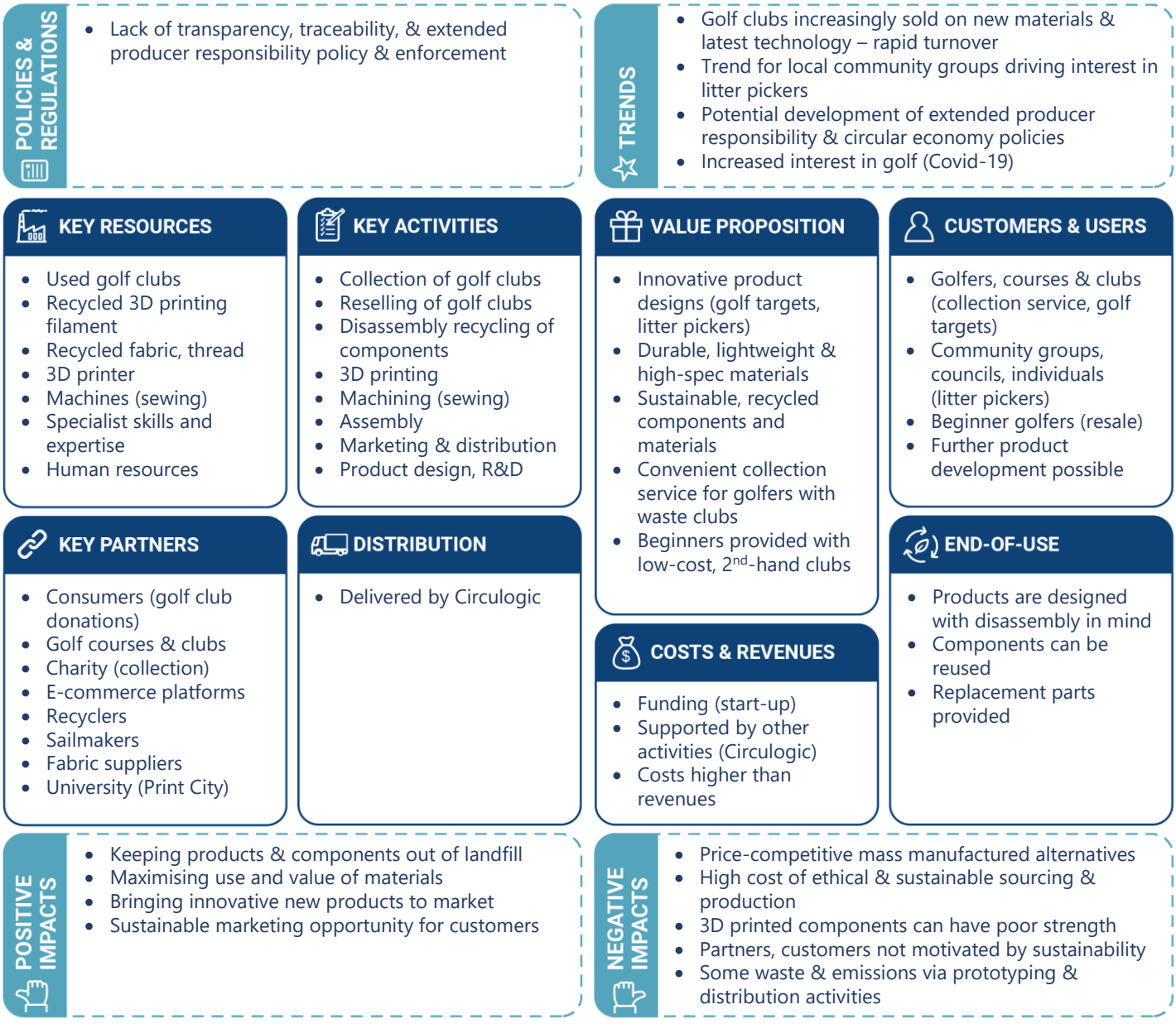

Figure 2: *CBMC of Circulogic's garage2green and EcoWoW initiatives.*

Value proposition

Circulogic is a resource and waste management consultancy specialising in innovative solutions supporting the transition to a circular economy. Building on their experience and expertise, they launched a pilot takeback and reuse service for unused and unwanted golf clubs called garage2green (www.garage2green.com). Accessing funding from the European Regional Development Fund via Zero Waste Scotland's Circular Economy Investment Fund[2], the pilot was launched in 2018. The project focused on golf clubs due to the rapid turnover of products, as a result of new performance technologies and advancements, as well as the non-recyclable nature of the composite materials that make up the central golf club shafts.

In the first instance, garage2green provides golfers, courses, and clubs with a convenient outlet for unused and unwanted golf clubs. The highest quality clubs are resold via e-commerce platforms, partner charity shops and/or distributed to school groups, meaning beginner golfers can benefit from access to quality clubs that they might not have otherwise considered investing in or been able to afford. The value of the materials and components in the remaining clubs are then maximised through disassembly and the recycling of metal components, such as club heads, and the reuse of non-recyclable components, such as the carbon fibre shafts. The latter are then used to make new products, such as golf chipping targets and litter pickers, through the addition of recycled plastic and fabric components as part of Circulogic's EcoWOW (www.ecowow.co.uk) initiative. These products are designed in such a way that they can be disassembled and made into new products at end of life.

