Circular Business Models in the Aerospace Sector

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Abstract

This thesis looks at the role that Circular Business Models (CBM) play in the development of a Circular Economy (CE) strategy in the aerospace sector. Currently, a transition from a traditional, linear economy to a CE is promoted by the EU and national governments. This thesis contributes to solving the many managerial issues or barriers when making that transition.

Using literature review and semi-structured interviews, this case study on Airbus Netherlands discovered that the term CE is badly defined. This causes confusion and misunderstandings when discussing the concept of a CE. Therefore, properly defining a CE should be the foundation of developing a CE strategy. When analyzing the current CBM frameworks, the most well-known are the ReSOLVE and loops framework.

The results further indicate that important barriers regarding the implementation of CBMs are technological and monetary challenges. On the other hand, implementing CBMs can have a positive effect on the reputation of the company and increase the chance of sustaining a supply chain. The best CBM strategies involve both a short- and long-term plan that focuses on where the aerospace sector, and Airbus Netherlands specifically can make the most changes like changing designs, swapping materials for less environmentally damaging ones and increase the recyclability of components. The interviews confirm issues found in the literature regarding the definitions and the barriers to implementing CBMs. In conclusion, it is evident that only by the combination of factors like regulations, proper definitions, internal motivation, financial feasibilities and technological developments, CBMs will be able to play a successful role in the developing of a CE strategy for the aerospace sector.

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List of Abbreviations

BMC – Business Model Canvas
CE – Circular Economy
CBM – Circular Business Model
CBMF – Circular Business Model Framework
CORSIA – Carbon Offsetting and Reduction Scheme for International Aviation
CSPS – Circular Smart Production System
CRC – Carbon Removal Credits
CRM – Critical Raw Materials
EC – European Commission
EoL – End of Life
ETS – Emission Trading System
EU – European Union
GHG – Green House Gas
IE – Industrial Ecology
LDE – Leiden Delft Erasmus
MRO – Maintenance, Repair & Overhaul
PaaS – Product as a Service
PLE – Product Life Extension
SAF – Sustainable Aviation Fuels
SDG – Sustainable Development Goals
SRQ – Sub Research Question
WWF – Word Wide Fund for Nature

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1 Introduction

1.1 Problem Statement

The current economy is a mostly linear one. Business models, which describe how a company is planning to make a profit, are mostly focused on taking resources and discarding them after they are no longer useful. Unfortunately, that approach is no longer possible. The effects of climate change due to human action become increasingly visible, and there is an increasing need and demand from society to make changes (Stein & Castermans, 2017).

In 2009, the concept of 'planetary boundaries' was created and described by Rockström et al. (2009). This concept describes 9 categories, such as climate change and biodiversity loss. When these boundaries are transgressed, there is an increasing chance irreversible effects on the earth. According to the latest update, we have crossed six of them, and are reaching the thresholds for the remaining three (Stockholm Resilience Centre, 2023). Thus, there is a large societal need to find solutions for this problem.

One of these solutions is transitioning from a linear economy to a Circular Economy (CE) on a national and international level. Though it is important to note that there is still a debate on its exact definition (Geissdoerfer et al., 2017). The lack of a standardized definition leads to a constant reinventing of the wheel, instead of building on earlier research and further develop the scientific area (Desing et al., 2020). CE is often brought in connection to the field of Industrial Ecology (IE) and is thus often researched with that perspective in mind (Rodrigues Dias et al., 2022). With CE as a new economic system, new business models like the Circular Business Models (CBM) are needed to help companies to increase their sustainability and circularity (Geissdoerfer et al., 2020). This leads to an important managerial challenge regarding changing and rethinking the way business is done. Franzò et al. (2021) claim that this process differs per corporation and case studies can be used to obtain more information about that process.

This leads to a new set of problems: companies that want to move to a more sustainable or circular way of business operation run into a wall of different opinions on how to achieve that.

1.2 Research gap

Multiple articles and reports have been written about CBMs and which one would be best for what kind of situation. There is still little known about the practical application of CBMs in companies, which is why case studies are needed to increase and broaden the understanding of the application of CBMs in practice (Geissdoerfer et al., 2020). This research aims to fill this gap and use the case study of Airbus Netherlands to analyze how CBMs can play a role in developing CE strategies. Additionally, this thesis will contribute to the scientific body by applying something that has been researched before, i.e. circular economy, to a new sector, i.e. the aerospace sector.

1.3 Research questions and scope

To address the research gap identified in the section above, this thesis aims to look at CBM frameworks (CBMFs) that are currently in practice and what could hinder the implementation of CBMs in practice by using a real company as a case study. The main research question to be addressed in this research is defined as: *What role do Circular Business Models play in developing a Circular Economy strategy in the aerospace sector?*

This main research question was broken up into three sub research questions (SRQ) which are listed below:

- *SRQ1: What Circular Business Model frameworks are in current use?*
- *SRQ2: What are the drivers and barriers for companies adopting Circular Business Models?*
- *SRQ3: Which Circular Business Models are best suited for future scenarios?*

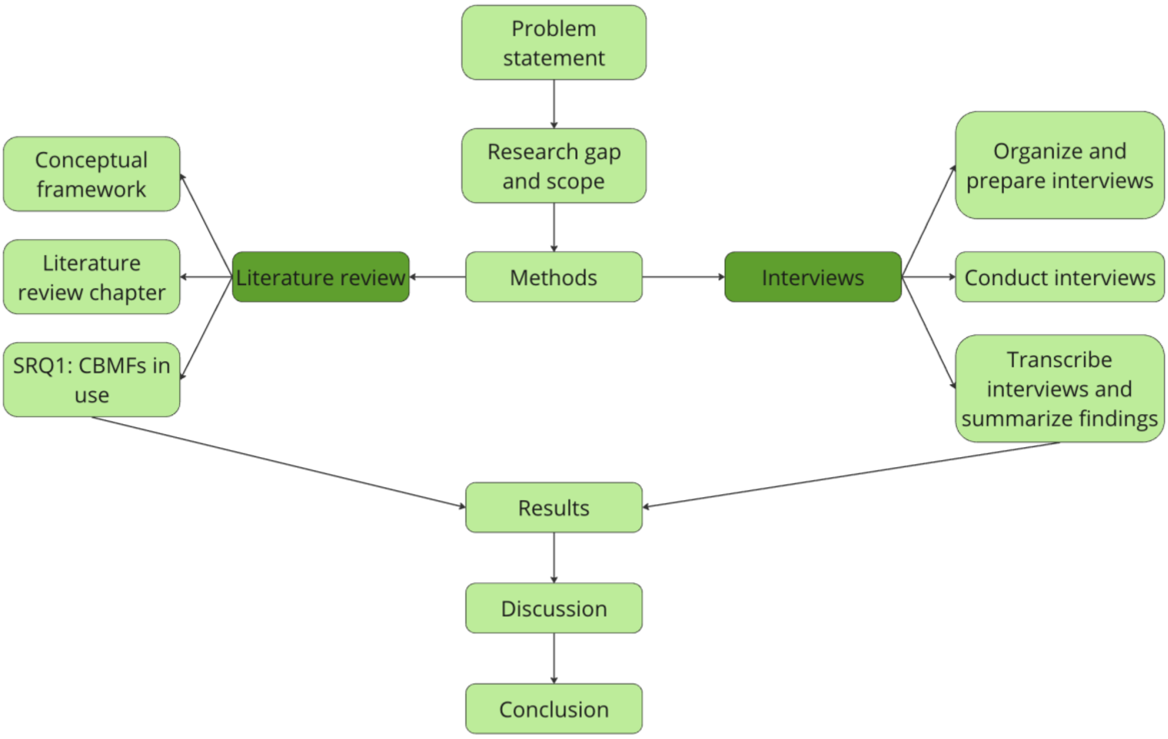
This thesis was written as part of the Leiden Delft Erasmus (LDE) thesis lab ‘Circulaerospace’, in collaboration with Airbus. The main research question takes the entire aerospace sector into consideration, and to help answer this research question, the case study of Airbus Netherlands will be used. Airbus Netherlands mostly focuses on space and military aspects of the aviation sector. Chapter 3, the conceptual framework, was limited to the Circular Economy and Circular Business Models as they are at the core of answering the research question, though there are many more concepts with unclear definitions such as sustainability. This thesis will not investigate human rights related to the obtaining of materials used in the aerospace sector or the details of the finances in the sector, nor will it go into depth about specific systems or products used or created in the sector. Instead, it will take into consideration the aviation sector, the Maintenance, Repair & Overhaul (MRO) and their influence on CBMs.

