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A managerial guide towards the practical implementation of circular economy pilot projects

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Circular economy is a sustainability concept that has recently received considerable attention in media, literature and legislation. The core of the theory rests on a reduction in humanity's resource dependency. While most applications focus on reusing end-of-life products as inputs in the value chain, the broader definition described hereinafter also encompasses a wider range of business models.

The purpose of this master thesis is to provide executives with a catalog of frameworks that facilitate selecting and implementing the right circular economy project for their company. Following extensive literature review, this thesis presents a structured way to approach each stage of the decision process associated with said project.

The thesis starts by proposing a rigorous definition of the circular economy concept and the various benefits attributed to it. It then presents concrete tools to identify environmental issues through an analysis of the operations along the value chain. Following this, a formula to prioritize among these issues is introduced. The last chapter details a brainstorming tool to find solutions for these prioritized issues and discusses the most commonly implemented business models in circular economy initiatives. Finally, standards for a vision statement and performance indicators are briefly presented. The thesis as a whole can be used as a frame of reference throughout the entire decision process, but its chapters can also be consulted independently.

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I. Introduction

Man-made climate change is happening on more than one front. The impact we have on our environment as a species is so big that studies have suggested to transition from the Holocene to a new geological epoch, the Anthropocene (Waters et al., 2016). The evidence that our climate is changing is overwhelming and if we want the earth to remain as habitable as it is today, urgent action is needed. Governments, businesses and academics alike have published extensive research on what the minimum changes necessary are and how the world can hope to achieve these targets.

Environmental metrics have entered legislative statutes just about everywhere in the world and businesses have ingrained them in their dashboards alongside traditional company health measures such as profit and loss statements. Often they are published as a faction of the firm's annual statements.

Since this has been a trend for the past few decades, it is not surprising that research into sustainability topics, both theoretical and practical, covers nearly everything one can imagine. A myriad of alternative theories for greener business operations have been proposed and many of them have been applied in practical forms. One of these alternatives is the Circular Economy, which will be the main topic of this thesis. The focal point of circular economy theory is waste reduction. In short, the primary proposition is that every item passing through a value chain may not end up as waste at the end, but should instead be reused as an input in said value chain. The concept stems from the premise that this is the way every natural (biological) lifecycle works.

The circular economy concept has more recently drawn considerable attention as well. Many reports have identified the benefits nations and businesses could extract from redesigning their operations in a more circular fashion (further summarized in the first introductory chapter below). Many successful use cases have also been described and some of them will be used hereinafter to illustrate the concepts in this thesis.

What has been missing from circular economy literature, however, is a managerial guide towards the practical implementation of the concept. This thesis aims to fill that gap by offering a collection of frameworks that help managers to kick-start their own pilot projects.

The methodology followed to come to the final result is that of an extensive literature review. Originally, the thesis was structured along the lines of the high-level strategy framework depicted below. This strategy framework is a personal summary of the cems strategy course taught by Bocconi University. It is traditionally reserved for big companies reviewing their overarching strategic vision, or for the startup phase of new business units (such as during an international expansion move). Because the foundation of circular economy theory is reimagining the way businesses do business, it makes sense to base its application on the same structure. Using this high-level strategy framework as a basis also ensures that the thesis does not stray into sector-specific solutions, as the original aim was for it to be as generally applicable as possible.

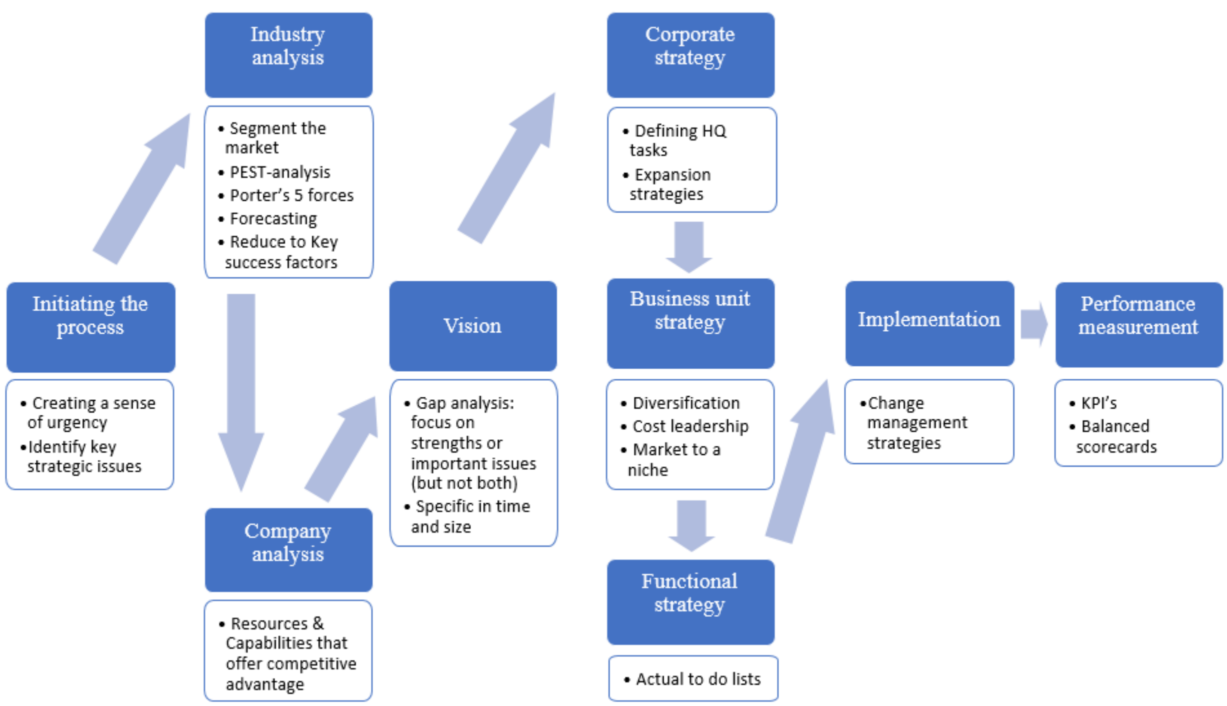


Figure 1. High-level strategy framework

For each step in the decision-making process (each blue box in the figure), a range of traditional and circular economy-specific frameworks was then collected from publicly available academic and industry sources.

Because the research question is to provide a managerial guide for pilot projects, this high-level framework ended up containing redundant chapters. Some of them were certainly more important than others and this thesis therefore consolidated the identified circular economy tools in a more concise overall structure. It follows the timeline of a simpler pilot project: Analyzing the impact of the operations in the value chain, prioritizing the most damaging ones, and reimagining how these operations can function in a more sustainable way.

This thesis describes a limited selection of the aforementioned list of theoretical concepts for each project phase. The phases are depicted in the next figure and each of the corresponding chapters of the thesis is briefly explained in the paragraphs below.

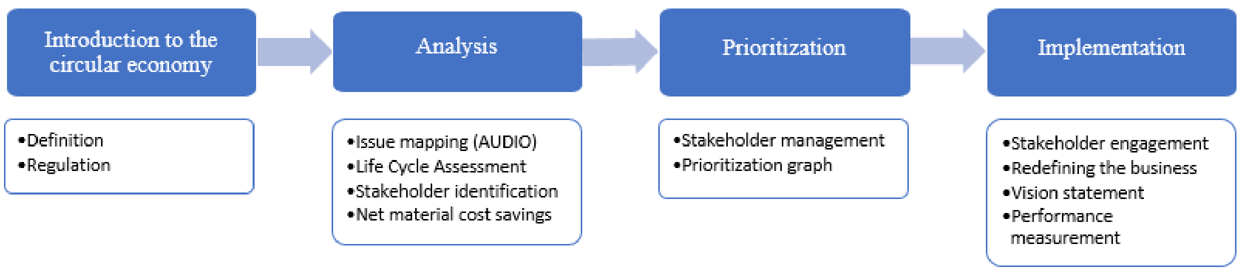


Figure 2. Structured summary of the thesis contents

In order to provide a frame of reference to the reader, all of the aforementioned strategy chapters are hereinafter preceded by a more in-depth introduction to the circular economy concept. Recent developments in sustainability-related regulation are outlined as well.

Analysis. What impact does the company have on its environment? How much energy do its production lines use? How much of the raw material inputs stem from sustainable sources or recycling centers? How are end consumers disposing of the products it manufactures? Before the company can choose where to focus its efforts, a thorough assessment of its value chain(s) is necessary. This chapter details frameworks to find and answer questions like the above.

Secondly, a methodology to identify relevant stakeholders and their potential influence on the project is presented. Cost and volume associated with the company's products are discussed, as well as price volatility.

Prioritization. Now that we have a detailed picture of the externalities linked to the company's products, how do we get a sense of what is the most damaging? In other words, by what variable can we aggregate the results of the analysis in order to get a clear overview? This chapter introduces a framework to pinpoint the most impactful and (cost-)effective way of starting the circular economy journey.

Implementation. Knowing where to start is half the work, but implementation can be daunting as well. Since the fundamental strength of circular economy theory is in redesigning the process from the ground up, as opposed to incremental improvement, this chapter discusses a related lean management and brainstorming framework. The most commonly applied business model changes are lined out as a practical aid for said brainstorming exercise. Stakeholder engagement strategy is briefly touched on to help identify who the company can cooperate with during this phase.

Pilot projects pave the way for more large-scale ventures if they can show positive results. This chapter therefore also details what comes after the solving phase. More specifically, design principles, a vision statement and performance measurement standards are discussed.

The main limitation of this master's thesis is that it draws its inspiration from literature and past use cases. Qualitative interviews with companies who implement it are needed to further improve the structure and frameworks recommended in this thesis.

Because this thesis aims to be practical in use and because frameworks are often theoretic, they are hereinafter illustrated with concrete examples. To ensure that each exhibit is coherent with the others, the examples are drawn from a single fictional company. Our imaginary firm employs 500 people in the production of 3D-printed prototypes and is arbitrarily referred to as DodoPrint, after the famously extinct bird. This thesis does not know of or is affiliated with any existing company under this name.

II. Introduction to the circular economy

This first chapter serves as an introduction to the main concepts of the circular economy. It also introduces the benefits their implementation could bring on a macroeconomic level, and the regulation to capture said benefits in the European Union.

2.1 Defining the Circular Economy

In a natural environment, landfills do not exist. Every living thing on Earth is in some way consumed by another at the end of its life, ensuring a long-term equilibrium between resource use and resource availability. Since the Industrial Revolution, humankind has stopped participating in this virtuous cycle by manufacturing large amounts of goods that are neither biodegradable nor eternally durable. Because nature can only accommodate part of this change, we are depleting the natural resource reserves available to us more rapidly than the environment can replenish them. To quantify this imbalance, the Global Footprint Network calculates each year on which date we have used the amount of resources the Earth can replenish in a year. From that they forward, we are then operating on symbolic credit. We have been taking credit at increasing rates since the start of the seventies. This date, called Earth Overshoot Day, falls on August 2nd in 2017, indicating a positive slowdown in the growth of our resource use, but nonetheless an increase in absolute numbers (WWF, 2017). Clearly, systemic change is necessary.

The most familiar way to reduce the size of landfills is waste recycling. A recycling process can be further split up into upcycling and downcycling. The former describes the conversion of a low-value material into a high-value product. In most cases this refers to a creative refashioning of a discarded product rather than an economically viable industrial process. For example, during the research phase of this thesis some of our lamps were not covered by lampshades. Instead of spending money on new ones, I made them myself by repurposing used milk cartons. Whether or not this could be a turned into a viable industrial product is out of scope here. However, since washing, cutting and folding these used milk cartons is a lot of work that could in essence be substituted by using simple aluminum foil, it is doubtful the concept will take off anytime soon.

Figure 3. Lampshade from upcycled milk cartons.

Downcycling is the exact opposite, where highly valuable products are reused as a low-value raw material. It is much more common in all modern day industries. In a successful circular supply chain, the second-hand raw material can be used as an equivalent input to the manufacturing process. Reynaers Aluminium, a producer of aluminium applications such as window frames, sources 49% of their aluminium needs from second-hand sources. They collect the existing frames from their clients when installing new ones and smelt them down. This process is 20 times more energy-efficient than procuring from bauxite mines (Martine Reynaers, personal communication, 2017). They are able to do so because the company minimizes the amount of impurities it introduces during their manufacturing process and because aluminium is relatively easy to extract. Other industries are limited to lower levels of recycled material because the buildup of impurities compromises the structural integrity of the final product. Plastic shopping bags, for example, cannot be sufficiently cleaned in a cost-effective way to be used in durable, small components (Marritz, 2011). They can be reused instead by pressing them into bricks for the construction industry, where the thickness of the material needed for structural integrity is less important. Alternatively, some materials can be reused a limited number of times before they become unusable. Newspaper agencies printing on recycled paper are obligated to add virgin material as the fibers of the paper become too short to reuse, but only after 5-7 cycles (Le Soir, personal communication, 2015).