Customers & users

Circulogic started garage2green, with the aim of repurposing a difficult to recycle waste stream (golf clubs) and maximising the value of their high spec materials. Logical customers for the recycled products produced, were golf courses, clubs and golfers. As such, golf chipping targets were created. Given that this demographic may be less motivated by sustainability, prioritising sporting performance, a range of product applications and customer groups have been targeted. By way of example, litter pickers are also being developed to target 'green' markets and customers. The company remains open to new product ideas but admits that they would likely need further funding to support the upscaling of production and sufficient marketing activity to drive forward sales.

Key activities

The first step in Circulogic's process is the collection of unused and unwanted golf clubs from strategic collection points located at participating golf courses. The golf clubs are picked up by a partnering charity, before being sorted. Those in the best condition are sold for reuse and/or distributed to schools and academies (to encourage new entrants to the game). Older antique golf clubs may also be sold to collectors.

The next step is the disassembly of the remaining golf clubs into their component parts. Those parts that can be recycled are sent for processing by a third party. The golf club shafts are then sorted and

[2] For further information on Zero Waste Scotland's Circular Economy Investment Fund, visit https://www.zerowastescotland.org.uk/circular-economy/investment-fund.

measured, as they all have slightly different dimensions and are not uniform. This is an additional, manual process that wouldn't be required if manufacturing new products, which adds to the time and cost of production.

Recycled plastic 3D printed components, such as ground pegs and grippers, are then printed with the assistance of Manchester Metropolitan University's PrintCity, an additive manufacturing hub. In the case of the golf targets, recycled ripstop fabric is also sourced from China and sent to a UK sailmaker to be sewn into tent-like structures to be stretched over the frames made from the golf shafts and 3D printed plastic components. Alternative means of constructing the textile part the golf target product, such as the use of glue and adhesives, were explored, however, these were deemed to be insufficiently durable and a potential barrier to disassembly. Assembly and distribution of products has, to date, been carried out internally by Circulogic.

Some aspects of the production process are likely to be adapted in future to achieve a more competitive unit cost. In the case of the golf targets, for example, the supplier responsible for machining (sewing) the textile components advised that they would need to increase costs for further runs due to the time-consuming nature of construction. As a start-up operation, garage2green's activities were supported by funding from the European Regional Development Fund via Zero Waste Scotland's Circular Economy Investment Fund[2] and Circulogic's other service income streams. Further funding may be needed to upscale the operation in future.

Figure 3: *Examples of Circulogic's EcoWOW golf chipping targets, incorporating recycled plastic 3D printed components.*

Key resources

Circulogic's material resources include donated golf clubs, recycled plastic 3D printing filament, recycled ripstop fabric, and thread for constructing the textile components of the golf targets. The filaments were sourced via PrintCity, whilst the fabrics were sourced from a supplier in China. Circulogic would like to source recycled fabric from local manufacturers in future, if possible, as previous attempts to identify these have so far been unsuccessful. In the case of the prototype litter pickers, additional functional components made from steel are incorporated.

In addition to materials, Circulogic also requires access to third party equipment, including 3D printers and machines (sewing) provided by key partners. Circulogic's operations also make use of partners' specialist skills and expertise, as the garage2green team is still very small, being a start-up. An example of this is Circulogic working in collaboration with experts at PrintCity to design golf target and litter picker products and components using computer aided design (CAD) and other software to generate 3D printable designs.

Key partners

As garage2green is a start-up initiative of Circulogic, the operation is dependent on the company's relationship with key partners. These include the golf courses that support the collection of unused and unwanted golf clubs, the charity that provides collection services, retail outlets for the resale of high quality golf clubs, 3rd party recyclers for processing the metal golf club components, recycled fabric suppliers and sailmakers (machinists) for the fabric components, and PrintCity for the design, development, sourcing and 3D printing of recycled plastic components. As such, Circulogic's operations sit within a much wider network of stakeholders that help to make the system function effectively.

Distribution

Distribution of products is currently carried out by Circulogic. Customers Recipients to date have included the golf courses associated with the garage2green project and affiliated golf professionals. Some of the golf targets have also been offered for free as part of promotional events, to raise awareness, or sold directly to individuals. If upscaling, the company may need to engage a distribution partner.

End-of-use

Circulogic's products are designed to be durable and long wearing. At end of life, they can easily be disassembled and separated into constituent components, which can then be reused in other products or recycled. Spare 3D printed components are also made available to support repair and product life extension, as these have been found to be the weakest part of the product.

Costs & revenues

Garage2green is an early start up (pilot) scheme, which has been supported with funding from the European Regional Development Fund to help cover initial set up and production costs. Without this investment, it would not have been possible to manufacture the products and put in place the necessary supporting systems (promoted through EcoWOW). Whilst 3D printing is beneficial in that it facilitates rapid prototyping and custom, on-demand production, ideal for supporting product innovation and producing the first product runs, it is not as cost and time efficient as mass manufacturing processes, such as injection moulding. Transitioning from 3D printing to injection moulding for the production of many identical components may therefore be a strategic decision as the business scales.

Likewise, machining (sewing) the textile components of the golf targets by a sailmaker in the UK entails considerable labour and therefore high costs. Lower cost alternatives, such as the use of adhesives, were found to be insufficiently durable for the intended product purpose, and to pose potential challenges for further recycling of the material at end of life. This is reflective of the challenges that developers of

circular products and solutions face, as compromises must often be made, particularly between circularity, performance and cost.

