Kaunas University of Technology

School of Economics and Business

Managing the Transition Towards Circularity by Approaching Challenges and Opportunities with a Focus on Digital Data Technologies

Master's Final Degree Project

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Innovation Management and Entrepreneurship (6211LX031)

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Summary

Relevance

Businesses face political, economic, environmental, and social pressures to act in a sustainable and circular manner. Circular economy (CE) emerges as an alternative to the linear way of producing goods and services and seems to successfully respond to the current need of companies to generate profits and be sustainable simultaneously. For those companies already established in the market and making use of linear models, the transition means a major challenge. This is especially relevant for the European region, due to its high levels of industrialization. In many cases, the problems that arise during this transition are not identified in advance and in some cases occur without the responsible managers being aware of them. Previous research has focused mostly on the field of industrial ecology, but few studies have analyzed the barriers that companies need to overcome from a managerial perspective. For this reason, the theoretical methodology available to explain, predict and understand challenges and opportunities (C&O) from a manager´s point of view, is limited. In addition, existing literature has demonstrated the central role of digital data technologies (DDT) as enablers in the transition and their potential to create sustainable competitive advantages (SCA) for the respective enterprise.

Subject matter

The process of transitioning from linear to circular business models in the context of European companies.

Research aim

Supporting managers in the transition to circularity by providing a theoretical framework designed to develop SCA by exploring the C&O and the potential of the use of DDT.

The research study was structured according to the following research objectives:

1. On the basis of thorough problem analysis, to expose the importance of the transition towards circularity by focusing on the pressures the companies face to act more sustainable and circular, and the role of data within that process.
2. To reveal the theoretical assumptions of the key aspects with regard to the research aim: the definition of CE, the managerial role in the transition to CE, the SCA, the identification of C&O in the transition towards CE, and DDT as enablers of this process.
3. Based on a review of previous literature, to support managers in the transition to CE by providing a theoretical framework designed to develop SCA by exploring the C&O and using DDT as enablers.
4. To define a methodology that allows validating the theoretical framework.

5. To conduct a case study to validate the theoretical model and to provide initial strategic recommendations to the company.

Methodology

A qualitative research was conducted in which data was collected from primary as well as secondary sources. It combined inductive and deductive approaches, as well as theoretical and empirical research.

First, an inductive approach was adopted to build the theoretical framework from the ideas gathered in the literature review. Then, to validate and test the developed conceptual model and its elements, empirical research was carried out with a deductive approach. An European company in the wind energy sector was selected due to the importance of the topic for the industry. Desk research was carried out to obtain general information about the company, and semi-structured interviews were conducted with five expert managers.

The coding of the interviews was done using a hybrid, deductive and inductive, approach. Themes and the first order of categories were predefined according to the findings in the theoretical part. Then, an inductive approach was used by creating, if necessary, new categories for those aspects that could not be included in the existing categories. By this means unexpected aspects could be used to enrich and adjust the model. MAXQDA Analytics Pro 2022 was the employed software to conduct the coding.

Research results

Among the most important theoretical findings are the research on the definition of the CE, the importance of the managerial role in the transition towards it, the generation of SCA, the challenges that arise in this transition, and the opportunities and DDT that can enable this process.

Then, on the basis of the theoretical findings, a conceptual framework was constructed that enriches the available theory on managing the transition to circularity.

The empirical research on the case study augmented the hitherto available theory on each of the model´s elements by adding the perspective of the analyzed company. In turn, the model provides insights into a possible path toward circularity that the analyzed company could take. It should be noted that the model was not designed exclusively for the wind turbine sector and that each company will have a specific outcome according to its own characteristics. Therefore the solution provided to the company can not be extrapolated to other companies without investigating the specific case.

Frei, Jimena. Perėjimo prie žiediškumo valdymo iššūkiai ir galimybės taikant skaitmeninių duomenų technologijas. Magistro baigiamasis projektas / vadovė prof. dr. Jurgita Sekliuckiene; Kauno technologijos universitetas, Ekonomikos ir verslo mokykla fakultetas.

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Santrauka

Aktualumas

Įmonės susiduria su politiniu, ekonominiu, aplinkosauginiu ir socialiniu spaudimu veikti tvariau ir žiediniu būdu. Žiedinė ekonomika (ŽE) atsiranda kaip alternatyva linijiniam prekių ir paslaugų gamybos būdui. Tokiu būdu ŽE, atrodo, sėkmingai reaguoja į dabartinį įmonių poreikį vienu metu gauti pelną ir dirbti tvariai. Rinkoje jau įsitvirtinusioms ir linijiniais modeliais besinaudojančioms bendrovėms šis perėjimas reiškia didelį iššūkį. Daugeliu atvejų šio perėjimo metu kylančios problemos nenustatomos iš anksto, o kai kuriais atvejais, jos iškyla atsakingiems vadovams apie jas nežinant. Ankstesniuose tyrimuose daugiausia dėmesio buvo skiriama pramoninės ekologijos sričiai, tačiau tik nedaugelyje tyrimų buvo analizuojamos kliūtys, kurias įmonės turi įveikti iš vadybinės perspektyvos. Dėl šios priežasties turima teorinė metodologija, skirta iššūkiams ir galimybėms (IIG) iš vadovo pozicijų paaiškinti, numatyti ir suprasti, yra ribota. Be to, esamoje mokslinėje literatūroje parodoma, kad skaitmeninių duomenų technologijos (SDT) atlieka pagrindinį vaidmenį pereinamojo laikotarpio metu ir gali sukurti tvarų konkurencinį pranašumą (TKP) atitinkamai įmonei.

Tyrimo objektas

Perėjimo nuo linijinio prie žiedinio verslo modelio procesas Europos įmonių kontekste.

Tyrimo tikslas

Padėti vadovams pereinant prie žiedinio modelio, pateikiant teorinį pagrindą, skirtą TKP vystymui, tiriant IIG ir SDT panaudojimo potencialą.

Tyrimas buvo struktūruotas pagal šiuos tyrimo uždavinius:

1. Remiantis išsamia problemos analize, atskleisti perėjimo prie žiediškumo svarbą, sutelkiant dėmesį į spaudimą, su kuriuo susiduria įmonės, siekdamos veikti tvariau ir žiediškiau, ir į duomenų vaidmenį šiame procese.
2. Atskleisti pagrindinių aspektų, susijusias su tyrimo tikslu, teorines prielaidas: ŽE sampratą, vadovų vaidmenį pereinant prie žiediškumo, TKP, IIG identifikavimą pereinant prie ŽE ir SDT kaip šio proceso įgalintoją.
3. Remiantis ankstesnės literatūros apžvalga, padėti vadovams pereiti prie CE, pateikiant teorinę sistemą, skirtą SCA vystymui, tiriant C&O ir naudojant DDT kaip pagalbines priemones.
4. Apibrėžti metodiką, kuri leistų patvirtinti teorinę sistemą.

5. Atlikti atvejo tyrimą, siekiant patvirtinti teorinį modelį ir pateikti įmonei pirmines strategines rekomendacijas.

Metodika

Atliktas kokybinis tyrimas, kurio metu duomenys buvo renkami iš pirminių ir antrinių šaltinių. Jame buvo derinami metodai: indukcinis ir dedukcinis, taip pat teorinis ir empirinis tyrimai.

Pirmiausia, taikant indukcinį metodą, remiantis literatūros apžvalgoje surinktomis idėjomis, parengta teorinis modelis. Vėliau, siekiant patvirtinti ir patikrinti sukurtą konceptualųjį modelį ir jo elementus, taikant dedukcinį metodą, buvo atliktas empirinis tyrimas. Dėl temos svarbos šiai pramonės šakai buvo pasirinkta Europos vėjo energetikos sektoriaus įmonė. Siekiant gauti bendros informacijos apie įmonę, buvo atliktas duomenų ir dokumentų tyrimas, bei su penkiais vadovais-ekspertais buvo atliktas pusiau struktūruotas interviu.

Interviu kodavimas atliktas taikant mišrų, dedukcinį ir indukcinį, metodus. Temos ir pirminės kategorijos buvo iš anksto nustatytos remiantis teorinės dalies išvadomis. Vėliau taikytas indukcinis metodas, prireikus kuriant naujas kategorijas tiems aspektams, kurie negalėjo būti įtraukti į esamas kategorijas. Tokiu būdu netikėti aspektai galėjo būti panaudoti modeliui praturtinti ir pakoreguoti. Kodavimui buvo naudojama MAXQDA Analytics Pro 2022 programinė įranga.

Tyrimo rezultatai

Tarp svarbiausių teorinių išvadų - ŽE apibrėžties, vadovo vaidmens svarbos pereinant prie žiedinės ekonomikos, TKP generavimo, iššūkių, kylančių šio perėjimo metu, galimybių ir skaitmeninių duomenų technologijų, galinčių įgalinti šį procesą, tyrimai.

Vėliau, remiantis teorinėmis išvadomis, buvo parengtas konceptualus modelis, kuris praturtina turimą teoriją apie perėjimo prie žiediškumo valdymą.

Atvejo studijos empirinis tyrimas papildė iki šiol turimą teoriją apie kiekvieną modelio elementą, įtraukdamas analizuojamos įmonės perspektyvą. Savo ruožtu, modelis suteikia įžvalgų apie galimą kelią, kuriuo analizuojama įmonė galėtų eiti žiediškumo link. Reikėtų pažymėti, kad modelis nebuvo sukurtas išskirtinai vėjo turbinų sektoriui ir kad kiekvienos įmonės rezultatai bus specifiniai, atsižvelgiant į jos ypatumus. Todėl įmonei pateikto sprendimo negalima ekstrapoliuoti kitoms bendrovėms, neištyrus konkretaus atvejo.

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Abbreviations:

CE	Circular economy
C&O	Challenges and opportunities
CBM	Circular business model
DDT	Digital data technologies
LE	Linear economy
IoT	Internet of Things
PSS	Product service systems
SCA	Sustainable competitive advantages

Introduction

Relevance

Circular Economy (CE) arises as an alternative to the current way of producing products and services, that seems to successfully respond to the current need of companies to be sustainable and profitable at the same time (Geissdoerfer et al., 2018). For those companies already installed in the market and making use of linear models and consolidated corporate strategies, the transition is a great challenge. Having clarity on obstacles and opportunities can provide insights for generating comparative advantages. In turn, given the characteristics of the CE, the use of data and digital technologies associated with it, play a central role in the transition.

CE is defined as a system in which the use of resources and generation of waste and emissions are minimized by narrowing, slowing and closing energy and material loops (Geissdoerfer et al., 2017). Contrary to common sense that sustainability increases costs, CE focuses on the resource cycles, decreasing the total amount of resources needed, and in this sense, minimizing expenses as well. Therefore, the concept of circularity, commonly used as a synonym for CE (Rizos et al., 2016; Cantú et al., 2021), is considered one of the most promising approaches to the future organization in terms of sustainable economic activity (Hazen et al., 2020).

The relevance of CE can be understood from many different perspectives. From a sociological point of view, the care for the environment is a trending topic that is penetrating people's minds, and consumer habits (O'Rourke & Ringer, 2015). In political terms, the international organizations, which directly impact the local businesses, fostered many agreements, such as committing to the Sustainable Development Goals (UNDP, 2021), and in many cases made circular business models (CBM) the norm (EC, 2021). The environmental reasons to be more sustainable are innumerable. There is a critical situation regarding waste production (Destatis, 2021), population growth (Population Matters, 2021), water pollution (Denchak, 2018), deforestation, and air pollution (CCAC secretariat, 2018), among many others which are a consequence of the current linear model of production. Economically, there has been a remarkable increase in the cost of materials, and closely related to this came the urgent need for more efficient management of resources (Stolze et al., 2012). Additionally, seeking to reduce risk and improve reputation, there has been an increase in sustainable investment (Morgan Stanley, 2020), which necessarily implies divestment in traditional ones. Besides the importance of CE itself, there is a need to focus on the transition, specifically in the European Union with its sizeable and already developed structure under linear product life cycles. The European Union itself accounts for approximately 30% of the global gross domestic product (Haas et al., 2015). Changing old structures is a difficult decision to make in which uncertainties associated with the feasibility of the transition can be appeased through the use of data (Kościelniak & Puto, 2015). As CE is in its essence a new way of managing resources, data management is at the core of its success.

Problem

If the benefits are clear, why is CE not mainstream? Hard challenges interpose on the way. Despite the broad knowledge of business models, design patterns, and tools to build a CBM, they have limited transferability in practical terms, as the challenges that arise in the process are often not contemplated (Lewandowski, 2016). Problems are not identified in advance and some impact the background without the manager's awareness. Regarding the identification of barriers, much research was done in the industry-ecology field, but few studies have analyzed the ones that need to be overcome by the companies from a managerial view. Thus, the theoretical methodology available to explain, predict and understand challenges and opportunities from a managerial perspective is limited (Garcés-Ayerbe, 2019). Therefore, it is essential to understand the aforementioned research gap, as greater clarity on the challenges and opportunities (C&O) could benefit companies in unlocking the lock-ins, but also in finding competitive advantages and defining the core technologies and data they will need to develop them. Indeed, digital data technologies (DDT) can enable different types of new capabilities, which can lead to competitive advantages (Cagno et al., 2021).

In the following pages, the results of exploratory research focused on gaining sustainable competitive advantages (SCA) by transitioning to CE by exploring the C&O and using DDT will be exposed. To complement the theoretical research a theoretical model that integrates all these elements with the aim of supporting managers in the transition towards circularity is created.

Despite the global relevance of the topic, the research scope of the thesis is on the European market and the manufacturing industry due to Europe's high levels of industrialization and the big potential of the manufacturing industry, to become more sustainable through improved use of resources (Haas et al., 2015).

To validate the model and demonstrate its usefulness in providing solutions, empirical research was conducted. In this sense, the model as the groundwork was tested within a European company in the wind power sector. In some industries, the pressure to be more sustainable and the general knowledge on the subject are greater than in others. The company was selected due to the relevance of the topic for the industry (European Commission, 2021) and because it would greatly benefit from CE.

The results of this research are relevant for different stakeholders, especially for those leading the first steps of change towards CE.

Since it is of utmost importance to fill the theoretical and empirical gap regarding the approaches available to transition to circularity, the research question that arises is: how to support managers in finding a path to circularity that will provide SCA? Which are the challenges that may hinder the transition? Which are the opportunities and DDT that can enable it?

Below, the research aim and objectives are summarized:

Research aim
Supporting managers in the transition to circularity by providing a theoretical framework designed to develop SCA by exploring the C&O and the potential of the use of DDT.

The research study was structured according to the following research objectives:

1. On the basis of thorough problem analysis, to expose the importance of the transition towards circularity by focusing on the pressures the companies face to act more sustainable and circular, and the role of managers and data within that process.
2. To reveal the theoretical assumptions of the key aspects of the research aim: the definition of CE, the managerial role in the transition to circularity, the SCA, the identification of C&O in the transition towards CE, and DDT as enablers of this process.
3. Based on a review of previous literature, to support managers in the transition to CE by providing a theoretical framework designed to develop SCA by exploring the C&O and using DDT as enablers.
4. To define a methodology that allows validating the theoretical framework.
5. To conduct a case study to validate the theoretical model and to provide initial strategic recommendations to the company.

Research methods

This master's thesis consists of qualitative research in which data was collected from primary as well as secondary sources. It combines inductive and deductive approaches, as well as theoretical and empirical research.

First, an inductive approach was adopted to build the theoretical framework from the ideas gathered in the literature review. Then, to validate and test the developed conceptual model and its elements, a deductive approach and empirical research were carried out in a European company in the wind energy sector. Desk research was carried out to obtain general information about the company, and semi-structured interviews were conducted with five expert managers.

The coding of the interviews was done using a hybrid, deductive and inductive, approach. Themes and the first order of categories were predefined following the findings in the theoretical part. Then, an inductive approach was used by creating, if necessary, new categories for those aspects that could not be included in the existing categories. By this means unexpected aspects could be used to enrich and adjust the model. MAXQDA Analytics Pro 2022 was the employed software to conduct the coding.

Limitations

The main source of information for the empirical research was the results of the interviews. Complementary methods such as observations, ethnography, focus groups and surveys, among others, could help to obtain a clearer picture of the company analyzed and dispel subjective biases. Furthermore, the interviewees made less time available than proposed, which limited the possibility to delve deeper into some aspects.

Additionally, it is important to note that each company will have different qualities and hence the solutions can not be extrapolated to other companies. Therefore, the empirical results should not be generalized to all wind companies. Finally, the model was validated with a single company. Testing with more companies would ensure that the model is suitable for different cases.

1. Problem Analysis

The population in the world is increasing up to a point that the global human population will reach 9 billion by 2050 (Stolze et al., 2012). This means 9 billion consumers needing resources. In 2003 already, the shortages in natural resources were categorized as one of the biggest security risks of the current century (Stolze et al., 2012). Even though CE responds with a solution to this particular problem, just 8.6% of the world's materials are circular. Therefore 91.4% of the materials used in the current industry are not being cycled back (Circle Economy, 2020). As most of the current businesses are not following CE practices, it is of utmost importance to change their current businesses. There are clear environmental, social, and political reasons which highlight the necessity to move towards CE (Ghisellini, 2016). Nevertheless, the established, internal and external, structures work as a lock-in that makes it very challenging for the companies to move forward (Chizaryfard, et al., 2020). CE solves the material scarcity problem by keeping the materials in the loop, reducing the need for virgin materials, and decreasing volatility in resource costs (Justenhoven & de Lange-Snijders, 2019). Shortly, CE proposes a sustainable yet cost-effective alternative (Geissdoerfer et al., 2017). It saves costs in manufacturing processes and provides income alternatives by selling valuable repaired, second-hand, reconditioned, remanufactured, upcycled products and recyclable materials (EU, 2017). Walter R. Stahel, one of the CE instigators, summarizes it by stating: "The products of today are the materials of tomorrow, at yesterday's prices" (Ellen MacArthur Foundation, n.d.).

Although the concept of CE is theoretically attractive, without supporting mechanisms and enablers, the complexity of CE is difficult to pursue effectively. By adopting CE practices, barriers and challenges will have to be overcome respecting each firm's capabilities, resources, and strategy (García-Quevedo et al., 2020). In all cases, information and data will be key aspects of the discussion (Jabbour et al., 2019), as CE implies at least some of the following aspects: "use of regenerated materials, shared products, optimized production systems, closed-loop strategies for end-of-life products, and emerging trends such as virtualization and exploration of cutting-edge and disruptive technologies" (Jabbour et al., 2019, p.546). The sharing of data is therefore a central aspect, not only to tracking materials but also to effectively relating with all the stakeholders involved (Genovese et al., 2017). Therefore reaching CE's potential will necessarily depend on innovative large and complex dynamic data collection and analysis (Despeisse et al., 2017). Thus, the transition toward a circular paradigm is surrounded by barriers, challenges, and complexity (Sopjani et al., 2020). Despite their potential pivotal role, little focus has been placed on DDT and how they can support the transition to CE and overcome the challenges and barriers that lie ahead (Pagoropoulos et al., 2017).

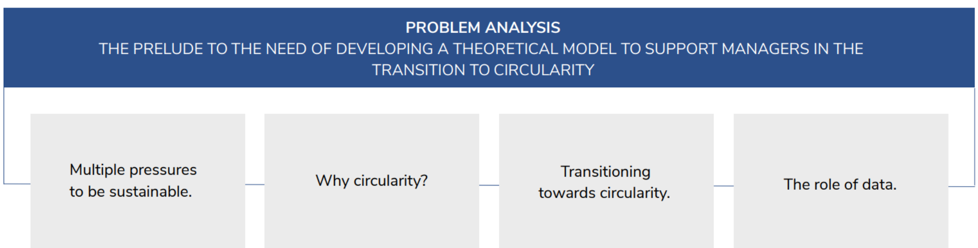

Fig.1. Problem analysis structure

To summarize, despite the awareness of the benefits of CE, it remains in an emergence stage with an ungeneralized, slow, and inconsistent progress (Kirchherr et al., 2018) and there are limited studies analyzing the drivers, practices, and barriers of the transition towards it (Govindan & Hasanagic, 2018). Hence, there is a big need to develop and structure knowledge for practical uses to support the adaptation of the current models. Although there is information on transitioning towards circularity, no research has been found in which C&O and the use of DDT have been used for broader management objectives, such as the pursuit of SCA that benefit the company as a whole.

The following subchapters will elaborate on the importance to focus on sustainable issues, and CE in particular, then on the transition to circularity, and finally on the role of data in the transition. Fig. 1 summarizes the aspects that will be covered in this section.

1.1.1. Relevance 1: Multiple pressures to be sustainable

The concept of CE as a solution to tackle global challenges like waste, climate change, biodiversity loss, and pollution is directly related to sustainability concerns (Ellen MacArthur Foundation, 2022). The various kinds of pressures that companies face to become more sustainable can be separated into four dimensions: the economic, the environmental, the political, and the sociological.

Table 1. Relevance 1: Multiple pressures to be sustainable

Dimension	Relevant facts
Economic	- Cost of commodities - Increasing sustainable investing - Need for cost-saving through efficiency
Environmental	- Waste production - Population growth - Water pollution - Deforestation - Air pollution - Lowered biodiversity - High use of natural resources - Contamination due to transportation and logistics - The melting of the polar ice - Climate change
Political	- United Nations: Sustainable Development Goals- - The European Commission: European Green Deal and the Circular Economy Action Plan - The Paris Agreement
Sociological	- Increased responsible consumer behavior

In economic terms, one of the biggest concerns of the companies is the increase in commodity costs. From the beginning of 2020, their prices have been increasing mainly because of the boost in demand and scarcity of resources. This includes energy, metals, minerals, and agricultural commodities (Stolze et al., 2020). Then, there has been a shift in the investors' behavior towards sustainability. According to the Morgan Stanley Sustainable Signals, sustainable investment is increasing (Morgan Stanley, 2020). Asset owners already practicing sustainable investing have identified clear benefits to reputation, stakeholder engagement, and risk mitigation. Among the investments addressing environmental themes, the CE, climate change, water solutions, plastic, and waste are the foremost environmental problems they seek to address (Morgan Stanley, 2020). Lastly, and closely related to the first point, there is a huge necessity to save costs through efficiency and the elimination and management of waste (Stolze et al., 2020).