1.4 Outline of thesis

This thesis will begin with a literature review on the regulations regarding the aerospace sector in the European Union (EU), as well as Airbus’ current sustainability approach and plans. Next, a more in-depth analysis will be provided on the CE and its definition. In the method section, the methods that are used in this thesis, literature review and semi-structured interviews, will be introduced and explained. This will be followed by the results section, the discussion and the conclusion.

Below, the research framework for this thesis can be seen in figure 1. It shows how the two different methods, the literature review and the interviews are combined in the result section of this thesis. Additionally, it also shows the parts of this thesis that were based on the literature review.

Figure 1: The research framework



2 Literature review

2.1 EU regulations for the aerospace sector

When talking about sustainability, the United Nations Sustainable Development Goals (SDG) are often mentioned. These goals focus on reducing poverty, increasing equality, and to improve nature and the environment. There are seventeen goals which are used as a foundation for many companies and institutions to base their sustainability, but also social programs on (UNDP, n.d.). An example of a target related to the SDGs, is to completely eradicate hunger and poverty from the world by 2030 (United Nations, n.d.).

Policies that stimulate circularity and sustainable practices, will often reference the SDG. The EU is another example of a regulatory and political body that has implemented sustainability regulations. Though many of the regulations are not sector specific, there are also specific regulations and goals for sectors such as the aerospace sector. Below, an overview will be provided of the largest policies. This will be followed by a section about the sustainability measures that Airbus has taken already. These sections are not complete: there are many more regulations, assessments, goals and plans available, but this section provides a general overview of the most relevant ones in the context of this thesis.

Sustainability is taking an important place in current EU policies. In table 1 below, an overview is given of some of the relevant policies from the EU for the aviation sector. It is important to note that, due to the number of policies and laws created, updated, and adapted, this is not a final list and is subject to future developments. Below, a short explanation of these laws and policies will be provided.

The European Green Deal is a collective of goals and measures designed by the European Commission (EC) which aims for a climate neutral EU by 2050 (European Commission, 2024). The Green Deal is an overarching list of multiple different laws and policies, some of them will be listed below. In table 1, an asterisk (*) after the name of the policy will indicate that it is a part of the European Green Deal.

The European Climate Law is one of the first laws from the Green Deal discussed above which makes the climate naturality a binding commitment for member states (European Commission, 2024). More specifically, it requires a 55% reduction in emissions in 2030 compared to 1990, to make sure that the climate neutrality goals can be achieved in 2050 (European Commission, n.d.-e).

The Climate Target Plan adapts the original target for Greenhouse Gas (GHG) emission reduction to the one also dictated by the European Climate Law. Originally, the plan was to achieve a 40% reduction in 2030 compared to 1990 levels. The Climate Target Plan increases that to 55% reduction in 2030 compared to 1990 levels. The ‘Fit for 55’ package of regulations that will be explained below, should make these higher goals achievable (Jensen, 2020).

As mentioned above, the ‘Fit for 55’ is a package of different regulations that aims to achieve the targets of the European Climate Law as defined by the Climate Target Plan. This package includes legislation on CO2 standards, a reform of the EU Emissions Trading System (ETS), and renewable energy (European Commission, n.d.-d).

The Green Deal Industrial Plan is part of the European Green Deal, but with a focus on European industry and how they can achieve climate neutrality. Technological developments take a large role and should be increased to achieve net-zero energy supply and products (European Commission, 2023a).

Circular Economy Action Plan aims to stimulate circular options for products in the EU. This is done by stimulating the rethinking and redesigning of products to improve circularity during the entire lifecycle (European Commission, n.d.-a). Additionally, it aims to lengthen the lifetime of products and promoting products-as-a-service (PaaS), for example subscription-based products (European Commission, 2020).

The EU ETS contains the regulations regarding the carbon cap and how the carbon emission allowances can be bought through auction. Additionally, it allows for trading in these allowances between companies if one company has a surplus, or another has more emissions than its allowances permit. The cap will be continuously lowered while the scope of the system is broadened. The cap is referenced to the latest sustainability goals of the EU, most recently the ‘Fit for 55’ regulations (European Central Bank, 2021). It is important to be aware that 66% of the aviation related emissions are non-CO_2. In the future, aviation companies will be required to monitor and report their non-CO_2 emissions which might lead to an extension of this system (European Commission, 2023b).

The Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) is an amendment to the aviation rules connected to the EU ETS described above. It dictates that due to the Covid-19 pandemic, the baseline for the maximum allowed carbon credits has been changed to 2019, instead of 2019-2020. This allows for airlines to have a higher baseline than if the reduced flight numbers during the pandemic had been used. The EU does not expect offsetting to be required until 2024 after the aviation sector has made a full recovery from the pandemic (European Commission, 2021).

The ReFuelEu Aviation focuses on the increased use of Sustainable Aviation Fuel (SAF) by airlines. It is part of the ‘Fit for 55’ legislation package mentioned above. One of the goals is to increase the share of SAF to 70% in 2050 at EU airports. Also, the act of ‘tankering’ should be reduced by limiting the amount of fuel taken aboard to the required amount for the flight, which will also reduce the emissions related to surplus fuel. Tankering is the principle of taking more fuel aboard ahead of time so you will not need to refuel with SAF. Finally, this rule is supposed to make sure that EU airports have the infrastructure available for the use of SAF (European Commission, 2023b).