"Commoditising circular design and manufacturing principles is hard when you're an early adopter ... and customers aren't necessarily prepared to pay a premium. Ideally, we need to see whole supply chains, including OEM's, making the shift to circular business models. This requires business enlightenment, supported by global adoption of policy levers such as Extended Producer Responsibility." Geoff Sampson, Director of Circulogic

The recycled fabric has so far been sourced from a supplier in China. If switching to a local manufacturer in the UK, it is likely that costs will again increase.

To test the market and its reception of the concept, a range of products incorporating waste golf club shafts have been developed to date, appealing to different sectors, so that those markets with the greatest potential may be identified. Some of these, such as the litter picker, have been designed to target groups that are known to have an existing interest in sustainability and the environment. The market response is being monitored so as to pinpoint the sweet spot between product price and the cost of production, whilst adhering to circular principles. As a new product innovation, EcoWOW's golf target and litter picker products have not yet been marketed on a large scale. Further funding is needed to upscale production and put in place additional processes, such as sales and marketing.

Policies & regulations

Circulogic explained that a lack of policy enforcing extended producer responsibility has led to the design of products that cannot be easily separated back into their individual components and materials, creating legacy waste that cannot be easily recycled. Golf club shafts are a good example of this, as these are manufactured from increasingly complex composite materials, such as carbon fibre, to achieve improved performance characteristics, like strength and light-weighting, at the expense of circularity and sustainability. If producers also had to deal with their waste streams, then perhaps there would be an incentive for improving the circularity of materials and products.

The adoption of use-based business models was also discussed as a possible way to encourage manufacturers to design products for durability, reuse, disassembly, and recycling. However, Circulogic explained that this would represent a significant divergence from the norm, requiring considerable policy and regulation instruments to instigate change.

Supply chain transparency and the traceability of materials was also highlighted as a further challenge, resulting from a lack of effective regulation and enforcement. Whilst Circulogic explained that they make every effort to ensure that their materials, such as recycled 3D printing filament and ripstop fabric, are sourced from genuine post-consumer sources, it can be difficult to verify this. To do so, would require Circulogic to physically inspect the entire supply chain, which is not really possible with complex, overseas supply chains comprising many long chains of custody. This is especially the case for small, start-up operations, as in the case of garage2green and EcoWOW.

Trends

The main motivation behind Circulogic's products is the high durability and performance characteristics of unused and unwanted golf club shafts, whilst being non-recyclable, and with a high product turn over. The complexity of the materials (resulting in an inability to recycle them) is due to the trend for constant development of new technologies and materials, combined with the prevalent 'product ownership' style consumption model, whereby performance improvements help to encourage product turnover and further sales. It was also highlighted that, as a distanced, outdoor sport, golf and the sales of related equipment have risen during Covid-19 related restrictions.

Circulogic noted the limited impact of sustainability incentives on the golfing market, however, suggested there is a growing wider trend for sustainability in other markets, which may help to promote the sale of circular products, particularly those used in environmentally-minded activities, as in the case of the litter pickers. There is a growing trend for more sustainability-minded community groups, who are arranging litter collections, who Circulogic's recycled products may align well with.

Positive and negative impacts

The first positive aspect of Circulogic's garage2green business model is the fact that golf clubs are being diverted from landfill, with their components and materials reused and recycled in new applications, achieving a circular economy. Circulogic complements this by sourcing the other materials and components used in their products from recycled plastic sources.

The company also contributes value by bringing innovative products, such as the golf chipping targets and litter pickers, to market. There exists potential for Circulogic's customers to benefit from reputational benefits by adopting the sustainable EcoWOW products manufactured by Circulogic and carrying out marketing activities to promote their sustainability.

In terms of negative impacts, Circulogic explains that a small amount of waste is generated during the rapid prototyping phase of new product development, as several models are made and tested. Additionally, packaging used to transport components from 3rd party suppliers to Circulogic further contributes small quantities of waste, although this is reused to package the company's own products wherever possible.

In some cases, creating components using 3D printing technology has also resulted in some less than optimal results, depending on the materials and processes selected. As such, there was an element of trial and error before an acceptable quality level could be achieved.

A further negative experienced by Circulogic, is the premium product costs incurred as a result of adopting sustainable practices. This can make it difficult to compete in markets where other businesses are employing unsustainable, mass manufacturing processes and non-recycled materials to achieve lower unit costs. This can be exacerbated when trying to sell products to a market that is not motivated by sustainability and therefore unlikely to pay a premium for it. Costs associated with procuring recycled

materials, the local manufacture of components and manual sorting, assembly/disassembly of non-standard products all add to the final product cost and, ultimately, the price charged to the consumer.

3. Circularity in the value chain

After analysing the company's current (circular) business model, a more detailed circularity assessment of the company and its activities in the value chain is made. The material and value flow map is presented, together with its adopted circular strategies.

3.1 Material and value flow map

The ultimate goal of a circular economy is for resources to flow in circles, with limited leakage out of the system. To evaluate this, it is important to map and visualise the current flow of materials and value within the company's value chain. The material and value flow map for Circulogic's garage2green scheme and EcoWOW products is presented in figure 3. The value flows (blue) indicate that value is being exchanged between actors and enables an analysis of the relationships amongst key partners. The circular material flows (green) show where the material comes from, where it goes and how it may return into the cycle.