Another way to lower resource consumption is to reuse products or parts that were discarded before. The basic premise is that if you double the lifespan of a product, the resource consumption is halved. This can refer to both household and industrial level reuse. On a small scale, clothes can be passed on to siblings. An example of a larger industrial scale reuse is the end-of-life process electronic circuit boards go through. Most of the integrated components are attached to the board with tin welder, which melts at lower temperatures than most other materials. It is therefore easy to dismantle the boards and to recover basic circuitry such as resistors, which can then be directly reused. However, this is only possible if the boards are all similar, otherwise it takes too much time to identify parts, so this is usually more the case when companies recover their own devices. Rising primary market prices and technological advances are making this type of recovery more marketable. Electronic waste recycling companies generally don't reuse parts, but mine precious metals such as copper and gold from the boards through shredding and smelting (Cui & Forssberg, 2003).

Finally, engineers everywhere look to increase efficiency by reducing the amount of raw material that goes into their products in the first place. A straightforward example is how solid structures can be replaced by a shell that is supported internally by some framework. 3D printers face a much larger than average cost and energy use per cubic centimeter of material. To remedy this, manufacturers often include software that transforms solid 3D-models to honeycomb structures, which have the highest material-to-support ratio (Thomas C. Hales, 1999).

All of the above, namely *reducing*, *reusing*, and *recycling* materials, are part of the definition of the circular economy. The term "circular economy" is used to describe a varying range of sustainability measures. Weetman et al. (2017) define it as a holistic collection of preceding theories, some of which are depicted in the image below. Discussing these theories is out of scope for this thesis. Instead, their foundations are summarized to show their part in defining the concept of circular economy.

- **Service / performance models**: Focus on selling performance or services instead of the good, thereby internalizing a large part of the value chain. The increased control and ownership duration allow companies to provide more qualitative solutions.
- **Resource productivity**: Lowering our use of resources by using them more efficiently, either by using fewer resources to produce the same effect, or by prolonging the life of the product through more qualitative design. While the concept of prolonging product lives does not immediately line up with the recent trend towards shorter innovation cycles, a performance model can help to close the gap between them (Steinhilper & Hieber, 2001).

- **Nature conservation**: On a global and local scale, take into account the capacity of nature to offset the resource use and emissions caused by the company's value chain.
- **Social and cultural ecology**: Improve the community surrounding the value chain. Walter Stahel (the Performance Economy, 2006) highlights social variables including peace and safety, democracy, equality, employment and integration, education, ethics, and natural heritage.
- **Biomimicry**: Look to nature for inspiration, both for materials and for product design.
- **Cascading nutrients and energy**: Cycle materials eternally, limit the toxicity introduced. According to the Cradle to Cradle principle two possible cycles exist, biological and technical. In a biological cycle, the product is made from biodegradable materials so that it can be composted at the end of its life without damaging the environment. In a technical cycle the product is designed in such a way that it can be disassembled at the end of its life, and the parts can be reused as inputs. This can be through refurbishment, by repurposing the parts, by melting them, or through any other process that does not involve landfilling them (De Troyer, 2008).

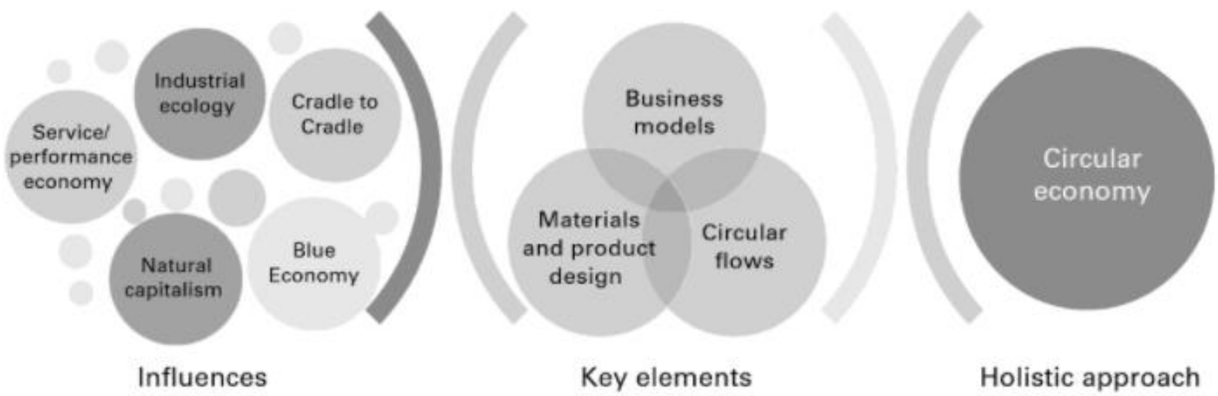


Figure 4. Evolution of the circular economy (Weetman, Frei & Waddilove, 2017, p13)

The key elements businesses can change to achieve the above goals are value chain (circular) flows, business models, and materials and product design. These three elements are further developed in the *implementation* chapter of this thesis. A company that successfully manages to bring these three key elements in line with the above list of principles can state that it is part of the circular economy.

To this thesis, this comprehensive definition can be summarized as follows:

A company that is in balance with its environment in every step of the value chain, is part of the circular economy.

So why do we need this concept? Is the circular economy then not simply an extension of the *reduce*, *reuse*, *recycle* framework, with the addition of certain social values? To some degree it is. The strength of the redefinition, however, is well described by McDonough & Braungart in their book The Upcycle: "Do more good, not less bad". Recycling, reusing and reducing are all incremental steps towards a "less bad" future. By looking at the value chain this way, the maximum achievable (but unlikely to be reached) target is a 100 percent reuse of materials. These changes can be implemented by a motivated local manager.

The circular economy starts from the premise that the way a company delivers its value proposition will have to be completely reinvented, rebuilt from the ground up, in order to be eternally in balance with its environment. This change intuitively requires a larger degree of cross-industry or at least interdepartmental collaboration. By thinking of sustainability issues this way, companies are more likely to "do more good" instead.

The image below is a variation on the "waste management hierarchy" as included in a European Commission Directive on waste [2008/98/EC]. The top layer is an addition to the original image.

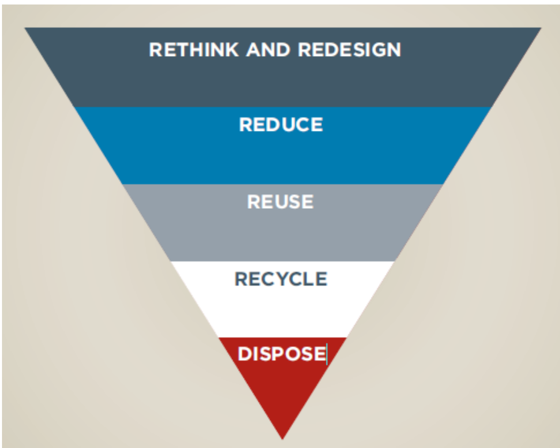


Figure 5. Hierarchy of waste (EMF, 2012)

2.2 Regulation in the European Union

Cutting environmentally damaging processes is increasingly seen as a day-to-day part of business, but many firms still perceive it as something that will cost their bottom line. This need not always be the case. On the contrary, reports estimate that adopting circular economy principles could generate a net economic benefit of 1.8 trillion euro by 2030, or a 7-percentage-point increase in GDP terms over the current European development scenario (McKinsey, 2015). This number is not accounting for possible improvements through digital innovation yet. The Ellen MacArthur Foundation valuates the annual net material cost savings at 380 to 630 billion USD for a subset of manufacturing sectors alone. In 2012, only 40 percent of waste materials were reused in some fashion, extracting a mere 5 percent of their original value (EMF, 2012). Resource-wise, raw materials and components make up 40 to 60 percent of the total cost base for the companies in this subset. By reincorporating these primary resources into the supply chain at the end of their valuable life, their consumption could drop by 32 percent by 2030 and up to 53 percent by 2050. Not only would this decrease current costs, but it would also serve to lower Europe's dependency on the import of goods that grow scarcer every day (EMF, 2015).

Regardless of how promising these numbers are, public intervention is still estimated to be necessary to help the change come into effect. Governments have a large influence through relevant infrastructure investments, setting standards, subsidies, and so on. With the signing of the Paris Agreement in December 2015, policymakers took new steps towards limiting our impact on the environment. They recognized that global emissions have to peak as soon as possible and gave assurances that developed nations will maintain the flow of continuous support to developing countries. Every participating country drafted comprehensive national climate action plans (Intended Nationally Determined Contributions) and agreed to track their own progress and report on it in a transparent way to the public. Generally the target goal for these INDCs is to keep global average temperatures below 2 °C above pre-industrial levels, and to aim to limit the increase to 1.5 °C, although not all of the drafted plans are sufficiently ambitious yet (European Commission, 2017).

In line with the promises made by its member states, the European Union put forward a Circular Economy Action Plan which aims to stimulate growth and job creation in sustainable activities. The proposed legislation includes financial incentives on several fronts. Innovative projects can apply for funding under the InnovFin research program, for which the European Investment Fund has reserved a budget of 650 million euro under the EU's Horizon 2020 initiative.

Among others, the European Commission encourages more holistic product design by differentiating taxes paid by manufacturers, based on the waste management costs associated with their products. The European Structural & Investments Fund (ESIF) set aside 5.5 billion euro for waste management infrastructure programs as the Action Plan covers activity in every step of the value chain, including the market for secondary raw materials (European Parliament, 2016). The majority is reserved for private household waste management, but smart firms will nonetheless be able to profit from this increase in recycling infrastructure, especially since most efficiency loss comes in at the customer level in developed nations (McDonough & Braungart, 2013)

Additionally the European Commission will soon propose new minimum design and labeling standards to improve the environmental performance of, among others, household appliances and communication technologies. These standards will make it easier to dismantle and reuse them under the Ecodesign directive, serving as both environmental protection and a prevention of the creation of barriers to trade (European Commission, 2017).

III. Environmental assessment of the value chain's operations (Analysis)

The first phase of any high-level strategic change is a thorough self-assessment. Before thinking about the circular economy, every firm will have to start by conforming to local legal requirements, so these provide a good basis to initiate the process.

Often customers will ask suppliers to be compliant with ISO standards. For environmental concerns, ISO 14000 is the internationally agreed requirements standard. Its focus lies mainly on efficiency in the way resources are used and on waste reduction. They provide guidance on every phase of setting up an environmental management system (International Organization for Standardization, 2015). To a large extent based on this is EMAS, an environmental management instrument developed by the European Commission that helps companies find the right tools to improve overall environmental performance. Both standards are verified by third parties (European Commission, 2017). Advice is also provided by third party networks such as the World Business Council for Sustainable Development or the Global Environmental Management Initiative.

Even with an environmental management system in place, most large companies have too many products in their portfolio to know on sight where a circular economy pilot project has the biggest potential. Pinpointing the right starting point through issue mapping is therefore the first step.

This chapter discusses issue mapping, life cycle assessment, stakeholder identification and different cost considerations as a prelude to the introduction of a prioritization formula. Every framework is accompanied by an example from DodoPrint, our fictitious 3D-printing company, for added clarity.

3.1 Issue mapping

Identifying issues and opportunities is a brainstorming activity at first, and then evolves into a structured in-depth analysis of the identified factors. Traditionally, the SWOT framework is omnipresent in the first half of this management exercise. It can be replaced by an AUDIO analysis in a sustainability context.

The first step of an AUDIO analysis is to list all the environmental factors the company somehow influences. The original authors of the framework (Esty & Winston, 2006) identified the ten biggest environmental challenges to the world in 2009 to be the following: Climate change, energy use, water use, biodiversity, toxic chemicals, air pollution, waste management, ozone layer (greenhouse gas emissions), ocean acidification, and deforestation.

A more recent set of environmental issues are the Planetary Boundaries (Rockström & Steffen., 2015). The boundaries serve as a reasonable, quantifiable limit beyond which the Earth becomes less habitable to the human race. They are set below the global thresholds or tipping points to act as warning signs rather than gloomy milestones, and to account for some uncertainty in their measurement. Because they are specific, they can help governments and corporations to focus on the most pressing issues in their policies (Rockström et al., 2009).