Regarding the environmental dimension, there are many issues associated with the current culture of production and consumption. The following facts shall serve as merely an example of such. Firstly, the production of waste. Only in Germany, 23.9 million tonnes of hazardous waste were generated in 2019 (Destatis, 2021). Secondly, the rising global population is projected to be 9.7bn in 2050, and 10.9bn in 2100 (Population Matters, 2021). Thirdly, the pollution of water. Less than 1% of the earth is freshwater, and the polluted water has severe consequences on the environment as well as on human health (Denchak, 2018). Fourthly, the continuity of deforestation. Each year approximately 10 million hectares of forest are cut down (Ritchie & Roser, 2021). Fifthly, the pollution of the air. Approximately 7 million people die from exposure to fine particles in polluted air each year. It causes stroke, chronic obstructive pulmonary diseases, heart diseases, lung cancer, and respiratory infections (CCAC, 2018). Sixth is the reduction of biodiversity. It is estimated that since 1900 there has been a reduction of native species, primarily in terrestrial habitats, of at least 20% (United Nations, 2021). Seventh is the excessive use of natural resources. The per capita use of raw materials in industrialized countries, including European countries, is estimated to be four times higher than in developing countries (Umweltbundesamt, 2021). Fundamentally, the disposal of products at the end of their useful life has severe consequences, since inappropriate and illegal disposal of waste can lead to toxic emissions and serious diseases. Moreover, this work is often carried out by children (Umweltbundesamt, 2021). Eighth is transportation, which is considered the main cause of air pollution whose consequences were shortly explained above. Road transport in the first place and then water transport are the main sources of NO2 pollution (Skrucany et al., 2018). Ninth, the melting of polar ice is increasing the levels of the oceans. In the paper "The Global Fingerprint of Modern Ice-Mass Loss on 3-D Crustal Motion", by Coulson et al. (2021), these changes are analyzed. Tenth, and last of the selection: climate change. This aspect is directly related to and a consequence of the above-mentioned issues. The renowned Eurostat webpage supplies updated and detailed information about the factors driving climate change and how the different European countries are doing in this regard. One interesting aspect to highlight is the differentiation of Greenhouse gas emissions: in 2019 approximately 26% was caused by transport and 24% by energy industries (Eurostat, 2021).

The political dimension refers mainly to the impact of the new objectives, agreements, and perspectives of the main international organizations on European companies in terms of sustainability. International policies are intimately related to the targets and pressures that are transferred to governments, and ultimately to the companies to achieve global and communal objectives. Despite there being a myriad of agreements and international organizations, only a few relevant examples shall be noted hereafter. The United Nations developed the Sustainable Development Goals. They were settled in 2015 "(...) as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity." (UNDP, 2021). They focus on enhancing a balanced interrelation of social, economic, and environmental development, through the generation of an alliance with countries that are committed to prioritizing these goals. Due to the influence of the United Nations, the Sustainable Development Goals became popular among other big organizations, with international and regional influence, like the World Health Organization, World Economic Forum, International Monetary Fund, and World Bank. Then, the report of the Finnish Environment Institute highlighted the need for chemical information throughout the product lifecycle, the connection between poverty reduction and CE, and the importance of relevant government initiatives to achieve the Sustainable Development Goals (Deineko, 2019). The European Commission set up the challenging objective of becoming the first climate-neutral continent by 2050. This challenge was framed by the European Green Deal, which is a set of policy initiatives to make this challenge real (European Commission, 2021) and the Circular Economy Action Plan was one of the topics mentioned. It aims to regulate and motivate the repairability and reusability of products, circular business models (CBM), and the digitalization of product information (DG Environment, 2021). In this sense, the action plan aims at making CBM the norm. It is also worth mentioning the Paris Agreement, which was the first universal and legally binding global agreement on climate change, adopted in December 2015. It joined forces of different countries in order to cope with climate change and support each other in their efforts. One of the main objectives defined was to limit global warming to below 2°C (European Commission, 2021).

Ultimately, the sociological dimension encompasses the changes in how people live and in this sense how they consume, which is the result of an increase in the awareness of society regarding climate change (Buerke et al., 2016). Nevertheless, even in those cases where people are aware and interested, there are some barriers they find to becoming more sustainable. Among others, these are availability, convenience, affordability, habit, product performance, and conflicting priorities. (World Business Council, 2008). Overall, there is a generalized increase of "responsible consumer behavior" which consists of a broad and embracive construct that refers to the intention of minimizing the harmful effects of consumption, and maximizing the beneficial ones, in societal (environmental, social, economic) as well as personal aspects (physical, financial, socio-psychological) (Buerke et al., 2016). This concept encompasses all those cases in which people decide to consume in a more sustainable way using their purchase "vote" to finance some products or/and services, and consequently, defund others.

In order to recapitulate the multiple pressures to be sustainable, Table 1, presented above, was constructed and the outlined factors of the four dimensions were briefly summarized.

1.1.2. Relevance 2: Why circularity?

There is a general agreement that sustainability is a broader concept than circularity and that both are connected and complementary (Walker, 2021). As mentioned in the previous chapter there are four dimensions that make sustainability critical and CE presents promising responses to these issues. Table 2 briefly presents the key aspects that emphasize the need for companies to be more circular.

Table 2. Relevance 2: Among all the possible ways of becoming sustainable, why circularity?

Dimension	Relevant facts
Economic	- Improvement of economic performance and efficiency. - Reduction of costs through sustainable supply chain management. - New revenue streams through a more effective life cycle management. - New revenue streams through the sale of waste.
Environmental	- Increase in green products. - The saving of energy and natural resources. - The reduction of pollution generation. - The restraint of chemical fertilizers, soil amendments, fossil fuels, and toxic substances. - The earth is conceived as a circular and closed system in which the society, economy, and environment have to coexist in equilibrium.
Political	- Increased popularization among policymakers. - Legislative structure influences decisions at the local, regional, national, and international levels. - CE is part of the agendas of supranational bodies.
Sociological	- Job creation. - Increase in the acceptance and adoption of circular products and services. - An increase in the offering of services helps companies to gather insightful information about customers. - The strengthening of the communication between the industry and society.

Regarding the economic dimensions, CE is associated with responses to an improvement of economic performance and efficiency, as the focus lies on improving and perfecting the management of resources with different strategies (Walker, 2021). As manufacturing companies in the European Union expend on average roughly 40% on materials, closed-loop models can raise their profitability, while sheltering them from the fluctuation of resource prices (European Commission, 2020). The development of new revenue streams through a more effective life cycle administration, the drop in costs through sustainable supply chain management, and the generation of revenues from the sale of wastes are only some of the economic benefits associated with CE (Kumar, 2019). Secondly, regarding the environmental dimension, by following CE principles there will be several positive impacts on the environment. The increasing variety of green products, the saving of energy and natural resources and the reduction of pollution generation, the restraint of chemical fertilizers, soil amendments, fossil fuels, and toxic substances are some few examples (Kumar, 2019). Furthermore, its concept is associated with the idea of the earth as a circular and closed system. In this regard, it is inferred that society, economy, and environment have to coexist in equilibrium (Geissdoerfer, 2017). Thirdly, focusing on the political aspects, CE has gained the attention of policymakers, and it is influencing decisions at the international, national, regional, and local levels. As it was presented in Relevance 1, supranational bodies incorporated CE concerns in their agendas, being the European Union's 2015 Circular Economy Strategy the most relevant one thus far (Geissdoerfer, 2017).

Fourth and finally, the social aspect cannot be considered independent of the other dimensions. Society and future generations will benefit from a healthier planet, clean water, and air, among other aspects associated with environmental care. Some authors have addressed the social benefits of the collaborative economy and have delved into different aspects, such as job creation (Rizos, 2016). It is estimated that by applying the principles of CE, the European GDP could increase a 0.5% by 2030 creating around 700.000 new job positions (European Commission, 2021). From the consumer market point of view, there is an evident increase in the acceptance and adoption of circular products and services, which indicates the growth of a market in this area (Calvo-Porral, 2020). Moreover, the increase in the offering of services helps companies to gather insightful information about customers and to strengthen the communication between the industry and society (Kumar, 2019).

1.1.3. Relevance 3: The importance of focusing on the transition to a CE

The first important aspect to mention regarding the transition from a linear to a CE is the high level of industrialization in the modern world. In the case of already industrialized countries or industries, it is a priority to focu s on the transition, so that the companies can become sustainable without going bankrupt on the way. The EU-27 is considered a highly industrialized region that concentrated approximately 30% of the global gross domestic product in 2005 which, in capital terms, was on average US$28,600 (Haas et al., 2015). Even though it is one of the regions which is taking the lead in terms of sustainable development and sustainable resource use policies, it is one of the biggest consumers of resources and producers of emissions. In 2005, the EU-27 used 12.4% of the materials extracted worldwide. This is a high percentage in relation to the 7.5% of the global population that it entailed (Haas et al., 2015).

The level of industrialization and environmental impact can also be measured with the number of imported materials. Approximately 20% of the European domestic material consumption is imported (Schaffartzik et al., 2014). Closely related to the industrialization topic is the fact that it is organized in a linear way of production. As previously mentioned, only 8.6% of the world's materials are circular (Circle Economy, 2020) and most of the current businesses are not following CE practices. There are clear environmental, social, and political reasons which make clear the necessity to move towards CE (Ghisellini, 2016). According to the research study by Cantú et al. (2021) on European small and medium enterprises, the main motivations to migrate toward a CE refers to saving resources, creating new markets, and creating competitive advantages. Nevertheless, while the benefits associated with CE are clear, the transition has not been straightforward (Cantú et al., 2021). The established, internal and external, structures work as a lock-in that makes it very challenging for the companies to move forward (Chizaryfard et al., 2020).

Despite the high number of studies focused on CBMs, there is a big industrialized structure, which has to be supported to switch. The transition to a CE can be inscribed in what is called "socio-technical" transitions. These are long-term transformation processes in which established socio-technical systems turn into more sustainable modes of production and consumption (Grin et al., 2010). These types of processes incite changes in the infrastructures and technologies, as well as people's competencies, practices, and world points of view (Geels, 2005). Therefore theoretical as well as empirical analyses are required, to develop a strong foundation for designing and adapting frameworks on the basis of barriers and opportunities identified (Shove, 2014). In general, new approaches are not viable as such when they emerge. In the beginning, there is an emergence of technological niches with unstable socio-technical configurations and low performance. Despite these novelties starting with small networks, they aim to create something new, initially restricted in terms of time, space, scope, and actors, but with the potential of having wider societal relevance through various up-scaling mechanisms (Geels & Schot, 2007). The emergence of a novelty is the moment in which the developers find and develop the most sensible and user-friendly way of providing solutions, users learn to use them and adapt them, and the regulators learn how to govern them (Smith, 2007). This relates directly to the problem this research study aims to explore, as there is actually a mainstream linear system and an emergent circular one. This is a key moment for learning and developing technological, social, and institutional competencies to unlock the lock-ins of mainstream structures. With this aim, theoretical and empirical studies are a good basis to support managers responsible for pushing the sustainable approaches, who are in a challenging position considering the pressures companies face to become more sustainable (Fernandez-Feijoo, 2013).

Table 3. Relevance 3: The importance of focusing on the transition to CE

Dimension	Relevant facts
Moving towards CE as a socio-technical transition	- Theoretical and empirical analysis are required, to develop a strong foundation for designing and adapting frameworks to support CE on the basis of barriers and opportunities identified.
Industrialization	- Highly industrialized world with linear structures.
Linear vs. nonlinear companies	- 91.4% of the materials used in the current industry are not being cycled back (Circle Economy, 2020). - Lock-in is caused by the established, internal and external, structures that make it very challenging for the companies to move forward (Chizaryfard et al., 2020).
Need for theoretical and empirical support	- High challenges regarding shifting to sustainable practices.

Table 3 summarises the key issues related to the importance of focusing on the transition to CE. Overall, there is a highly industrialized world with a linear mode of production whose change would imply a socio-technical transition. Those responsible for leading this change are faced with a major challenge in which theoretical and empirical support would be helpful.

1.1.4. Relevance 4: The potential of data to help in the transition to circularity

Since all aspects of management in the modern age rely heavily on information to thrive, the need for better data quality and information in enterprises has been increasing and data management is receiving increasing attention (Adeoti‑Adekeye, 1997)

The prospect of an advanced CE has as its main attribute a high level of automation and digitalization (Kintscher, 2021). While disassembly processes are in general needed for recycling, the current recycling area is mostly dominated by manual processes, and it seems to be more complex to automatize disassembly processes rather than the assembly ones. In these processes, information is key, and previous research studies identified the lack of information as one of the principal obstacles to CE (Blömeke et al., 2020). In the CE the information has to be documented and handed on over the entire life cycle of products. Therefore an information flow working reliably is essential for the processes and for making the right decisions (Kintscher, 2021). CE requires not only the gathering of all available information on parts and materials, over the whole lifecycle of a product, but also specific information about its composition. In this regard, an IT-based information system seems to be key (Knieke et al., 2019).

Not only the information on the side of the producer has to be targeted, but also integrated cross-stakeholder channels have to be created so that materials and resources can be used by other companies and industries if convenient. As cross-industry networks of multiple supply chains are of high complexity, industrial symbiosis driven by big data is highly valued (Tseng et al., 2018). There is a huge loss of value caused by the lack of information for optimized reuse based on necessities. In order to successfully implement such systems, a holistic information management concept is required. With this aim, a fully-digitized product equivalent, commonly known as a “digital twin”, could be used to exploit the potential of data to analyze and plan life cycles (Tao et al.,2019).

Additionally, as deciding to change a linear structure can be a risky decision, convincing all the stakeholders, and acquiring support are formidable. Contrary to decisions based on intuition, nowadays decisions have to be supported by data. Thus, data can help to increase the certainty regarding the potential selection of paths and have a better overview of the consequences associated with the decisions (Kościelniak & Puto, 2015). This will help to clarify and balance expectations and make the transition feasible. They have to be used to establish a portfolio-management approach to define the people, processes, and technology in which a company invests to fulfill and benefit the corporations. The analysis and visualization of data would be used to determine the actions to take (Miller & Mork, 2013).

The exhaustive literature review on digital technologies as enablers of CE conducted by Cagno et al. (2021), which is exposed in more detail in the following chapter, confirmed the relevant role of digital technologies in enabling and supporting the CE transition. In this regard, there is an unfulfilled gap in research studies exploring the use of DDT as enablers of the transition in a way to support the overall business success and enhance the general strategy.

They identified that the research so far focused more on theoretical descriptive analysis of CE, but it was not merged into more operative and structured frameworks. Another issue they highlighted is that DDT were related to particular CE elements or processes, and not to the benefits of these technologies to the overall CE transition (Cagno et al., 2021).

Table 4. Relevance 4: The potential of data to help in the transition to CE

Dimension	Relevant facts
Processes of disassembly	- Need for automation and digitalization.
Cross-stakeholder relation	- Holistic information management system to connect the stakeholders.
Decision-making	- Data is used to establish a portfolio-management approach to define the people, processes, and technology in which the investments will be done.
Reduction of uncertainties	- Use of data to clarify and balance expectations and possibilities, and make the transition feasible.
DDT as enablers of CE	- DDT play a relevant role in enabling and supporting the CE transition.

In order to summarise the potential of data to assist in the transition to CE, Table 4 was constructed, which highlights the need for data in key CE processes, such as assembly and information transfer, as well as the potential to reduce the uncertainty involved in making a change to established linear approaches. Finally, DDT have been shown to play an important role in enabling circularity.

2. Theoretical Analysis

CE proposes an alternative to the “take-make-dispose" linear model. In a CE the products and materials are shared, leased, reused, repaired, refurbished, and recycled. The transition to these models requires the proactivity of a managerial role in coordinating and administering tasks (Horvath, 2019). In the literature review, it stands out that there were few academic articles focused specifically on the C&O of the transition to CE from a managerial perspective. Most of them focused on very specific problems, or on the biological or technical aspects of materials. Therefore, the identification and selection of papers were more challenging than expected. As this chapter serves as a prelude and baseline to the building of the theoretical framework, it combines the following aspects: CE, C&O, DDT, and management of the transition towards CE.

2.1. Circular Economy

In the following section the concept of CE will be defined in opposition to the linear economy and various definitions and frameworks of CE will be presented. In addition, the concept of the “circular business model" will be outlined and examples of CBM will be given for each of the business actions of the ReSOLVE model, one of the frameworks for understanding CE that will be presented.

2.1.1. Differentiating linear and circular economy

The current industrial system, which foundation was laid back in the industrial revolution, is founded on one primary characteristic: a linear model in which the resource consumption follows a ‘take-make-dispose’ pattern and the product’s lifecycle is finite. This pattern consists of the extraction of resources (take), production, distribution and consumption (make), and disposal at the end of the life cycle (waste) (Lieder, 2016). As there has been a direct relationship between economic growth and resource extraction, which inevitably entails a loss of resources and an unnecessary waste generation (Sariatli, 2017), the challenge is to overcome the existing linear model and shift to a self-sustaining and wasteless circular one. This requires re-thinking current ways of producing, providing, and using materials. To raise the resource productivity and reduce environmental impact, by closing the loops of technical components, reducing the rate of resource depletion, and increasing the sustainable renewable materials, decoupling resources seems to be the solution (Kjaer, 2018). Waiving economic growth does not seem to be an option and an increase or continuity in resource consumption either. Therefore, shifting from a linear economy to a CE is a feasible way for the continuity of economic growth.

2.1.2. Defining CE

After a detailed search for a unique definition of CE, it was revealed and confirmed by many academic articles that there does not exist one globally accepted definition of CE. Kirchherr et al. (2017) analyzed 114 CE definitions and concluded that CE is most often represented as a combination of reducing, reusing, and recycling actions (Kirchherr et al., 2017). Salvioni et al. (2021) approached this problem by collecting different definitions of CE:

Table 5. Definitions of CE (Salvioni et al., 2021)

Author	Definition
European Commission (2014)	"A development strategy that enables economic growth while optimizing consumption of resources, deeply transforms production chains and consumption patterns, and redesigns industrial systems at the system level".
European Parliament (2015)	"The circular economy is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible. In this way, the life cycle of products is extended. In practice, it implies reducing waste to a minimum".
Ellen MacArthur Foundation (2015)	"The circular economy is one that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles. This new economic model seeks to ultimately decouple global economic development from finite resource consumption. It enables key policy objectives such as generating economic growth, creating jobs, and reducing environmental impacts, including carbon emissions".
OECD (2016)	"With an expected global population of 9 billion by 2030, including 3 billion middle-class consumers, future consumption demand will create unprecedented pressure on natural resources. The Forum reflected on the importance of the "circular economy" in decoupling economic growth and job creation from the use of natural resources. Turning the ambition of the SDGs into reality will require robust data to capture progress, ensure effective monitoring and provide evidence to inform decision making".
Sauvé et al. (2016)	"Model of production and consumption of goods through closed loop material flows that internalize environmental externalities linked to virgin resource extraction and the generation of waste (including pollution)".
Circular Academy (2017)	"A circular economy is a transformative economy redefining production and consumption patterns, inspired by ecosystems principles and restorative by design, which increases resilience, eliminates waste and creates shared value through an enhanced circulation of material and immaterial flows".
Geissdoerfer et al. (2017)	"We define the Circular Economy as a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling".
Murray et al. (2017)	"The Circular Economy is an economic model wherein planning, resourcing, procurement, production and reprocessing are designed and managed, as both process and output, to maximize ecosystem functioning and human well-being".
Kirchherr et al. (2017)	"A circular economy describes an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operational at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations".

Korhonen et al. (2018)	"Circular Economy is a sustainable development initiative with the objective of reducing the societal production-consumption systems' linear material and energy throughput flows by applying materials cycles, renewable and cascade-type energy flows to the linear system. Circular economy promotes high value material cycles alongside more traditional recycling and develops systems approaches to the cooperation of producers, consumers, and other societal actors in sustainable development work".

To simplify the diversity, the definition of the Ellen MacArthur Foundation, was selected, as it is the leading organization in the development and promotion of CE worldwide. It defines CE according to three principles: the circulation of products and materials, the elimination of waste and pollution, and the regeneration of nature (Ellen MacArthur Foundation, 2021).

The well-known butterfly diagram (Fig. 2), developed by the previously mentioned institution, visually differentiates the technical and biological cycles in a CE.

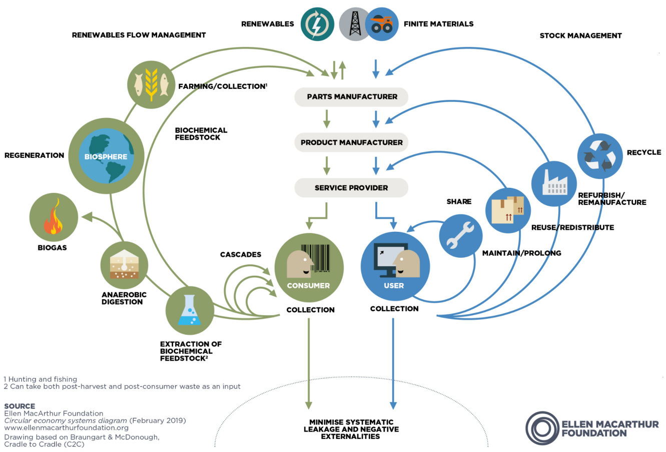

Fig. 2. The CE butterfly diagram (Ellen MacArthur Foundation, 2021)

While the technical cycle refers to recovering and restoring finite materials, the biological cycle involves the flows of biological materials regenerated in the cycle. Closing material loops is possible through different procedures, such as repair, maintenance, reuse, recycling, refurbishing, and remanufacturing.