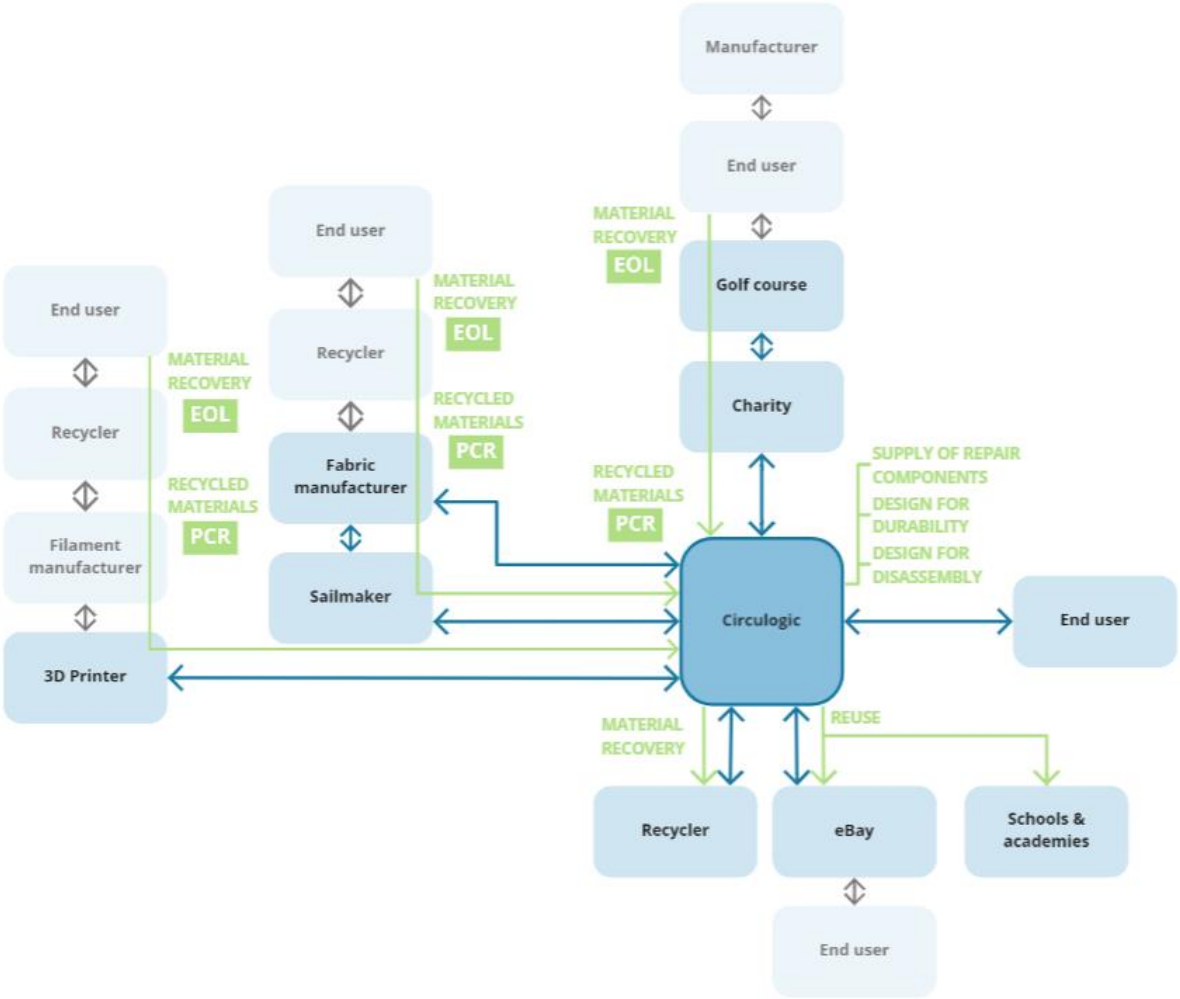

Figure 4: *Material/value flow map of Circulogic's garage2green scheme and EcoWOW products (with PCR: post-consumer resin and EOL: end-of-life materials)*

3.2 Circular strategies

Figure 3 shows the flow of materials and value throughout Circulogic's supply chain and operations. Circulogic applies multiple circular strategies: recycled materials, repair and circular design. Each of the strategies is further explained below.

Recycled materials

Circulogic repurposes and upcycles unused and unwanted golf club shafts to create their products. Additional components are made from recycled plastic 3D printing filament (golf targets and litter pickers), and recycled ripstop fabric (golf targets).

When disassembling the golf clubs, any recyclable components, such as the metal club heads, are sent for recycling, whilst the (graphite) shafts are repurposed in Circulogic's products.

In terms of recycled plastics, the company has experienced some challenges regarding the strength and durability of 3D printed parts, which required some trial and error with different filaments. If scaling up production in the future, it may make more sense for these parts to be mass manufactured, whereby an alternative, recycled plastic will need to be sourced. Having said this, as the golf club shafts differ in their dimensions, 3D printing does offer the benefit of mass customisation.

Circulogic would also like to opt for a local source of the recycled synthetic rip-stop fabric if scaling up production in future. The current material is certified as being manufactured from post-consumer plastic waste; however, this is difficult to verify, as production is based in China. Previous searches for a local supplier of suitable recycled fabrics proved unsuccessful, but this may be revisited in the future.