The set, which is depicted in the image below, includes the following factors:

- **Biosphere integrity**, further split into Genetic and Functional diversity. Genetically, the extinction rate of species today is estimated to be 1.000 to 10.000 times the natural extinction rate, as 0.01 to 0.1% of Earth’s species disappear every year (WWF, 2017). Functional diversity measures the loss of biodiversity components at the level of biome/large ecosystems, representing functional differences in the earth’s habitats, such as rainforests being turned into grasslands as animal grazing grounds.
- **Land-system change** measures the changes such as the desertification of forests. Specifically, it measures the surface covered by forests as a control variable for how much land-system changes influence the climate.
- **Freshwater use** measures the amount of natural blue (potable) water use compared to the locally available reserves from rivers, lakes, or groundwater stores.

- **Biogeochemical flows** are mainly based on nitrogen (N) and phosphorus (P) concentrations, as well as others such as silicon. Both N and P overconcentration originate largely from agricultural fertilizers.
- **Stratospheric ozone depletion** is perhaps the only success story in the list, as the gap in the ozone layer is closing since the phasing out of certain ozone-depleting gases.
- **Ocean acidification** originates from too high CO_2 levels and endangers certain marine life forms, causing a disruption in oceanic food chains.
- **Climate change** as measured by radiative forcing, which is the difference between the amount of energy (warmth) absorbed vs irradiated by the earth from/into space. This change in energy intake is caused by solar irradiance changes as well as greenhouse gases.
- **Aerosol loading** represents any kind of harmful pollutants released into the atmosphere.
- **Novel entities** measure the potentially dangerous ecosystem changes caused by the introduction of man-made novel entities, such as lasting chemical pollution, which could evolve out of control.

Of these nine boundaries, two are estimated to have been crossed already, although two more are nearing critical levels. In the image below, a green color (inner circle) signifies a stable environment. Yellow factors are between the lower and upper limits of the boundary. This uncertainty exists because the boundaries are necessarily quantified through control variables which are both hard to measure and not a perfect representation for the boundary. Finally, red zones signify boundaries that have been crossed beyond reasonable doubt and are at high risk of causing systemic change to the environment (Rockström & Steffen, 2015).

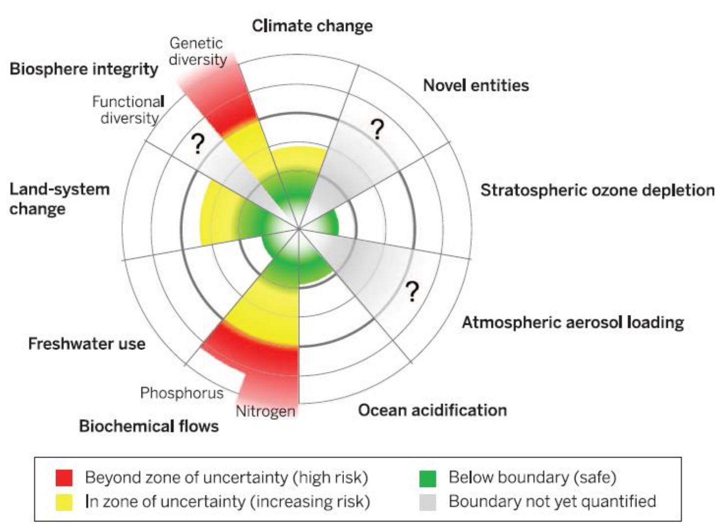


Figure 6. Planetary boundaries (Rockström & Steffen, 2015, p1)

Apart from a range of pressing environmental issues, the examined factors can also be industry- or location-specific. A further list of example questions the company may ask itself is provided below as a guide.

Company Operations	How big is our environmental footprint? What resources are we most dependent on (energy, water, materials), and how much do we use? What emissions do we release into the air or water? How do we dispose of waste? How up-to-date is our environmental management system? What are our chances of a spill, leak, or release of hazardous materials? Have others in our industry had problems? What local, state, federal, or international regulations apply to our business? Are we in full compliance? Are these requirements getting tighter?
Upstream	What resources are our suppliers most dependent on? Are they abundant or constrained, now and in the near future? Do our suppliers pollute? Do they meet all applicable laws? Will legal requirements get tighter for them? What substances go into the products suppliers sell to us? Are they toxic?
Downstream	How much energy (or water or other resources) does our product require customers to use? Are there hazardous substances in our products? What do customers do with our products when they are done with them? What would happen if we were required to take them back?

Figure 7. Identifying environmental risk (Esty & Winston, 2006, p117).

The next step in the AUDIO analysis is then to go over these factors and, for each of them, identify the following:

- **Aspects**: Specifically, how the company touches on this environmental issue. Let us take DodoPrint, our fictional 3D printing company. For the climate change factor, they identify CO_2 emissions from energy use as one of the Aspects.
- **Upstream**: How do suppliers influence this Aspect? DodoPrint estimates that the main influencers are the suppliers of raw material inputs that have to be mined, such as aluminium. A second aspect Upstream are emissions in transport towards them.

- **Downstream**: How do our customers influence this Aspect? Transport towards customers is done by a third party carrier, who has to deliver very small packages to varying locations, causing emissions.
- **Issues**: Due to its large energy use, DodoPrint causes much higher than average emissions. They face carbon charges from the local government.
- **Opportunities**: By advising customers on the impact and qualities of their choice of material, they may be able to produce more plastic prototypes to replace aluminium ones in the future. This would drastically cut energy use because the heat required to melt aluminium for printing is much higher than that of plastic.
  Alternatively, some of their B2B customers have been repeatedly ordering small parts. In cooperation with these companies, they may be able to transport those parts in batches.

The first draft can be a very superficial overview and can be done in an hour. To ensure input from all sides of the company, this is best done in a meeting with representatives from different departments and from every stage in the value chain, including for example purchasing agents, CSR representatives, designers, customer service, and so on.

The reason Upstream and Downstream values are important is “extended producer responsibility” legislation. Depending on location, the extent of this responsibility varies and can be mandatory, negotiated or voluntary. However, regardless of obligations, Up- and Downstream issues can represent a large reputational risk for a manufacturer. The in-house production lines might be completely devoid of toxic metals, but if a component supplier uses them, they still end up in the final product. Not being directly involved does not shield from responsibility as consumers will still blame the brand that is on the label.

In some cases, issues can be opportunities if they are bigger issues for the competition. In these cases industry leaders should encourage more stringent regulation, as it will hit the competition harder than it will the company itself. Additionally this gives off a very positive signal towards external stakeholders (Esty & Winston, 2006).

As a further example, the first part of the AUDIO analysis as done by DodoPrint:

DodoPrint					
Challenge	**Aspects**	**Upstream**	**Downstream**	**Issues**	**Opportunities**
1. Climate Change	CO_2 emissions from energy use	Mined raw materials	Transport towards customer	Expensive carbon charges	Advise customers to replace aluminium by plastic
		Transport in distribution			Batch orders for transport
2. Waste Management	No control over disposal of prints		Customers order too many parts to account for possible broken ones	Unnecessary loss of material and energy	Give stronger quality assurances, as we check this anyway
			Customers dispose of prints through inappropriate channels	Certain rubbers cause dangerous leakage in landfills	Offer to collect these rubbers so they can be reused as inputs
	Packaging material	Raw materials are overly well packaged	Large amounts of packaging necessary due to fragility of the prints	Customers complain of this waste of material	Replace plastic packaging chips with organic alternative, such as popcorn

Figure 8. Example AUDIO analysis for DodoPrint

If a certain Aspect raises more questions than answers, more product-specific frameworks can be turned to. Subdividing the Aspect into several sub-factors or product categories will facilitate the analysis process. The most commonly used framework in this regard is Life Cycle Assessment (hereinafter LCA). Since a LCA for each product is a mandatory stage in getting ISO 14044:2006 certification, chances are that the company has already done them (Environmental Protection Agency, 2010).

3.2 Life Cycle Assessment

While some firms have so many products that they prefer a macroscopic view on all the possible issues, there are those on the other side of the spectrum, such as DodoPrint, who have a much smaller range of products. For managers at these firms an AUDIO analysis yields overly diffuse results and it is more effective for them to go over issues and opportunities product by product instead. In a LCA, the environmental impacts of each process in every single stage in a product's life are listed, all the way from raw material to disposal. A LCA is similar to an AUDIO analysis in that the same environmental facets (rows) can be used to assess each stage. A LCA commonly starts with the definition of the scope of the product and the identification of the Aspects looked at, as done in the AUDIO analysis. A flow chart of all the relevant activities to illustrate what the value chain looks like is then drawn out (Manuilova, 2003). For DodoPrint, a LCA of their aluminium prints looks as follows.

First, a flow chart is set up detailing all the activities:

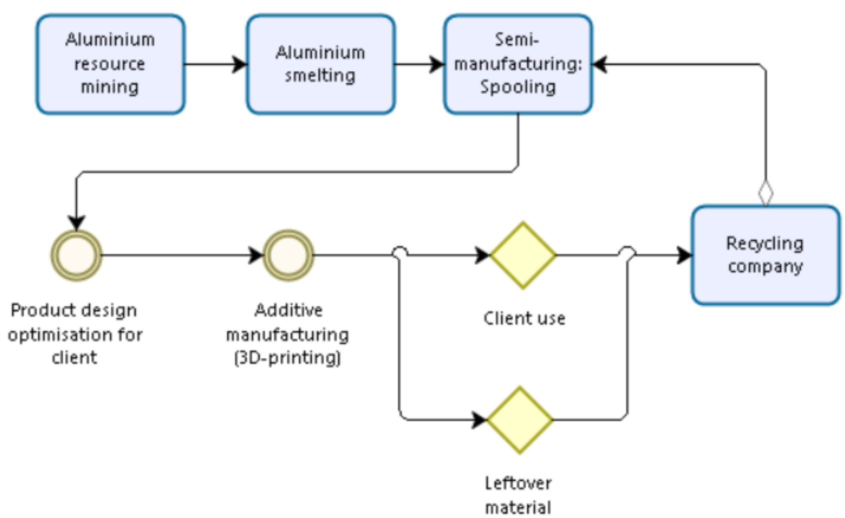
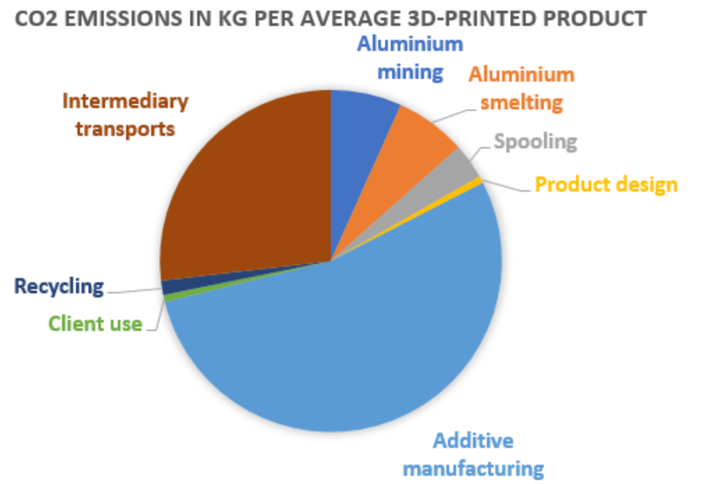


Figure 9. Life Cycle Assessment DodoPrint

Then, a Life Cycle Inventory (LCI) is calculated for each facet by aggregating the impact of each stage in the flow chart. This makes cross-comparison between products possible. All externalities caused by the product's existence, such as energy use or transport emissions, are also accounted for (Curran, 2006).

To continue our example of CO_2 emissions, this looks as follows for Dodoprint (numbers are indicative, no actual study was done to calculate them):



Aluminium mining	10
Aluminium smelting	10
Spooling	5
Product design	1
Additive manufacturing	80
Client use	1
Recycling	2
Intermediary transports	40
Total	149

Figure 10. Life Cycle Inventory DodoPrint

LCA gives rise to opportunities by highlighting the most environmentally damaging phases in the product's lifecycle. A manufacturer can leverage these, especially in a B2B context, by investing in a change that will benefit them either directly or indirectly. The latter can potentially be a cost shared with clients, suppliers, or other industry players. An example would be to ship the aluminium in bulk by partnering with other local aluminium customers.