The tighter a loop of the butterfly diagram, the better. The repair and maintenance loops aim to extend the product's lifespan to its owner and prolong the product lifetime. This decreases the overall material required, making consumers hold on to their product for a longer time. As a consequence, a product's replacement is delayed (Cooper, 2005). This requires the development of integrated production and consumption systems, encompassing the intersectoral, inter-organizational, and global value chains and life cycles, where there are cyclical material flows, as well as cascading-type energy flows and renewable energy is used (Korhonen et.al, 2017).

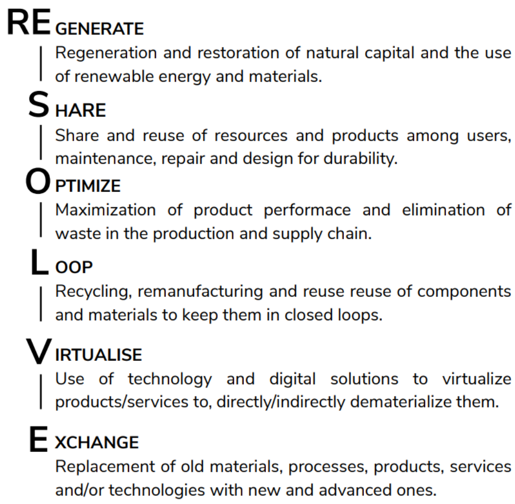

Fig. 3. ReSOLVE model (adapted from Gower, 2016)

There is a second key framework to understand CE developed by the Ellen MacArthur Foundation which is called the ReSOLVE model. It summarizes six axes on which CBM can be built (Gower, 2016). ReSOLVE (Fig. 3) stands for: regenerate, share, optimize, loop, virtualize, and exchange. *Regenerate* refers to an enhancement of the resilience of the ecosystem through the regeneration and restoration of natural capital and the use of renewable energy and materials; *share* proposes a maximization of the use of assets and products by sharing them among users, reusing them and prolonging their lifespan through maintenance, repair and designing them for durability; *optimize* focuses on increasing the performance and efficiency of the product and includes the movement of waste in the production and supply chain; *loop* refers to recycling, reusing and remanufacturing components and materials to keep them in closed loops; *virtualize* involves the use of technology and digital solutions to virtualize products and services and consequently to, directly or indirectly dematerialize them; and *exchange* replaces old materials, processes, products, services and/or technologies with new and advanced ones (Jugend, 2020).

2.1.3. Circular Business Models

CE is commonly associated with a myriad of other concepts, however, CBM is especially relevant due to its focus on value creation through circularity. As CBM is a type of business model, this concept will be explained in the first place.

Despite the many definitions of a business model, there is common agreement on the fact that it is related to how an organization creates and captures value. This concept goes beyond what the company sells or the technologies it has, as it considers what the activities are and how they articulate to create value (Chesbrough, 2007). The creation of SCA is central to business models as it is related to the creation of value and the positioning of the company in the market. Business models can even change the conditions of the market, by altering their own processes, products, and services among other aspects to provide a SCA (Boons et al., 2013). The concept of SCA will be detailed in later chapters.

Then, CBMs are closely related to the business model, but in this case, the definition is extended to "how an organization creates, delivers, and captures value by decelerating, closing, or tightening resource loop flows" (Oghazi & Mostaghel, 2018, p.3). CBMs also tend to be service-oriented models and are based on close collaboration with clear agreements and mutual trust between customers, suppliers, and partners (Oghazi & Mostaghel, 2018).

Table 6. Overview of circular business models (Lewandowski, 2016)

ReSOLVE Area	**Model**	**Description**
Regenerate	Energy recovery	Conversion of non-recyclable waste materials into usable heat, electricity, or fuel. E.g. Ralphs and Food 4 Less installed an "anaerobic digestion" system.
	Circular Supplies	Use of renewable energy. E.g. Iberdrola.
	Efficient buildings and sustainable product locations	Location of business activities located in efficient buildings and eco-industrial parks. E.g. Kalundborg Eco-industrial Park.
	Chemical leasing	Sell of the functions performed by the chemical, so the environmental impacts and use of hazardous chemicals are minimized. E.g. Safechem.
Share	Maintenance and Repair	Extension of the product life cycle through maintenance and repair. E.g. Patagonia, Giroflex.
	Collaborative Consumption, Sharing Platforms, Product Service System (Product renting, sharing, or pooling)	B2C and B2B models with a shared access or ownership of products. E.g. BlaBlaCar, Airbnb, ThredUP.
	Product lease	Use of products rather than ownership. E.g. Mud Jeans, Dell, Leasedrive, Stone Rent-a-PC
	Availability based	Availability of products or services for a specific period of time. E.g. GreenWheels.
	Performance-based	Revenue according to the delivered solution, effect, or demand-fulfillment. E.g. Philips's "Pay per Lux" solution; the need for a new housing model for young starters in Malaysia.
	Incentivized return and reuse or Next Life Sales	Return of used products or collection of products to be repaired and resold. E.g.Vodafone Red Hot, Tata Motors Assured.
	Upgrading	Replacement of modules or components with better quality ones. E.g. Phonebloks.

	Product Attachment and Trust	Creation of products to be loved, liked, or trusted longer. E.g. Apple products.
	Bring your own device	Provision of services to user's own devices. E.g. Citrix pays employees for bringing their own computers.
	Hybrid model	Durable products containing short-lived consumables. E.g. Océ-Canon printers and copiers.
	Gap-exploiter model	Exploitment of “lifetime value gaps” or leftover value in product systems. (e.g., shoes lasting longer than their soles). E.g. printer cartridges outlasting the ink they contain.
Optimize	Asset management	Internal collection, reuse, refurbishing, and resale of used products. E.g. FLOOW2, P2PLocal.
	Produce on-demand	Production when demand is present and products are ordered. E.g. Alt-Berg Bootmakers, Made, Dell Computer Company.
	Waste reduction, Good housekeeping, Lean thinking, Fit thinking	Waste reduction in the production process and before. E.g. Nitech rechargeable batteries.
	Product Service System: Activity management/outsourcing	More efficient use of capital goods, materials, and human resources through outsourcing.
Loop	Remanufactured, Product Transformation	Restoration of a product or its components to “as new” quality. E.g. Bosch remanufactured car parts.
	Recycling, Recycling 2.0, Resource Recovery	Recovering resources out of disposed of products or by-products. E.g. Desso.
	Upcycling	Reuse of materials is reused and upgrading of their value. E.g. De Steigeraar (design and build of furniture from scrap wood)
	Circular Supplies	Using supplies from material loops, bio-based- or fully recyclable. E.g. Royal DSM
Virtualize	Dematerialized services	Virtualization of physical products, services, or processes. E.g. Spotify
Exchange	New technology	Employment of new technologies in production. E.g. WinSun 3D printing houses

There are many ways of building CBMs. In order to provide examples and make the concept more tangible, Table 6. summarizes the extensive literature review by M. Lewandowski (2016) on CBMs based on the six aspects that the ReSOLVe model. Changes in the product design are often considered a major element of CE, as products are then adapted for multiple lifecycles and upgradability (Oghazi & Mostaghel, 2018). Nevertheless, as it can be seen in the table above, product design is not and should not be considered the only path towards circularity. For further exploration of product design for CBMs strategies, the study of Bocken et al. (2016) is also highly recommended.

2.2. Managing the transition

The transformation to a CBM involves methods, strategies, and changes in viewpoints. On the one hand, product and supply chain design, together with supporting technologies and infrastructure, is essential. On the other hand, there is a complex organizational restructuring needed (Oghazi & Mostaghel, 2018). There are many theories of sustainability transitions that emphasize a systemic perspective (Kanger, 2019). These perspectives address transformational change by going beyond the closing of materials, components, and product loops, and focus on how resources are exploited, used, and managed throughout the system. (Nielsen, 2015). E. Iacovidou et al. (2020) state that there are five interconnected subsystems to be considered in the transitions to CE: governance, regulatory framework, and political landscape; resource flows and provisioning service; infrastructure and innovation; user practices; and business activities and the market.

In the literature, it is often ignored that there is the key role of collaboration of all the stakeholders in the shift to a CE (Ghisellini et al., 2016). A shared responsibility among all stakeholders, including suppliers, customers, and infrastructure would be in this sense the best way to shift to a system where the people, planet, and profit succeed. The positive attitude of managers is highlighted as a key driver for expecting positive outcomes by transitioning towards CE, as they are responsible for creating synergies among the stakeholders (Sharma et al., 2020). In this sense, there are two significant managerial factors in the transition which are cooperation and coordination among multiple channels (consumer acceptance, social norms, business practices especially within the supply chain, government policies, and government) (Sharma et al., 2020). This means a huge challenge for managers of established companies in their industries, as their firms are subject to strong external and internal forces that make it hard to change the corporate strategy (York & Venkataraman, 2010). In this sense, by transitioning to CE, the corporate strategy will be affected necessarily.

2.2.1. Corporate strategy and sustainable competitive advantages

Despite various definitions of strategy across disciplines and authors (Jarzabkowski & Wilson, 2006; Hafsi & Thomas, 2005), strategy in a firm's context can be defined as the search for a convenient and competitive advantage against competitors in the industry (Porter, 1996). Therefore based on the analysis of the environment, the industry, and the company's mission and vision, the corporate strategy would be selected or developed to strengthen the competitive position and achieve above-average profits (Hitt et al., 2017; Porter, 1996). With this aim, the companies need to have clarity regarding their weaknesses and strengths in order to identify possible improvements and differ from competitors (Planning, 2018).

Additionally, the mission and vision are important concepts as they are the starting points for the formulation of a corporate strategy (Hitt et al., 2017) and the basis and core of the company's identity (Ingenhoff & Fuhrer, 2010). While the corporate mission refers to management issues in the present and the reason for the existence of the company, in other words, its purpose, the corporate vision depicts the company in the future and is therefore forward-looking (Ingenhoff & Fuhrer, 2010).

The SCA can be defined after internal competencies and resources that are valuable, rare, imperfectly imitable, and organized (Fig. 4) and that have to be harnessed into a coherent strategy (Almarri & Gardiner, 2014).

P. J. Knott (2015) presented four questions that should be asked about a resource or capability to assess its sustainable competitive potential: "Value: does a resource enable a firm to exploit an environmental opportunity and/or neutralize an environmental threat? Rarity: is a resource currently controlled by only a small number of competing firms? Imitability: do firms without a resource face a cost disadvantage in obtaining or developing it? Organization: are a firm's other policies and procedures organized to support the exploitation of its valuable, rare, and costly to imitate resources?" (Knott, 2015, p.16)

According to N. Cardeal (2012), a resource creates value when it supports the firm to formulate and execute strategies that will enhance its effectiveness and efficiency. Resources are not valuable by themselves. They create value and become a resource if they enable the exploitation of opportunities and/or the minimization of threats. Regarding the rareness, if most competitors possess the same valuable resources and use them in similar ways, this would not result in any company achieving a SCA. If resources are valuable and rare, they still have to be difficult to imitate in order to be a SCA. Resources tend to be more difficult to imitate if, i.e. there are legal property rights, or the process of their imitation by other companies is long and/or complex. Lastly, regarding the organizational aspect, SCA stems from the way a firm operates and is organized so that it can exploit its resources and capture the value from them. Succinctly, the right strategy and processes to acquire, use and monitor the possessed resources are key as even companies with valuable, rare, and imperfectly imitable resources may not be able to create a SCA (Cardeal, 2012).

As a SCA is not inherent in some resources and capabilities, but in a compounded network of capabilities and resource interactions, it may not always be easily identified. Therefore, even the managers of top firms do not know in some cases the source of their competitive advantage, which precludes them from leveraging and replicating the advantage elsewhere (Almarri & Gardiner, 2014).

Fig. 4. VRIO (de Bruin, 2021)

In this sense it is important for the firms to own unique resources that consist of heterogeneous characteristics as they are a potential for a SCA over their rivals. Especially those aspects that are particular to a firm and not perfectly mobile to others allow firms to sustain their competitive advantage for prolonged times (Almarri & Gardiner, 2014).

Grant (1991) proposed an action plan (Fig. 5) for executives to identify their resources and capabilities, assess their competitive advantage, and then define an accurate strategy to exploit these resources and capabilities in the best possible way (Almarri & Gardiner, 2014). In this sense, Grant's model traces the interrelations between resources and capabilities and their potential to create a competitive advantage. If a resource is categorized as a competitive advantage, the managers should determine the following aspects: what type of resource is it; under which conditions does it add value; to which capabilities is it linked; if it qualifies as a sustainable (long term) competitive advantage; how can it be exploited; and what measures will be used to appraise its outcome on the general performance. This model focuses on how to allocate resources based on alignment with strategy, and identify the value of those resources and the capabilities necessary for the organization's competitive advantage (Almarri & Gardiner, 2014).

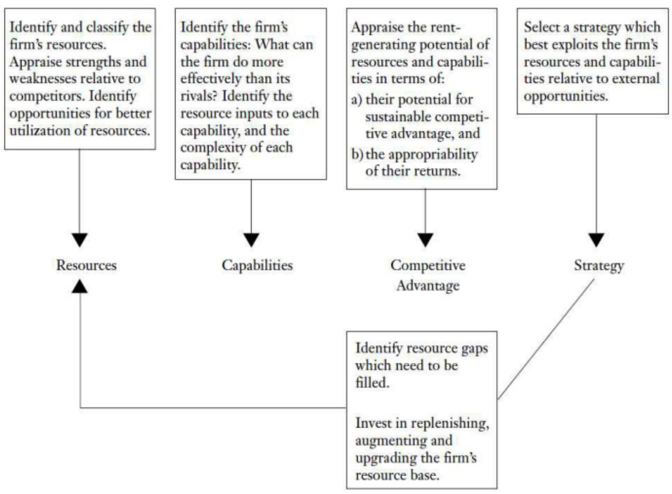

Fig. 5. Grant's resource-based approach to strategy analysis (Almarri & Gardiner, 2014)

The role of strategic management will be to shift to a CE by strengthening or developing competitive advantages. Circular strategies can develop resilience and competitive advantage by addressing risks and challenges such as material-price fluctuation, market differentiation, product life-cycle, geographic and political supply risks, increased commoditization of products, and customer loyalty, among other possible challenges (Mont et al., 2017). Once the circular model and its relation with the corporate strategy are clear, the implementation phase follows. The intentions will have to be translated into actions, the challenges will have to be faced, and the possibility of success and feasibility of the circular model will have to be evaluated. Implementation management from a strategic perspective will operationalize strategies, policies, programs, and action plans in a way that the resources are used to profit from opportunities (Harrington, 2006). A new network will be required and actors as intermediaries between the corporations and their environment will have to arise (Veleva & Bodkin, 2018). Therefore, transitioning to a CE implies a strategic decision that necessarily affects the corporate strategy.

2.2.2. The role of managers in the transition to CE

Despite the complex nature of organizational and societal aspects, among other dimensions, there is an important role of particular executives in the transition toward CE (Iacovidou et al., 2021). In this regard, managers have a significant responsibility in changing this scenario in which the linear economy keeps its dominant position, even with a progressive penetration of sustainability concerns. Thus, top managers are considered the micro foundation of the CE transition as they are accountable for shaping their business sustainability strategies and operations and implementing them (Koistinen, 2022).

Due to the characteristics of CE, and especially of the transition, there are three crucial elements that have to be taken into account when organizations are transitioning from linear to CBMs: a re-evaluation of the role and the place of raw materials; the conversion of products into services, and the improved utilization of functionality (Crittenden & Crittenden, 2008). Moreover, data management strategies and business models based on large-scale data are a crucial support for the companies and supply chains in their transition towards CE (Jabbour et al, 2019).

Considerable authors emphasized the role of data and argued that CE success will depend on the ways of collecting and analyzing big/large-scale data (Despeisse et al., 2017). Furthermore, the right management of large data can contribute to unlocking the full potential of circularity (Lieder & Rashid, 2016). In this sense, managing this data implies taking decisions regarding the gathering of massive, dynamic, and complex data, as well as its analysis (Orlikowski & Barley, 2001). In general, the literature states data analytics is a core capability of organizations (Akter et al., 2016).

The use of instruments will be a big source of information. In this regard, managers will have to first ask themselves which kind of information they want to gather or observe. Then, they will have to choose indicators to measure and communicate impacts, and reliable sources of data and information to assess CE performance. It was demonstrated that current corporate practices aiming to advance in zero waste lack effective indicators for measuring impacts and notifying employees, hindering the reuse or remanufacturing of the products (Veleva & Bodkin, 2018b). Thus, the use of different tools to gather data is key for the transition.

As to pursuing CE models, there is a need for supporting mechanisms and enablers, especially to help with the information flows throughout the supply chain (Jabbour, 2019), the incorporation of tools is of utmost importance. However, technology on its own will not lead to the improvement of social and environmental performance, as they will need proper management controls and incentives so that the tools manage to combine environmental and social aspects (Johnson, 2013). Additionally, not the same technologies will be necessary for all companies all the time. Different tools will be relevant to different companies, at different times. Therefore, it is a managerial responsibility to choose the most suitable tools for particular needs. Consequently, tools should be practical, adaptable, and consider the human factor during implementation (Johnson, 2013).

To sum up, the shift to CE implies a new product's life cycle and the availability of information on the whole cycle as well as on product design characteristics (Lieder & Rashid, 2016) which will be paramount for successful CE principles deployment. Besides the biological and technical aspects of CE, the managerial capabilities, especially those related to information management are key for the transition to CE (Ritzén & Sandström, 2017). There is an indisputable need for data and technologies to support the processes, but these can not be used as replacements for human action (Malmborg, 2003), and without the proper management they will fail to combine social and environmental aspects into the daily routines (Schaltegger & Burritt, 2005).

2.3. The role and type of digital data technologies in CE

By understanding the ReSOLVE model, it becomes clear that there is a large amount of information and digital tools that underpin each of the pillars of the model as CE needs materials that can be used for longer, and have numerous life cycles. Therefore, there is a consensual opinion among various authors that digital technologies are the main drivers of the transition to the CE paradigm in terms of the management of the product's life cycles (Oliveira & Soares, 2017). Digital technologies allow efficient and flexible processes, while also enabling transparent access to resources and product consumption (Cagno et al., 2021). Additionally, the growth in complexity of products has led to corporate unbundling, in which most companies focus on their core activities and outsource secondary activities, leading to a large value chain distributed among several organizations. In this decentralized structure, intensive collaboration between all the stakeholders (i.e. consumers, a network of retailers, and producers) involved in the product life cycle activities need to be connected and will need strong IT and data management support as enablers (Oliveira & Soares, 2017).

Two technologies stand out due to their capacity to influence the speed and success rate of the adoption of CBMs: Big Data and the Internet of Things (IoT) (Jabbour et al., 2019). There is still a third type of technology to mention which is the product-service systems (PSS), as the transformation from products to services is part of the strategies to become circular (Jonker et al., 2017).

Big Data is one of the key digital technologies that can be used for CBM. It can be defined by four V's: volume, variety, velocity, and veracity (Lukoianova & Rubin, 2014). The difference between Big Data and 'data' is in the first place, the volume. Big Data allows massive amounts of data to be generated continually. The variety of data refers to the generation of different sorts of data such as images, videos, and voice records. Then, the velocity is related to how fast data can be analyzed, through predictive methodologies allowing data to be analyzed even prior to storage. Finally, by approaching the right methodologies, accurate data of high quality can be achieved (Lukoianova & Rubin, 2014). With exponential growth in data coming from every possible source, sometimes in real-time, companies have to take action in order to make the use of the large data landscape by carefully selecting key data for specific investigations, and innovatively adjusting large integrated datasets to support specific needs and analyses. Complex and large data sets do not automatically translate into useful insights, therefore a data value chain - a series of activities involving data that creates and builds value - and a framework for holistic data management will be used for decision making for a variety of stakeholders (Miller & Mork, 2013).

There are various opportunities for Big Data to contribute to circularity by providing organizations with valuable insights about product design, -e.g. by optimizing components design based on Big Data analytics- and usage - e.g. by improving the usage rates of products-, and creating possibilities for organizations to make their circular models stronger (Nobre & Tavares, 2020). Unfortunately, most companies have restricted knowledge about how to utilize their own data, or do not store it which hinders the necessary process of data being generated, transmitted, and stored to support and connect the manufacturing chain (de Oliveira & Soares, 2017).

Another major digital technology is IoT, which is an emerging technology that enables data acquisition, transmission, and exchange among electronic devices and targets enabling integration with every object through embedded systems (Xia et al., 2012). It can be defined after three main components: asset data gathering, asset digitization, and computational algorithms to control the system formed by the interconnected assets. IoT can be used in any activity involving data monitoring and control, information sharing and collaboration, linking together diverse supply chain partners, providing transparency as well as helping in the optimization of costs, services, agility, and resilience (de Oliveira & Soares, 2017; Nobre & Tavares, 2020). Therefore the principal aim of the IoT, in this case, is to enable a smart information cycle along the entire product lifecycle. The use of the IoT is particularly important during the manufacturing, sales and retail, and use and service product lifecycle phases. Firstly, during the manufacturing phase, IoT can help by improving production efficiency. Secondly, during the sales and retail phase, it can support the collection of valuable data regarding consumers' preferences. Thirdly, during the use and service phase, the IoT enables firms to track their products, offering opportunities to get a better understanding of product behavior and to manage their related services (de Oliveira & Soares, 2017).

Equipping products with all sorts of sensors makes it possible to generate real-time data about the state of products and understand how they are used and experienced by the customer (Rymaszewska et al., 2017), which can contribute to the improvement of product design and development of predictive maintenance. Then, the analysis of the data gathered can be used to design new products and services to better fit customers' needs, expand the longevity of the products, and improve the product lifecycle management (de Oliveira & Soares, 2017; Nobre & Tavares 2020). The high volumes of data that are generated along the whole lifecycle through IoT opens an opportunity for the application of Big Data. Then, the data can be analyzed in order to capture knowledge and come up with improvements in product lifecycle activities (de Oliveira & Soares, 2017).