Repair

Circulogic's EcoWOW products are designed so that any broken components can be easily removed and replaced. An example of this is the avoidance of adhesives. Repair is then further encouraged with the provision of spare ground pegs, in the case of the golf chipping targets. These are actually repurposed from previous production runs of different design iterations of the ground peg, a further example of efficient resource use and reuse within the company.

Design for circularity

Design for circularity by Circulogic manifests itself in three ways: *design for recycling*, *design for durability and performance* and *design for disassembly*.

Design for recycling

The materials used to make Circulogic's garage2green products are from post-consumer recycled sources and are also recyclable themselves. The products are also designed in such a way that the different components and materials can be easily separated to facilitate further repurposing or recycling. Circulogic does not currently offer a take-back service due to their small scale, so it is up to the end user to recycle the components at end of life.

"The product design and development ethos applying to all EcoWOW products is that they should be easy to disassemble (avoiding the use of glues) so that individual components can be replaced or upgraded if needed" Director, Circulogic

Design for durability and performance

Circulogic focused on the recycling and reuse of golf club shafts due to their durable and high-performance characteristics, as well as the fact that they are not recyclable and have a high product turnover. As such, the main structural components of their EcoWOW products are extremely robust and long-lasting, with the potential to be recovered and reused time and time again in a variety of applications.

To match the durability of the main golf shafts, Circulogic has ensured that the other components in their products are also designed for durability. In the case of the golf chipping targets, there have been several design iterations of the 3D printed ground pegs, experimenting with different geometries and recycled plastic materials to achieve a suitably robust part. Circulogic also experimented with different means of constructing the fabric components of the golf chipping targets and, while. Although the use of adhesives has potential to be the fastest and simplest construction method, the company opted for machining (sewing) by professional rope and sail makers to achieve the necessary level of strength along the seams. The products are therefore designed to be sufficiently durable to be used in outdoor applications and over a long functional lifespan.

Design for disassembly

As stated above, Circulogic's products are designed to be assembled without the use of permanent fixings, such as adhesives. This allows for easy disassembly, aiding in both the repair and replacement of damaged elements, as well as the reuse and recycling of materials and components at end of life.

As part of the product development process options to lease/loan items for short periods of time have also been explored. Whilst not taken forward, a suite of modular play den structures was conceived and prototyped, the idea being to loan these (e.g. over summer holiday periods), recognising that children outgrow such toys so outright ownership may not always be the most resource efficient model.

4. Circularity of operational activities

After assessing the circularity of the company's activities within its value chain, a more detailed assessment of the circularity of the company's operational activities has been completed. A visualisation of the operational process is presented, together with its adopted circular strategies.

4.1 Operational process map

To get a better understanding of how the company's operational activities are affected, an overview of the process is made, see figure 4. This includes circular sourcing of materials, the production process and quality assurance of products. Each of the steps will be further explained below.

