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**Working Paper**

## Aviation Industry – Opportunities and Challenges for a Green Future

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Carl Heinz Daube, Alex Dulachyk, Leon Podinovic, Hendrik Ruschmeyer, Melissa Spiegel<sup>1</sup>

## ***Aviation Industry – Opportunities and Challenges for a Green Future***

### **Abstract**

The aim of this working paper is to examine the current state of Circular Economy (CE) implantation in the aviation industry, with a particular focus on Lufthansa. The aviation industry must integrate Circular Economy principles to address environmental concerns and achieve sustainable growth. CE practices, such as reducing, reusing and recycling, can significantly reduce waste, optimize resource use and lower greenhouse gas emissions. Lufthansa initiatives in sustainable fuels and innovative technologies highlight the practical application of CE concepts, enhancing both sustainability and operational efficiency. However, challenges include high costs, stringent safety standards and regulatory changes. Despite these hurdles, coordinated efforts among stakeholders and advancements in technology and policy are essential for successful CE implementation in Aviation Industry.

### **Zusammenfassung**

Ziel dieses Working Papers ist es, den aktuellen Stand der Implementierung der Kreislaufwirtschaft (CE) in der Luftfahrtbranche, mit besonderem Fokus auf Lufthansa, zu untersuchen. Die Luftfahrtindustrie muss Prinzipien der Kreislaufwirtschaft integrieren, um Umweltprobleme anzugehen und nachhaltiges Wachstum zu erzielen. Praktiken der Kreislaufwirtschaft, wie "Reduzieren", "Wiederverwenden" und "Recyceln" können Abfall erheblich reduzieren, zu einer effizienteren Ressourcennutzung führen und Treibhausgasemission senken. Lufthansa Initiativen in nachhaltigen Kraftstoffen und innovativen Technologien zeigen die praktische

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Anwendung von Konzepten der Kreislaufwirtschaft und verbessern sowohl die Nachhaltigkeit als auch die Betriebseffizienz. Allerdings gibt es Herausforderungen wie hohe Kosten, strenge Sicherheitsstandards und regulatorische Aspekte. Trotz dieser Hürden sind koordinierte Anstrengungen aller Beteiligten und Fortschritte in Technologie und Politik entscheidend für die erfolgreiche Umsetzung der Kreislaufwirtschaft in der Luftfahrt.

## 1. Introduction and definition of terms

The aviation industry, a cornerstone of global connectivity and economic development, faces a significant challenge in balancing its growth with environmental sustainability. As the industry expands, its environmental footprint, particularly in terms of greenhouse gas emissions, has come under increasing scrutiny. This has led to growing pressure on airlines, manufacturers, and related stakeholders to adopt more sustainable practices. One approach that has gained considerable attention is the Circular Economy (CE), which offers a promising alternative to the traditional linear economic model of "take, make, dispose."

The Circular Economy emphasizes the importance of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems. By integrating these principles, the aviation industry can minimize resource consumption, reduce waste, and lower carbon emissions, thereby contributing to global sustainability goals. This working paper aims to explore the current state of CE implementation in the aviation industry, with a particular focus on Lufthansa, a major player in global aviation.

According to the Lufthansa's initiatives, this paper will examine how CE principles are being applied in practice, the benefits they offer, and the challenges that arise in the process. From sustainable fuel innovations to advanced recycling and reuse technologies, Lufthansa's efforts highlight both the potential and the complexities of transitioning to a circular model in a highly regulated and safety-critical industry. Ultimately, this paper seeks to contribute to the broader discourse on sustainable aviation by offering insights into the opportunities and challenges of adopting CE practices in this vital sector.

## 2. Aviation Industry

### 2.1 Circular Economy

The concept of a Circular Economy (CE) is an alternative to the traditional linear economic model, which follows a 'take, make, use, and dispose' sequence. Based on sustainability principles, the CE aims to redefine the concept of growth, focusing on positive society-wide benefits.

The idea is to keep resources in use for as long as possible, extracting maximum value from them while in use. Subsequently, at the end of each service life, products and materials are

regenerated to create further value. This system attempts to minimize waste and make the most of resources.<sup>2</sup>

The foundational principles of the Circular Economy can be summarized as.