Regarding the third type of technology, the shift from products to services is a key element of CE. By designing PSS, which can be done in very different ways, such as renting, leasing, or loaning, the producer remains the owner (Jonker et al., 2017). In the PSS, tangible products and intangible services are combined to fulfill specific customer needs and reach the goals of sustainable development (Shimomura, 2007). Data management gives organizations the opportunity to actively and effectively monitor how products are used. To support this aim, IoT enables companies, through the use of sensors, to get a high volume of information about the state of the product (Rymaszewska et al., 2017). Smart products can also be updated with newer software, preventing them from becoming outdated (Pialot et al., 2017). Therefore Big Data and IoT play a big role in PSS.

The combination of these three technologies enables high levels of network communication, encompassing people, equipment, products, and services, as well as business-to-business communication. The World Business Council for Sustainable Development (2011) reported that in a sustainable value network, the streams are more complex than up and down streams and they consist of interactions and value exchanges where the lines between production and consumption are blurred. This is particularly relevant for advancing a CE, as it requires to change from individual technologies towards new systems based on cooperation between stakeholders (Veleva & Bodkin, 2018). In this regard, technologies such as cloud technologies; cybersecurity and blockchain; and horizontal/vertical system integration were found in CBMs (Cagano et al.,2021).

Shortly explained, cloud technologies are models enabling on-demand network access to shared resources like servers or networks; cybersecurity and blockchain are tools, guidelines, policies, and technologies guaranteeing the security of the cyber environment, enabling confidentiality, availability, and integrity of data-; and horizontal/vertical system integration are automated value chain among or within firms enabling universal data integration network, which allows the linking of products, plants, manufacturers, customers, and suppliers.

2.3.1. Digital data technologies and the ReSOLVE model

As the ReSOLVE model has shown to be a relevant tool to operationally guide industrial firms, Cagano et al. (2021) focused on exploring DDT in the context of this framework through an extensive literature review. Big Data and IoT and PSS were in this case related to sectors of the ReSOLVE model and other DDT were identified. Table 7 summarizes the insights of Cagano et al. (2021).

Table 7. Digital data technologies and the ReSOLVE model (adapted from Cagno, 2021)

ReSOLVE Area	Technology	Use
Regenerate	IoT	Monitoring and optimization of the product. Closer support and provision of value to the customer. Information symmetry among systems in the manufacturing phase.
	Big data	Support in decision-making processes. Analysis of data in the reutilization/recycling phase. Insights to foster reverse logistics and improve waste management in the manufacturing phase.
	Horizontal/ Vertical system integration	Information symmetry among systems in the manufacturing phase.
	Cybersecurity and blockchain	Handover of secure information to different customers in the usage phase. Traceability of elements in a secure and transparent way.
Share	IoT	Monitoring and tracking use and condition of products, to enable its reuse.
	Big data	Analysis in order to enable cooperation among the tiers of the value chain.
Optimise	IoT	Extension of the product lifetime. Monitoring and optimization of processes and resources in real-time.
	IoT and Big data	Collection, processing and sharing of information.
	Cloud technologies	Exchange of information. Management of the inventory.
	Cybersecurity and blockchain	Sharing of product information among stakeholders, and streamline the paperwork and supply chain activities in a transparent and secure way.
Loop	Horizontal/Vertical system integration	Real-time data management throughout the whole chain by facilitating the loop strategies.
	IoT	Monitoring, tracking and enabling looping in the recycling process. Sensors to track the product history and monitor different processes in real-time. (The remanufacturing process needs data related to the product, such as the status, the maintenance, the disassembly and instructions for reassembly.)
	Big data	Management of complex data gathered with IoT. Definition, organization and optimization of the disassembly processes.
	Augmented reality	Support in the disassembly processes by helping in the visualization of the information and equipment needed for the process. Training of operators.
	Additive manufacturing	Production of materials from CAD models. Simplification of the building of parts with geometrical and material complexity.

	Simulation	Support in remanufacturing processes. Determination of the quality of products.
	Autonomous robots	Recycling process. Support in the disassembly processes.
Virtualize	IoT and big data	Collection of data. Monitoring of data. Evaluation of conditions of the products. Communication between suppliers, customers and organizations.
	Additive manufacturing	Customization of products.
Exchange	IoT and big data	Sharing of information in networks.
	Cloud technologies	Exchange of information.

Regenerate

Opportunities for regeneration, according to Cagano et al. (2021), seem to be more feasible in the manufacturing, usage, and reutilization or recycling stages of the life cycle of a product. IoT seems to be the most relevant DDT as it is related to the extension of the product lifetime and its monitoring and optimization, as well as the support to the customer.´Then, big data analysis is key as it enables the proper use of data to support decision-making processes. In the manufacturing phase, in particular, it seems to be fundamental to gain information symmetry among systems. To reach this aim, not only IoT, but also Horizontal/Vertical system integration, Cybersecurity and Blockchain are relevant. In the usage phase, Blockchain seems to be the most promising technology to support the handover of secure information to different customers, and make the traceability of elements transparent. Big data analysis is mentioned as the most important technology that enriches the reutilization/recycling phase, as insights gathered through data can foster reverse logistics and improve waste management.

Share

The most important digital technology in the *share* area is IoT, which allows to monitor and track the use and condition of products, to enable their reuse (Cagano et al., 2021). Once again IoT has to be complemented by big data as large amounts of data would be collected and should be analyzed in order to enable cooperation among the tiers of the value chain.

Optimize

In the *optimize* area, which is mainly associated with resource efficiency, IoT and big data analysis play a pivotal role as they allow for the monitoring, control, and optimization of processes and resources in real-time. In this sense, IoT and Big data would enable the collection, processing, and sharing of information. For the exchange of information, cloud technologies could be used to manage the inventory. To support this process, cybersecurity and blockchain could be employed to share product information among stakeholders, and streamline the paperwork and supply chain activities in a transparent and secure way.

Loop

The *loop* area of the ReSOLVE model is related to the disassembly, remanufacturing, and recycling of products. Horizontal/vertical system integration would be key in these cases to allow real-time data management throughout the whole chain by facilitating the loop strategies.

For disassembly, augmented reality technologies - an interactive computer simulation in which the user experiences a sense of reality despite being in a created programmed environment - can help to plan the disassembly steps and visualize all the information and equipment needed in the process. Additionally, it can support the training of operators. Then, the use of autonomous robots, which can be programmed to work completely autonomously and to interact with each other and with humans, have a huge potential in the disassembly processes. Nevertheless, due to its high costs, it has not yet been adopted as a very feasible technology. On the contrary, virtual simulations - the physical world is reflected in real-time in a virtual environment - and big data analysis are considered more feasible technologies for defining, organizing, and optimizing disassembly processes.

The remanufacturing process needs data related to the product, such as the status, the maintenance, the disassembly, and instructions for reassembly. IoT via sensors would enable it to track the product history and monitor in real-time different processes. Then, additive manufacturing, which refers to the production of materials from CAD models, offers the possibility of building parts with geometrical and material complexity reducing costs related to, for example, the set-up. The simulation could also be used to support remanufacturing processes and to determine the quality of a product.

Regarding the recycling process, IoT would be beneficial for monitoring, tracking, and enabling looping and big data should be used to manage the complexity of the data gathered. Lastly, autonomous robots would be highly useful for the recycling process.

Virtualization

In the *virtualization* area of the ReSOLVE model, once again the role of IoT and big data stand out due to their potential of collecting and analyzing data to monitor and evaluate the conditions of the product as well as foster the communication between suppliers, customers, and organizations. Additionally, additive manufacturing showed a high potential for the customization of products.

Exchange

In the *exchange* area, opportunities are found in the optimization of resources used, the sharing of information in networks, and the creation of infrastructures for the tracking and monitoring of materials or products. The literature so far focused on the adoption of IoT and big data analysis and emphasized the potential of predictive analytics. Cloud technologies were also mentioned to be key in the exchange of information.

ReSOLVE

This subchapter summarizes some key insights regarding the relation between digital technologies and the ReSOLVE framework as a way of enabling circularity. It became evident that the collection, analysis, and exploitation of data are key in the different areas of the framework. It can be concluded that IoT and big data are the most important technologies as they play important roles in all the areas of the ReSOLVE model. Both technologies are in most cases combined to support specific tasks of each of the stages of the product life cycle product design; monitoring and tracking of the product; technical support and maintenance; optimization of product use, upgrade, and renovation; and provision of information and analysis, in many cases in real-time.

Job to be done	Digital technologies
Data collection Data storage Data analysis Information exchange Information security Virtualization	Internet of Things Big data analytics Cloud technologies Cybersecurity Blockchain Horizontal/Vertical system integration Simulation Augmented reality Autonomous robots Additive manufacturing

Fig. 6. Digital technologies and their functionalities

Overall, it can be confirmed that the presented DDT enable companies to optimize their material flows, processes, overall performance, and stakeholder relationships (Fig. 6). They further increase or develop revenue streams through data collection; data storage in large central databases; data sharing that improves collaboration with parties within the supply chain; data analytics that enables data-driven decision making with respect to product/service process optimization; the virtualization of products/services and processes; and the measurement of information, that can be stored and shared in a reliable and transparent manner.

2.4. Challenges and opportunities in the transition to CE

Various research studies with regard to CE approached C&O from very different perspectives. The scope ranges from thermodynamics to governance and management (Korhonen et al., 2017). Most of the research studies found were not suitable for the purposes of this Master's Thesis, because they focused on very specific topics or only focused on barriers but not on opportunities. Furthermore, in most cases, they did not have a management perspective, but a technical or biological orientation.

After collecting the C&O, they were clustered in order to be organized and presented (Figure 7). The first big differentiation was between external factors, tangible or intangible aspects that are out of the scope of the company and which the company has limited possibilities to influence, and internal factors, tangible or intangible aspects that can be controlled and are within the scope of the company.

Fig 7. Categories for internal and external challenges and opportunities

Within the external factors, the C&O were grouped under social and political aspects, finances, and inter-organizational characteristics. Within the internal factors, the grouping refers to structure and organization, infrastructure within the company (technology and equipment assets), finances, and product/service structure and design.

The social and political dimension concentrates on aspects related to how society thinks, feels, and organizes itself. The cultural and historical aspects as well as the norms that derive from them correspond to this dimension. External finance refers to the dependence and interrelation of the company with external actors in relation to its economy. The last external dimension is the inter-organizational one, which refers to the relationships, including the interdependencies of the company with other stakeholders, partners, and organizations in general.

Moving on to the internal aspects, structure and organization refer to how the company is organized considering the corporate culture and mentality, the formal or informal norms that arise from it, as well as how it is organized in its structure. This dimension is similar to the external social and political dimension but within the firm. The infrastructure within the company refers to the technical infrastructure and equipment, which are necessary to support the key tasks and how they support the activities. Internal finance refers to the internal organization of economic resources and how the company organizes its finances. The structure and design of products and services refers to how products and services are constructed. In this sense, the components of the materials and the way in which they are combined in their design to obtain a product or service, as well as how they should be used by the customers, are part of this dimension.

2.4.1. The challenges

The lack of enabling conditions and the interposition of challenges that firms face during the implementation of CE are stated to be huge determinants in the success or failure of the circular model (Sousa-Zomer, 2018). After conducting an extensive literature review, it could be found that many barriers were mentioned in more than one research article. Below detailed information regarding the challenges identified is exposed.

Table 8. Challenges in the transition to CE

Categories	**Insights from Literature Review**	**References**
External		
Social and political	Lack of awareness of remanufactured products. Bad perception of recycled or reused products (e.g., unclean). Low willingness to pay. Culture of ownership. Lack of connection between pre-user and a possible re-user. Lack of policies, regulations, and incentives. Lack of law enforcement. Poor accountability of governments. Governmental prioritization of short-term problematics. Lack of collaboration mechanisms working effectively. Unstable, informal, unregulated, or corrupt political conditions. A mismatch between current legislation and legislation aimed at achieving a CE. Lack of defined national goals towards CE. Lack of education campaigns toward sustainability in general and CE in particular.	(Franco, 2017); (Rizos et al., 2016); (Dominish, 2018); (Vermunt, 2019); (Bressanelli, 2018); (Shahbazi, 2016); (Geng & Doberstein, 2008); (Adam et al.;2017); (J. Kirchherr et al., 2018); (Govindan & Hasanagic, 2018); (De Jesus & Mendonça, 2018); (Ormazabal, 2016); (Garcés-Ayerbe et al, 2019); Cagano et al. (2021)
Financial	Lack of support and resources. Need for high up-front investment and long-term return of investment. Low financial support from the government. High costs are linked to the recovery, transportation, and sorting of waste.	(Rizos et al., 2016); (Govindan & Hasanagic, 2018); (Adam et al.;2017); (Govindan & Hasanagic, 2018); (De Jesus & Mendonça, 2018); (Ormazabal, 2016); (Garcés-Ayerbe et al, 2019)
Inter-organizational	Lack of partners for eco-industrial chains. Lack of transparent and secure information sharing. Lack of trust among partners. Complex and unmanageable supply chains. Suppliers resistance to change. Difficulties in tracing, collecting, and storing products, parts, and materials. Geographically dispersed supply chains. Incompatibilities between partners. Power is unbalanced and concentrated in the buyers.	(Rizos et al., 2016);(Adam et al.;2017); (Govindan & Hasanagic, 2018) (Ormazabal, 2016)
Internal		
Infrastructure within the company (technology and equipment assets)	Lack of management systems. Lack of high-tech technologies (e.g., to separate the biological or technical mixes). No availability of appropriate technology to support CE. Low maturity level of the desired technology. An informal sector that is not integrated into the waste management system.	(Sousa-Zomer, et al., 2018); (Lieder et al.,2016);(De Jesus & Mendonça, 2018); (Agyemang, 2019); (Cramer, 2018); (De Oliveira,

	Lack of traceability of materials and products. Lack of effective separation, collection, and recovery infrastructure (which has as a consequence limited availability of quality and quantity of recycled materials).	2019);(Ormazabal, 2016)
Financial	Uncertainties regarding the viability and profitability of circular models. Large costs of monitoring, machinery, and transactions, among others. Risk of higher implementation costs as expected. Lack of knowledge of the necessary investment.	(Rizos et al., 2016); (Adam et al., 2017);(De Jesus & Mendonça, 2018); (Govindan & Hasanagic, 2018); (Ormazabal, 2016)
Structure and organization	Corporate governance with powerful stakeholders opposed to change. A corporate culture with generalized resistance to change. Strong administrative structures. Inflexible hierarchical structures that hinder innovation. A point of view in which sustainability is seen as a cost and not an investment. Risk aversion. Low environmental awareness. Limited knowledge of CE. Inaccurate definition/Unclear explanation of the circular model in cases of CE implementation. CE is not integrated into the strategy, mission, vision, or goals of the company. End-of-pipe solutions. Silo mentality. Key performance indicators are created for the success of linear models. No support and guidance to the employees. Linear mindset for top managers and employees. Lack of qualified and motivated professionals in CE. Lack of qualified and motivated professionals across different organizational functions. Resistance of employees and/or managerial roles. Lack of qualified and motivated professionals capable of implementing CE. Lack of training and education.	(Rizos et al., 2016); (Dominish et al., 2018); (Vermunt, 2019); (De Jesus & Mendonça, 2018); (Ormazabal, 2016); (Govindan & Hasanagic, 2018); (Geng & Doberstein, 2008); (Kirchherr et al., 2018)
Product/service structure and design	Complex structures of products (e.g., different types of plastic). Products not designed for disassembly, reuse, or long-term use. Aesthetics are affected due to the need for change in the design for disabling or reuse. Design constraints (e.g., the need to use materials able to be recycled). Products are designed to be owned. Need for further technical development.	(Franco, 2017); (Rizos et al., 2016);(Dominish, 2018); (Shahbazi et al., 2016); (Bianchini, 2019); (Govindan & Hasanagic, 2018); (Kissling et al., 2013); (Singh & Ordoñez, 2020); Cagano et al. (2021)

As an overview of the external challenges, in the social and political fields the main problems are related to the cultural aspects of the society that hinder the integration of CE, and political aspects are mainly related to the lack of provision of structures and support. Regarding finances, there is the need for high up-front investment and a lack of support from some stakeholders, mostly due to the underinvestment of long-term projects and the prioritization of projects with short-term investment returns. Focusing on the network dimension, the need for strong structures and the existence of complex supply chains stood out.

On the internal side, CE requires new infrastructure in terms of technology and systems, especially related to materials and component management. The internal finance dimension concerns the need of reallocating the budget and uncertainties about the amount of investment required. Then, the organizational dimension refers to corporate governance that does not encourage the implementation of CE, a corporate culture that does not favor or even hinders the development of CE, and the existence of structures organized for linear models. Finally, the design of the product and/or service must be readapted, which entails challenges in terms of aesthetics, materials, assembly, and ownership culture.

2.4.2. The opportunities

In order to facilitate the connection between the challenges and opportunities, the latter were categorized within the same dimensions described above. Below the main finding from the review of literature is summarized.

Table 9. Opportunities in the transition to CE

Categories	Insights from Literature Review	References
External		
Social and political	Approach of consumers willing to pay more for CE products and services, Offering of Product as a Service. Lower price offerings for circular products. Enhancement of collaboration with customers (e.g. encouragement to return packaging through promotions or offering personalized services or products). Use of certifications and standards established to show sustainable material usage and improve the brand image. Inform consumers about the concept of the CE and the circular offerings. Provision and promotion of evidence regarding the reliability of the product (e.g., offering warranty options or 'behind the curtain' view of the development processes). Shape governmental policies through lobby.	(Vermunt et al., 2019); (De Jesus & Mendonça, 2018); (Agyemang et al., 2019); (Hazen et al., 2017); (Moreno, 2019)
Financial	Use of CE to increase sales through prestige. Sale of waste. Enter or development of new markets. Alternative access to funding such as crowdfunding.	(Ormazabal et al., 2016); (Riesener et al., 2019)
Inter-organizational	Connection of the pre-user (interested in the monetization of the "residual" product) and the re-user on a digital platform or marketplace. Peer-to-Peer on a digital platform or marketplace as a replacement of ownership. Mobilization of actors to set up common circular initiatives or goals. Enhancement of the cooperation between actors along the supply chain. Development of a business case that is welcomed or accepted by all the stakeholders. Use of information systems to connect the different stakeholders. Use of tools to improve the logistics in the supply chain. Development of a reverse supply chain for the return of resources.	(Sousa-Zomer et al.,2018); (Franco, 2017); (Lieder & Rashid, 2016); (Vermunt et al., 2019); (Bressanelli et al., 2018); (De Oliveira, 2019); (Govindan & Hasanagic, 2018); (Kissling et al., 2013); (Gong et al.,

	Identification of suppliers with low environmental impact.	2020);(Zhu et al.,2011)
Internal		
Infrastructure within the company (technology and equipment assets)	Implementation of technologies for optimization, collection, separation, recycling, or remanufacturing of materials. Development and execution of control and preventive measures to minimize power consumption. Blockchain-based documentation is a traceability system for materials and products, so that information is shared in a trustworthy, transparent, and secure way. Smart data to support the recording of the inventory and predict material flows. Big Data technologies, IoT, and sensors to get insight after available data and advanced data analytics (e.g.:Big Data Technologies to shorten the cycles; smart data to support the recording of the inventory; to support the prediction of the material flows.) Logistics platform. Digital Waste Management: automated processes to organize the waste flows in a centralized way across the process chain; automated processes to provide proof of relevant documents and certificates, like the legal handling of waste and dangerous substances.	(Sousa-Zomer et al.,2018);(Lieder et al, 2016); (De Jesus & Mendonça, 2018); (Agyemang et al., 2019); (Riesener et al., 2019).
Financial	Conduction of pilot programs to minimize risk.	(Sousa-Zomer et al.,2018);(Brassanelli et al., 2018); (Romero-Hernández, 2018);(Gong et al., 2020)
Structure and organization	Integration of CE into the strategy, mission, vision, goals, and KPIs. Development of independent and new business units for cultural adaptation and reinforcement of sustainability principles. Internal transformations and development of cross-functional capabilities to adapt to new scenarios and integrate the functions and employees. Systems thinking approach for CE implementation. Development of dynamic capabilities to be able to build, exploit and transform new knowledge to address change. Development of dynamic capabilities in order to be able to reconfigure the source of the resources to respond more efficiently to changes and create value. Development and execution of measures to minimize power consumption and to redesign products. Development of control measures (reactive behavior) to be able to adapt to new changes and structures. Creation of a reward program that incentives the familiarization with circularity and sustainability. Provision of training and development of knowledge related to CE. Use of communication technologies (e.g. platforms). Improvements in the communication of CE strategy and its concept. Diffusion of CE success stories. Increase in availability of information (e.g., a business model visualization tool for CE).	(Garcés-Ayerbe et al, 2019); (Lieder & Rashid, 2016); (Vermunt et al., 2019); (De Jesus & Mendonça, 2018); (Bressanelli et al., 2018); (Gupta et al., 2019); (Bianchini et al., 2019); (Kissling et al., 2013); (Mura et al.,2020); (Moktadir et al., 2018); (Gong et al., 2020); (Moreno, 2019); (Sousa-Zomer et al.,2018); (Lieder & Rashid, 2016); (Rizos, et al., 2016); (Vermunt et al., 2019); (De Jesus & Mendonça, 2018); (Bressanelli et al., 2018); (Agyemang, 2019); (Gupta et al., 2019); (Mishra, et al., 2018)

	Identification of competitive advantages (internal resources and competencies that are valuable, rare, and difficult to imitate, considering that resources are scarce). Training for the development of internal capabilities and skills related to CE. Incentives to the employees to relate and enhance CE. Incorporation of human resources with technical capacities and technical know-how.	
Product/ Service structure and design	Use of modular designs for a more convenient recycle, reuse, and upgradability. Focus on reducing product obsolescence. Remote services and maintenance. Functional decoupling. On-demand functionality and updatability.	(Riesener et al., 2019); (Lieder & Rashid, 2016); (Bressanelli et al., 2018); (De Oliveira, 2019) ;(Govindan & Hasanagic, 2018); (Linder et al., 2017)

Starting with the first category of external opportunities, which is the social and political aspects, the findings suggest closing ties with customers, especially with those who have some knowledge or familiarity with the CE. This can be achieved through lowering prices, providing customized information or offers, etc. Approaching the government through lobbying is also mentioned. In terms of finance, circular models allow for new ways of generating profits and raising funds. With respect to networks, most of the results support the improvement of connections with stakeholders, through soft and hard skills as well as technologies.