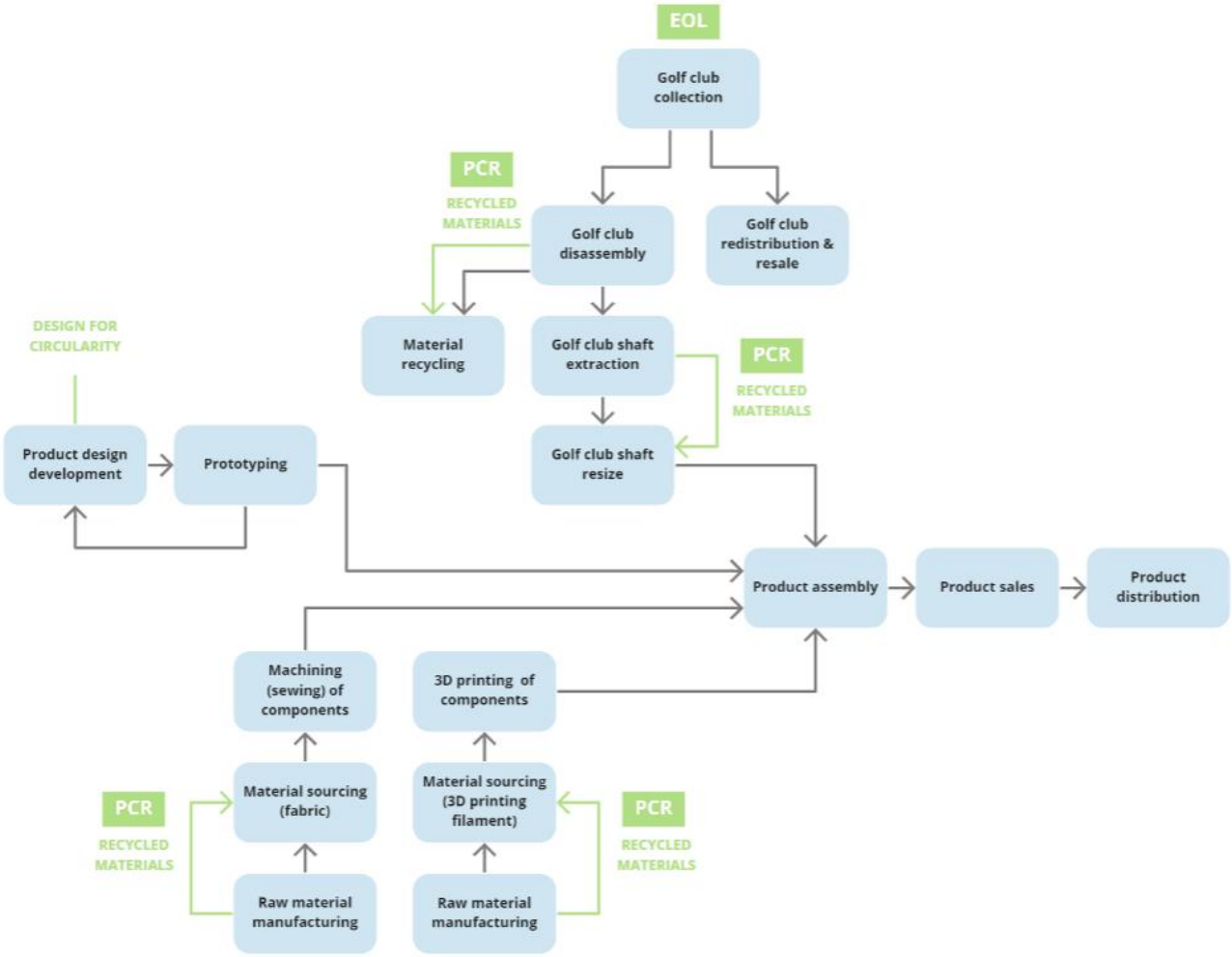

Figure 5: *Operational process map of Circulogic's garage2green scheme (with PCR: post-consumer resin and EOL: end-of-life materials)*

4.2 Circular sourcing and design

The preliminary process consists of recycled material sourcing, product design and development, and prototyping. Circulogic also employs product reselling and recycling to close the loop on any unused products and materials arising from the process.

Material sourcing

Used and unwanted golf clubs are sourced from a select number of partnering golf courses in Scotland, with a collection service provided by a partnering charity. The range of golf clubs donated vary significantly in terms of make, construction, composition, and dimension. The highest quality golf clubs that remain in a good condition are resold via e-commerce platforms and charity shops, or passed on to schools and beginners. Some of the older antique golf clubs may also be purchased by collectors. Those without resale value are disassembled into their constituent parts, with any recyclable elements, such as the metal club heads, sent to a 3rd party for recycling. As the increasingly common graphite golf club shafts are non-recyclable, yet made from light weight and durable materials, these are extracted and used in the construction of Circulogic's EcoWOW products. Before this can happen, some pre-processing of the golf club shafts is required.

Synthetic rip-stop fabric made from post-consumer recycled polyethylene terephthalate (rPET), such as drinks bottles and food packaging, is sourced from a supplier in China. This was chosen for its durability and strength, as well as its suitability for outdoor applications.

Recycled plastic 3D printing filament is sourced from a supplier via PrintCity, Manchester Metropolitan University's additive manufacturing centre, the services of which have been employed as part of Circulogic's garage2green initiative. Selection of materials has involved some trial to ensure parts are of sufficiently high quality and strength.

Product design and development

Product design and development is an important step in Circulogic's process. They adopt a novel, circular approach, using the recycled and repurposed materials and components as inspiration for further products. This has involved a significant level of trial and error, resulting in a range of options, from a children's' play den, through to the latest development – a litter picker. A number of criteria need to be considered when developing Circulogic's EcoWOW products. Firstly, components need to be able to be disassembled easily, whilst maintaining the necessary strength for any given application, which requires substantial design and development. Secondly, products need to be relatively quick and easy to manufacture and assemble, as this helps to keep costs low enough to support economic sustainability. In the case of the golf chipping targets, the cost of machining (sewing) the outer fabric components in the UK proved to be high and would likely increase for future orders. As such, this puts pressure on any profit margins. Related to this is a further consideration, which is the resale value of the final product. This needs to be high enough that Circulogic's products can compete with others available on the market, without relying on their sustainability credentials alone. The higher the price that can be achieved, the more flexibility there is in terms of production costs, allowing for local and sustainable material sourcing and manufacturing. The design process itself involves an element of market research and product ideation. Circulogic has received support from PrintCity for the design and development of products, where three-dimensional computer aided design (3D CAD) software can be used to model

different design options, along with the SMART Cheshire programme, focused on helping businesses innovate.

Prototyping

The use of 3D CAD to model products and components can help to minimise waste, by providing three-dimensional visibility of numerous iterations without the need to physically create an object. However, once a suitably developed design has been established, rapid prototyping using 3D printing can quickly and efficiently facilitate the physical creation of a product or component. This is also achieved at minimal cost compared to other manufacturing alternatives, such as mould making and injection moulding or subtractive methods. Once a prototype has been created, it's then possible to assemble and test the finished product. In the case of the litter pickers, testers were able to feedback that the strength of the first-generation gripper design was insufficient, allowing for further design development.

4.3 Production process

Being a small company, Circulogic outsources a significant proportion of their production processes to 3rd parties. This includes the 3D printing of components and the machining (sewing) of fabric components. Product assembly, sales and distribution are handled in-house.

3D printing

3D printing is outsourced to PrintCity. Here, Circulogic can gain access to specialist 3D CAD software and 3D printers, as well as expert knowledge and skills. PrintCity also provides the recycled plastic 3D printing filament, matched to requirements. As 3D printing is quite a technical process, material and printer selection, as well as the adjustment of a range of parameters and settings, including temperature, print speed and bed adhesive, must be taken into account. As the orientation of a print's design can also make a significant difference to the success of the print and whether any support structures are required, working with experts in this field can help to reduce the time it takes to achieve a successful end result.