Life Cycle Assessments generally take a cradle-to-grave approach. For those companies who wish to take their LCA to the next level, the Ohio State University Center for resilience developed the Eco-LCA (Singh & Bakshi, 2009). The latter considers an even broader range of ecological impacts. Contrary to a conventional LCA, an Eco-LCA also accounts for the ecosystem surrounding the steps in the product's lifecycle. The methodology quantitatively takes into account the following related services:

- Supporting services
- Regulating services
- Provisioning services (providing facilities and permissions)
- Cultural services

An example for the first stage in the aforementioned aluminium process for DodoPrint takes into account the following:

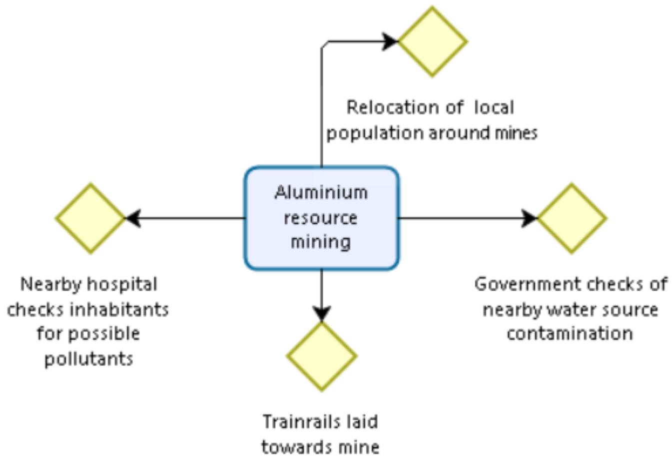


Figure 11. First stage of an Eco-LCA

Impacts measured through LCA and especially Eco-LCA can be difficult to compare across products without aggregation of results due to the myriad number of parameters that have to be interpreted. The finest scale at which data can be represented is in base units such as energy. Some analyses convert mass and energy into different factors for aggregation, such as carbon emissions. There is no standard way of doing this and information is often lost in the process. For example, cumulative mass consumption never includes solar energy contributions as this cannot consistently be converted to mass units. Nonetheless there can be value in the increased ease of interpretation. Some example aggregation methods are discussed by Zhang (2008), Hau & Bakshi (2004), and Ukidwe & Bakshi (2007).

3.3 Stakeholder identification

As described under LCA, there are several valid ways to categorize materials and products. A straightforward way is to categorize them by toxicity level first. This is also what is usually done by third parties when they perform audits for Cradle to Cradle product certifications. Equally important are all the related interest groups, which is what the Eco-LCA tries to account for.

In identifying stakeholders, companies can take a narrow or a broad view (Mitchell, Agle & Wood, 1997). The former considers only those interest groups who have a direct stake in the company (Freeman & Reid, 1983), or those who have a legitimate moral claim (Freeman, 1994). In both cases, executives handle stakeholders on a justifiable "just enough" basis. The broad view, on the other hand, takes into account everyone who could possibly affect the business regardless of the legitimacy of their claim.

In the context of a circular economy, both are clearly important. In fact, this thesis argues that because the whole point of the CE exercise is to do more good, the company should try to identify everyone who is or could be affected by their operations, regardless of their influence or the legitimacy of their claims. This follows one of the broadest definitions of stakeholders in literature:

"any group or individual who can affect or is affected by the achievement of the organization's objectives" (Freeman, 1984:46).

Not all stakeholders will have the same importance, but taking them into account is not exclusively about a moral obligation towards their well-being either. Deeper analysis may reveal hidden stakeholders, who depend greatly on one of the resources discussed but are not generally taken into account because they lack both influence and urgency (Vogler et al., 2017). The perfect example are non-human stakeholders. Some papers have argued for existing user-centered strategic design frameworks to be applied to animal persona, in order to map them as one would a human stakeholder (Frawley & Dyson, 2007). Doing so seems both the right and the cautious thing to do, as these stakeholders might find human representation at some point in the future. Imagine that some of DodoPrint's operations emit a loud noise during printing. The disruption to wildlife quickly causes local species to disappear. While there is no immediate repercussion for this, one can imagine a judge may grant a vocal NGO an injunction to stop these specific printers. Regardless of how realistic this scenario is, the internet gives vocal stakeholders power: A loss of brand image can be much more costly than noise filters.

Mapping every possible stakeholder is a complex task. This thesis therefore recommends to do this during the LCA phase, by noting them as an Aspect, on an equal level with CO_2 emissions or energy use.

For each of the identified stakeholders, consider (Crosby, 1992):

- Key interests, such as expectations, rights, benefits and losses
- Potential impacts of the planned circular economy project or of the status quo
- Potential influence, measured by the resources available to them or their legitimacy

3.4 Net material cost savings

LCA and AUDIO identify which change would bring the most profit to the environment but neither identifies at what cost this change would come to the company. It is therefore important that the company couples the initial issue mapping to an in-depth analysis of the market factors surrounding said product or the sub-products linked to it. This helps to put issues and opportunities from the previous analyses into perspective.

In order to get a picture of the possible cost savings a circular economy project may introduce, the company will have to come up with an estimate. Because this stage falls before the prioritization phase, and thus also before the solutions phase, this thesis recommends calculating a reasonable best-case-scenario as a replacement for an estimate of a concrete solution.

Products with larger volumes are naturally better candidates for circular supply chains because they provide economies of scale to offset the initial investment cost of the implementation.

To calculate the visible cost savings associated with the refurbishment, remanufacturing, or recycling of a product, the Ellen MacArthur Foundation takes into account four different inputs: cost of material, cost of labor, cost of energy, and cost of carbon emissions (if applicable to the company through taxation). In this phase as well, it is relevant to not only consider your company's personal inputs, but the inputs made by every participant of the value chain. Even if some investments do not seem to directly profit your company, there might be a way to in-source some of them, to set up agreements with suppliers to share costs and benefits, etc. (EMF, 2012).

To calculate the cost savings associated with the raw materials used as inputs in the production chain, the following driver tree can be used. The same logic structure applies to all four inputs, so you can either calculate them separately in their own units (for example, by replacing material with full-time equivalents), or you can assign a cost to each of them and aggregate all four.

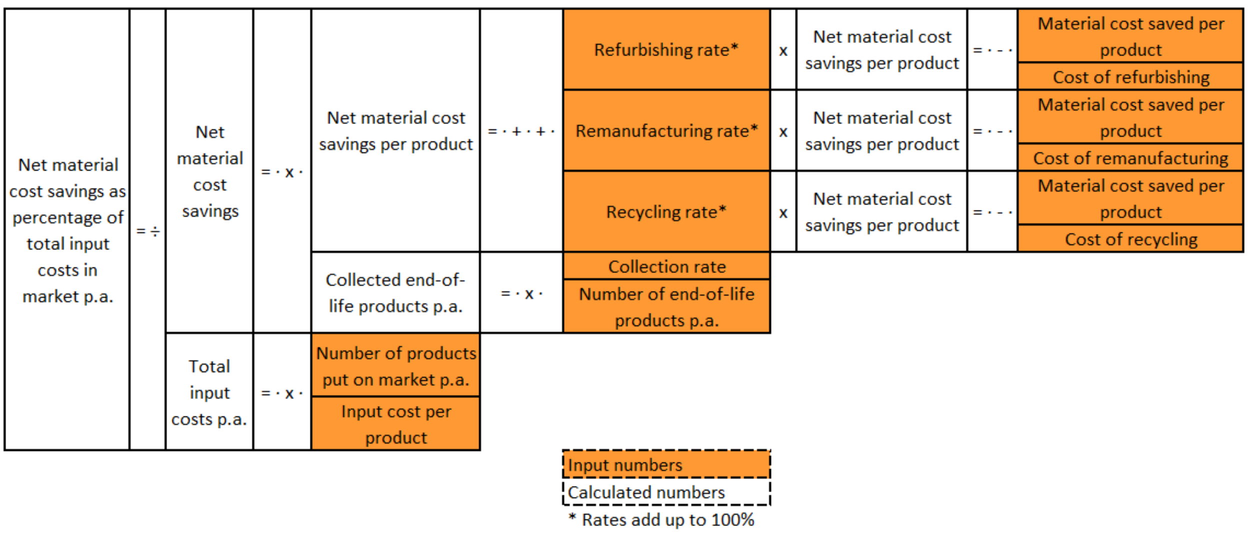


Figure 12. Driver tree: Factors affecting net material cost savings as a percentage of total input costs. Edited for clarity and to correct a mistake in the original source (EMF, 2012, p87)

To illustrate the concept, the table below showcases this calculation for aluminium prototypes made by DodoPrint. As the size of their prints differs a lot, they opt to aggregate the total in kilograms. Since most of their prints are iterations in their clients prototyping stages, these can be recollected at the end of their valuable life. Some 30% are pure aluminium and can therefore simply be reused by the company in their printers, meaning they regain the equivalent of their suppliers' raw material price. The other 70% are a mix of materials and have to go through a recycling company at a small cost. In the end, a best-case-scenario recollection program would save them a total of € 3168 p.a. (per annum), or just below 50% of their annual spending on aluminium.

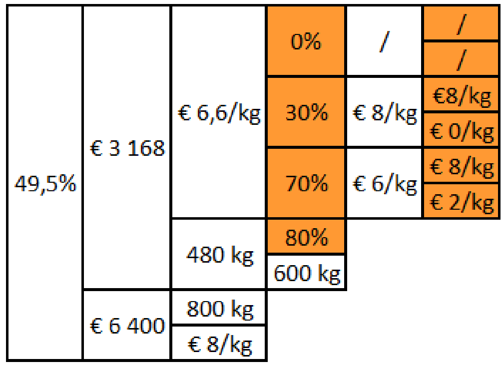


Figure 13. Driver tree: Factors affecting net material cost savings as a percentage of total input costs filled in for DodoPrint.

A closed loop supply chain as per the above driver tree only works if there is a market for the refurbished or remanufactured products. Customers have to be willing to buy them and although they are often claimed to have the same quality as the original product, consumers tend to have a lower willingness to pay for the remanufactured version (Guide & Li, 2010; Michaud & Llerena, 2011). Therefore, these are often priced below the original product, further affirming their perception as inferior (Abbey et al., 2015). This should be reflected in the above cost calculation if it is applicable. Alternatively, if the change is well marketed this perception can also have the reverse effect of being perceived as identical in quality, but greener. The latter scenario is especially the case for reused raw materials rather than components.

Additionally, as mentioned before, there may be government subsidies for circular economy-related projects that can be taken into account when estimating the profitability of recycling, remanufacturing or reusing.

3.4.1 Price volatility

During the financial crisis of 2008, raw material prices spiked exponentially. Price volatility also rose, with the observed spread between minimum and maximum prices on average per year rising from 40 percent to 163 percent in the period between 2005 and 2008. After the crisis, demand dropped again and prices followed suit. However, during the crisis many contracts changed towards monthly recalculation instead of yearly recalculation to accommodate the decreased certainty. Moreover many raw materials' supply markets saw the main industry players consolidate, which caused the increased price volatility to stay long after the crisis (Schuh, Strohmer & Zetterqvist, 2011).

Demand for commodities and therefore prices are predicted to further rise between 30 and 80 percent by 2030, mainly as a result of an increased purchasing power among the emerging middle classes in developing countries (Harvey, 2014).

Volatility is not as easy to quantify as current prices for the above calculation and this thesis therefore advises to look at it as a separate consideration. If your products use materials that are highly dependent on a certain type of raw material, it is good practice to check the evolution of market prices for said material. If prices are forecasted to rise or fall aggressively in the future, respectively more or less weight can be given to the cost consideration in the overall prioritization process. Raw materials for whom the earth's natural reserves are running out are more probable to be subject to price hikes in the future. Implementing a circular supply chain makes even more sense in such cases.

To get a feeling of how pressing of a concern this can be, natural reserves can be compared to the global use of said raw materials. Some examples from the semiconductor industry to show how long natural supplies will last under the status quo (Diederen, 2010):

- Terbium: 12 years
- Gold and zinc: 17 years
- Copper: 31 years

IV. Selecting the most fitting operations (Prioritization)

In the previous chapter, four measures were discussed:

- AUDIO: Environmental Aspects influenced by operations along the value chain and related issues and opportunities
- LCA Inventory: How much each product contributes to the influence on these Aspects
- Stakeholders: Everyone who can affect or is affected by company operations
- Profitability of best-case-scenario's, possibly weighted by future price hikes, increasing volatility and government subsidies.

In this chapter, a structure to bring these four elements together is proposed. The goal of this exercise is to facilitate the identification of those products that have the highest potential for a successful circular economy pilot project.

4.1 Stakeholder management

Looking at the above four measures, only two are numerically quantifiable. This makes any form of numeric aggregation impossible. This is why, in the previous chapter, this thesis advised to list stakeholders for each product during the LCA. In order to quantify the stakeholders, this thesis recommends assigning a weight to them to be multiplied with the LCA Inventories previously calculated.

Stakeholder power analysis generally categorizes stakeholders by their potential threat level and the benefits that may come from cooperating with them. This utilitarian approach is not very suitable in the context of this thesis, as it starts from the assumption that ethical considerations are inferior to financial considerations (Mayers, 2005). Instead, this thesis proposes to rank them by how much they are affected by the product in question, omitting their potential to affect the business entirely (only for the duration of this step). While countless frameworks describe how to categorize and deal with the former, very little literature has been published on the categorization of the latter.