In relation to infrastructure, and starting with internal opportunities, the need for different technologies, such as blockchain, information technologies, sensors, platforms, and data analytics, was mentioned. In terms of internal funding, the most creative opportunity to address the lack of clarity on what to invest and in what amount was the development of pilots. In the organisational dimension, the merging of the CE with the overall strategy, the development or recruitment of new skills, and the enhancement of internal communication are the key points that contain and relate to the many aspects mentioned in this dimension. Finally, in terms of product and material characteristics, modular designs, incorporation of remote service and maintenance, and functional decoupling seem to be the key solutions.

2.5. Theoretical framework

Due to the pressures companies face to become circular, a theoretical framework was designed to support responsible leaders in the transition. By making use of this model, a company would find a specific circular path that would ensure the development of SCA and add value to its overall strategy. The model consists of a workflow that effectively combines insights and findings from each of the elements of the literature review.

Before building the model, some aspects were taken into account: it had to be general enough to be used by different companies working with linear models in various sectors, it had to be easy to understand by company leaders, and it had to be able to support managers in executive decision-making and strategy creation. Fig. 8 summarizes the model showing the most important elements and their relationships and it is followed by an in-depth explanation of the model.

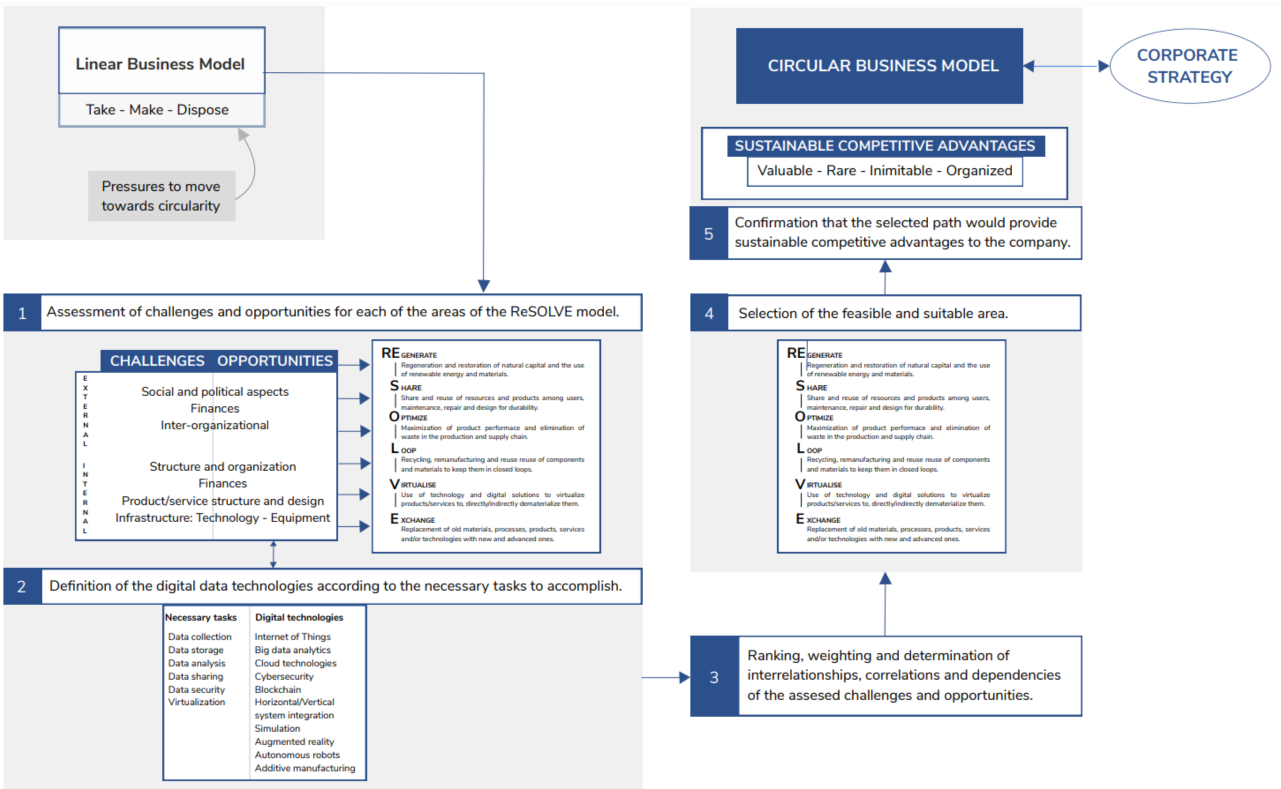

Fig. 8. Theoretical framework

<u>The Theoretical Model</u>

The starting point is a company that employs a linear business model and comes under pressure to shift to a CBM. As discussed in the Problem Analysis section (see 1.), this need can stem from multiple aspects.

The first step of the model is to analyze the status quo of the company by assessing the C&O in each of the areas of the ReSOLVE model. The exploration of each of the areas in terms of C&O is represented by the six individual arrows within the model´s graphical representation.

The objective of this first step is to investigate all circularity options. The six categories of the ReSOLVE model need to be evaluated in order not to miss out on an interesting action path that the company could take. Each area should be explored in terms of C&O, since the challenges that stand in the way of the transition to circularity can threaten its realization (see 2.4.). Therefore, this stage allows the organization to become aware of the challenges each stage would imply and the opportunities to be harvested to overcome them. In exploring the C&O, the company will have to analyze, indirectly, its resources and capabilities and consider those aspects in relation to circularity that the company may be already performing marginally or even unintentionally.

Without categories or starting points on what the challenges may be, important and valuable aspects may remain unidentified and overlooked. The theoretical categorization of C&O presented above (see 2.4.) is a valuable support to structure possible C&O within a targeted company. Given the extensive literature review on which the categories were built, the vast majority of newly identified company-specific aspects should be possible to be assigned to these categories. However, new ones may be created if the C&O found do not fit the pre-established categories. In summary, this first step of the theoretical framework combines the theoretical parts related to the definition of CE (see 2.1.) and C&O (see 2.4.).

The second step is to define the needs that each of the areas would imply in terms of DDT. Furthermore, it would be necessary to assess whether the company has these technologies and knows how to use them, or whether it would be able to develop or acquire them. According to observations from the literature review, DDT are both enablers and a condition for success in the transition to circularity, which requires a high level of digitization (see 2.3.). In this case, the research conducted on DDT (see 2.3.) would be used to gain perspective on what kind of DDT exists, their roles, and the use that companies had made of them so far in terms of circularity. Since the theoretical framework´s analysis focuses on the ReSOLVe model, the insights presented in the subchapter "Digital data technologies and the ReSOLVE model" (see 2.3.1) are highly useful. Within this subchapter, the use of technologies was related to each of the areas of the ReSOLVE model and it can be seen which technologies were used to support each of the areas.

The third step consists of ranking and weighing the C&O list, in order to identify which are the major and minor challenges, as well as the most and least feasible opportunities. It would also be important to establish the interrelationships, correlations, and interdependencies between the challenges, as well as the potential for some opportunities to address more than one challenge. Thus, it would be possible to reflect on the complexity of the real situation within a company.

Fourthly, by having created a ranked and weighted overview of the different areas of the ReSOLVE model in terms of their C&O, the areas should be compared and the one with the best chances of overcoming its challenges should be selected. The possibility of overcoming the main obstacles would be a determining factor, as it is the minimum condition for CE to occur.

Finally, it is necessary to confirm whether the selected area would generate SCA. In this sense, it must be corroborated that the solution is valuable, rare, inimitable, and organized (see 2.2.1.).

If some of the aspects to achieve SCA cannot be confirmed, the process should be repeated, by focusing on that weak point. For instance, if the solution was not rare, the workflow should be repeated, by paying special attention to the resources and capabilities that are different from those of other companies; by focusing on opportunities to create qualities to differentiate from other companies; or by choosing another area in which the generation of competitive advantages can be ensured. If the solution was easily imitable, the company could focus on opportunities that would make imitation difficult or evaluate the possibility of developing circularity in another less imitable area.

In all these cases, the model should be reviewed taking into account the resources and capabilities that the organisation has or can develop in order to choose a path that can ensure SCA.

Based on the conclusions drawn at this point in the model roadmap, the CBM would be integrated into corporate strategy. The connection between a CBM and corporate strategy goes in two directions, as when a CBM is integrated into a corporate strategy, it will probably have to be adapted to encompass such CBM (see 2.2.1). The role of management will be crucial to ensure that these aspects are harmonized.

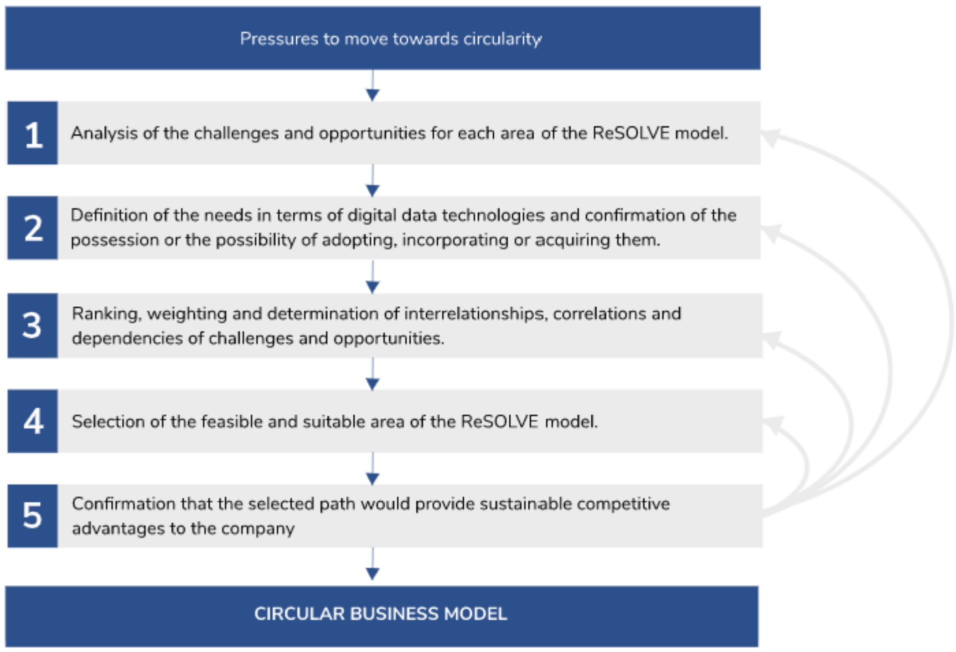

Fig. 9. The steps of the theoretical framework

Fig. 9 helps to understand the order of the steps and through the gray arrows visualize the possibility of retracing some steps in the eventual case that the generation of SCA cannot be ensured.

3. Research methods

3.1. Research design

As mentioned in the literature review, theoretical and practical research is needed to support the transition to circularity. Following the theoretical part in which the literature review was conducted, the outlined theoretical model has been depicted and elaborated. This chapter focuses on the methodology selected to test the model. While an inductive approach was taken to build theory, a deductive one was used to test it.

Due to the complexity of the theoretical model and the fact that it must be understood as an initial stage of scientific groundwork, it is necessary to explore it in terms of its ability to provide solutions and test how the elements of the framework interact with each other to provide solutions. For research studies that intend to explore a new phenomenon, disclosing and explaining the connection among aspects is suitable to apply qualitative methods that allow for analysis, comparison, and interpretation (Sekliuckiene et al., 2016). Qualitative research is very precise in this regard, as it places the researcher's voice at the center of the research process and allows him or her to focus on a small number of participants' worldviews. Therefore, the approach is less structured, more open, and flexible so that participants can reveal their in-depth perspectives on the investigated phenomenon (Azungah, 2018).

The case study method was selected as it is one of the most common scientific approaches to gathering unique facts, clustering complex information, and achieving deeper insights. It allows a comprehensive understanding of a phenomenon and to get diverse viewpoints on the same object being analyzed (Sekliuckiene et al., 2016). Additionally, the choice of one sample company is consistent with other research studies on complex organizational processes (Stendahl, 2020).

As specified in the Problem Analysis, the transition to a CE is particularly relevant for manufacturing companies. Such firms are characterized by high usage rates of non-renewable resources. At its core CE intends to reduce such resource use, this is why the outlined theoretical model is designed for the application within established industrial companies aiming to transition to a CBM. From a business geographic perspective, Europe has a significant concentration of established, industrialized companies. With this in mind, a European company in the wind energy manufacturing sector, where pressures to become more sustainable are widespread, was selected for this case study. For confidentiality reasons, both the company and the interviewees, were anonymized. Then, to ensure the validity and reliability of the analysis, data triangulation was carried out by complementing primary and secondary data analysis (Sekliuckiene et al., 2016). The former consisted of in-depth semi-structured interviews and the latter of desk research.

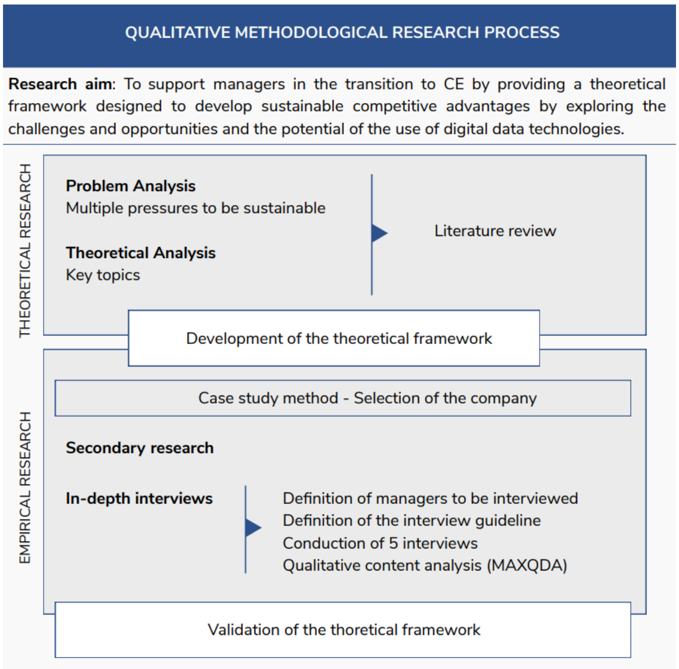

Fig. 10. Qualitative methodological research design

Fig. 10 summarizes the methodological process carried out to achieve the research objective and covers the theoretical and empirical research approaches.

3.2. Case selection

As mentioned when describing the Research Design (see 3.1.), there is a large concentration of established industrial companies in Europe that face pressures to become circular and would benefit from the use of the model. As an exemplary case study, a European company active within the wind energy manufacturing sector was selected. General information about the sector and information about the company will be outlined briefly below.

Wind energy is estimated to be the technology that will deliver the most considerable contribution to the European renewable energy targets. The EU currently has the largest floating wind power capacity in the world (approximately 70%). It is estimated that by 2030 the total available generation capacity would be able to supply up to 24% of electricity demand, by reaching 350GW. According to the European Commission, there are two major industry challenges, one related to the need to improve knowledge on the potential impacts of wind energy turbines on the environment and the other related to increasing the circularity of wind energy technology, considering the end of life of turbines and material dependence. In this regard, there is a great need for research and innovation in the EU to decrease costs and improve the performance and reliability of the technology in the wind energy sector (European Commission, 2021).

Based on the information retrieved from the conducted interviews and provided by the company´s website, which can not be disclosed due to confidentiality reasons, it builds and markets onshore wind turbine systems that are installed worldwide. It provides services for wind farms ranging from the simple delivery of wind turbines and their installation to the turnkey construction of a complete project. In this case, a network of service units is established to ensure that wind turbines are comprehensively supported throughout their entire service life. The company is focused on further reducing the cost of energy for society by building up more production capacity of renewable energy production plants and aims to consolidate its position as one of the world's leading suppliers of wind turbines. They aim to meet their goals by using regenerative and environmentally-friendly technologies and place the satisfaction of their customers at the core of their priorities. The feedback of their customers and the understanding of their needs is what steers the development of their products and services.

3.3. Data collection and analysis

Given their key role in executing the corporate strategy and the importance of their agency in the transition towards CE (see 2.2.2), the research study focused on top managers in the case study company. They were selected based on their in-depth knowledge of the company's sustainability, data, or technology operations and strategy, as these are the key topics of this research study. The aim of this diverse selection was to collect different perspectives on the phenomenon and to allow cross-referencing of information provided by different informants (Stendahl, 2020). The interviews that took place in April 2022 and were conducted through video calls in the English language, had a duration of between 40 and 45 minutes. They were supported by an interview guideline (Appendix 1), recorded, and transcribed upon the agreement with the interviewees. To increase willingness to participate, the estimated time of the interview was anticipated and it was clarified that the ReSOLVE model was to be used as the definition of CE, which is important due to the multiple definitions of CE. In all cases, a brief summary of the questions was provided in advance and privacy was ensured by anonymizing the cases (Brinkmann & Kvale, 2018). In total, five interviews were conducted. Table 10 presents the role and departments of the interviewees in the order they were interviewed. Further information regarding their role follows in the next chapter.

Table 10. List of Interviewees

Interview	Interviewee position in the firm	Department
1	Project Manager for Technology Management	Service
2	Head of Sustainability	Sustainability
3	Manager on Continuous Improvements	Global Quality
4	Environmental Technical Sustainability Specialist	Sustainability
5	Head of Technical Improvements	Global Service

The data, in text form, was processed using a coding system supported by MAXQDA Analytics Pro 2022 software. It allows the sorting of the information according to the elements of the framework. Relevant codes and extractions of the transcript, presented as quotes, were used to focus on important aspects for the validation of the model (Stendahl, 2020).

Table 11. Themes and categories for data analysis

Theme	**Categories**
Relevance of CE	Relevance for the industry, Relevance for the company, Economic dimension, Environmental dimension, Social dimension, Political dimension
External challenges for CE	Social and political, Financial, Inter-organizational relations
Internal challenges for CE	Structure and organization, Financial, Product/service structure and design, Infrastructure within the company
External opportunities for CE	Social and political, Financial, Inter-organizational relations
Internal opportunities for CE	Structure and organization, Finances, Product/service structure and design, and Infrastructure within the company
DDT	IoT, Big data technologies, Cloud technologies, Cybersecurity, Blockchain, Horizontal/Vertical system integration, Simulation, Augmented reality Autonomous robots, Additive manufacturing
ReSOLVE model	Regenerate, Share, Optimize, Loop, Virtualize, Exchange
SCA	Valuable, Rare, Inimitable, Organized, Resources and capabilities

For the coding of the transcripts a hybrid approach was employed (Fereday, 2006). The themes and first-order categories followed a deductive approach, as they were defined after the main elements of the theoretical framework and the findings of the theoretical part (Table 11; Appendix 3). Then, an inductive approach was used, creating, if necessary, new categories for those aspects that could not be included in the existing categories. The different interviews and the subsequent analysis, as well as interpretation, were used to find differences, and similarities and to generate a solution for the company using the model.

4. Research findings

4.1. Overview of the interviews

Through the interviews it was possible to identify commonalities and discrepancies across the different fields of experience, which enriched the research findings with different points of view.

First, the interviewees will be presented according to their position and role in the company. Then, two types of analysis will be carried out, one focused on each of the interviews, and the other one on key elements and themes of the model. At the end of the analysis, the solution for the company will be presented as a conclusion.

The first interview was with the Project Manager for Technology Management in the Service Department. He/she works globally on broad serial issues affecting wind turbines. Critical complex problems and accidents, such as collapsing and burning turbines, general crisis management, etc. are his/her core activities.

The second interviewee was the Head of Sustainability. Her/his department is responsible for the global strategic approach to sustainability which encompasses a broad range of tasks. The development and implementation of the sustainability strategy, the evaluation of the life cycle assessment of turbines, the development of climate strategies for sustainability reporting, and the communication of sustainability topics both internally and externally were the tasks highlighted. Regarding the last point, the Sustainability Department is in contact with many different stakeholders, investors, and customers in order to collaborate on achieving sustainability. He/she also anticipated that the department will focus on sustainable sourcing and responsible sourcing in the near future.

The third interview conducted was with the Manager of Continuous Improvements in the Global Quality Department. He/she works on the improvement of processes and methods of working inside the organization by developing projects with cross-functional structures. His/her current scope is the supply chain quality, particularly the introduction of new products in the supply chain, and the improvement of the quality of the products in order to increase the satisfaction of the customers and reduce the overall costs.

Fourthly the Environmental Technical Sustainability Specialist was interviewed. He/she works within the Sustainability Department as the interface to the Engineering Departments. In this regard, there is a connection between the sustainability concerns and the ones related to the product itself, in this case, the wind turbines.

The fifth interviewee was the Head of the Technical Improvements Department within the Global Service. He/she has two main responsibilities: firstly, to present the Global Service and all strategic development projects, which consist of ensuring that each turbine fulfills the specific requirements for turbine operation up to 35 years, including maintenance strategy, exchange tools, and implementations; secondly, as soon as a serious problem is detected, to implement the solution developed by central engineering.

4.2. Individual analysis of interviews

Interview analysis 1

The first interview was conducted with the Technology Project Manager of the Service Department. His/her understanding of the CE focused on the reduction of time, materials, steps in the supply chain, and consumption. He/she also sees this topic as relevant not only for the particular industry nor for the company, but for all industries and emphasizes the environmental and social reasons for circularity.

Despite the challenges covering both internal and external aspects, the first ones were emphasized. The external aspects focused on logistics and interactions with supply chain stakeholders. Within the internal ones, structure and organization were the key pain points mentioned. As circularity is not established as a priority, resources are not allocated accordingly. There is a contradiction between a very centralized and very delocalized company. Efficiency improvements tend to be centralized solutions, but laying the focus on the customer and trying to be as close as possible to each customer requires a decentralized point of view. This contradiction was mentioned as an obstacle to CE. In the decentralized approach, there is the challenge of bridging the gap between what the customer needs and delivering it well without requiring modifications later.