- *Design out waste and pollution:* From the design stage, plan to eliminate waste and pollution. Therefore, after usage, the product does not end up as waste, but rather as an input for a new use.<sup>3</sup>
- *Keep products and materials in use:* By designing products to last longer and be reused, the lifespan of the product is extended and the need to create new products is reduced.<sup>4</sup>
- *Regenerate natural systems:* This principle acknowledges that some resources, like fossil fuels, are not renewable and emphasizes the use of renewable resources.<sup>5</sup>

In essence, a circular economy promotes zero waste and sustainable economic growth, making it a powerful tool in the fight against climate change and resource depletion.<sup>6</sup> The core principles of the Circular Economy are often described using the 3R framework: Reduce, Reuse, and Recycle. Here, we unpack these pillars within the context of the aviation industry.

*Reduce* stands for minimizing the input of resources at the start of the lifecycle. For the aviation industry, reducing resource inputs could mean designing lighter, more fuel-efficient aircraft that require fewer materials and less energy to operate, or developing engines that can run on sustainable aviation fuel to cut down on carbon emissions. The *reuse* pillar emphasizes extending the usage lifespan of products to decrease the need for new goods and resource extraction. In aviation, a key example of reuse might be the practice of "aircraft part-out", where parts from decommissioned aircraft are refurbished and used in operational aircraft. Not only does this save resources, but it also slashes considerable costs. When products can no longer be reused, the focus shifts to recycling. *Recycling* involves the recovery of materials from used products to reintroduce them into the manufacturing cycle. The aviation industry may recycle various components of an aircraft, including metal from the airframe and parts of the cabin like seats and overhead bins.

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<sup>2</sup> Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017): The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, 143, 757-768.

<sup>3</sup> Webster, K. (2015): *The Circular Economy: A Wealth of Flows*, Retrieved from Ellen MacArthur.

<sup>4</sup> Stahel, W. (2016): *The Circular Economy*, *Nature News*, 531(7595), 435-438.

<sup>5</sup> Ellen MacArthur Foundation (2013): *Towards the Circular Economy Vol. 2: Opportunities for the Consumer Goods Sector*.

<sup>6</sup> Ellen MacArthur Foundation (2015): *Delivering the Circular Economy: A Toolkit for Policymakers*.

In addition to the 3Rs, it is also important to consider the other Rs that are important for a circular economy.

Refurbishment involves repairing and refreshing a product without changing its original form. In aviation, refurbishing can have countless applications, from upgrading aircraft cabins to overhauling engines, allowing for extended use without the need for complete replacement. Remanufacturing goes one step further and involves dismantling a product, restoring and replacing components, and then reassembling it. Remanufacturing is common in the aviation industry, especially for costly components like jet engines.

By incorporating these 'R' principles, the aviation industry can work towards a more sustainable and efficient operation, reducing its environmental impact, and saving on costs related to materials and waste management. The aviation industry, like many others, faces the challenge of improving its environmental sustainability. One approach that is increasingly being focused on in this regard is that of the circular economy.

Implementing the circular economy in the aviation industry has the potential to make the sector more sustainable. This involves measures such as reusing and recycling aircraft parts, reducing energy consumption via more efficient technologies and processes, and utilizing renewable energies.<sup>7</sup> For instance, AkzoNobel and Royal Dutch Airlines have started a joint project to recycle old aircraft parts into furniture.<sup>8</sup> Airbus is also making attempts to design its aircraft for easy disassembly at the end of their service life to allow more efficient recycling of materials.<sup>9</sup>

Design is a crucial aspect of the circular economy as it dictates a product's life cycle.<sup>10</sup> This holds true for the aviation industry where aircraft need to be designed from the outset for easy disassembly and reuse or recycling of parts at the end of their operational life. Digital technologies like 3D printing can support such design strategies.<sup>11</sup>

Transitioning to a circular economy also requires support in the form of appropriate policies and laws. Governments and international organizations can play a pivotal role through the

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<sup>7</sup> Bocken, N.M.P.; de Pauw, I.; Bakker, C.; van der Grinten, B. (2016): Product design and business model strategies for a circular economy, in *Journal of Industrial and Production Engineering*, 33(5), 308–320.

<sup>8</sup> EU Green Week (2018): Dutch airline pioneers circular economy initiatives.