This is perhaps due to the wider range of variables that could be important to stakeholders who are affected by the company. The International Association for Impact Assessment (IAIA, 2003) defines social impacts as anything that affects any of the following:

> People's way of life, their culture, their community, their political systems, their environment, their health and well-being, their personal and property rights, and their fears and aspirations.

Since people themselves assign different values to the above, these can indeed be hard to quantify. The most straightforward way of assigning weights to stakeholders is rank them vaguely by how much they are affected and to then divide that ranking into a select number of importance levels. Ask whether the operations linked to the product in question have a major impact on the way of life of the stakeholder or if they are merely a nuisance, and categorize them into primary, secondary, tertiary, … Stakeholders accordingly. Society as a whole can also be a primary stakeholder, for example when looking at carbon emissions. Business stakeholders are here omitted, because companies tend not to have feelings.

4.2 A formula for prioritization

All of the above can now be brought together in one graph, so that a visible pattern emerges to help prioritize the right product(s) or operation(s). This thesis proposes that for each of the analyzed AUDIO Aspects, which should be limited in numbers, the *profitability for the environment* a project would have is plotted against the *profitability for the company*. The reasoning behind these two is simple: It is this thesis', and hopefully the reader's, goal to do as much good for the world as possible. Projects that are highly profitable to both the environment and the company are more likely to be implemented and sustained on a long-term basis. Moreover, three low-cost, medium-impact projects tend to have more impact than one high-cost, high-impact project.

However, since the previous chapter calculated potential company profits without accounting for a fixed initial cost of investment, they are not a real representation of the company's profit. Due to the nature of our circular economy definition, which stipulates that the process has to be reinvented from the ground up, it is impossible to estimate an initial cost of investment before looking at specific solutions for products.

In order to estimate the financial return on investment, this thesis goes on with the assumption that the cost of investment for the implementation of a circular economy project is linearly related to the total spending on inputs. It is by this reasoning that the best-case-scenario profitability was calculated as a percentage of the total inputs in the previous chapter - as an estimate for overall company profitability.

This means that on the horizontal axis, the best-case-scenario profitability of the product r material is plotted. This is the percentage identified in the chapter on cost considerations (cfr. 4.4)

On the vertical axis, the impact or profit of the environment is charted. This thesis proposes to calculate this as follows:

Impact = *[Toxicity x volume]*

x

[(Number of negatively impacted primary stakeholders x weight of primary stakeholders) + (Number of negatively impacted secondary stakeholders x weight of secondary stakeholders) + (Number of negatively impacted tertiary stakeholders x weight of tertiary stakeholders) + …]

Where toxicity stands for the total contribution of the product to the environmental Aspect, as identified in LCA Inventory. Volume stands for the amount of new products brought into circulation per year. The first line thus represents the total impact on the Aspect.

The second line scales that impact by the weighted total number of stakeholders. It does not really matter whether the company previously identified a small or a large number of stakeholders, as long as the depth of the analysis is consistent across products. The above formula gives more weight to those products that have a higher number of stakeholders overall as well as extra weight to those with more primary stakeholders. The exact weights depend on the difference in importance assigned to the stakeholder categories by the company and is therefore at the reader's discretion. In the interest of seeing how much a circular economy project would change the products' influence on the Aspect, it may be good to make a second, identical graph without the stakeholder part.

Supposing that DodoPrint does this for all of their products, the resulting graph might look like figure 10 below for the Carbon Emissions Aspect. The numbers on the Y-axis are arbitrary.

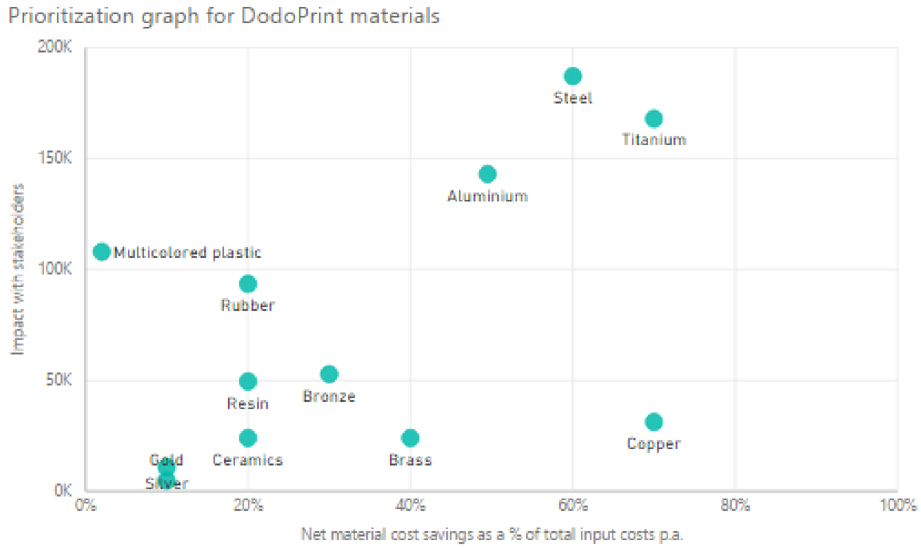


Figure 14. Impact vs Profitability.

The same graph without the stakeholders' weighting looks similar, but shows how not accounting for stakeholders places plastic higher and heavy metals lower. This would be a cause of the large impact heavy metals mining can have on the environment. This thesis recommends using the graph above to prioritize products, and the graph below to check two things: First, their actual impact on the Aspect, because this is what will be used to track the company's progress. Second, as a control measure to ensure the weights given to stakeholders do not exacerbate the importance of one of the products.

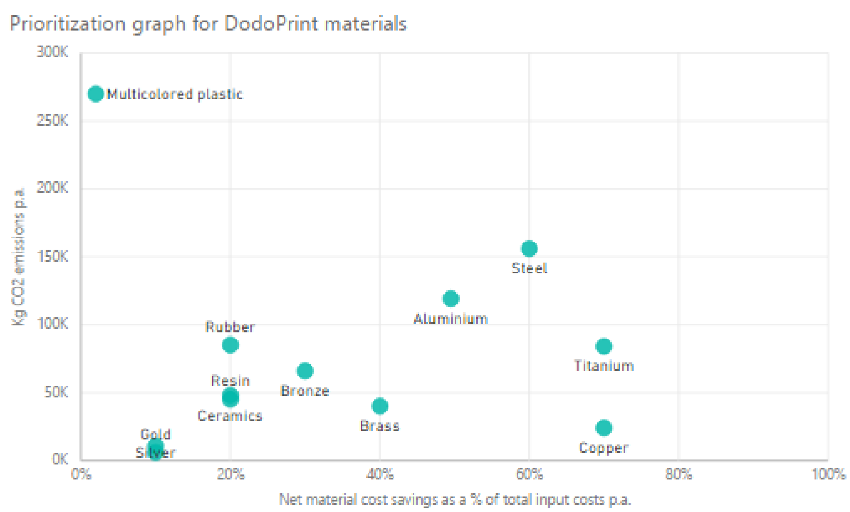


Figure 15. Kg CO2 emissions vs Profitability.

DodoPrint's executives then choose to focus their brainstorming efforts in the next phase on Steel, Aluminium, Titanium and Multicolored plastic. The above graph only depicts the carbon emissions Aspect. If the company previously did analyses for multiple Aspects, they would select a small number of products (those closest to the top right) for each Aspect. In a very limited number of cases the units can be converted (such as energy use into carbon emissions) to be able to join the graphs. Most others, such as phosphorus use and deforestation, are so independent from one another that they cannot be converted to one scale, and have to be compared through a different method. However, since that is a study on itself and this thesis is mostly looking to identify outliers for every Aspect, such aggregation methods are out of scope here. The overall number of identified priority materials should either way be small enough to go over during a brainstorm session.

V. Reimagining the business model (Implementation)

Now that there is a list of products with potential on a whiteboard somewhere, the company can start to think of solutions. This chapter suggests a brainstorming framework that helps to rethink the business models surrounding the identified products. After that the focus lies on the most common business model changes in a circular economy context, to provide a reference for the above brainstorming exercise if inspiration falls short at some point. As such it is to a certain extent an expansion of the introduction to the circular economy given in the first chapter of this thesis. The main part of the chapter is preceded by a framework on stakeholder engagement, because the identified stakeholders can be a strong resource during this phase.

5.1 Stakeholder engagement

Engaging with these stakeholders will inevitably bring new problems to the surface. It will probably also lengthen the overall timeline of the project. However, introducing additional different points of view will also lead to a wider set of creative solutions, which is exactly the goal of this exercise (Richards et al., 2004). Furthermore, the project is less likely to face opposition (such as from employees whose job description changes) if the stakeholders were involved in the process and informed about the compromises made (Mascia et al., 2003).

Employees who do not have a direct connection to the project can be an often overlooked resource. Through open management techniques, such as decentralized decision making, these supportive stakeholders can be involved without putting too much strain on the initiative (Savage et al., 1991). An all-round inclusive approach is important for the aforementioned practical reasons, but also for social reasons. A theory driven approach to substitute the lengthier stakeholder discussions usually fails to achieve an outcome all parties are equally happy with (Sterling et al., 2017).

How the company engages with its stakeholders traditionally depends on the following factors: The intensity of the issue, the power of & potential for collaboration with the stakeholder, the legitimacy of their claim and the urgency of the issue (Mitchell, Agle & Wood, 1997). Stakeholders were previously identified and classified by how much they were affected by the company's operations, covering the intensity and urgency of the issue as well as the legitimacy of their claim. These stakeholders, especially the primary ones, all have to be kept in mind during the solutions phase. First, the company will want to know who they can send invites for the brainstorm meetings. To do so, they focus on the remaining factor: the stakeholders' potential for threat and cooperation with the organization. They are summarized in the table below.

		Stakeholder's potential for threat to organization	
		High	*Low*
Stakeholder's potential for cooperation with the organization	*High*	Stakeholder type: **Mixed blessing** Strategy: **Collaborate**	Stakeholder type: **Supportive** Strategy: **Involve**
	Low	Stakeholder type: **Nonsupportive** Strategy: **Defend**	Stakeholder type: **Marginal** Strategy: **Monitor**

Figure 16. Diagnostic typology of organizational stakeholders (Savage et al., 1991, p65).

By categorizing the stakeholders in the table above, the company can decide who to collaborate with or at minimum involve in the process. The bottom-left tactic of taking a defensive position is more focused on risk management and less relevant in this exercise. The following list of questions can help to decide where to place everyone.

	Stakeholder's potential for threat	Stakeholders' potential for cooperation
Stakeholder controls key resources needed by organization	Increases	Increases
Stakeholder does not control key resources	Decreases	Either
Stakeholder more powerful than organization	Increases	Either
Stakeholder as powerful as organization	Either	Either
Stakeholder less powerful than organization	Decreases	Increases
Stakeholder likely to take action supportive of the organization	Decreases	Increases
Stakeholder likely to take non-supportive action	Increases	Decreases
Stakeholder unlikely to take any action	Decreases	Decreases
Stakeholder likely to form coalition with other stakeholders	Increases	Either
Stakeholder likely to form coalition with organization	Decreases	Increases
Stakeholder unlikely to form any coalition	Decreases	Decreases

Figure 17. Factors affecting stakeholders' potential for threat and cooperation (Savage et al., 1991, p64).

Of course, the firm can list a million parties with whom cooperation might be beneficial - that doesn't mean these parties are willing to invest their time in the project. In that case the firm will have to substitute them by theoretical constructs or third party networks. In these cases third parties or cross-industry cooperation are essential. Companies can unilaterally set up collection efforts for competitors as well, thereby achieving economies of scale. In some cases the initial costs of cooperation are too high to allow for new entrants and the government has to intervene through subsidies or cross-industry think-tanks and networks.

Some examples of networks are mentioned here and later in this thesis, but there are numerous other global and local organizations in the world. The Ellen MacArthur Foundation started the CE 100, a global innovation platform established to help organizations transition towards circular systems. It brings companies, universities and governments together in one network. Small and Medium-sized Enterprises as well as entrepreneurs can search for advice through INNEON, a network funded by the European Commission since 2014 (Garro, 2016).

5.2 A brainstorming framework

The real start of the implementation phase is forming cross-departmental teams similar to the ones that did the AUDIO analysis, usually consisting of someone in purchasing, someone with an environmental studies background, someone from the design or R&D department, someone from marketing, some of the external stakeholder representatives, etc. These teams can then explore options for the materials that came out of the previous analysis as priority materials. Involving a third party, such as an external stakeholder, is a good idea in this step because the companies' own management is at risk of being too ingrained in the current business model to think of new ones (Sahlman, 1997).