Machining (sewing)

For the initial batch of the EcoSHOT chipping target, recycled rip-stop fabric sourced from a supplier in China was sent to a rope and sailmaker in Scotland to be machined (sewn) into the required tent-like structure for the golf chipping targets. As detailed in Section 2.1, the high-quality stitching employed results in a strong and durable finished product, superior to alternative fixing methods, such as the use of adhesives, which were originally evaluated. Despite this, the machinists fed back that the fabric components that Circulogic required were more challenging and time consuming to create than originally anticipated. As such, a higher price is likely to be charged for further runs. This may result in Circulogic reassessing options for this element's construction in future, and/or options to update the design and source material.

"The value proposition for products embedding circular design and manufacturing principles needs to take into consideration the whole life of the product, recognising that the component parts and materials may pass through a number of use cycles. Competing (with mass-produced items using virgin materials) on sales price alone is challenging. Alternative use models, such as leasing and sharing, require greater consideration." Director, Circulogic

Product assembly

As Circulogic's garage2green and EcoWOW initiatives remain a start-up, all products are currently manually assembled in-house. If scaling up in future, it is possible that this process will also be outsourced in order to cope with demand. As the products themselves contain relatively few components, assembly is a relatively straightforward process.

4.4 Quality assurance and product sale

Due to the scale of Circulogic's garage2green initiative, quality assurance, product sales and distribution are all handled in-house.

5. Conclusion and recommendations

Based on the outputs derived from all three interviews with Circulogic, strengths of the business model and operational process with regards to circularity are identified, barriers and enablers for circularity are summarised, and opportunities for circularity are described.

5.1 Strengths for circularity

Circulogic is a company focused on circular economy solutions. Their garage2green initiative was launched in response to an observed increase in the accumulation of non-recyclable golf clubs due to evermore complex material composition and higher technical performance expectations of end users. Circulogic has taken multiple steps towards ensuring that their repurposed products are as circular as possible, using a potentially redundant end-of-life component as the basis for designing a new suite of products (under the EcoWOW brand). They have been able to do this by building on existing internal knowledge and expertise in circular economy, which is a significant strength and advantage.

As a start-up initiative in receipt of funding, Circulogic's garage2green initiative has benefited from the flexibility afforded by being small and agile. Without a large and established supply chain, Circulogic has had the opportunity to consider circularity at every stage of their products' development, seeking out recycled plastic materials to complement the recovered and repurposed graphite golf club shafts.

Circulogic have also benefited from rapid prototyping, using 3D printing technology, which has allowed the company to develop, print and test various design iterations of their components, without the need for expensive moulds and minimum order runs. This has enabled them to innovate quickly and efficiently, leading to the development of multiple product designs.

5.2 Barriers and enablers for circularity

To ensure circularity for Circulogic and its value chain, several barriers and enablers can be pointed out.

The biggest barrier for garage2green's success is in scaling up, whilst achieving an economically feasible business model. As discussed previously, Circulogic received funding for the initiative in order to realise their product designs. Ongoing activities, including the collection and disassembly of golf clubs, sourcing of materials, design and development, product assembly, sales and distribution are now carried out internally, without financial compensation. Service providers, such as the sailmakers, have also advised that costs would likely increase for future orders, due to how time consuming the process was found to be. Indeed, earlier design concepts, such as children's play-den, were aborted early in the project, due to their complexity.

Circulogic has experienced some challenges regarding product sales and market demand. In the case of the golf chipping targets, it was observed that the golfing market was not especially motivated by sustainability. Owing to the innovative design, end users were more likely to purchase these based on their performance qualities. With this in mind, Circulogic is exploring the development of litter pickers, targeting the 'green' market, where consumers are more motivated by sustainability. However, as a product that is already widely available, Circulogic must compete with mass-produced, low-cost

alternatives on the market, which may prove difficult when scaling up, due to the high per-unit costs associated with their own products. These challenges are also exacerbated by the fact that Circulogic has taken the repurposed golf club shafts as the inspiration for their product development, seeking possible uses for these materials. This is in contrast to a typical product development model, whereby a consumer need or demand is firstly identified, and the necessary materials sourced to best meet this. This highlights a further challenge associated with developing a circular economy business model.

"In order to have an impact, circular products need to achieve market success, displacing sales of traditional, linear products. Maintaining a competitive price, whilst staying true to circular principles, is often challenging, but essential for ensuring the long-term sustainability of a circular business model." – Director, Circulogic

The biggest enabler for Circulogic's garage2green initiative has been the funding received to set up and deliver the pilot project. This provided the opportunity and necessary resources to experiment with various product designs using the recovered golf club shafts, and to explore the practical and financial feasibility of the accompanying business model, with minimal risk. Having funding and resources available is essential for product and business model innovation.

Other barriers and enablers have been mentioned and explained before and are summarised in table 3 below.