Table 1: An overview of EU Regulations

Name	Date	Source	Short description
European Green Deal*	2019	European Commission (2024)	Climate neutrality for the EU in 2050.
European Climate Law*	2021	European Commission (n.d.-e)	55% less GHG emissions in 2030 compared to 1990.
Climate Target Plan*	2021	Jensen (2020)	This plan increases the goal for emissions reduction from 40 to 55% in 2030, compared to 1990 levels. The 'Fit for 55' package should accomplish this goal.
Fit for 55*	2021	European Commission (n.d.-d) European Commission (n.d.-b)	Package of legislation to reach the goals of the European Climate Law.
Green Deal Industrial Plan*	2023	European Commission (2023a)	This plan includes faster access to funding needed to achieve the climate goals, legislation that simplifies the regulations for sustainable businesses and overall create a more optimal environment for the industry to achieve the net-zero in 2050 goal.
Circular Economy Action Plan	2020	European Commission (n.d.-a)	Both legislative and non-legislative measures to stimulate circularity in product lifecycles.
EU ETS*	2005 (first version)	European Commission (2015); European Commission (2023c)	The Emission Trading System describes how Carbon emission allowances can be bought and traded with other aircraft operators to stay within the carbon cap.
CORSIA	2019	European Commission (2021)	The CORSIA regulation dictates that carbon emissions above certain limit should be offset for EU-based airlines. This limit is lowered over time.
ReFuelEU Aviation*	2023	European Commission (2023b)	This law focuses on the increased use of SAF.

*= part of the European Green Deal

2.2 Airbus and sustainability

Airbus currently has listed on their website many ways in which they claim to be contributing to a more sustainable aviation sector. These initiatives are used by Airbus to achieve these desired future scenarios. For instance, a charity founded by the Word Wide Fund for Nature (WWF), the CDP, the United Nations Global Compact and others provide guidelines for the aviation sector to accomplish reductions scenarios of net zero (Science Based Targets, n.d.).

Additionally, Airbus has established specific goals for three different scopes and their emissions. The three scopes are defined as follows: the first scope accounts for the direct emissions, in Airbus' case the emissions of the production processes. The second scope accounts for the emissions associated with the production of energy that is purchased by the company. Scope 3 focuses on emissions that are associated with the up- and downstream parts of the value chain, for instance the use of the airplanes (Herth & Blok, 2022).

For scopes 1 and 2, the goal is to reduce all emissions with 63% in 2030, when taking 2015 as the baseline. For scope 3, Airbus wants to reduce the CO_2 emissions by 46% in 2035 compared to 2015 (Airbus, n.d.-b).

Another objective listed by Airbus on their website, is that they want to be net zero in their carbon emissions in 2050 compared to 1990. They claim that they have already achieved a 50% reduction and are looking mostly at SAF and new aircraft technologies to reduce the other 50% (Airbus, n.d.-a). It is important to know that this objective only looks at CO_2 emissions, and not at all emissions created by Airbus.

Airbus has created a climate action plan which contains multiple elements to accomplish decarbonization. Besides the earlier mentioned SAF and the fleet renewal with better technologies, this includes optimizing aircraft operations, discovering new technologies that allow for carbon free flying like hydrogen engines and contributing to research on emissions besides CO_2 that are emitted during the use phase of a plane. The final element they mention is the purchasing of Carbon Removal Credits (CRC) (Airbus, n.d.-a).

In 2019, the CTOs of seven major aviation manufacturers signed a document showing their commitment to making the industry more sustainable by achieving 50% CO_2 reduction in 2050 compared to 2005 levels. They define three elements that are crucial to achieving that: aircraft and engine design and development, the development of sustainable alternate aviation fuels and the 'third generation' of aviation. This 'third generation' refers to an overhaul of all technologies, mechanical elements and designs used in aviation, as well as the use of digitalization and artificial intelligence (Vittadini et al., 2019).

An Ethics, Compliance and Sustainability Committee (ECSC) was established in 2020 to oversee the sustainability strategy of the company (CDP, 2022). Additionally, Airbus is ISO 14001: 2015 certified (DNV Business Assurance, 2023).

In their 2022 yearly non-financial report, Airbus lists their commitment to the development of a CE model (Airbus, 2022). This model contains elements such as: Avoid, Reduce, Repairability/Reuse/Second life and Recycling. Examples of measures taken include using 3D printing techniques to reduce the number of materials needed, or the reduction of waste. Furthermore, the conversion of passenger to freighter planes allows for a longer use phase of a plane.

Airbus is a global company with subdivisions in many different countries, for instance in the Netherlands. Airbus Netherlands, the case study for this thesis, focuses on projects mainly in the space and military. Examples of products they make are solar arrays, instruments for monitoring from space and training systems for defense aircrafts. These products have a much lower production number than the airplanes Airbus is most known for and are customized according to the requirements (Airbus Netherlands, n.d.).

3 Conceptual framework

There is, both in scientific literature and in practice, no consensus on a definition of the concept 'Circular Economy'. Therefore, it is important to establish what definition is being used; to know in which contexts the results of this study should be placed. Below, multiple influential scientific articles that define a CE, are discussed. This section of the thesis shows that there are disagreements on the definition of a term that inspires a lot of research. As one of the articles describes themselves, it is important to agree on one single definition, so that future research can build on existing research, rather than trying to reinvent the wheel every time (Geissdoerfer et al., 2017). The EU has attempted to create some form of standardization regarding the term 'sustainability' through the EU taxonomy for sustainable activities, there is no clear definition provided. There is no such taxonomy yet for circularity or CE (European Commission, n.d.-c). CBMs are also discussed, since they are closely related to the concept of a CE.

3.1 Circular Economy

Circular Economy is a concept that has attracted more attention of the last few years with it now being the primary goal of the Dutch government to achieve in 2050 (Rijksoverheid, n.d.). However, there is much discussion on what a 'Circular Economy' is as there are more than a hundred definitions available in literature (Geissdoerfer et al., 2017). This confirmed by Kirchherr et al. (2017), who discuss in their article 114 definitions of CE.

According to Geissdoerfer et al. (2017), the concept of CE was first introduced late last century by Pearce & Turner (1989). They also claim that the most well-known definition of CE was created by the Ellen McArthur Foundation, namely: "an industrial economy that is restorative by intention and design" (2013, p. 14). In their article they define CE as follows: "a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling." (Geissdoerfer et al., 2017, p. 759).

In their review article, Kirchherr et al. (2017) claim that the different definitions can be attributed to the different stakeholders involved in CE, a concept with such high levels of attention. They are worried that those differing definitions can lead to vagueness about the concept and that might lead to a reduction in use and attention as they have seen before with the concept of sustainable development.

Kirchherr et al. (2017, pp. 224–225) define CE as follows: "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 operating 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." The authors stress in their paper that it is crucial to them to include the time reference, to make sure that CE is seen as a long-term commitment and not something that will quickly lead to results, since this might deter companies or civilians (Kirchherr et al., 2017). Furthermore, they reference the definition of CE as described by Ellen MacArthur Foundation (2013) as the most used one in their literature sample, the definition that Geissdoerfer et al. (2017) also considers to be the most well-known.

The third article which will be discussed is the one by Bocken et al. (2016). Though this article does not give a set definition in a single sentence, it describes multiple elements a CE should contain. For instance, the term ‘cradle-to-cradle’, considering the planet as a system and the generation of profit through the flows of materials over a longer period. Furthermore, they discuss how the terminology used to describe CE has been diverging, instead of converging with it synonymously used for closed loop (Bocken et al., 2016).