Global collaboration was also mentioned as a major challenge. Different countries have different regulatory, cultural and commercial requirements and, for these and other reasons, there are many risks in the international supply chain. Being at headquarters it difficult and in some cases not possible to support colleagues and to know what is going on in the turbines outside Europe. These structural aspects are closely related to the technological infrastructure, which is developing but not in time or not sufficiently.

In terms of opportunities, there are things that the company is doing but needs to further develop and strengthen, such as developing globalized IT tools, considering customer feedback, establishing global processes to help find solutions to specific problems around the world, and incorporating tools for this purpose. It was also mentioned that gathering ideas and methods of operation from other industries with agile supply chains could be an opportunity.

Considering the existing incentives and focusing on optimizing performance, resource usage, quality, and product design, the optimization path was the chosen one.

The need in terms of technology would be to have tools to transfer information in real-time about what is happening in a turbine, among other aspects. The technologies mentioned were virtual reality, which makes it possible to "be" in the turbine in real-time to solve the problem. In addition, horizontal and vertical integration of the system that is transparent to the entire supply chain is needed.

Although the possibilities for the company in terms of optimization are high and fit its capabilities and status quo, continuing to focus on optimization will not be enough to strengthen the company's uniqueness and its difference compared to competitors in order to develop a competitive advantage.

Interview analysis 2

The second interview conducted was with the Head of Sustainability. His/her preconception of circularity focuses on the reuse or recycling of materials once the product reaches the end of its life cycle. As in the first interview, the relevance of CE applies to the industry and the company without distinction. There are social pressures that the company receives from their customers and the media; political ones, as there are more and more regulations on non-disposal or recyclability percentage; and economic ones which are the need to reduce the use of materials and the decrease of costs of waste treatment. It was also mentioned that as the whole world is moving towards renewable energy, there will be even more waste in the future.

This interviewee emphasized both the external as well as the internal challenges. There is a low maturity of technology and infrastructure capable of recycling wind turbine blades, among other materials. From the perspective of the interviewee, this exceeds the company, and solutions are expected from the sector of waste treatment. Although there is interest in these issues, stakeholders are not yet willing to pay for them. Moving to the internal challenges, they are mostly related to the organization, as it is necessary to focus on circularity so that resources are allocated accordingly.

There were two opportunities regarding the issue of the blades that were mentioned. One that relies on collaboration with other institutions and industries to find solutions to common problems, and another one based on the search of the company for another technology to replace the blades. The first one was highlighted as the most feasible one from the interviewee's point of view.

In terms of paths towards circularity, the possibility of being 100% circular was discarded due to the pain point of the blades. Besides, as the company is already working on the optimization of the performance and efficiency of its products and its own resources and capabilities to do so, the optimization path was selected. No specific focus on technology was mentioned, as this is not his/her expertise.

Regarding the development of competitive advantages, it was mentioned that the goal is not to be particularly distinct from competitors or to build a competitive advantage, but rather to avoid a disadvantage.

Interview analysis 3

The third interview conducted was with the Manager of Continuous Improvements in the Global Quality Department. His/her previous understanding of CE was focused on the end of the lifetime of the product, mainly on the reuse of the materials, not only for turbines but also for other possible purposes. He/she considers CE highly important for the industry and the company in the same way.

The key factors of relevance highlighted were that the customers are demanding it, and the economic benefits of working under circular principles.

In terms of challenges, only internal ones were highlighted. The main dimensions mentioned were structure and organization, product service design, and infrastructure within the company. The company, as a global organization, has very complex supply chains and in some cases, there is an unclear distribution of roles and responsibilities. There are resources and capabilities that are used incorrectly and instead of creating value for the customer, generate waste and costs for the company. This is reflected in the products and services offered. The current objectives of improving the use of infrastructure still need to be developed further.

In terms of opportunities, the interviewee proposed a series of steps. First being aware of the problem, the Sustainability Department has played a key role in infusing ideas into the organization, but the potential to do much more was highlighted. Afterward, the circularity goals and ambitions need to be clarified, and a standard, with structures, procedures, and policies in place should be created. Next, in the implementation phase, the digital technologies and supporting systems need to be chosen. In this sense the selection of technologies comes once it is defined what their purposes are going to be and foundational aspects are defined. Nevertheless, integrated networks to support the supply chain are something that is undoubtedly needed.

By considering the ReSOLVE model, the optimization, focused on the reduction of waste was proposed. On the one hand, this path would help in cost reduction, as waste was understood as an input that has been paid and not used, and on the other hand, the company's possession of expertise and capabilities were mentioned.

The possibility of building a competitive advantage by deepening optimisation was difficult for the interviewee to conceive, given the high level of development of some competitors. However, the fact that each company relies on different technological solutions, and has different human resources, in this case with distinctive technical skills and a high capacity to adapt to change, the deepening of optimisation remains a potential for generating SCA.

Interview analysis 4

The fourth interview was with the Technical Environmental Sustainability Specialist in the Sustainability Department. Her/his conception of CE was an economic system in which waste is avoided or minimized and products and raw materials are kept in loops for as long as possible. This includes recycling and recovery of materials and their use for as long as possible without reducing their value.

She/he believes that the topic of CE is relevant for all industries and particularly for wind energy due to environmental and economic reasons. As all the companies in the sector produce, despite small differences, the same products, it's a relevant issue for every company to the same extent.

The impossibility to recycle the blades and accessing some recycled components in the market were the external challenges mentioned. As for the internal ones, the lack of motivation of the company to take care of the end of the product was highlighted. Once the ownership of the turbines is moved to the customer, it ceases to be the company's property and responsibility. Thus, she/he noted the lack of internal focus and human resources allocated to these issues.

By focusing on opportunities, there is the possibility of improving the durability of the products by working on the design. From her/his point of view, if all efforts are in production and design, the efforts are made once, and then the product can live for a longer time. Simultaneously, more attention could be paid to the incorporation of secondary materials or renewed materials.

In terms of technology, artificial intelligence and predictive maintenance were mentioned, as well as the need for digital infrastructure. As recycling companies need to know what components the materials contain, a product passport would be very useful so that the materials can be tracked.

Considering that the company is already working on waste elimination and is currently highly focused on the product design to increase durability, and is good at it, optimization was the chosen path towards circularity. In this sense, it was mentioned that in the service sector they are working to improve the exchange of components, making use of predictive maintenance systems, artificial intelligence, digital tools, and software to predict when to change components. In this sense, not having a pre-established interval of the durability of components, but detecting when a certain component is going to fail, so that a part can be changed, is an interesting path that the company is exploring and should focus on.

As for the possibility of building a unique solution, on-site projects and design improvement seem to be a distinctive and new approach. However, finding something unique or impossible to imitate is difficult as competitors are more advanced.

<u>Interview analysis 5</u>

The fifth interview was with the Head of Technical Improvements, whose understanding of CE covered the avoidance of waste generation, the reuse of resources and materials in their own products, to ensure that after the lifetime of the product the material is not wasted and can be recycled or used in other products within the company.

The relevance of the topic was considered particularly important for the company as it is on the stock market, and has to provide an annual environmental report, in which the global carbon footprint is exposed. Additionally, the customers are demanding decommissioning concepts, especially for the blades made of carbon fiber which is quite difficult to reuse or recycle.

From her/his point of view, circularity is part of the product offered by the company, as a lot of steel is used, which can be reused and recycled, but the big challenge lies in the blades. There is an additional challenge of reducing material use that is related to the design and quality of the product.

There is a delicate boundary between what is the minimum amount of material that can be used without affecting the quality of the product. Less material leads to less waste and costs, however, it may affect quality and components may have to be changed more often among other possible problems.

In terms of opportunities, he/she proposes a strong focus on data for continuous improvement. When designing a product, simulations are run and data is collected and analyzed to predict how the product will perform over its lifetime. Then, once sold, the performance is measured over its lifetime and compared against different KPIs, such as annual energy production. All the data collected is used to take further action, for example in relation to maintenance activities. The predictive models that the company focuses on are in the service department and, in this sense, do not focus on the design of the product itself, but on its performance, once it is already owned by the customer and operated by the company. Once the turbine approaches the end of the calculated lifetime, the possibilities of extending the durability by changing some components to ensure the integrity of the structure are evaluated.

For monitoring and obtaining immediate information, and the possibility of making predictions based on the information obtained, the IoT is an indispensable technology. As for the development of competitive advantages, although it assumes that competitors develop similar predictive models, he/she considers those developed by the company to be particularly distinctive and a possible foundation on which to build competitive advantages.

Considering what the company is already doing and should continue to explore, the optimization path would be the recommended one.

4.3. Comparative analysis of interviews

In order to develop a solution for the company, the interviews were analyzed in terms of their similar and complementary aspects, as well as contradictory ones. Nevertheless, as there were no relevant contradictory perspectives, the interviews were complimented for taking an outcome.

The interviews were coded by taking into consideration the themes and categories presented above (Table 11; Appendix 3). These contained all mentioned aspects, so the creation of additional categories did not become necessary.

The analysis found in the following subsections relates to the data collected and coded from the interviews. Although some quotations are presented in the analysis, Appendix 2 includes all relevant quotations in relation to the categories that justify the conclusions drawn. The following subsections directly relate to the elements of the model: Relevance of CE, C&O towards CE, Possible paths towards CE, DDT, Selection of the circular path, and Development of SCA.

<u>Relevance of CE</u>

As the move to CE will only be initiated if there is a need to do so, one of the first questions in the guideline was related to how the interviewees assess the relevance of the topic. The importance of CE was confirmed in all cases and environmental, economic, social, and political aspects were mentioned. All interviewees attributed the importance specifically to the industrial sector the company operates in. One argument was, that as the industry provides green energy, it is important to be "green" from start to finish, and to support new products within CE: *"On the one hand we're green energy and at some point it's important to be really green from end to end and to support new products of the circular economy (...)"* (Appendix 2, Interview 3). Additionally, it was mentioned that stakeholders and customers expect circular approaches and that, as the stock-listed company delivers yearly reports, it should take into consideration its environmental impact: *"As the company is on the stock market, we have to provide on a yearly basis, an environmental report (...). Also, our customers within the tenders are asking us to provide decommissioning concepts, especially for the blades made of carbon fiber which is quite difficult to reuse or recycle."* (Appendix 2, Interview 5).

Regarding the economic dimension, the use and purchase of fewer materials would reduce costs in general, as well as those associated with the subsequent treatment of waste: *"If you reduce waste, you have potential, or benefits in other areas. First of all, you buy less materials and then you need to pay less for the waste treatment. So, there are also cost-saving potentials, related to that topic."* (Appendix 2, Interview 2). In the environmental dimension, global climate change was highlighted: *"Yes, It's important in general in every industry, especially considering climate change and the world becoming more global."* (Appendix 2, Interview 1). In terms of the social dimension, there is a change in customers´ behavior, as they now expect circular solutions: *"More and more customers are integrating this topic in their decision. That's also very important to keep in mind."* (Appendix 2, Interview 2). With respect to political terms, the increase in regulations regarding non-landfill or the percentage of recyclability that is already required in certain markets and will increase in the future: *"(...)regulations regarding no-landfilling or percentage of recyclability that is required in certain markets already and this will increase in the future."* (Appendix 2, Interview 2).

Challenges towards CE

Overall, interviewees stated more internal than external challenges. The external ones focused on the financial and inter-organizational dimensions. First, the path to circularity would be costly and stakeholders are not willing to invest in it: "*(..) cost pressure in our industry is the most important KPI to make decisions. It has to be kept as low as possible and despite our stakeholders would like us to have recycling options, they are not really willing to pay for it. So, that's another issue. These things are affecting the industry in general, not only our company."* (Appendix 2, Interview 2). Secondly, risk assessment within the complex and global supply chain of the company appears to be missing *"We have a geographically distributed supply chain, and it's very complex in terms of transport and risk assessment. It's necessary to have shared information to know what is happening. There is a lack of transparency and information in the supply chain"* (Appendix 2, Interview 1). Third, all interviewees highlighted the limitations to reuse or recycle turbine blades. Although this issue can be approached from an internal or external point of view, the external one was particularly emphasized. In this regard, there is a lack of solutions from the waste treatment sector or the wind turbine sector in general, among other industries working with this material *"The low maturity level of the desired technology is a very important point. It's not only a problem of the company, but it's actually from the waste treatment sector (...). It is then connected to industries like the waste treatment industry, which is not able to actually treat the waste."* (Appendix 2, Interview 2).

In terms of internal aspects, the dimension that incorporated most of the challenges outlined is the structure and organisation of the company, followed by the structure and design of the product/service. In relation to these aspects, infrastructure and technical equipment also play an important role. Regarding structure and organization, the lack of focus and priority in this area was highlighted. There are also different perspectives on what circularity should look like. They may be aligned in the general picture but not in the detailed one: *"(...) there are always different perspectives in the top management, maybe the broad pictures are aligned, but when it goes to the details, then the fights begin."* (Appendix 2, Interview 3). One of the interviewees related this to a contradictory objective of the company to work in a centralized and decentralized manner simultaneously. While focusing on efficiency would work well with a centralized approach, focusing on the customers and tailoring the product to their needs would require a decentralized one: *"(...) contradiction of being very centralistic and very delocalized. If you want to be efficient you have to be as central as possible but if you want to be close to your customer and close to the delivery and close to the product, you need to be as decentralized as possible. This is an obstacle."* *(*Appendix 2, Interview 1). Another challenge mentioned was the fact that the company is currently in a phase of rapid growth and expansion and there are many instances of disorganization in terms of structure, roles, and responsibilities. Finally, optimizations often arise from a reactive perspective. This last point was mentioned in the context of the product design. There appears to be a lack of a proactive attitude to improve the product through novel design follow-up measures aiming at further improvements. Although the company already controls many parameters, it adjusts the product in a reactive way, following problems and the demands that arise from the customer *"It's challenging to do things the first time right, according to the needs of the customer and having an organization which is really reflecting the needs of the customers."*(Appendix 2, Interview 1). With respect to concerns regarding technical infrastructure, there is a great need for a developed global structure, which today is underdeveloped and does not function well in many cases. Fundamentally, there is a lack of IT infrastructure outside Europe, which is important if the company intends to have international coverage: *"There is a big infrastructure in Europe, but internationally it is not easy. In Chile SAP is not linked, and it's not possible to know what is happening in the turbines in other companies from a material perspective. There are processes already going on, but globalized IT tools are necessary. Networks need to be reinforced, to have a global IT."* (Appendix 2, Interview 1).

<u>Opportunities towards CE</u>

In the same way that more internal than external challenges were encountered, the internal opportunities outweighed the external ones and focused on the same dimensions. With respect to External opportunities, strengthening collaboration with other institutions and organizations for blade recycling was highlighted: *"(...) we need other strategic partners to work with. Recycling* *companies all over the world that can help us with the logistics infrastructure. So I think one of the challenges is to create a network of strategic partners to work on those challenges together."* (Appendix 2, Interview 4).

Regarding internal structure and organization, one interviewee suggested the following steps be established and followed: (1) Understanding the problem, changing the mindset, and infusing new perspectives into the organization; (2) Defining what the company's position and objectives are going to be in regards to CE; (3) Establishing procedures and practices; (4) Defining technologies; and (5) Implementing chosen technologies and processes to improve internal structure and organization.

There were also opportunities related to product/service structure and design, primarily focused on extending product durability and product improvement through data generation, processing and prediction models: *"There are many qualitative initiatives related to the development and improvement of the product. Many focused on the design of the product, which has to be designed to work for many years."* (Appendix 2, Interview 1); *"(...) it's using data, using monitors, generating data and processing this data. All of the information prior to the building of the product, in the simulation moments and data we have we predict how the product will behave within the next year."* (Appendix 2, Interview 5). Also mentioned was the incorporation of customer feedback into the product design (Appendix 2, Interview 1), the search for alternative blade technology that can be recycled or reused (Appendix 2, Interview 2), and the integration of other product characteristics (Appendix 2, Interview 3).

Digital data technologies

DDT were associated with the need to share information in real-time, organize roles and responsibilities, connect a global structure through transparent and secure information exchange, track materials and products, and support maintenance, data collection, analysis, and forecasting systems. In this regard, some technologies stand out. First, IoT, which seems to be totally indispensable for all the real-time information gathering used in the Service Department to manage information about the turbines It depicts the basis for generating data to monitor the assets, and linking such data to prediction models: *"In service, we work a lot with data. We do a lot of preventive analysis using monitoring systems, we do monitoring of the lifetime, consumption, and many parameters."* (Appendix 2, Interview 4). Secondly, the use of horizontal and vertical systems was proposed, as well as a data integration network to share information, but also to clarify roles and responsibilities, in order to interconnect the company´s complex global structure and supply chain that derives from it (Appendix 2, Interview 1 & Interview 3 & Interview 4).

The use of simulations in the design phase to predict product performance was mentioned, but not particularly emphasized and covers a very specific part of the design process (Appendix 2, Interview 5). The use of blockchain was mentioned as a great solution for quality-related issues but far outside the possibilities of the company: *"I am a big fan of blockchain topics, especially for* *quality, they super interesting, but we at the moment are not ready for that. As long as we don't have the process we can't apply these kinds of great solutions."* (Appendix 2, Interview 3).

Possible paths towards circularity

As mentioned in the theoretical part, each of the areas consists of different aspects. Only some of them may be relevant to the company. Regarding the areas of ReSOLVE, the optimization area was mentioned and highlighted in all interviews. Regarding the areas of sharing, looping and exchange, they were mentioned in some interviews. The share area incudes the maximization of the use of assets and products by sharing them among users, reusing them and prolonging their lifespan through maintenance, repair and designing them for durability. Despite no aspect of sharing between users was noted, the potential to extend the durability of wind turbines through product improvements was mentioned, as well as the development of maintenance options: *"Our engineers are working really hard to create or design products that can live or that can be used for a really long time."* (Appendix 2, Interview 4). The loop option referred to the increased use of secondary or refurbished materials and recycling of materials, including blade materials: *"Recycling has been identified as important. So that's already good and it's all included in our new sustainability strategy to have a fully recyclable blade by 2032. So, this already shows that the company is willing to allocate some resources on that."* (Appendix 2, Interview 2). Then, regarding the exchange area: *"There is a lot going on in service for the exchange of the components, there are predictive maintenance systems using almost artificial intelligence, like digitalized or software to predict when to exchange components. I think this is also really helpful not to have a standardized interval, but to actually see when a component will fail, so that it needs to be exchanged."* (Appendix 2, Interview 4).

Optimisation was mentioned and highlighted in all cases. The company is already working on energy cost, efficiency, organisational performance, product performance and reducing waste and material use in general. Not only is it working on this, but interviewees noted that the company is good at it. Although they have the human resources to address these issues, there is still more potential and much to explore and improve in this regard. All key quotes in this regard can be found in Appendix 2.

Selection of the circular path

To determine the optimal path the company should follow in order to reach a CBM, the company's possibilities to solve its challenges with the mentioned opportunities were evaluated. In Table 13, different colors have been used to differentiate the obstacles with more or better opportunities from those with non or fewer. Regarding digital technologies, those that could fit the company were selected, and integrated as part of the opportunities to overcome challenges and move forward on a circularity path (see 2.5.). IoT and Horizontal/Vertical systems were selected as enablers to overcome opportunities, and simulations and blockchain were excluded as they played an irrelevant role or were not feasible to implement.

Since external challenges play a minor role compared to internal ones, the inter-organizational opportunities were marked as solutions of low feasibility or low relevance. In addition, the proposed opportunity, which is to improve collaboration with other institutions to find a solution to the blades recycling, does not guarantee that this solution will be found. As for external financial challenges, no opportunity was mentioned.

Moving to the internal aspects, there were important and recurrently mentioned challenges in the structure and organization. The opportunity stated requires a strong change of mindset and internal alignment. This strategy seems to be less feasible compared to those which relate to aspects that the company is already working on and that can serve as an impetus for opportunities in the CE. In summary, the challenge outweighs the opportunity. Therefore, in this case, the color orange was selected. Moving on to product/service structure and design, many opportunities were highlighted for the company in terms of product and service improvement. Opportunities encompass different approaches to seek improvements, such as including the customer's perspective, moving from a reactive to a proactive approach, exploring and deepening the use of technologies such as IoT to monitor new areas for improvement.

In the case of infrastructure, this is closely interrelated with the structural and organizational issues previously mentioned. In this sense, the globalized and complex supply chain does not have an adequate and sufficiently developed technical infrastructure to share information and organize the tasks and roles of a global organization.

Table 12. Evaluation of challenges and opportunities

Challenges		**Opportunities**	**Remarks**
External			
Financial	Stakeholders lack of willingness to invest in CE.		
Inter-organizational	Lack of solutions from the waste treatment sector or the wind turbine sector, among other industries to reuse or recycle the component of the turbine blades.	Strengthening collaboration with other institutions and organizations for blade recycling	The opportunity does not ensure the finding of a solution to this concrete problem.
Internal			
Structure and organization	Complex supply chains.		
	Disorganization in terms of structure, roles and responsibilities.		

	Lack of focus, priority and alignment.	Understanding the problem, defining the position and objectives of the company in regards to CE, establishment of procedures and practices, definition of technologies and implementation.	The problem seems to outweigh the solution. It has been emphasized that achieving focus on circularity is a challenge in itself rather than a solution.
	Lack of solutions for the reuse or recycling of components of the turbine blades.		The solution is expected to come from a collaboration between organizations or from other organizations. No internal opportunities were mentioned.
Product/Service structure and design	Lack of a proactive attitude to improve the product by establishing in the design new follow-up measures to achieve further improvements	Extending product durability and improving products by generating, processing and tracking data; focusing on maintenance and repair; incorporating customer feedback into product design; finding solutions by drawing on ideas from other products; maintenance options	
Infrastructure	Underdeveloped digital global structure.	Horizontal and vertical systems to share information and support the organization of roles and responsibilities in the complex global structure and supply chain.	IoT/Horizontal and vertical systems

Color coding based on the insights retrieved from the interviews

	No solution mentioned
	Solution mentioned with low feasibility or low relevance
	Feasible opportunity, which partially solves the problem
	Feasible opportunity, which shows a high potential of solving the problem

By having analyzed the C&O, the selection of a suitable and promising path to circularity remains. The focus on collaboration and problem finding for blade recycling would fit into a loop perspective, nevertheless, this area was previously considered non-suitable in the analyzed company´s case. In terms of structure and organization issues, no major viable opportunities or an area of the ReSOLVE model that could be associated with it could be identified.