Table 3: *Barriers and enablers for enabling circularity at Circulogic.*

Barriers	Enablers
• Confined to the specifications of reclaimed and reused materials (e.g. golf club shafts) • Lack of uniformity of reclaimed and reused materials, requiring manual assembly • Strength limitations associated with certain recycled 3D printing filaments and printed parts • Trade-offs between circularity and product performance and price • Competition from un-sustainable competitors • High cost of circular materials and manufacturing processes (e.g. avoidance of adhesives) • Circularity is not always an important factor for consumers • Being a small-scale start-up makes some activities (e.g. marketing, take-back scheme) impractical	• Start-up funding to support product and business model innovation • Internal circular economy expertise, knowledge, and networks • Existing connections to waste stream stakeholders (e.g. golfing community) • Access to technical expertise (e.g. 3D printing via university) • Access to rapid prototyping for design development (e.g. 3D printing) • Growing environmental awareness in some markets (e.g. community litter picking groups) • Development of truly innovative products with desirable performance characteristics (e.g. golf chipping targets) • Locally available recycled materials

• Verifying the circularity claims of suppliers in complex supply chains is challenging	

5.3 Opportunities for circularity

As a pilot project, Circulogic's garage2green initiative is still in a relatively early stage of commercialisation. The aim was to explore the feasibility of setting up this type of take-back and reuse service for the selected waste stream, i.e. used golf clubs. By developing a range of prototype products, valuable lessons have been learned about the required partners, suppliers, operations and processes required. At the same time, market insights have been gained for the circular economy solutions created, helping to identify those products with the most potential, and where the costs involved stack up against the revenue generated.

If scaling up in future, Circulogic will need to establish more formalised processes for activities, such as the collection and dissassembly of the golf clubs, and the assembly and distribution of the final EcoWOW products, as many of these are currently completed in-house on an as-needed basis. With this will come both further challenges and opportunities for embedding circularity within the business.

Material sourcing

Circulogic has expressed an interest in sourcing recycled synthetic fabrics locally, within the UK, if upscaling in future. It is suggested that reaching out to local and national networks and organisations involved in the reclamation and redistribution of waste and surplus fabrics, such as Offset Warehouse (www.offsetwarehouse.com), TRAID (www.traid,org,uk) and Stitched Up (www.stitchedup.coop) may help in the sourcing of the required materials. Upscaling may present an opportunity to access new suppliers of innovative, circular resources, as the business will have greater buying power, whereby minimum order quantities may be met. In terms of the recycled 3D printing filaments, Circulogic may follow the progress of the Transform-CE project to explore the potential for turning single use plastic waste to be used for this purpose.

Access and takeback

Circulogic's current garage2green business model is focused on the sale of products. If scaling up, it may be possible to implement an access-based model, whereby Circulogic retains the ownership of EcoWOW products, , which are then leased to end users for an 'access' fee. Such a move would be well supported by garage2green's EcoWOW products, which have been specifically designed to be highly durable, easily repairable, and able to be used for a long time. If operating a take-back system, products could be redistributed to new users, or disassembled and the parts used to create new products. This would increase the income generated from the physical resources embodied in each product, without adding further production costs, potentially allowing Circulogic to achieve a higher profit margin. However, this is likely to work best for unique and high-value products, where it is not possible to easily purchase a cheaper alternative. The processes for this type of operation would also need to be formalised, so that products in the system may be tracked and the relevant payments taken. Such a model may well appeal to customers and end users with limited cash flow or who only require the products for set periods of time.

New product development

The development of new products as part of garage2green and EcoWOW may help Circulogic to access new markets, particularly those in which consumers are more strongly motivated by sustainability. Additionally, by diversifying to create new and innovative products that are not currently available elsewhere on the market, Circulogic will help to set apart its product offering, without having to compete on price alone. This is especially important, as achieving an acceptable price point for circular products has been highlighted as a key challenge.

To summarise, Circulogic's garage2green initiative and EcoWOW products are an exemplary demonstration of what's possible when adopting circular design principles to tackle a difficult waste stream and generate added value through innovative, new products with sustainability at their heart.

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About the project

The problems associated with plastic waste and in particular its adverse impacts on the environment are gaining importance and attention in politics, economics, science and the media. Although plastic is widely used and millions of plastic products are manufactured each year, only 30% of total plastic waste is collected for recycling. Since demand for plastic is expected to increase in the coming years, whilst resources are further depleted, it is important to utilise plastic waste in a resourceful way.

TRANSFORM-CE aims to convert single-use plastic waste into valuable new products. The project intends to divert an estimated 2,580 tonnes of plastic between 2020 and 2023. Two pilot plants will be set up, one in Almere (NL) and one in the UK. The plants will make use of two innovative technologies – intrusion-extrusion moulding (IEM) and additive manufacturing (AM) – to turn plastic waste into recycled feedstock and new products.

Moreover, the project will help to increase the adoption of technology and uptake of recycled feedstock by businesses. This will be promoted through research into the current and future supply of single-use plastic waste from municipal sources, technical information on the materials and recycling processes, and circular business models. In-depth support will also be provided to a range of businesses across North-West Europe, whilst the insights generated through TRANSFORM-CE will be consolidated into an EU Plastic Circular Economy Roadmap to provide wider businesses with the 'know-how' necessary to replicate and up-scale the developed solutions.

Lead partner organisation
Manchester Metropolitan University

Partner organisations
Materia Nova
Social Environmental and Economic Solutions (SOENECS) Ltd
Gemeente Almere
Save Plastics
Technische Universiteit Delft
Hogeschool Utrecht
Hochschule Trier Umwelt-Campus Birkenfeld Institut für angewandtes Stoffstrommanagement (IfaS)
bCircular GmbH
Viridor Waste Management Limited

Countries
UK | BE | NL | DE

Timeline
2019-2023

www.nweurope.eu/transform-ce