Before launching into ideation meetings, check what others are doing. There is a good chance that similar companies somewhere in the world already have set up a recycling system for the material you aim to reuse. Copying them or outsourcing to the same third party recycler will be much easier than reinventing the wheel by yourself. The concept of materials pooling, joining forces to support individual or collective goals of reducing or eliminating wasteful materials, is not reserved to industry competitors. For example, Nike, Harley Davidson, Herman Miller, and Ford—A footwear company, a motorcycle manufacturer, a furniture maker and a car manufacturer—run a joint effort to reduce toxins and waste in their purchase of leather and industrial feedstock (Makower, 2009).

The three main factors in bringing a product in line with circular economy principles are the business model, end-of-life material flows, and the original design, often in a combination of all three. Hereinafter this thesis discusses the Business Model Canvas as a tool to brainstorm about these factors, followed by an extensive review of existing applications.

The Business Model Canvas (hereinafter BMC) is often seen as a tool reserved for startups and entrepreneurs. However, to fully take advantage of the circular economy theory's potential, executives have to be able to reinvent the way their company does business. The BMC helps companies do exactly that. Circulab has published a slight variation of the BMC specific to the circular economy, which can be found below. The original BMC is also a very useful tool in this stage, although Circulab's version makes it somewhat simpler to keep the business models and suggestions hereinafter in mind.


POSITIVE IMPACTS
What are the positive economic, social and environmental impacts for your organisation, society, the planet?
NEGATIVE IMPACTS
What are the negative impacts of your organisation?
What waste is generated, and what are the consequences on health and on nature?
CIRCULAB board
TEAM
ISSUE
KEY ACTIVITIES
What are our key activities creating value?
What expertise do we have?
What expertise can we acquire?
NATURAL RESOURCES
Which natural resources are necessary?
Is a circularity of resources possible?
Are they biodegradable?
TECHNOLOGICAL RESSOURCES
Which technological resources are necessary?
Which components, machines or other composite materials are used?
FUNCTION
What is the main function of the offer?
What essential needs are met by the offer?
PARTNERS
Who are our key partners and suppliers for the creation of value?
What activities and expertise do they provide?
ENERGY RESOURCES
Which energy resources are required?
Are they fossil fuels or renewables?
Is an independent energy supply possible?
REVENUE
What are the existing or potential sources of revenue?
COST
What are the necessary costs and investments?

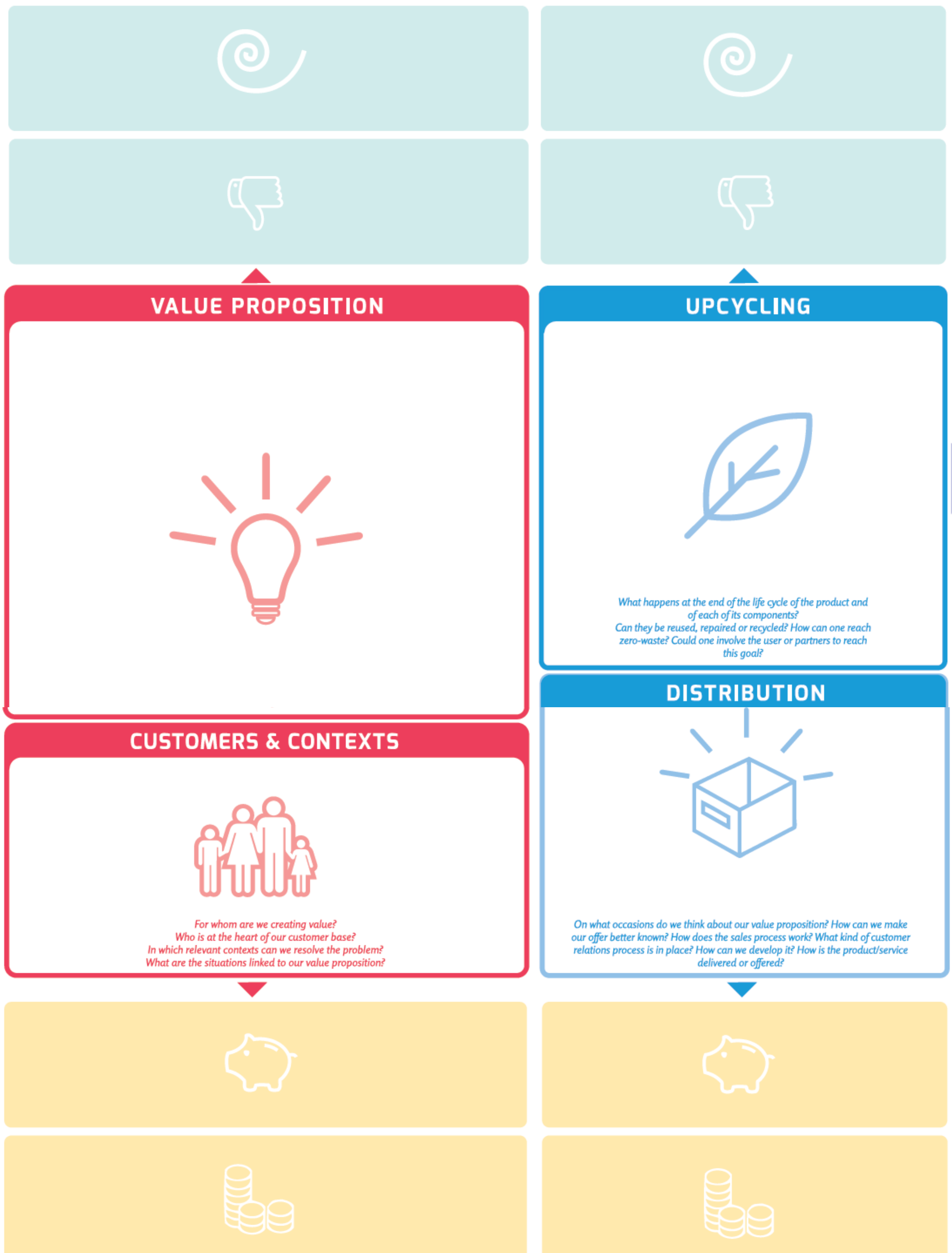


Figure 18. Circulab business model canvas (Circulab, 2017)

On the next page, the canvas is filled in for DodoPrint's aluminium-related (product-related) carbon emissions (Aspect) as an example. The process follows the canvas from left to right. Green, black and red colors are used to highlight the links between the different boxes.

The first thing to write down is the function of the product, or the need that it fills in society. "Supplying customers with 3D-printed aluminium prototypes" is not the function but rather the value proposition, or the way DodoPrint has been fulfilling a need in the past. The elementary function could here be described as "Providing customers with a durable 3D-model for visualization or prototyping purposes". It should be noted that other frameworks use the terms function and value proposition interchangeably, so to avoid confusion, be sure to stick with the same terminology if the company uses multiple frameworks.

The second column are Key Activities and Partners. These have all been identified in the LCA stage so can easily be written down. Focus on those that have the largest impact on the Aspect under scrutiny.

The third (green) column is directly linked to these and can be filled in with the data from the LCA as well. The Circulab framework splits resources into natural, technological and energy resources. This column allows to further detail where the key activities have an impact on the Aspect in question. It is a bit redundant in the DodoPrint example because a product is made of a single resource, but this would not generally be the case.

In the fourth column the (primary) stakeholders are listed under customers & contexts. The Value proposition is then to be filled with as many creative business models as the company can come up with. The only requirement is that it reduces carbon emissions whilst satisfying the needs of customers and stakeholders as defined under "Function".

The fifth column has an Upcycling box specifically aimed at recycling, reusing, or remanufacturing the product. While completely new ways of delivering the same value fall under the previous column, changes in how the product is handled at end-of-life fall under this box. Distribution is somewhat awkwardly named, as it does not concern distribution of the product (this would be under Key Activities). "Propagation" would perhaps be a more apt title as this box is reserved for the ways in which the change in business model will be advertised or made known to the public.

Finally, there are two rows on top of the framework where positive and negative impacts can be outlined for each column. Financial revenues and cost estimates are kept track of at the bottom of the framework to ensure the suggestions made in the brainstorming session stay within the boundaries of reality.

The framework is colored fairly arbitrarily, which somewhat impacts the overview during the brainstorming session. This thesis recommends printing or projecting it in grayscale, so that colored Post-its or pens can be used to link activities, partners, resources, impacts, etc. This is also the recommendation given in the original business model canvas framework (Osterwalder & Pigneur, 2010).


POSITIVE IMPACTS
What are the positive economic, social and environmental impacts for your organisation, society, the planet?
NEGATIVE IMPACTS
What are the negative impacts of your organisation? What waste is generated, and what are the consequences on health and on nature?
30 kg C02 / product
80 kg CO2 / product
CIRCULAB board
KEY ACTIVITIES
- Aluminium Mining, Smelting & Spooling
- Product design
- Additive manufacturing
- Recycling
What expertise do we have?
What expertise can we acquire?
NATURAL RESOURCES
Aluminium
TEAM
ISSUE
Carbon emissions from Aluminium
TECHNOLOGICAL RESSOURCES
Delving machines
Spooling machines
3D-printers
FUNCTION
Providing customers with a durable 3D model for visualization or prototyping purposes
What is the main function of the offer?
What essential needs are met by the offer?
PARTNERS
- Aluminium supplier
- Spooling company
- Recycling company
What activities and expertise do they provide?
ENERGY RESOURCES
- 3D-printing: Nuclear
Delving, & Spooling:
- petroleum
REVENUE
What are the existing or potential sources of revenue?
COST
What are the necessary costs and investments?

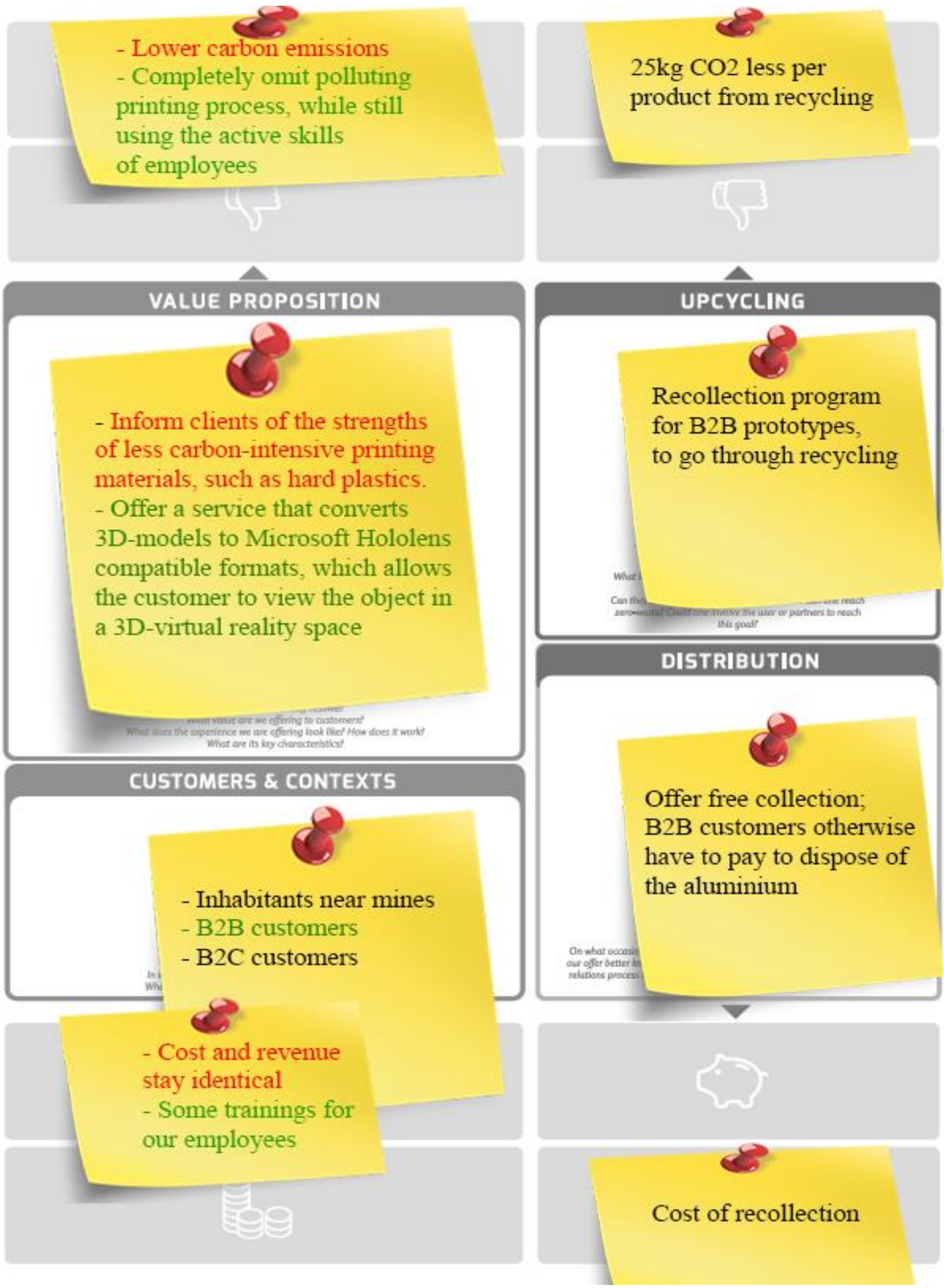


Figure 19. Circulab Business Model Canvas filled in for DodoPrint.