Then, optimization opportunities were associated with product/service design and structure. The company is already working intensively on the performance and efficient behavior of the products and services it offers, as mentioned above (see 4.3.2). Not only does it have the expertise and human resources to do so, but it also sees it as part of customer satisfaction and cost reduction. Therefore, the optimization option was identified as the most important and feasible one. Although the respondents explicitly mentioned optimization, aspects related to increasing the durability of the products were also recurrently highlighted, which corresponds to the ReSOLVE area of *share*. In this sense, the solution for the company should combine aspects from the areas of *optimize* and *share*.

Development of SCA

As mentioned above (see 2.2.1.), there are key correlated and interdependent aspects that must be in place for a solution to provide SCA. As suggested by the VRIO model (Fig. 4), resources and capabilities have to work in a valuable, rare, inimitable, and organized way.

Although it was clear in all cases that the solution added value to the company, it was not possible to corroborate the other aspects. Regarding the possibility of the company building a unique and inimitable solution, there is a general understanding that all companies in the wind turbine industry work in a very similar way and that some competitors are more advanced. This makes it difficult for the case study company to find a rare and inimitable solution, but not impossible: *"(...) our competitors, are a little bit farther than us on this now. At least, it feels like the way they are selling it. I don't know how far they really are, (...) considering it from that perspective I would say it's difficult to imitate, (...) because, the technology is slightly different (...) our organization and our people are specific. Some parts can be imitated but in general I guess ,it's difficult to imitate."* (Appendix 2, Interview 3); *"The only competitor I know of that has a dedicated circular economy strategy is Vestas, or at least that they have published that, and to exceed this would be quite difficult. It was nominated the most sustainable company in the world. I am afraid within the same industry, it would be quite difficult to completely differentiate, we would need to come up with a really special solution."* (Appendix 2, Interview 4).

Since the interviewees were unsure about the possibility of creating a SCA, further analysis was needed in order to confirm the uniqueness and inimitability of the solution and then to continue the exploration regarding the organizational character, which is the last element of the VRIO model.

4.4. Initial recommendations to the company

The main objective of the model was to develop a workflow that the analyzed company can employ to find a path to circularity. Despite the limitations of testing it with a few short interviews, it was possible to determine that the company should focus on the ReSOLVE areas of *share* and *optimise*. This has to be understood as an initial verdict and solution and could be specified based on more intensive in-depth research.

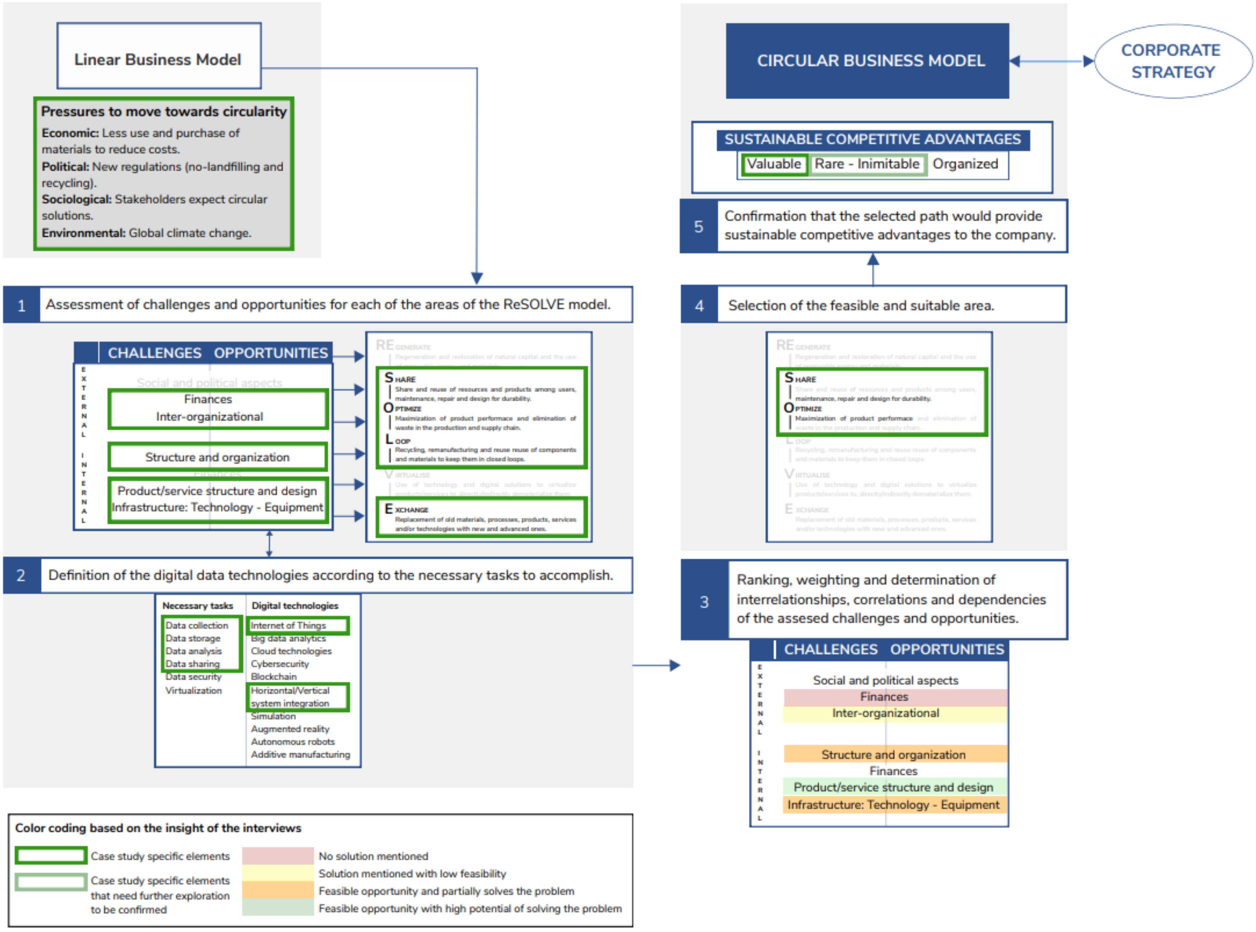

Fig. 11. Theoretical framework applied to the case study

Fig. 11 represents the workflow showing how it was experienced in the case of the company analyzed. In this sense, the pressures to which the company is subjected are presented: in economic terms, the need to reduce the use of material and its purchase to reduce costs; in political terms the new regulations related to non-landfill and recycling percentage; in the environmental dimension, climate change; and in sociological terms, the expectation of stakeholders for circular solutions.

As for the first step in which C&O were assessed, only the categories in which C&O were mentioned were selected. Thus, social and political aspects and internal financing were discarded. For DDT, IoT and horizontal/vertical integration systems were highlighted. Turning to the areas of the ReSOLVE model, only *share*, *optimize*, *loop* and *exchange* were marked, as no aspects related to the other areas were mentioned.

When it came to classifying and weighting the C&O, it could be observed that no opportunity was mentioned for the external financial challenge, there was one opportunity with low feasibility of realization in the inter-organizational dimension, and there were only feasible and potential solutions related to the structure and design of the product/service.

The next step was to define the area to focus on. As can be seen in Fig. 11, *optimize* and *share* were selected, only maintaining the aspects of maximization of product performance, maintenance, repair and design for durability.

Finally, with respect to SCA, as the interviewees did not explicitly state that this pathway would provide a rare and inimitable solution, further exploration seems necessary to ensure the creation of SCA. In case any of them cannot be confirmed, as mentioned in the model, some steps would have to be taken again until a solution is found that provides the desired SCA.

Without repeating the information mentioned above, *share* and *optimize* would allow the company to focus on performance and efficiency, as well as durability of products and services, leveraging its strengths in terms of resources and capabilities.

If the complex issue of wind turbine blade recycling cannot be resolved, it will not be possible to achieve 100% circularity in the company or in the industry. However, according to interviewees, this is seen as an external rather than an internal problem and there is no objective to gain a competitive advantage in this regard. Therefore, the company should focus on another aspect that allows it to leverage its strengths and opportunities with more potential. Improving and developing expertise in the performance, efficiency, maintenance, repair and durability of its products would allow the company to address a path to circularity that is not only feasible, but aligned with its resources and capabilities.

4. 5. Discussion

4.5.1. Reflexions

The conducted case study allowed to examine how each of the elements was expressed from the company's perspective. It was also possible to prove that the combination and relationship of the elements proposed by the model effectively result in a path towards circularity.

As each of the areas of the ReSOLVE model consists of different aspects, in this case the path does not consist of aspects from only one area, but from the combination of aspects from two areas of the ReSOLVE model. Some of *optimize*, such as efficiency and performance, had to be combined with monitoring and extension of the lifetime of the product, which corresponds to the ReSOLVE model´s share area. Thus, other aspects of optimization and share would be left out, such as the sharing of parts and components between users.

Regarding the particular elements of the developed model, despite new challenges could be identified, the pre-established categories were able to contain those specific challenges of the case study company. In terms of DDT, no additional ones to the those established were mentioned. Overall, the individual elements of the model were validated and proved to be usable for the analysis of the company.

Altogether, the model did not have to be adapted after the interviews, as no element was questioned or affected in a broader sense and the categories served to cover company-specific aspects. Nevertheless, for a more accurate validation, more time and information gathering methodologies need to be employed. Detailed reflections related to the limitations of this research study are offered later in this chapter.

4.5.2. Theoretical and managerial implications

This research has been able to bring together and relate atomized concepts to build a practical tool that can be applied in the real world. The research done on the individual elements is in itself valuable. By reading this thesis, managers will find many reasons to move towards circularity organized in four dimensions (Economic, Environmental, Political, and Sociological). The research on the relevance of this topic can serve as an input that can be used to justify and sustain the need to move towards circularity. Despite the great importance of this transition, not all stakeholders are aware of it. In this sense, the gathered information with respect to the transition´s relevance itself is valuable and raises awareness of its importance.

The research study also provides an in-depth understanding of CE. The concept itself can be understood from many points of view and consists of more than one definition. As the actions to be taken in relation to circularity will be based on its definition, the research conducted on the definition is already insightful. As a broad definition can give rise to new approaches and strategies, in this research study, the ReSOLVE model has played a fundamental role. Intimately related to the concept of CE, the concept of CBM was defined and examples were given. In this sense, managers are empowered to know how different companies organize their CBM around different areas of the ReSOLVE model.

Moving on to DDT, the accumulated knowledge of DDT related to circularity was explored and summarized. Due to the major importance of the role of DDT as enablers of circularity, the theoretical research conducted in this field is essential. To facilitate the bridge between DDT and CE, and to be consistent with the ReSOLVe model, which was used throughout this study, DDT were directly related to each of their areas. As a result, managers can explore the role that DDT have played in each area in other companies and use this knowledge when developing their own strategies.

Another point of significant value to managers is the fact that the research defines their role and relevance in the process according to theoretical research. Closely related to their role, is the theoretical analysis provided on SCA and their relationship to the overall strategy of the firm. Once again, theory is expounded to provide managers with a definition of SCA and to help them to identify their own SCA.

Finally, the empirical research conducted on the wind turbines company enriched the hitherto available. It exposed what is the relevance of CE for the company, and drew the first conclusions on what would be its C&O, how it would use digital technologies, and what would be a possible way to build circularity in its case.

4.5.3. Limitations and prospects for future research

This study had the ambitious goal of defining and combining elements to develop a theoretical model. For a preliminary test, the model was tested with interviews. Nonetheless, future research could improve the established model even further.

Since the model proposes the evaluation of the status quo of a company by assessing C&O, further research could lay in the development and selection of methods for assessing C&O. In the empirical part of this study, interviews were conducted to obtain the respective information. However, there are many alternatives or complementary methods such as observations, ethnography, focus groups, and surveys, among others, that could help to get a clearer picture of an analyzed company and dispel subjective biases.

Regarding the ranking and weighting of C&O, methodologies on how to handle complex weighting and ranking scenarios with variables that may be related or interdependent could be investigated.

In terms of model testing, although the ideal time for the interviews would have been a minimum of 90 minutes, the managers contacted were not able to offer such an extensive period of time. Thus, the proposed time was adjusted to 40 minutes and the guideline was adapted respectively. This posed a great challenge and limitation in terms of being able to carry out each step suggested by the model, explore each area of the ReSOLVE model in terms of C&O, and weigh and rank them during the interview.

Finally, the model was only tested with respect to one company in the wind turbine sector. Validating it with several companies across the globe would ensure that the model is functional for companies of various sizes, locations, and industry sectors. It should also be clarified that the empirical results should not be generalized to all wind power companies.

Conclusions

This master's study undertook to support managers in the transition to CE by providing a theoretical framework designed to develop SCA by exploring the C&O and using DDT as enablers.

This main objective was broken down into smaller objectives. Therefore, it was necessary to corroborate the relevance of the problem, lay the theoretical foundations on which the model would be built, and perform a first validation of the model. The objective and their principal results are presented below.

1. On the basis of thorough problem analysis, to expose the importance of the transition towards circularity by focusing on the pressures the companies face to act more sustainable and circular, and the role of data within that process.

The analysis of the current relevance of companies to become more sustainable and circular was divided into economic, environmental, political, and sociological dimensions. The economic need for companies to be more sustainable was related to the rising cost of raw materials, the increase in sustainable investments, and the need to save costs through efficiency. The relevance of circularity in this regard was related to improving economic performance through efficiency, reducing costs through sustainable supply chain management, and generating new revenue streams through more effective life cycle management and the sale of waste. At the environmental level, the need to be more sustainable is associated with a number of issues related to, or arising from, climate change. The importance of CE in this regard is linked to the possibility of saving energy and natural resources, reducing the generation of pollution, and preventing chemical fertilizers, soil amendments, fossil fuels, and toxic substances. In turn, the earth, according to CE, is conceived as a closed, circular environment where society, the economy, and the environment must coexist in balance. In political terms, international organizations are intensively promoting sustainability. A clear example is the Sustainable Development Goals set by the United Nations, which have a strong global impact, and specifically in relation to circularity, the Circular Economy Action Plan of the European Commission could be named. Finally, in sociological terms, there is an increase in responsible consumer behavior. In relation to circularity it implies an increase in the acceptance and adoption of circular products and services, an increase in the offer of services or products as services that break the linear chain in which a product is used and discarded, and a strengthening of communication between industry and society.

Another central aspect of the problem analysis was the need to design a model for transition. This is relevant in the context of an industrialized world in which there are strong linear structures that generate blockages and there is a lack of theoretical and empirical analyses that work on the identification of C&O for the transition to CE. Finally, there is a great need for data to help in this process. It is key in assembly activities and information transfer, and has the potential to reduce the uncertainty involved in changing the established linear approaches. In addition, DDT have been shown to play an important role in enabling circularity.

2. To reveal the theoretical assumptions of the key aspects with regard to the research aim: the definition of CE, the managerial role in the transition to circularity, the SCA, the identification of C&O in the transition towards CE, and DDT as enablers of this process.

Moving to the conclusions of the literature review, which consist of the basis of the model, it was found that there is no one definition of CE. This research focused on the ReSOLVe model, developed by the Ellen MacArthur Foundation, which stands for: regenerate, share, optimize, loop, virtualize, and exchange. In the business environment, CE is associated with the concept of the CBM, which is related to how companies can create and capture value through circularity. In this regard, the ReSOLVE model summarizes six pillars on which CBM can be built. The creation of SCA is central to business models as an important aspect of the value creation and positioning of organizations in the market. SCA can be defined as the existence of valuable, scarce, imperfectly imitable, and organized internal resources and competencies, which must be harnessed for a coherent strategy. In this sense, by moving to CE, the corporate strategy will necessarily be affected, and the role of managers will be key to making this transition possible. They will need to shift to a CE by reinforcing or developing competitive advantages, and addressing the challenges can help in this objective.

Rather than limiting itself to understanding the challenges, this research aimed to focus on how to overcome them. Therefore a theoretical analysis was made on the information so far available on C&O in the transition to circularity. As an overview of the external challenges, it can be said that in the social and political field the main problems are related to cultural aspects and the political aspects are mainly related to the lack of provision of structures and support. Opportunities, in this sense, are related to strengthening ties with clients, especially those who have some knowledge or familiarity with the CE, and approaching the government through lobbying. In terms of finance, there is a need for high upfront investment and a tendency towards low investment support for long-term projects and prioritization of projects with short-term investment returns. In this sense, circular models could concentrate on profit generation and fundraising alternatives. Focusing on the network dimension, the need for strong structures and complex supply chains stands out. This needs to be addressed through soft and hard skills as well as technologies.

Regarding the internal dimensions, the financial complexity refers to the need to reallocate the budget and uncertainties about the amount of investment required. In this sense, the creation of pilots can help to address this lack of clarity. Next, problems in the organizational dimension refer to corporate governance that does not encourage the implementation of CE, a corporate culture that does not favor or hinders the development of CE, and the existence of structures organized for linear models. Merging CE with global strategy, developing or recruiting new skills, and increasing internal communication are key points to address these challenges. Finally, the transition to CE often implies the need to readapt product and/or service design, which brings challenges in terms of aesthetics, materials, assembly, and ownership culture. Opportunities in terms of circularity are associated with modular designs, the incorporation of remote servicing and maintenance, and functional decoupling. CE requires new infrastructures in terms of technology and systems, especially related to the management of materials and components. The use of different technologies, such as blockchain, information technologies, sensors, platforms, and data analytics, are some key opportunities to tackle these barriers.

Delving deeper into DDT, the research studies conducted so far confirm that they are key to the transition to circularity. This literature review analyzed the technologies through the lens of the ReSOLVE model. It became clear that data collection, analysis, and exploitation are very important in the different areas of the framework and that IoT and big data are the most important technologies as they play an important role in all areas of the ReSOLVE model. In a general conclusion, it can be confirmed that the digital technologies presented enable companies to improve their material flows, processes, overall performance, and stakeholder relations. Furthermore, they increase or develop revenue streams through data collection; data storage in large central databases; data sharing that improves collaboration with parties within the supply chain; data analysis that enables data-driven decision making with regard to the optimization of product/service processes;

virtualization of products/services and processes; and information assurance, which can be stored and shared in a reliable and transparent manner.

3. On the basis of a review of previous literature, to support managers in the transition to CE by providing a theoretical framework designed to develop SCA by exploring the C&O and using DDT as enablers.

Based on the literature review, the theoretical framework was designed. It consists of a workflow that starts with a linear business model and is followed by an assessment of the C&O for each of the areas of the ReSOLVE model. This stage can be supported by the categories for C&O and, optionally, particular C&O identified in other companies. Then, it is necessary to determine for each of the areas, the key DDT that would be required. These would be included in the analysis as opportunities, and it should also be assessed whether the company has such technologies, or assess the capacity to acquire and implement them. Once this has been done, weighting and ranking as well as determining the correlations and dependencies of the identified C&O must be done. Next, the most suitable area of the ReSOLVE model will be selected and its ability to provide SCA will have to be assessed. If the solution is able to deliver SCA, a potential pathway to a CBM has been defined. The role of the managers will be key to ensuring that the potential business model can be adapted to the corporate strategy and vice versa. Therefore, the manager's perspective is crucial throughout the process. It should be clarified that the model contemplates the eventual case that, the SCA are not ensured. It would then be necessary to retrace some steps to guarantee the generation of SCA by transitioning towards CE.

4. To define a methodology that allows validating the theoretical framework.

To validate and test the developed conceptual model and its elements, a deductive approach and empirical research were carried out by a European company in the wind energy sector. According to the European Commission, there is a great need for research and innovation in the European Union to reduce costs and increase the performance and reliability of wind energy technology. Desk research was carried out to obtain general information about the company, and semi-structured interviews with five managers was conducted to get in-depth information. The coding of the interviews was done using a hybrid approach. In a deductive way, themes and first-order categories were predefined following the findings in the theoretical part. Then, in an inductive way, unexpected aspects were retrieved and categorized in order to enrich and adjust the model, only if necessary. MAXQDA Analytics Pro 2022 software was used to support the coding.

5. To conduct a case study to validate the theoretical model and to provide initial strategic recommendations to the company.

By conducting the case study, it was possible to examine how each of the elements was expressed and related in a real company. Although new challenges could be identified, the pre-established categories were able to contain those challenges specific to the case study company. In terms of DDT, those mentioned in the model matched those mentioned in the case study. Although the model did not exclude the possibility of two areas of the ReSOLVE model being combined, this outcome was unexpected. Overall, the model did not have to be adapted after the interviews, as no elements were questioned or affected in a broad sense and the categories served to cover company-specific aspects. However, for a more accurate validation, the duration of the interviews should be longer, a variety of data collection methodologies should be used, not only interviews, and the model should be tested with several companies to ensure its suitability for a variety of cases.

Through the use of the model, it was possible to gain initial insights into a possible circular path for the company by combining aspects of the ReSOLVE areas of share and optimise. Although the industry has an overarching challenge to find a solution to the recycling of blades, according to the interviewees, this is considered an external rather than an internal problem and there is no objective to gain a competitive advantage in this regard. Therefore, pathways of circularity were sought in other directions that would allow the company to build on its strengths and focus on the opportunities with the most potential. Improving and developing expertise in the performance, efficiency, maintenance, repair, and durability of its products would enable the company to address a path to circularity that is not only feasible but aligned with its resources and capabilities. The key DDT to use and leverage in this case is IoT, which appears to be indispensable for all real-time data collection for turbine information management, monitoring, and data generation for the development of predictive models. As the interviewees did not explicitly state that this pathway would provide a rare and inimitable solution, further exploration or retracing steps would be necessary to ensure the creation of SCA through the choice of these pathways.