Korhonen et al. (2018, p. 39) describe CE as follows: “Circular economy is an economy constructed from societal production-consumption systems that maximizes the service produced from the linear nature-society-nature material and energy throughput flow. This is done by using cyclical materials flows, renewable energy sources and cascading-type energy flows. Successful circular economy contributes to all the three dimensions of sustainable development. Circular economy limits the throughput flow to a level that nature tolerates and utilises ecosystem cycles in economic cycles by respecting their natural reproduction rates.”.

They create this definition from a sustainable development point of view, with the three dimensions as a foundation: economical, environmental, and social. Furthermore, they describe how the CE should focus on capturing the highest economic value possible for resources by extending the current business systems. This should be done to achieve what they consider to be the environmental purpose of CE, to reduce the use of virgin materials for production and consumption, energy use, and waste production. The economic objective is to reduce cost and stimulate innovation. Finally, the social objective is the creation of a sharing-economy where cooperation and community are above the individual consumer (Korhonen et al., 2018).

Some authors consider CE not to be an entire new economic system, but rather a new business model or a “sustainability pattern” (Ghisellini et al., 2016, p. 12). The authors do not provide a clear definition of CE, but as with the article by Bocken et al. (2016), provide elements or components of what a CE is. They do provide a clear definition on other things however, such as the Chinese CE laws and the concepts of Reuse and Recycle (Ghisellini et al., 2016). Different ways Ghisellini et al. (2016, p. 18) describe CE include: “CE may rather be considered a way to design an economic pattern aimed at increased efficiency of production (and consumption), by means of appropriate use, reuse and exchange of resources, and do more with less.”, and “waste at the end of their life should be released to the industrial food web, both as material and energy flows” (Ghisellini et al., 2016, p. 25). They also give a warning, that in current CE discourse, recycling seems to be prioritized over reuse. They stress the importance of the other elements of the 3R strategy and provide the Netherlands as an example of a country that has high recycling rates, but also struggles to move to a CE. Additionally, they claim that CE cannot be combined with a growth-oriented economic system due to the rebound effect and market mechanisms but should be combined with a steady-state oriented economic system instead (Ghisellini et al., 2016).

In different articles assessed above, R frameworks are described as an essential part of CE. There are multiple variations, the simplest one is the 3R version with Reduce, Reuse, and Recycle as mentioned in Ghisellini et al. (2016). Geissdoerfer et al. (2017) describe in their definition 5 different Rs, they add Repair, Remanufacturing and Refurbishing but do not mention Reduce. A 4R version, which adds Recover, is also mentioned by Kirchherr et al. (2017), who acknowledge that there are many different versions of the R frameworks such as the 3R, 4R, 6R and 9R versions. The 3R framework can be extended into a 9R framework described by van Buren et al. (2016).

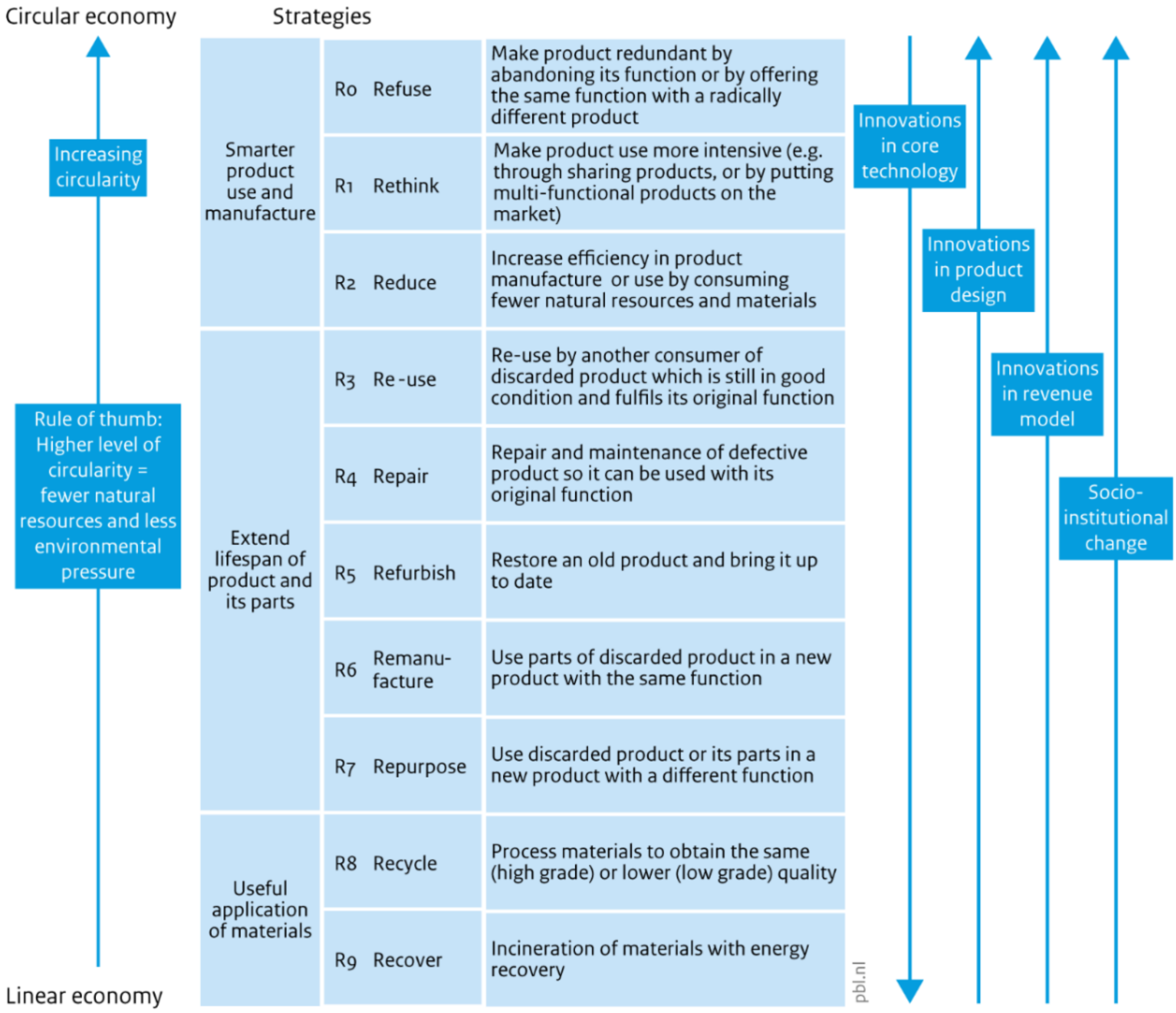
The Dutch government currently uses a 10R strategy which is written out in a report by Potting et al. (2017), which is visible below in Figure 2. It shows the ten different Rs, with the most circular one, Refuse, listed on top with the lowest number R0. It ends with R9 Recover, which is the least circular option. The Rs are ranked based on the amount of value retention and resource saving. Reusing (R3) a product without making changes to it, requires less resources than Remanufacturing (R6) it into something else. When you get to the lower part of the circularity ladder, from R7-R9 in figure 2, you will need a replacement for the original part since its original function can no longer be performed by that product.

It is important to note that R frameworks that consist of more than three elements, are expansions of the 3R framework but the ideas behind it do not change.