5.3 Business models

By asking what value the company is adding to the life of its customers rather than what it is trying to sell them, a company can fundamentally change the way it works instead of just becoming more efficient at what they do. As a source of inspiration, the most prevalent upcoming business models for the circular economy are listed hereinafter. The series described is an aggregation of those indexed by the Ellen MacArthur Foundation (2012), those identified by participants to the Disruptive Innovation Festival (2016) and an Accenture report by Lacy, Keeble & McNamara (2014).

5.3.1 Product-service systems

In this business model traditionally owned goods are either sold in a leasing format, through a buyback contract, or the functionality of the product is sold per use and the ownership remains with the manufacturing company. Long lasting machinery that would otherwise become outdated can more easily be updated and repaired in time as the manufacturer holds more control over the product after the moment of sale. Smart monitoring through IoT services is causing a rapid advance in this field (EMF, 2016). An additional benefit of this prolonged relationship with the customer is that it opens up opportunities for incentive schemes such as educational programs or other more comprehensive service packages, which increase customer loyalty (EMF, 2012).

A common example was started by Philips Circular Lighting. They realized their customers were not really interested in buying lamps, but rather in lighting their office space. Instead of lamps, the company switched to selling light per hour. For customers the service is both cheaper and more convenient, as they no longer have to worry about contacting repair services. Internally, the system directly incentivizes business units and employees at all levels to put more effort in increasing the life span of the lamps, designing them for simpler replacement and recycling processes, etc. This because the quality of the lamps now visibly keeps influencing the bottom line of the business unit after the installation. (Philips, 2017)

5.3.2 Peer to peer/sharing platforms

These platforms promote collaboration between end consumers. By eliminating to some extent the underutilization of assets, they ultimately help to lower the amount of unnecessary labor and raw materials used. For a company it might seem counterintuitive to start a service that essentially cannibalizes their own product, but this has to be weighed against two factors: Firstly, the company may reach consumers that were previously unable to buy their product anyway because they do not use it enough to warrant the investment. Secondly, it is better to deal with a level of internal cannibalization than to face said competition from a third-party provider.

An example of such a third-party provider is Peerby, a Dutch company that enables users to locate and borrow or lend out tools to neighbors, who often need it only once (Peerby, 2017).

5.3.3 Product life extension

This model presents a counter to planned obsolescence programs. Through more qualitative product design and different contracting options, some of the most common reasons for premature disposal can be solved (EMF, 2012).

- Weakest link fails: The entire product is discarded when the weakest component fails. More even wear and tear can be a solution, but also a more modular design that allows for easier replacement of the component.
- Fashion obsolescence: The new model replaces the old model before it is fully used. For example, in the US alone, 130 million functional smartphones are estimated to be lying around in drawers (EarthTalk, 2015). Modular design that allows for updates can be a solution here as well.
- Economic obsolescence: The cost of usage becomes larger than the cost of buying an entirely new product. High costs of repairs in older cars are a common example. Design for easier part replacement or a better take-back system, both of which the car industry has already implemented to some extent, can be a solution.

- Accounting obsolescence: Firms often retire things for legal purposes, such as the warranty running out. Refurbishing or reselling these products rather than discarding them can be a valuable source of income if they were originally designed to last longer.

While sales may initially decrease with a reduction in planned obsolescence, it will cause cheap, high cost per use producers to go out of business on the longer run. The Fairphone project is an example of a company making semi-modular smartphones with the aim of vastly extending their valuable life (Miquel, 2017).

5.3.4 Virtualize the product

Traditional industries have in some instances disappeared completely in the digital revolution. Omitting the manufacturing process entirely is clearly the fastest way to reducing the company's reliance on raw materials. The most famous example is probably the rise of streaming services such as Netflix, which caused DVD-rental companies such as Blockbuster to go bankrupt (Satell, 2014).

5.3.5 Closed loop supply chains

CLSCs are an umbrella term for value chains that reuse end-of-life products as inputs. They are often the first thing that comes to mind when people think of the circular economy. These reverse flows started to gain attention following the introduction of more stringent take-back regulation under the name of extended producer responsibility (EPR). In many sectors that produce merchandise which cannot be disposed of through the regular household waste channels, legislators hold manufacturers physically and financially responsible for what happens to their products after the end of their valuable life (Souza, 2013).

The reverse flow of these potentially valuable commercial product returns exceeds $100 billion per year in the United States alone (Shear, Speh & Stock, 2002). Product return rates range from 11 to 20 percent in consumer electronics, although this is in part due to firms' return policies being more lenient than legally obliged. Manufacturers on average only manage to recapture a small fraction of this value, leading to a large number of regrettable losses (Guide et al., 2006).

The Comet Circle, published by Ricoh, provides a basis to check which CLSC solutions are available to the company. The Comet Circle is a detailed depiction of all the technical and biological cycles a product can go through before it is eventually discarded. Materials often pass more than one cycle, moving from left to right, before they are deemed too impure to be further recycled. Reuse through the inner circles rather than outer circles reduces the amount of materials contamination introduced and is therefore more efficient, reducing the amount of virgin material necessary (Ricoh, 2017).

All of the circles have been proven to be profitable both economically and ecologically if handled well. *(Steinhilper & Hieber, 2001).*

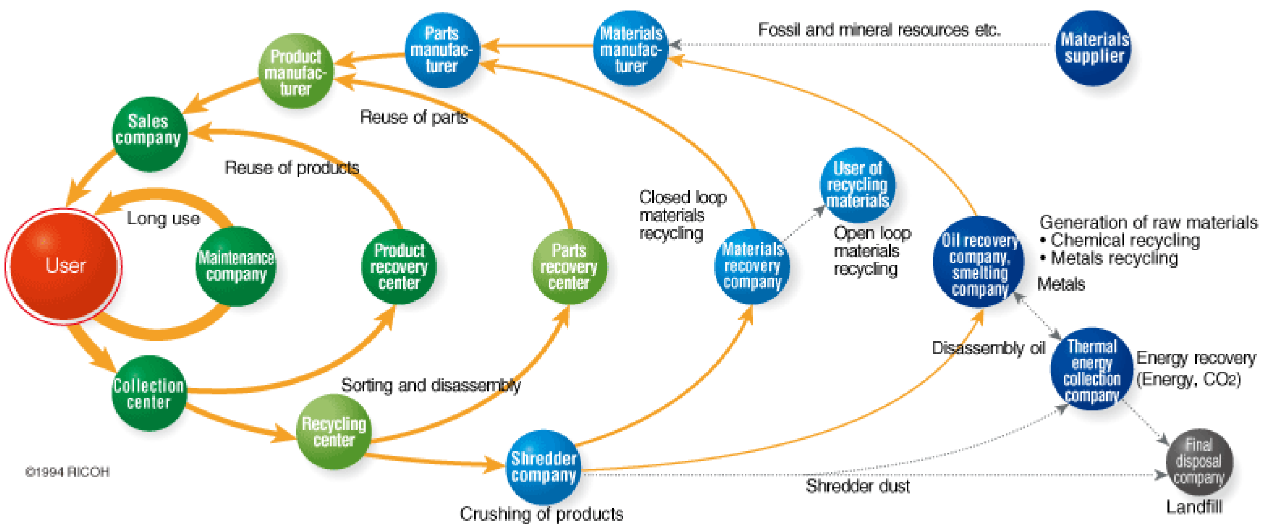


Figure 20. Ricoh's Comet Circle (Ricoh, 2017).

5.4 Design principles

Product design plays a major role in facilitating the repurposing of end-of-life products as inputs to the value chain. It is most relevant to the “Upcycle” box of the Circulab Business Model Canvas as it is not really a change in business model, but rather a boost in the resource efficiency of the product (Either in manufacturing, or in end-of-life reverse flow processing). Design principles do not really fit in the strategic framework this thesis follows, but a brief introduction is nonetheless given because they are a key pillar of several circular economy-related theories.

The most straightforward way of adhering to circular economy principles in design is to follow the requirements set out by the Cradle to Cradle Certified Products Program. As one of the best-known circular economy certificates it has the additional benefit of serving as a positive signal towards customers.

It is a publicly available and third-party verified methodology that supplies criteria and requirements for the continuous improvement of products and their inputs. The program primarily advocates for the use of healthy and environmentally safe materials that are perpetually recyclable. The C2C institute and its partners offer free online design classes, which are rather limited but nonetheless help to grasp the surrounding mindset. The institute also offers paid consulting services to companies who want to have their products analyzed. All guides towards certification are supplied on their website, so even if a company is not interested in third-party verification, it can still adhere to the requirements (C2C institute, 2017). The C2C design process stresses “eco-effectiveness” rather than what they call “eco-efficiency”, which boils down to striving for products that have positive impact rather than the more limiting view of reducing negative impact (Braungart, 2017). The five main quality categories for product optimization considered are (EMF, 2017):

- Material health (safe chemistry)
- Material reutilization (at end of life)
- Renewable energy and carbon management
- Water stewardship
- Social fairness

While the C2C institute provides criteria for what the final product should look like, it does not offer much help on how to get there. In that regard the 12 Principles of Green Engineering can be used as a tool to systematically improve the product design (Anastas & Zimmerman, 2003). Originally drafted for the ACS Green Chemistry Institute, they are general enough to be applicable to other industries (McDonough, Braungart, Anastas & Zimmerman, 2003):

- **Principle 1** Designers need to strive to ensure that all material and energy inputs and outputs are as inherently non-hazardous as possible.
- **Principle 2** It is better to prevent waste than to treat or clean up waste after it is formed.
- **Principle 3** Separation and purification operations should be designed to minimize energy consumption and materials use.
- **Principle 4** Products, processes, and systems should be designed to maximize mass, energy, space, and time efficiency.
- **Principle 5** Products, processes, and systems should be “output pulled” rather than “input pushed” through the use of energy and materials.
- **Principle 6** Embedded entropy and complexity must be viewed as an investment when making design choices on recycle, reuse, or beneficial disposition.
- **Principle 7** Targeted durability, not immortality, should be a design goal.
- **Principle 8** Design for unnecessary capacity or capability (e.g., “one size fits all”) solutions should be considered a design flaw.
- **Principle 9** Material diversity in multi-component products should be minimized to promote disassembly and value retention.
- **Principle 10** Design of products, processes, and systems must include integration and interconnectivity with available energy and materials flows.
- **Principle 11** Products, processes, and systems should be designed for performance in a commercial “afterlife”.
- **Principle 12** Material and energy inputs should be renewable rather than depleting.

These 12 principles can also be used to think of ways to improve a product during the brainstorming phase. They provide a checklist of things a product should be conform with before it can be called circular. An example of principle 7: It is better to design a smartphone case in a durable material that can be reshaped, than to make it rock-solid for eternity. After all, the rest of the phone will stop functioning after a few years.

5.5 Vision statement

Once a selection of pilot projects has been made, the company can start to implement them. Every change starts with a vision. Some circular economy solutions disrupt the entire market, but chances are that improving its product designs to facilitate remanufacturing is as far as this first executive exercise went. Most companies that work towards a more sustainable future are not suddenly able to use 100 percent biodegradable inputs because its management found a brilliant alternative. Instead they will have to motivate employees to gradually work towards alternatives. To achieve that, management has to give a strong signal by declaring internally, and preferably also externally, their commitment to change.

The statement should be accompanied by specific deadlines and goals. In the final subtitle on performance management some key process indicators relevant to the circular economy are discussed in more detail. Deciding what the company is willing to commit to is not always easy, as there is danger in both over- and under-promising when communicating externally. A company that gives a press conference to present unambitious goals will not receive much applause from the public, but if the stated goals seem too good to be true, they will backfire if they are not reached.

As a general rule, the example set by the Apollo 11 says that more will be achieved if the highest imaginable standards are set as a goal for employees to work towards (McDonough & Braungart, 2006). A company that sets high goals and ends up falling slightly short of reaching them in time will still be perceived as good, as long as there is a general perception that the company is indeed doing as much as it can to achieve those goals. Publishing targets signals to all the stakeholders that the company is genuinely committed to achieving them. Circular economy pilot projects have the same signaling function: thy help the marketing department to promote a green brand image for a product line, which in turn strengthens the green perception the public has of the overall company (Varadarajan & Menon 1988). The company thus enters a virtuous cycle as customers are also more likely to buy a product from a brand they think of as a green brand, regardless of the information on the product itself (Suki, 2013).