In summary, this research study provided an extensive and structured theoretical investigation on the topic of transition to circularity and provided a flow chart designed to help companies in finding a path to circularity through the identification of C&O and the use of DDT. At the same time, through the case study, it was not only possible to validate the model but also to enrich the hitherto available knowledge on the elements of the model by presenting the case of a wind turbine company. It is hoped that the results of this study will provide a good solid basis for further research on the transition to circularity and help managers to make the shift possible.

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Appendices

Appendix 1. Interview guideline for semi-structured interviews

Topic	Question	
Warm-up		
Interviewee description	1	Which is your job position? Could you briefly describe it?
CE definition	2	What do you understand about CE?
CE relevance	3	Do you think it is relevant for the industry?
	4	Do you think it is relevant for the company?
Status quo		
Current CE	5	Are there things the company is already doing to be circular?
	If yes	
	5.1	Which ones?
C&O exploration	5.2	What are the challenges the company is facing to become more circular?
	5.3	Are you applying solutions already to these challenges? And if so, which ones?
	5.4	Are there other solutions that should be implemented to address these challenges?
DDT	5.5	Is there a specific DDT that is central to the success of this path to circularity?
ReSOLVE Areas Exploration		
Diving deep into the current aspects of circularity/building circularity	6	Are there resources or capabilities that would you highlight as characteristic and distinctive of the company?
	7	Looking at the ReSOLVE model and considering the capabilities and resources that the company possesses and make it unique: do you think the path the company is taking is the right one / is there a circularity path that the company should follow?
	8	What are the resources and capabilities, if possible, that make the company unique and different from others that make the chosen path the right one?
C&O	9	What are the challenges that the company will face if it wants to succeed in the chosen path?
	10	What resources and capabilities do the company have to overcome these challenges if any, and which ones should it develop?

Topic	Question	
DDT	11	What DDT do you think would be absolutely key and essential to succeed on this path?
Ensuring the development of SCA		
SCA	According to your knowledge and experience, do you think that if the company chooses the X path, uses its resources and capabilities and/or develops the necessary ones and applies the chosen technologies…	
	12	would be choosing a unique and original approach differentiated from the competitors?
	13	could be easily imitated by competitors? Why?
	If the answer to 10 is that it would be a unique solution that it could not be easily imitable:	
	14	Would other policies and procedures of the company make synergy with this path in a way that will support the exploitation of the rare and difficult to imitate solution?
Closing		
	15	Is there anything else you would like to add regarding the topics discussed?
	16	Thanks for the interview.

Appendix 2. Table of Coding - Case study

Theme	Category	Quotes
Relevance of CE	Relevance of CE for the Industry	*"It's important in general in every industry, especially considering climate change and the world becoming more global."* (Interview 1) *"Yes, I think it's highly relevant for our industry, for a lot of materials, this is already working very well and we have established processes."* (Interview 2) *"So, a lot of waste is coming. Now, it's actually starting because the first blade generation or the first turbine generation is now getting to an end and it will now increase exponentially. And if we, as a society, really have the aim to get 100% or close to 100% of electricity from renewables, we will have a lot more blade waste in the future. So, it's highly relevant."* (Interview 2) *"On the one hand we're green energy and at some point it's important to be really green from end to end, and to support new products of the circular economy, for me, this is a package that somehow fits together on the one hand."* (Interview 3) *"I think it is relevant for every industry in the whole world and I would say that in our industry in particular."* (Interview 4)
	Relevance of CE for the company	*"It is also expected from our stakeholders. Customers are pushing for that a lot."* (Interview 2) *"As the company is on the stock market, we have to provide on a yearly basis, an environmental report, so we have an environmental department for that ensuring that our global footprint and carbon print is not that big. Also our*

		customers within the tenders are asking us to provide decommissioning concepts especially for the blades made of carbon fiber which is quite difficult to reuse or recycle." (Interview 5)
	Economic	*"If you reduce waste, you have potential, or benefits in other areas. First of all you buy less materials and then you need to pay less for the waste treatment. So, there are also cost saving potentials, related to that topic."* (Interview 2)
	Political	*"(...)regulations regarding no landfilling or percentage of recyclability that is required in certain markets already and will increase in the future."* (Interview 2)
	Sociological	*"More and more customers are integrating this topic in their decision. That's also very important to keep in mind."* (Interview 2) *"(...) it's a highly relevant topic in society and the media, (...)"* (Interview 2)
	Environment	*"Yes, It's important in general in every industry, especially considering climate change and the world becoming more global."* (Interview 1)
Challenges towards CE	External	
	Financial	"*(..) cost pressure is in our industry the most important KPI to make decisions. It has to be kept as low as possible and despite our stakeholders would like us to have recycling options, they are not really willing to pay for it. So, that's another issue. These things are affecting the industry in general, not only our company."* (Interview 2)
	Inter-organizational	*"We have a geographically distributed supply chain, and its very complex in terms of transport and risk assessment. It's necessary to have shared information to know what is happening. There is lack of transparency and information in the supply chain"* (Interview 1) *"We have a lot of waste in our supply chain. We transport materials from a, b, c, d, e, f , with a lot of risk. (...) If we don't optimize transport, we are very dependent on in. With shipping and transport we have a lot of risk and cost. In transport there are delays, additional fees and many risk aspects in logistics that are not being considered."* (Interview 1) *"The low maturity level of the desired technology is a very important point. It's not only a problem of the company, but it's actually from the waste treatment sector that we don't have a treatment method that is efficient and economically feasible at the moment. This is not only related to the company but to the topic of recyclability. It is then connected to industries like the waste treatment industry, which is not able to actually treat the waste."* (Interview 2) *"More difficult topics such as the blades recycling.. this is something that we cannot do just on our own."* (Interview 4)
	Internal	
	Structure and organization	*"The challenge is here to understand how this should look like, because this is typically the fight, it's first about what should this affect the most effective way look like and there are always different perspectives now in the top management, maybe the broad pictures are aligned, but when it goes to the details, then the fights begin."* (Interview 3) *" (...) contradiction of being very centralistic and very delocalized. If you want to be efficient you have to be as central as possible but if you want to be close to your customer and close to the delivery and close to the product, you need to be as decentralized as possible. This is an obstacle."* (Interview 1) *"Local requirements are not translated in a general project development.*"(Interview 1)

		"Resources are not used correctly." (Interview 1) *"We do a lot of preventive analysis using monitoring systems, we do monitoring of the lifetime, consumption, and many parameters. We still could do more or better. The more people you have, the more fancy dashboards and data analytics and statistics that you can do."* (Interview 1) *"We don't do it proactively, we always do it reactively. It would be good to move from the reactive to proactive approach, in which we can decide all we want to monitor from the design. It's not part of the design now."*(Interview 2) *"But I think what we would actually need is still further management focus on that topic to really go ahead"* (Interview 2) *"It's actually about allocating more resources to that topic. (...) The company could have a higher focus on that topic and push it further."* (Interview 3) *"Getting all this whole thing in order and giving it structure, roles and responsibilities, defining who's doing what… I guess this is something that we should focus on."* (Interview 3) *"Infrastructure, structure and organization are the big parts."* (Interview 3) "*Our supply chain is in a big transition now being a global and fast growing organization."* (Interview 3) *"Structured organization plus infrastructure, these are the biggest things from my point of view, and it also determines the products and services and design that come out of it."* (Interview 3) *"It is necessary to have human resources that actually deal with this topic to really focus on it and overcome those challenges"* (Interview 4)
	Product/ service structure and design	*"We don't do it proactively, we always do it reactively. It would be good to move from the reactive to proactive approach, in which we can decide all we want to monitor from the design. It's not part of the design now."* (Interview 1) *"Every waste we produce is something we've paid for, but we don't use. There are materials, time or resources and capacities we use that can be used more effectively, or in a different way so that they are not wasted."* (Interview 3) *"Once we sell the turbines they become the property of the operators so it's technically not our responsibility anymore to deal with the waste or the product at the end of life so the motivation is of course a bit more limited as if it was our own responsibility."* (Interview 5) *"Of course it's very good to avoid waste, it's good to use less materials. In the end it is all cost driven. It's always a thin line between using too much and using not enough material that can affect the product. And then of course, this is a thread for the product itself and then the cycle is not working anymore because you have to exchange components."* (Interview 5) *"The only hard element to recycle is the blade."* (Interview 5) *"It's challenging to do things right the first time right, according to the needs of the customer and having an organization which is really reflecting the needs of the customers."* (Interview 1) *"Then there is a gap that is not fulfilled regarding the needs and what is provided. If what the customer requires is not delivered there are many problems that arise, because then some things have to be done again and many problems are associated with that."* (Interview 1)
	Infrastructure and technical equipment	*"There are global IT tools and they are developing infrastructure tools, but now we have many problems with that and things that are not working well."* (Interview 1) *"There is a big infrastructure in Europe, but internationally it is not easy. In Chile SAP is not linked, and it's not possible to know what is happening in the turbines in other companies from a material perspective. There are processes already going on, but globalized IT tools are necessary. Networks need to be*

		reinforced, to have a global IT.” (Interview 1) *“At least from my quality thinking if we have a good processes with the organization aligned to it, we can then build the infrastructure around it that's fit for purpose from this just belongs together, but as we're currently in some kind of a post merger situation with a lot of changes in the organization”* (Interview 2) *“Structured organization plus infrastructure, these are the biggest things from my point of view, and it also determines the products and services and design that come out of it.”* (Interview 3)
Opportunities towards CE	External	
	Inter-organizational	*“We are active in industry sector initiatives (...) we are working together with specific companies that are working on the re or down cycle of the blades. And we are also looking into further collaborations with startups for example that try to find solutions for this project for that problem.”* (Interview 2) *“(...) we need other strategic partners to work with. Recycling companies all over the world that can help us with the logistics infrastructure. So I think one of the challenges is to create a network of strategic partners to work on those challenges together*.” (Interview 4)
	Internal	
	Structure and organization	*“What we need, always to have on things is focus. (...) We need an understanding of the problem, having the team together to define how it should look like. What should the circular economy at the company look like? I think this is something that is a really big thing from my point of view.(...) The first thing is being aware of the problem. Knowing this is something we need to take care of. Bringing the understanding into the company I guess is one of the first steps now (...) What the sustainability department is doing is the core where it starts as they are infusing the ideas into the organization. (...) The challenge is here understanding, how this should look like, because this is typically the fight. Maybe the broad pictures are aligned, but when it goes to the details, then the fights begin. That's the first step, but if this is something that can be aligned I'm pretty sure, but then bringing that into play and making that a standard everybody works from now. (...) define how we would like to work, who's doing what and then put it into digital technology like SAP or whatever kind of system we would like to use, because I've seen quite often that we buy technology for a purpose, but we're not thinking it to the ends. We see something we think, is something we need, then it's being implemented and then people start using it and noticing it's actually not what they would like to have. We need to change this behavior first” (*Interview 3) *“not only defining but really making it your day to day business that affects all of us, basically. I think this is the biggest challenge we have because we as humans sometimes tend to step back to old behaviors not for bad intent but because we've learned that it takes effort to change and that's something that is really taking the biggest effort from my daily business. Defining something how it looked. I can give you an example, it took effort, but it was quite fast, but then saying take this definition, make it a standard and implement.* (Interview 3) *We need to have certain structures, procedures, policies in place to make it happen and I wouldn't say they are not but maybe they're not in a way, we can use it instantly now or it's easy to access. I think we really need certain rudimentary and basic processes in place to make it happen and the better this framework grows, the better our circularity ambitions may be reflected in that and we will achieve the targets we would like to see. I think it's all very much linked to each other.* (Interview 3) *Then from an organizational perspective, reinforce the globalization of some*

		engineering aspects that are now more centralized as globalized, as well as reporting activities. There is global support but it has to be reinforced. (Interview 1)
	Infrastructure: Technology - Equipment	"*(...) shared information to know what is happening. There is a lack of transparency and information in the supply chain."* (Interview 1) *"Then there is an IT infrastructure, but it is not totally global, and this is very necessary and has to be reinforced. There are many silo solutions in some countries and this doesn't allow them to work globally."* (Interview 1) *"When you know when you know what the players are delivering you know how much delay you can get. Then you are able to react. When you can closely monitor the part you bued and transport you can react faster."* (Interview 1) *"Data integration network, we can also think about value in supply chain integration vertically and horizontally, and yes, this is something we're striving for, and it is definitely something we need."* (Interview 3) "*(...) define how we would like to work, who's doing what and then put it into digital technology like SAP or whatever kind of system we would like to use, because I've seen quite often that we buy technology for a purpose, but we're not thinking it to the ends. We see something we think, wow this is something we need, then it's being implemented and then people start using it and noticing it's actually not what they would like to have. We need to change this behavior first"*. (Interview 3) *"So we said I'm really coming from the supply chain topic and without having this all on hand what is horizontal versus vertical or supply chain will not be able to succeed."* (Interview 3) *"I would think it is necessary to have more human resources that actually deal with this topic to really focus on it and overcome those challenges and digital infrastructure of course internally is also needed."* (Interview 4)
	Product/service structure and design	*"The feedback of the customer is considered but this has to still be reinforced to improve the design."* (Interview 1) *"There are many qualitative initiatives related to the development and improvement of the product. Many focused on the design of the product, which has to be designed to work for many years."* (Interview 1) *"Either we have the blades that we have currently and find a way to treat them properly, or the other option is to change the blade technology, but that's rather really related to our industry that we change the blade technology. So it's easier to recycle."* (Interview 2) *"I have a very strong product development focus here. We can take materials and ideas from other products. We can take maybe something from somewhere else and put it in our products."* (Interview 3) *"Sure, it's using data, using monitors, generating data and processing this data. All of the information prior to the building of the product, in the simulation moments and data we have we predict how the product will behave within the next year."* (Interview 5)
Possible paths towards circularity	Optimize	*"So considering these aspects, would you say that there is one of these, in which the company is focusing? Yes, optimize."* (Interview 5) *"I think optimizing is crucial. I just think that we are already really good at that. This is something that people work on every day, we are already quite good"* (Interview 4) *"I think that these prediction models are very important for the optimization in regards not to the design, but of the product you have sold already. It is key for optimizing the performance of the product, optimizing the product and his behavior, after you sold it. Then once that the turbine is close to the end of the calculated lifetime we conduct the LTE, possibilities of life time extension, so that you may change some components you ensure that the structure integrity is*

		ensured, and then you can extend the lifetime. This is possible." (Interview 5) *"I think the most important part to talk about is the optimization part. The company is working on the cost of energy and the performance. The company has increased the performance and efficiency of its products immensely over the past years. That's of course a very important point because the carbon intensity and the waste intensity energy intensity, of course, reduce per generated megawatt hour if that efficiency increases. The optimization is focused on the performance of the turbines. Then the company it's also working on reducing the waste and use of materials in general, reducing the use of hazardous materials."* (Interview 2) *"Optimization path may work very well, I mean we're doing this every day as a company with new products, new processes, new structure, new organization and new people, so this is something we can do very, very fast because it's in the DNA of the company."* (Interview 3) *"If all efforts are in the production, and then you put the efforts once and then the product can live for a long time so I would say this is definitely an aspect and elimination of waste and production is definitely something that we are actively working on in the sustainability department so all the sites they need to report on a quarterly basis about waste and their activities to reduce waste."* (Interview 4) *"As I mentioned, it's all about data. Let's say two categories. so, it's during the design phase and by selecting the right measures. So, prediction and calculation models about how products would behave in this specific area. I also think design, so very important. There is a lot of potential to improve, also on the feedback from the legacy feed, and as well prediction models for turbines or products which are started already based on the exit data the product is generating. We take data and try to know how the product will perform in the future."* (Interview 5)
	Loop	*"We need to use more secondary materials or also refurbished materials."* (Interview 4) *"Recycling has been identified as important. So that's already good and it's all included in our new sustainability strategy to have a fully recyclable blade by 2032. So, this already shows that the company is willing to allocate some resources on that."* (Interview 2)
	Share	*"Incentives focused on the design of the product, which has to be designed to work for many years."* (Interview 1) *"Our engineers are working really hard to create or design products that can live or that can be used for a really long time."* (Interview 4)
	Exchange	*"There is a lot going on in service for the exchange of the components, there are predictive maintenance systems using almost artificial intelligence, like digitalized or software to predict when to exchange components. I think this is also really helpful not to have a standardized interval, but to actually see when a component will fail, so that it needs to be exchanged."* (Interview 4)
DDT	IoT	*"(...) tracking materials would be quite helpful, because often when it comes to recycling then the recycling companies need to know what is actually what materials are actually in the components so is it made of steel or plastics, or whatever so tracking those materials would also be quite helpful, having like a product passport."* (Interview 4) *"(...) internet of things. We are gathering all data from the product, we are processing that and trying to gain information, out of the processed data and out of this information, take actions for example regarding maintenance on demand, maintenance activities. That's the main task of the global service organization."* (Interview 4)

		"In service we work a lot with data. We do a lot of preventive analysis using monitoring systems, we do monitoring of the lifetime, consumption, and many parameters." (Interview 4) *"What we could start off as of today and we're currently doing is Internet of Things, I think it's something you can introduce quite well. I am a big fan of of blockchain topics, especially for quality, they super interesting, but we at the moment are not ready for that, as long as we don't have the process we can't apply these kind of great solutions."* (Interview 2) *"This is part of the Internet of things. IoT is everything. It is the basis to generate data to supervise our assets, but generating data and supervising based on thresholds of data but the more complex systems behind or interfering with this data are the prediction models. Then we use statistics programs like R."* (Interview 5)
	Horizontal/ Vertical system integration	*"(...) shared information to know what is happening. There is lack of transparency and information in the supply chain."* (Interview 5) *"Horizontal and vertical system integration. When you know when you know what the players are delivering you know how much delay you can get. Then you are able to react."* (Interview 5) *"Data integration network, we can also think about value in supply chain integration vertically and horizontally, and yes, this is something we're striving for, and it is definitely something we need."* (Interview 3)
	Blockchain	*"I am a big fan of blockchain topics, especially for quality, they super interesting, but we at the moment are not ready for that. As long as we don't have the process we can't apply these kinds of great solutions"* (Interview 3)
SCA	Rare	*"I would also say I'm a little bit skeptical on this point, because maybe our competitors are doing it extremely well. We simply don't want to recognize it, so it's a very interesting and difficult question, but I would say yes we would be able to do that."* (Interview 3)
	Inimitable	*"I can see the other way around our competitors, a little bit farther than us on this now. At least, it feels like the way they are selling it. I don't know how far they really are, but they are good at selling it and, considering it from that perspective I would say it's difficult to imitate, because the products, the same they may look like, they are different in the details, you know, maybe we can copy one or the other thing and we can imitate, but in the end it's a technology and it needs to be considered as one system, generating energy from wind and this whole system what works in the details differently, so I guess it's it's difficult to imitate because, the technology is slightly different and the way we set up our supply chain may follow standards that that we do the same as our competitors do, but I think there's a typical typical things we just to the company as usual, because our organization our people, we have specifics. Some parts can be imitated but in general, but I guess it's difficult to imitate."* (Interview 3) *"The only competitor I know of that has a dedicated circular economy strategy is Vestas, or at least that they have published that, and to exceed this would be quite difficult. It was nominated the most sustainable company in the world and exceeding that would be difficult. I am afraid within the same industry, it would be quite difficult to completely differentiate, we would need to come up with a really special solution. That's also one of the challenges, or makes it a bit special in this industry because our wind farms also have turbines from other companies, we even buy blades from other companies. So it is not only the company and it would be quite difficult to have a specific solution for the circularity because we would also need to deal with other products from other competitors. If they develop something we will benefit from it as well and if we do something, they will benefit so I think that is something particular about this*

		industry that we are kind of working together.” (Interview 4)
	Resources and capabilities	*“Regarding the capabilities, I think it's the expert knowledge of our engineers and the expertise that the company has.”* (Interview 2) *“The people, the company has a strong focus on people and change. It's a company that's very good at changing. People are used to finding solutions quickly, I think this is the most valuable resource. People that are flexible in adapting and changing quickly on all levels, this is what makes us different to our direct competitors.”* (Interview 3) *“I'm afraid we're not a lot different or at least don't have more competencies than our competitors so of course we have strong sustainability department, some human resources that work on this and also in close collaboration with engineering for example there we also have a lot of people who are motivated and know the issue. I can also say that we already considered those aspects like sustainability circularity recycling in the design phase of the product design. This is something new.”* (Interview 4) *“A5: Despite they maybe not really differ from other companies, would you highlight something as specific of the company? B5: Our prediction models. These are quite developed in the company.”* (Interview 5)

Appendix 3. Themes and categories for data analysis used in MAXQDA Analytics Pro 2022 Software

- **Codesystem**
  - Relevance of CE
    - Economic dimension
    - Environmental dimension
    - Relevance for the company
    - Relevance for the industry
    - Political dimension
    - Social dimension
  - ReSOLVE model
    - Exchange
    - Virtualize
    - Loop
    - Optimize
    - Share
    - Regenerate
  - External challenges for CE
    - Inter-organizational relations
    - Financial
    - Social and political
  - Internal challenges for CE
    - Infrastructure within the company
    - Product/service structure and design
    - Financial
    - Structure and organization
  - External opportunities for CE
    - Inter-organizational relations
    - Financial
    - Social and political
  - Internal opportunities for CE
    - Infrastructure within the company.
    - Product/service structure and design
    - Finances
    - Structure and organization
  - Digital data technologies
    - Additive manufacturing
    - Autonomous robots
    - Augmented reality
    - Simulation
    - Horizontal/Vertical system integrati...
    - Blockchain
    - Cybersecurity
    - Cloud technologies
    - Big data technologies
    - IoT
  - Sustainable competitive advantage
    - Resources and capabilities
    - Organized
    - Inimitable
    - Rare
    - Valuable
- **Sets**