This chapter shows the many different definitions that a CE has, and thus the importance of knowing what definitions the authors of a paper use when writing academic articles about the topic. Having different understandings of the term can easily allow for miscommunication and hinder the scientific discourse to further develop this field of knowledge. Additionally, with the different definitions for CE, there is also a high risk for the perception of greenwashing if there is disagreement about what makes a CE. For this thesis, a CE is defined according to the definition provided by Kirchherr et al. (2017), as this is the most complete definition, though its length makes it not the easiest for daily use. For ease of reading this definition is repeated below:

A CE is: “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 operating 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.”(Kirchherr et al., 2017, pp. 224–225)

Figure 2: The 10R framework according to Potting et al. (2017)



3.2 Circular Business Models

Where a linear economy has business models, a CE has CBMs. CBMs are “business models that enable systems that are regenerative by nature” (Salvador et al., 2020, p. 1). Just as with business models for companies in a linear economy, there are many different variations of CBMs depending on the type of company it belongs to. In this thesis, a CBM is a business model that works towards a CE according to the definition of Kirchherr et al. (2017).

4 Methods

4.1 Framework chapter

In this thesis, the concept of CE is used, one that does not have a standardized definition (Geissdoerfer et al., 2017). Therefore, literature review was used to collect definitions from journal articles. Multiple definitions from literature are provided, after which the definition of the concept for this thesis has been given. Mostly peer-reviewed articles are used, except for cases in which the articles themselves reference a non-academic source, as done by Geissdoerfer et al. (2017), who reference Ellen MacArthur Foundation (2013) when defining CE.

To define a CE in chapter 3 earlier in this thesis, the following methodology was used. In the Web of Science and Scopus databases the concept was searched using search words described below in table 2. The search words were applied to the title, keywords and abstract. The results were ordered by the number of citations with the publications with the highest number of citations listed above. This was done to find the most influential publications, regardless of their publication date or document type. For the concept, the top 5 results that provided a definition were chosen for both databases, which can be found in the table as well. If there was overlap in the results, the duplicates were removed from the list. Additionally, before selecting the document for further research, the abstract was checked to see if it was relevant to this study. If that was deemed not the case, the next best alternative was selected. The downside of this selection method is that newer publications, who have not had the chance yet to be cited much, are not taken into consideration. Furthermore, snowballing was used to supplement the literature, by adding publications that were mentioned in the chosen articles.

Table 2: The search key words for CE

Concept	Search key words	Chosen literature from databases
Circular Economy	"Circular Econom*"	Bocken et al. (2016); Geissdoerfer et al. (2017); Ghisellini et al. (2016); Kirchherr et al. (2017); Korhonen et al. (2018)

4.2 CBM Frameworks in current use

Regarding the CBMF in current use, articles from the literature review chapter were used as a foundation. Through snowballing and expanding the search using the key words used in chapter 3, more literature could be located. Additionally, a specific paper was recommended by one of the supervisors for this project which was then used as well (Geissdoerfer et al., 2020). Since this sub question focuses on current use, results were filtered based on year of publication, choosing 2020-2024.

The search was expanded by using the search terms "Circular Business Model* Framework", which yielded 1 and 2 articles in Web of Science and Scopus respectively of which 2 unique results.

Another search term was used: "Circular Business Model*" AND Framework AND aerospace. The same temporal filter was chosen. This resulted in 2 more unique results.

Finally, the search term “Circular Business Model*” AND Framework, was used again, with the temporal filter with the purpose of finding articles that are connected to the case study of this thesis, Airbus Netherlands or the aerospace sector in general. This was assessed by reading the abstract. There were few articles that matched the criteria, but those were used in section 5.1.

4.3 Interviews

For this research, semi-structured interviews were conducted with academic experts and people working in the aerospace sector. In total, five interviews were conducted. Two interviewees were found through the LDE thesis lab, the other three through the first supervisor and then through snowballing. All interviewees are working in the industry or doing research on the topic of circularity and sustainability in the aerospace sector. This method of finding interviewees has both up- and downsides. It provides interviewees with relevant knowledge, but potentially who are all in the same ‘bubble’ and thus not providing a balanced overview. The interviews lasted around 45 minutes and were mostly held online due to geographical constraints. The interviews were recorded and transcribed with the use of software imbedded in Microsoft Teams. These interviews will provide necessary knowledge from inside the industry, or from researchers who are familiar with this area of research. The questions that were asked in the interviews can be found in table 5.

5 Results

The results of the research executed according to the methodology described in chapter 4, will be discussed in this section. This section is structured around the SRQ's for clarity.

5.1 CBM frameworks in current use, literature analysis results

For this section, a CBMF is defined as an overarching framework that consists of concepts or ideas that themselves could be described in a CBM. Thus, this section will not list individual CBMs, but CBMs evolve from these CBMFs. Examples of CBMs that are connected to the CBMF are provided.

Geissdoerfer, Morioka, et al. (2018) describe in their paper a framework that discusses five different loops to achieve a more circular supply chain. These are: dematerializing loops, intensifying loops, slowing loops, narrowing loops and closing loops. These loops focus on the use and EoL phase by encouraging the reduction of materials required (dematerializing loops), increasing the intensity in the use phase but also prolonging it (intensifying and slowing loops), increasing the efficiency of the product (narrowing loops) and recycling the materials at the EoL (closing loops). These elements are discussed in another paper by the some of the same authors, but the slowing, narrowing and closing loops are replaced by extending and cycling (Geissdoerfer et al., 2020). Geissdoerfer, Vladimirova, et al. (2018) again describe the five loops as the essential pathway to a CE.

Bocken et al. (2016) describe a similar framework, but with only three loops, excluding the dematerialization and intensifying loops. They envision the loops as a method to stimulate the reuse of materials and extend the lifetime of products. At the EoL, recycling closes the loop from old to new resources. Furthermore, they stress the importance of incorporating the loops at an early stage of design processes of products, to make sure the products follow circular principles.

CBMs that are related to the loop framework focus on extending the lifetime of products and on providing services to consumers (such as car or tool sharing) instead of selling physical products. Merli et al. (2018) also mention the loop framework, but only discuss the slowing loop and closing loop.

A second framework is called Circular Smart Production System (CSPS) (Nascimento et al., 2019). This framework focuses on CBMs in a manufacturing industry and discusses circular approaches to waste and the production using 3D printing to reduce production waste. Using the newest technological developments, they attempted to achieve a CE. Additionally, the separation of waste streams is very important to increase the recycling possibilities.

Lewandowski (2016) describes the ReSOLVE framework, which aims to Regenerate, Share, Optimize, Loop, Virtualize and Exchange. Though this framework is originally described by the Ellen MacArthur Foundation (2015), it is also mentioned by Merli et al. (2018) in their paper. This framework has aspects of the first CBMF mentioned in this chapter, the closing and narrowing down of loops. Within these CBMF, CBMs such as the sharing of products, production on demand, remanufacturing and dematerialization of services are included. They also describe the Business Model Canvas (BMC) that was designed by Osterwalder & Pigneur (2010). The BMC can be used to conceptualize CBMs, not just traditional business models (Lewandowski, 2016).