In deciding what exactly the vision statement will entail it is desirable to involve as many related stakeholders from the previous chapters as possible. At the very least, the statement should be run by them first to ensure the well-meant goals do not backfire. Even if your company is the industry leader in environmental protection, action groups might still take offense if they deem the target goals to be too low, where previously no-one paid attention to the issue.

An example of this is how Levi Strauss & Co., the largest buyer of cotton worldwide in the last decade, started sourcing two percent of their cotton needs organically in continuation of their history of social responsibility policies. At the time, only the much smaller Patagonia was using organic cotton for its products. However, when asked about the policy, the company declined to talk about the program entirely. The reasoning was that regular cotton is a huge pesticide consumer, so if they publicized an Eco-line with two percent organic cotton, the public would understandably ask them why the other 98 percent was not being sourced organically (a commitment that was impossible at the time due to organic cotton supply market constraints, but has by now been achieved by the company) (Makower, 2009).

For each of the Aspects that were analyzed and discussed in this chapter, the organization can adopt a set of minimum environmental requirements for all future products on top of the possible pilot projects. This strategy is especially valid in companies with a high rate of inventory turnover or new product development. An example would be to demand that a certain toxic chemical is no longer used in newly built production lines, thereby causing it to phase out without disrupting the flow of current products.

Such a strategy relies more heavily on a motivated middle management at the BU level. In order to achieve the aspired circular economy goals within the organization, management and employees have to share both the vision and the accompanying social mindset (Hambrick, 1995). Pay-for-CSR-performance schemes offer a straightforward way of aligning managers' interests to those of the company, regardless of their personal preferences. An example was set by Alcoa Inc.: After tying a mere 20 percent of the executive annual bonus plan to social and environmental metrics, the company saw a 5 percent decrease in CO2 emissions the same year (or 400,000 tons, the equivalent of approximately 2 billion km driven by an average car) (Ferracone, 2011).

Nevertheless, it should also be noted that incentive systems can suffer from a potential crowding-out effect. Studies have shown that motivation in a CSR context is most prominently reputational and that financial incentives might not always be sufficient to stimulate additional social effort. In some cases pay-for-CSR-performance schemes have even been seen to have a negative impact on motivation as previously driven managers did not want others to think they were doing it for the money (Frey & Oberholzer-Gee, 1997). Therefore, the vision statement's convincingness is essential to this strategy's success, although the benefits of CSR performance schemes have also been shown to outweigh the potential side effects overall (Epstein, 1996).

Now suppose DodoPrint has gone through all of the aforementioned stages in this thesis and wants to issue a vision statement. How much would they be able to commit to, without endangering their operations or reputation?

Since the targets have to be specific, they decide to use the four most impactful best-case-scenarios identified in the prioritization phase. They therefore settle on a total reduction of 600 tons in yearly C02 emissions. After conferring with all the primary stakeholders on the likelihood of a successful end-of-life recollection program, they cautiously estimate it will take approximately 18 months to set up the new operations. They simultaneously also commit to make their machines more silent in order to be more in balance with local wildlife. This is a relatively cheap investment to accommodate a primary stakeholder and will increase the press attention the statement receives.

Internally, they also tie the yearly bonus payment to the reduction in carbon emissions achieved before the end of the year. Moreover they start a pilot project to replace all of their traditional plastic packaging chips by organic alternatives, but given the large uncertainty surrounding this project, they only communicate this commitment internally.

5.6 Performance Measurement

Perhaps one of the biggest mistakes one can make in corporate social responsibility schemes is the lack of importance attached to monitoring it. A lack of quantifiable eco-related trackers puts the circular economy project (or any sustainability effort) at a high risk of being overlooked (Nelson, 2007). This final chapter therefore discusses some of the most commonly used standards for performance measurement in sustainability reporting.

Measuring and spreading sustainability-related results has several benefits. Perhaps most importantly it signals the commitment of the company management internally, raises awareness for related projects among employees and determines them to act more responsibly. By providing a standard language and methodology throughout the company, the level of internal coherence is improved. Metrics add a more practical framework to the values of the company, both of which make it easier for new projects to take off. Externally having these measures at hand will facilitate and legitimize the interaction with stakeholders (de Colle, Henriques & Sarasvathy, 2014).

Ingraining eco-related key process indicators in the companies' main dashboards instead of periodically sending them out as separate reports further strengthens the perception of environmental commitment.

Apart from the above benefits, public companies with over 500 employees are also obliged by law to disclose a range of non-financial metrics to the public, including environmental measures (European Commission, 2014). The reported information is encouraged to follow the format of recognized organizations such as the previously described ISO standards, the Global Reporting Institute's Sustainability Reporting Guidelines (described hereafter), or the United Nations's Global Compact framework (Sustainable Business, 2014).

Other known sustainability performance frameworks include, but are not limited to, the Triple bottom/top line, the Strategic concept of CSR, CSR DNA, OECD Guidelines, the United Nations' Guiding principles on Business and Human rights, etc. (Crisan & Borza, 2015)

One of the largest databases of practical, implementable metrics is maintained by the Global Reporting Initiative (hereinafter GRI). Their Sustainability Reporting Guidelines contain a list of Key Process Indicators that can be used to monitor environmental performance. The GRI Standards claim to be the first global best practice for environmental reporting.

Many of the GRI Standards relate to economic or social impacts, such as anti-corruption metrics, meaning they are not necessarily relevant to a circular economy project. The environment-specific standards are categorized under the GRI 300 series and can be downloaded separately by topic (such as materials, energy, …) on their website (GRI, 2017).

Of course, frameworks like the GRI are only indicative. The implementation of a new circular economy strategy also requires company-specific KPIs to be added. One may want to monitor every aspect identified in the Audio analysis at the start of the process. If the company has set up pilot projects, these will have specific KPIs as well. If they are hard to quantify, there should at minimum be a way to track whether or not the project is on schedule.

This third chapter of the thesis focused on brainstorming about solutions for the previously identified harmful operations in the value chain. It discussed which stakeholders to include in the process for more creative results, and detailed commonly applied solutions as well as design principles to draw inspiration from.

Additionally, vision statements and performance measurement were discussed as a way of incentivizing internal stakeholders to get on board and as a signal to the world that the company is committed to its circular economy journey. In the traditional strategy framework presented in the introduction, performance management is followed by regular review. That means that this last subtitle completed the circle: We have come back to the start of the analysis chapter.

Hereinafter this thesis summarizes the contributions it made to literature, the limitations encountered, areas for further research following these limitations, and one last page with dreamy ideas for future studies.

VI. Conclusion

6.1 Summary and contributions

This thesis set out to emphasize the value of the circular economy theory and to provide companies with a basis for constructive improvement discussions in the field of sustainability. As a whole, its intention is to serve as a practical guide towards the implementation of circular economy pilot projects. Managers who, for example, already know the problem cases in their company, can use its chapters independently to get a clear view of what the circular economy is and how they can go about implementing it. The structured figure from the introduction is repeated below to visualize the contents of the thesis.

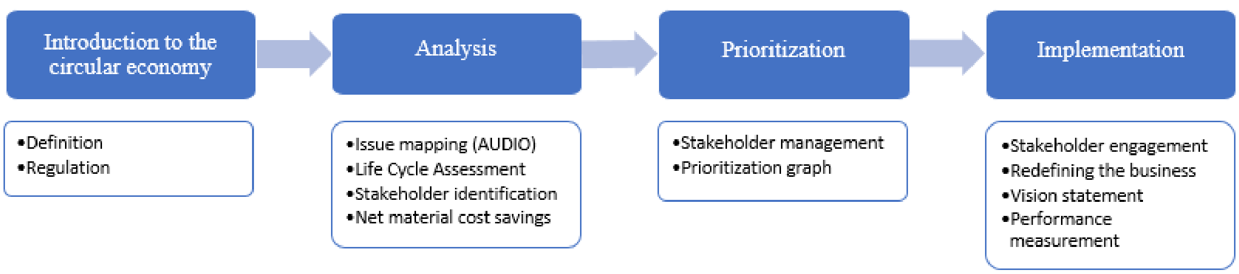


Figure 21. Structure of the implementation process

When executives look to make their companies' activities more sustainable, the circular economy is a concept likely to come up at some point. This thesis started by bringing together a range of related theories in order to form an uncomplicated, clear definition of the concept, to be kept in mind as the baseline throughout discussions.

The first step in starting these discussions is knowing where to look. Companies tend to have a myriad of activities and their environmental impacts are not always glaringly obvious. The first half of this thesis has therefore introduced a new framework to prioritize among the many products, materials and operations present in the value chain. To do so, it uses standardized assessment tools as inputs because companies may already have gone through them in previous sustainability moves.

Based on this in-depth assessment and resulting prioritization phase, companies can start to conceptualize cardinal solutions to decrease their resource dependency. As a guide for this second phase of the discussions, the most commonly seen business models and standards to date have been summarized in the final chapter of this thesis. These models were drawn from a variety of academic literature, industry examples, and publications by innovation think-tanks to ensure none were left out.

6.2 Limitations

The main limitation of this thesis has been a lack of industry contacts for qualitative interviews. While implementation cases undoubtedly exist, companies do not commonly publish their strategic methodology as it is often seen as a source of competitive advantage. Secondly, because this thesis aims to be as generally applicable as possible, interviewing a small subset of players from a certain industry may have skewed the result more than this thesis would have benefited from it. The prioritization framework that was proposed has therefore not been checked in a practical use case. The methodology of choice has instead been to apply the framework to a hypothetical use case from a sector that would not be among the first to come to mind when thinking of the circular economy.

6.3 Implications for further research

Literature on the impacts of a more circular global economy is widely available. Private consulting companies offer company-specific advice to those willing to pay for it, but freely available strategy tools and frameworks are not as abundant. More research into practical tools and the validity of the concepts proposed in this thesis is therefore necessary.

Secondly, many stakeholder-related frameworks take into account the impact of stakeholders on a business, but not how the company's operations impact stakeholders. Although they are clearly interrelated, a separate framework that would allow for the categorization of stakeholders by how much they are affected, would be a useful addition to literature.

However, frameworks and tools only work if they are being used. An argument can be made for further studies into ways of spreading awareness, but it is also fair to say that the vast majority of executives worldwide are already aware of the pressing environmental concerns our planet is facing. Since the benefits of circular value chains are also quite clear, the reason companies have been reluctant to implement them must be that the risk of change outweighs the possible rewards. Indeed, sometimes theoretically valid business models fail because of unexpected factors. In the sharing economy for example, amazingly well-built platforms may fail if end consumers mistrust the sanitary habits of their neighbors. It is understandable that executives might be hesitant to invest in a radical overhaul of their business model. More research is therefore needed to investigate measures that counter the uncertainty associated with these business models. An example could be publicly funded insurance schemes for end consumers participating in the sharing economy.

6.4 Ideas for further research

Global access to the internet and falling prices of connected products are enabling manufacturers to keep better tabs on their products after the point of sale. This should allow for better reverse flows and new contracting options such as automatic maintenance right before a product breaks down, but they are still fairly limited. More research is needed to find new applications for these technologies.

On the topic of creativity, the recent crowdsourcing trend may offer a helping hand. It has been proven that stakeholder involvement has positive effects on the profitability and sturdiness of strategic plans, but it is also a costly process that takes up precious time. Dividing a problem into specific sub-problems to solve and then asking the world to solve it through a crowdsourcing platform can be a very efficient way of exchanging knowledge and finding solutions. Platforms specific to the circular economy already exist (InnoNatives, for example), but they would profit from more research into their effectiveness so as to motivate hesitant companies to join.

Alternatively, while the digital revolution brings exciting new opportunities, it sometimes overlooks demographic groups. In the sharing economy for example, elderly people are the ones owning the largest portion of unused capital. They are also the demographic group that can spare the time that sharing systems sometimes demand more easily. Initiatives that find ways of connecting them without forcing them to use a smartphone application or an online system they mistrust would be a valuable addition to circular economy theory.

6.5 Acknowledgement

As a final note, I would like to thank Valérie Swaen for her remarkably quick responses and comments when I needed them. Without them, this thesis would not have gotten where it is today.

I am also grateful to the UC Louvain for introducing sustainability-related courses in the standard curriculum. These courses have the potential to have enormous impact by inspiring graduating students to strive for environmental greatness in their future careers. Without them, I probably would not have chosen circular economy as the main topic of this thesis.

It is my hope that, like these courses, this thesis will inspire someone to kickstart or further improve their environmental program, so that eventually it might contribute to a more balanced world.

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