Geissdoerfer et al. (2020) have created in their article an overview of CBM reference models, they list five different publications, including the aforementioned Lewandowski (2016) that use the BMC as a starting point. Similarly, they list three different publications that discuss variations of the loop framework. Two of those are described earlier in this chapter, Bocken et al. (2016) and Geissdoerfer, Morioka, et al. (2018).

When looking at the aerospace sector, there are few papers that discuss CBMs, CBMFs, or CE strategies. Those who do are mentioned below.

Leonard & Williams (2023) look at CBMs as a solution to space debris, and the increasing chance of a Kessler-style collision event. Additionally, CBMs that focus on in-orbit servicing, which are performing actions like repairing or refueling whilst in-orbit, aim to extend lifetimes of satellites and prevent orbital debris.

Rodrigues Dias et al. (2022) describe the loop system, without referencing the loops itself. They discuss maintaining products to keep them in circulation for the longest possible time to maintain and recreate value. Additionally, they mention closing material cycles. Their focus, however, is on the ReSOLVE framework described above.

5.2 Drivers and barriers for companies adopting CBMs, interview results

There are many different drivers and barriers for companies who are looking to adopt CBMs. In this section, an overview of some drivers and barriers that were found in literature will be provided. These lists are not exhaustive, instead they function to provide a general overview of what can be found in literature.

The tables with drivers and barriers from literature are listed first, followed by a table that contains the summarized results of the interviews that were held with academic experts and people working in the aerospace sector.

Below, table 3 provides an overview of the drivers that companies experience when looking to adopt a CBM.

Table 3: The drivers for companies in the aerospace sector to adopt a CBM

Driver	Source
Leads to financial gain	Lewandowski (2016)
Can lead to competitive advantages for customer preference	
Contributing to a more sustainable world and against climate change	
Alternative income streams through repair, remanufacturing and refurbishment	
Large number of parts and components are used in production processes that have high pollution levels	Rodrigues Dias et al. (2022)
Recovering materials at EoL can reduce the need for virgin natural resources	

In table 4 below, barriers to the adoption of CBMs that were found in literature are described.

Table 4: The barriers for companies in the aerospace sector to adopt a CBM

Barrier	Source
Customer restrictions – there need to be customers willing to buy the circular products	Linder & Williander (2017)
Technological challenges – making circular products, but also remanufacturing and refurbishing come with technological challenges	
Return flow difficulties – especially with CBMs based on PaaS, it can be a challenge to retrieve the product at the EoL	
Financial risks for PaaS – when a product is leased instead of sold, the financial risk remains with the producer	
Regulations – current regulations do not support CBMs	
CBM have higher business risks than traditional, linear business models	Lewandowski (2016)
High reliance on fossil fuels	Rodrigues Dias et al. (2022)
CBMs can demand high upfront investments	Brändström et al. (2024)

Finally, semi-structured interviews were held as part of this research, the summarized findings of these interviews can be found in table 5 below. For ease of reading, table 5 contains all interview results, not only the results related to the drivers and barriers to adopting CBMs.

Table 5: An overview of the findings of the interviews

	Tim Hoff (DLR)	**Derk-Jan van Heerden (AELS)**	**Joséphine Koffler (DLR)**	**Ligeia Paletti (DLR)**	**Airbus employee**
Do you experience in your work a lot of attention for sustainability?	Yes, especially recently from industry and government. Sometimes terms like sustainability and circularity can be used in a buzzword meaning.	Yes, but it really depends. Most people work for his company because of their love for aerospace, not because of the sustainability aspects. Though that is also important to them.	It is becoming more and more important. People now want to work on the topic.	There are two groups, it is a bit age-related. Generally speaking, younger colleagues have a strong connection to the concept, older colleagues less, unless it is beneficial for them. This is changing and people are becoming more interested.	It depends. There is attention for sustainability, but it is a challenge to choose sustainable options when there are commercially (financially) more interesting alternatives, even when intrinsic motivation is present. Additionally, there are some employees who find it very important, and they try to make additional changes.
Are there currently elements that are considered sustainable or circular but were implemented for other reasons?	The checks and repairs are quite like the 9R strategy already, but it is only done for monetary reasons. Also, the MRO is done by other companies, not by Airbus themselves. Also, leasing, pay per use, pay per hours and certification.	The reuse of parts in the aviation sector and weight reduction to reduce fuel costs.	Reusing. In space there is so much money, sustainability is not a priority, so there is no need for the recycling of satellites since they prefer to send a new one. This is specific for the space sector.	The modularity aspect of aviation, codification to ensure quality of repair and maintenance and thus safety. Airplanes are leased, not bought. Large second-hand market for parts and materials. Also weight optimization, but always connected to making money.	Weight saving as a goal in airplanes. Reduced weight leads to reduced fuel costs which is also saving money. Changing materials due to reduce cost, that also have a lower environmental impact

What do you know about CBM?	Knows some CBMF but does not know if they are used in the industry since is not really discussed in the industry.	Finds it very interesting, considers circularity as the new term for recycling.	It is very new, but she is reading some papers and learning more about it.	A little bit, but nothing too much in detail. Other metrics are used instead of return on profit or direct operating costs. There is a lot of unclarity about the meaning of concepts such as 'circular economy' or 'sustainability'	Not enough, according to their own judgement. CBMs should focus on creating financial value but give equal importance to environmental and social aspects (E&S) and work towards E&S goals.
What do you think are drivers and barriers for companies in the aerospace sector for adopting CBMs?	**Drivers:** Regulations, for instance on European level. Potential to earn money with them. **Barriers**: Regulations, complexity of implementing CBMs in their current processes, money, their current business plan is going very well so there is no need to change it.	**Drivers:** Regulations to restore the financial incentives for recycling and the use of recycled materials. **Barriers:** quantity of available materials and the cost of recycling materials from an airplane. Technical solutions to recycling different alloys.	**Driver:** Regulatory compliance. Reputation of the company, reduction of cost by using recycled materials. **Barrier**: Investments to achieve cost benefits. Resistance to change and to use sustainability and circular economy. The production capacities and costs of SAF.	**Drivers:** Guaranteeing a supply chain of materials and parts. Regulations. **Barriers:** economic reasons, it needs to make sense economically. Whole sector needs to be on board, not just one actor.	**Driver:** Regulations (preferably global), CO_2 credits/tax. **Barrier:** first mover principle, investment costs. Safety regulations can hinder remanufacturing.

What could be drivers and barriers for Airbus Netherlands?	**Driver**: When a product is in space, it is quite circular because it needs to function on their own. If it shows (monetary) potential by using the availability of CRMs as an example. **Barrier**: technological challenges to increase the products whilst they are in space through reparation or reusing a product for another purpose.	**Driver:** Regulations. But also societal changes. **Barrier:** The perspective of companies and people to think only short term, and not wanting to put a lot of effort into solving something complex and difficult.	**Driver:** Regulations. Dependence on CRM. Supply chain risks, e.g. with SAF. **Barrier:** military has less barriers due to the amount of money involved, same for space. There is not a lot of public awareness about the environmental cost of space activities, the focus is on aviation. Certification prevents the easily swapping of parts for ones with more sustainable materials.	**Driver**: Fewer certification requirements. Military: regulations, possibly local manufacturing and they are not profit oriented. **Barrier**: technological challenges in the space sector.	**Driver:** Projects financed by the government can demand a level of sustainability or circularity in their tenders due to accountability for them spending public money. **Barrier**: high risk of downcycling. For space projects that are not funded by a government, there is less incentive from the client to demand high levels of sustainability or circularity.
What aspects of your work should CBMs focus on to have the most effect?	Airbus Netherlands: potentially recovering materials from satellites, or a repair service. General Airbus: get more of the value chain in their hands to increase circularity. Also, there needs to be more focus on repairing, remanufacturing and refurbishing.	People need to agree on definitions of terms so that they are always used in the same way. SAF, but that might not be possible. Focus on the big wins. It should also be looked at with the complete image in mind: it is a sum of positives and negatives, there is no one 100% sustainable alternative and it is a complex issue.	Reusing and recycling satellites, remanufacturing in space, maintenance and repair in orbit. Refueling of satellites. These still need to be studied but have high potential. Most room to improve is in the design phase, it should focus on circularity.	Focus on the civil aviation, drop the space and military. Find out what to do with the airplanes that are currently out there. Less customization in aviation, to increase modularity in structural components. Make sure that materials and parts are kept in aerospace sector, not to a different one.	Substituting materials for lesser impact ones. Focus on reducing emissions from aviation, for instance by focusing on hydrogen. Also focus on reducing the number of launches into space, increasing the lifetime of satellites.

5.3 CBM strategies best suited for future scenarios, interview results

When assessing the best suited CBM strategies for future scenarios, table 5 is used for its insights from the interviewees.

Companies who are looking to transition from a linear economic model to a CE oriented model, will need strategies and plans to implement CBMs. These strategies contain the goals the company wants to achieve, and how they will accomplish these goals. Ideally, the strategy contains both short-term and long-term actions. A CBM strategy is thus an overarching plan to successfully implement CBMs.

The goal of a CBM strategy could be to make sure that the supply chain is not affected by developments regarding CRM, as suggested by Ligeia Paletti and Tim Hoff. A company can have multiple CBM strategies as part of an overall CE strategy.

After establishing the goals of the CBM strategy, a plan needs to be made to implement said strategy. This plan can have both a short-term aspect and a long-term aspect. In their interview, the Airbus employee mentioned that some sustainability or circularity actions can take place in the short-term. For instance, the swapping of materials used in products for materials that are less polluting. Though this depends on technological developments to make sure that the less polluting materials provide a good enough function. In the short-term, current regulations can provide guidance on what to focus on. Another short-term example of a plan is the implementation and growing of the use of SAF, though there are still many practical limitations to this like the lack of infrastructure or presence of enough biofuels, as mentioned by Joséphine Koffler. External oriented plans are also possible, for example the implementation of industrial symbiosis with other companies on eco-industrial parks (Ghisellini et al., 2016).

Regarding the long-term plans, there are multiple possible directions to implementing CBMs. For instance, the design of airplanes or satellites could be changed to increase the reusing of materials or components, or to better prepare for recycling, as described by Joséphine Koffler. She also described that altered designs could enhance Product Life Extension (PLE). Additionally, over time, international guidelines and regulations (preferably global), as mentioned by the Airbus employee, can drive the implementations of CBMs and provide specific goals to aim towards. Other long-term plans depend on technological changes, as described by Tim Hoff and Ligeia Paletti, with the Airbus employee specifically mentioning hydrogen as a long-term solution. Finally, as part of the long-term plan to implement CBMs, societal changes towards flying and the aerospace sector in general should be taken into consideration, according to Derk-Jan van Heerden and Joséphine Koffler.

Safety is the most important factor of the aerospace sector, more important than weight saving to reduce fossil fuel use or saving money. This also means that new, more circular options, will only become interesting for aerospace companies if the safety standards are met. This is currently guaranteed by the strict certification processes, as mentioned by Tim Hoff and Ligeia Paletti. This certification also allows for the reuse of parts in airplanes if they meet the safety requirements.

This ties into the high level of modularity in aviation. Due to the high value of airplanes, it is more cost efficient to only replace the parts that are broken, instead of buying a new airplane, as described by Ligeia Paletti. The modularity aspect of aerospace and aviation was mentioned by almost all interviewees and is strongly connected to the safety requirements and certification described above.

6 Discussion

As mentioned in the literature review section of this thesis, there are currently many different policies and laws in the EU regarding aviation. Though these provide guidelines for the aviation sector by stimulating the use of SAF, and to reduce the carbon emissions, they fail to provide guidelines for aerospace companies seeking to transition into a CBM, or to develop a CE strategy.

Therefore, it is also important to look at the feasibility of the EU laws. Joséphine Koffler raised the question if it is possible to create enough SAF to achieve the targets set by the EU. We can also wonder if the ETS achieving its intended purposes? Are these policies achieving their goal, which is to create an aviation and aerospace industry that fits in a CE?

Both literature and the experts interviewed for this thesis agree that there is an important place for policies and regulations to stimulate a true transition to circular practices in the aerospace sector. These policies and regulations will have to become a driver for companies like Airbus to implement CBMs. Currently, the decision-making processes for any company, not just Airbus, does not favor CBMs due to all the barriers. CBMs will have to bring profitability, or revenue streams to become more attractive.

Additionally, the interviewees and the literature both discuss the importance of sharing definitions of core concepts and the lack of agreed upon definitions regarding CE (Geissdoerfer et al., 2017). They all call out for standardization of concepts regarding circularity and sustainability, to prevent misunderstandings. Additionally, Geissdoerfer et al. (2017) stress the importance of standardization for the growing of sustainability and circularity as a research field. This is to prevent vagueness regarding the topic and to make sure that research can move further, instead of staying at the definition stage, as also mentioned by Ligeia Paletti during the interviews. Furthermore, it is important to maintain a balance between having a definition which is complete and extensive, and workable, so not too long. As can be seen in chapter 3, some definitions were almost a paragraph, for instance the ones provided by Kirchherr et al. (2017) and Korhonen et al. (2018). This is also important from an Industrial Ecology perspective, to be able to further develop the research field of CE.

Most of the interviewees used terms such as ‘reuse’, ‘recycle’ and ‘remanufacturing’ which are connected to the 10R framework designed by Potting et al. (2017). It has been established that CBM strategies that focus on the lower Rs on the 10R ladder like reusing have more effect on achieving circularity than strategies that merely focus on the higher Rs like recycling. Though reuse is common already in the aerospace sector, for structural components there is still a large step to be made. Additionally, it is important to prevent downcycling to make sure that materials used in the aerospace sector do not leave it.

When comparing the different interviews, there are quite a few similarities. These are most prominent when looking at the first question, if they experience a lot of attention for sustainability in their work. Almost all interviewees describe how there has been an increase in attention to sustainability recently, but also that age is an important factor for how passionate people are about sustainability, with younger people generally finding it more important than older people.

Additionally, when asked about current practices that are sustainable or circular, but were not implemented with those aspects in mind, almost all of them mentioned the modularity of the airplanes and the reusing and repair of elements which is made possible by the strict certification processes which in turn are to ensure high safety standards. Furthermore, implementing new materials or other measures to save weight in an airplane, and thus fuel, were mentioned by two interviewees. Only one interviewee also mentioned that the leasing of airplanes is common practice in aviation.

An interesting finding from the interviews is that all interviewees expressed their interest for CBMs, but also acknowledged that they did not know much about it. Three interviewees were working on extending their knowledge and understanding of the concept. This also confirms to the conceptual framework part of this thesis. With CBMs and CE gaining more traction and interest from professionals looking to work on the topic, it is important that the concepts are properly defined to prevent miscommunication.

When looking at the drivers and barriers for companies working in the aerospace sector who want to implement CBMs, all interviewees stress the importance of supportive regulations as a driver. One interviewee considered the current regulations a barrier to companies implementing CBMs, which matches with the findings of Linder & Williander (2017). Additional drivers include the reputation of the company and the possibility of guaranteeing a supply chain, as described by Joséphine Koffler and Ligeia Paletti.

The interviewees also described important barriers to implementing CBMs, such as high investment costs and high business risks, especially if a company is very successful with a traditional business model. This is confirmed by Linder & Williander (2017) and Lewandowski (2016).

During the interviews it became apparent that three interviewees do not think of military and space, the sectors that are at the core of Airbus Netherlands' activities, as the places where most progress can be made using CBMs. Instead, they think that the priority should go to where the most progress can be made, in aviation. However, there is a disagreement on how this should be achieved. Some argue for changes in the design phase to increase the modularity of structural components of airplanes, and others want to focus on the fuel use during flights. This would indicate that the overall Airbus company can make more progress, rather than Airbus Netherlands specifically.

Furthermore, an important way Airbus Netherlands can be stimulated to adopt CBMs, is to stress their benefits. Though initial costs might be connected, it has the potential to make money in the future through the company's reputation, or even potentially allow for a continuation in production. Airbus Netherlands depends on CRMs, and according to Tim Hoff, reusing and recycling components that contain those materials so they can temporarily maintain production as CRM becomes increasingly critical, whilst looking for a more permanent alternative.

Overall, there are many different CBMF, CBMs and ways to implement them to move towards a CE. When looking at the literature, especially at the most cited articles, most of the discussed ideas can be linked back to two common CBMF: the ReSOLVE framework and the loops framework in all its varieties. This is also where the strong influence of the Ellen MacArthur foundation can be spotted. It created the ReSOLVE framework, and is also known for the butterfly diagram, which has elements of the loops framework in it (Ellen MacArthur Foundation, n.d.). When looking to implement a CBM strategy, the frameworks can be used separately or combined. To provide an example, Rodrigues Dias et al. (2022) describe in their article many CE initiatives, structured according to the ReSOLVE framework.

When building a CBM strategy, it is important to have clear goals and to map what the drivers and barriers are to reaching that goal, some examples are listed in section 5.2. Using both short- and long-term plans CBMs can be implemented. Different CBM implementation strategies can be used at the same time, to achieve different circularity goals. Though the CBM strategy plan in section 5.3 is written specifically for the aerospace sector, the ideas behind it can also be used for other sectors.

In summary, this discussion highlights that there is currently no common ground when discussing circularity and CBMs. Additionally, they are often mixed or confusingly described. Currently, when comparing the circularity actions and CBMs chosen by companies with the 10R ladder described by Potting et al. (2017), there is a preference for actions that are low on the ladder like recycling. This is because it is easier to since it requires little investment, and more importantly, little change in the current way of designing and producing. For a production company like Airbus, an added factor is that they only produce, the maintenance and EoL are in the hands of other actors. Whilst PLE strategies are more circular, they are harder to implement due to its complexity. Though Airbus has implemented some strategies that can be considered circular, helped by the certification processes to guarantee safety, there is still much progress to be made. The literature reviews in chapter 2 reveals a chaotic combination of EU regulations, the Conceptual Framework in chapter 3 reveals disagreements about the definitions to use and the results in chapter 4 reveals disagreements on how to solve these problems. So, while the climate and resource constraint are urgent, real action is hard to instigate. What we need more than anything is time, but unfortunately that is the one thing we do not have and cannot get more of.

7 Conclusions

This thesis aimed to identify the role of CBMs in developing a strategy for a CE in the aerospace sector.

Currently, CE is seen as the solution to a large societal problem: the crossing of the planetary boundaries. To achieve a CE, companies need to change their ways of doing business by implementing CBMs. Unfortunately, there is little known about how companies should approach this transition. This thesis was written to support management of the company of Airbus Netherlands in this transition.

At present, there are multiple CBMF in use, though most of them can be traced back to two main CBMF. First, the ReSOLVE framework that was created by the Ellen MacArthur foundation. Second, the loops CBMF which discusses the different loops and their purposes like slowing, intensifying and closing loops. It is important to note that there are many variations of these frameworks that only slightly differ from each other but might carry different names.

Furthermore, using interviews and literature review, key barriers and drivers were mapped regarding the adoption CBMs. Key barriers include lack of financial stimulation either through investments required or other cost, and technological limitations to finding more circular alternatives for the current ways of doing business. On the other hand, regulations both on a national and international level have been found to be important drivers. Additionally, the position of a company in the market and society is becoming more and more important for driving the transition towards a CE. Companies that can prove they are circular can use that in their marketing to attract customers who are becoming increasingly aware of the effects of climate change.

The best CBM strategies clearly define a goal and both short- and long-term plans on how to achieve those goals. Whether the goal is on maintaining the supply chain, or creating new designs for increased reusability and recyclability, the goals should be well-defined with clear plans on how to achieve them. CBMF like the ReSOLVE or loop framework can support the successful implementation of these strategies.

In conclusion, CBMs are crucial in developing a CE strategy for the aerospace sector. To transition from a linear way of doing business to a circular way of doing business, the loops or ReSOLVE CBMF can be used as a foundation to finding CBMs best suited to the CBM strategy. It is important to find solutions to barriers that will hinder the implementation of CBMs and to make full use of the drivers identified.

This thesis was limited by the time available for performing the research. Only five experts were interviewed for this thesis, providing a limited overview of the sector. Additionally, a limited literature review was performed, which excluded potentially relevant publications. Furthermore, due to the selection process of the articles for the literature review and conceptual framework chapter, less popular papers that had very relevant information were not selected and used.

For future research, it is important that there is a clear understanding of the concepts that are used in the discourse surrounding achieving a CE. Therefore, these concepts should be properly defined. Additionally, focus groups with the case study company could give new insights into the perception of the case study company regarding CBMs and what would work best for their future scenarios. Furthermore, it is important to note that the aerospace sector, and Airbus as a company, have a lot of funds connected to them. They have the funds to allocate to investments needed for a CE strategy. Further research should investigate how this would apply to sectors that provide goods with less value, like laptops or other consumer electronics. Finally, it would be interesting to assess if the findings of this thesis would be applicable to other sectors that also rely heavily on CRM. For example, sustainable energy sources like wind turbines, sustainable (green) hydrogen or other.

Overall, it has become clear that there is no one right answer for this case study. Experts differ in opinion on where the focus of a CE should be, and the literature suggests that there are dozens different ways of approaching this challenge. The most important takeaway from this thesis is that this challenge is not a simple one, and approaching it as if it is one, undermines finding the right solution. In the end, it is only a combination of politics, regulations, economic stimuli, societal pressure, technological advancements and new designs that can bring this goal of a CE closer to a reality.

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