<sup>9</sup> Airbus (2020): Building a sustainable future, <https://www.airbus.com/sites/g/files/jlcbta136/files/2021-06/Full%20Report-Airbus-SE-Annual-Report-2020.pdf>.

<sup>10</sup> Urbinati, A., Chiaroni, D., & Chiesa, V. (2017): Towards a new taxonomy of circular economy business models, in *Journal of Cleaner Production*, 168, 487–498.

<sup>11</sup> Ellen MacArthur Foundation (2016): *Intelligent Assets: Enabling the circular economy*.

creation of incentives and setting standards that encourage companies to implement circular economy strategies.<sup>12</sup>

Technological innovations are vital to the success of the circular economy in the aviation industry. For example, new materials and technologies can improve energy efficiency and reduce the need for resources. Furthermore, advancements in business models and digital technologies can aid in managing the life cycle of a product and in tracking products and materials along the value chain.<sup>13</sup>

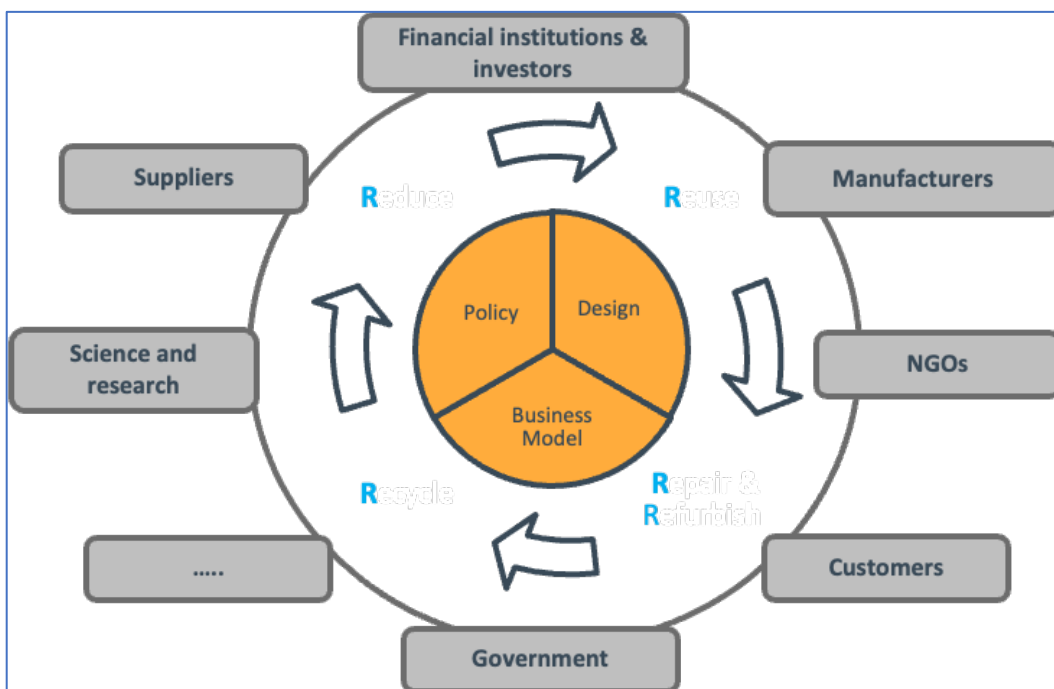


Figure 1: Stakeholders and Factors of a Sustainable Circular Economy.<sup>14</sup>

The figure one illustrates the CE model, focusing on the interactions between different stakeholders and key actions that drive sustainability in a circular system. Furthermore, the figure provides a holistic view of how different stakeholders contribute to a circular economy by engaging in various activities. The central elements of policy, design, and business models are crucial in driving these activities, making the circular economy a collaborative effort across the entire supply chain and beyond.

<sup>12</sup> Geissdoerfer, M.; Savaget, P.; Bocken, N.M.P.; Hultink, E.J. (2017): The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, 143, 757–768.

<sup>13</sup> Urbinati, A., Chiaroni, D., Manfredi, L., & Chiesa, V. (2019): Exploring the links between Circular Economy and Industry 4.0: Multiple case-study analysis in the manufacturing sector, *Business Strategy and the Environment*, 29(2), 1043–1058.

<sup>14</sup> Lewandowski, M. (2016): Designing the Business Models for Circular Economy—Towards the Conceptual Framework, *Sustainability*, 8(1), 43.

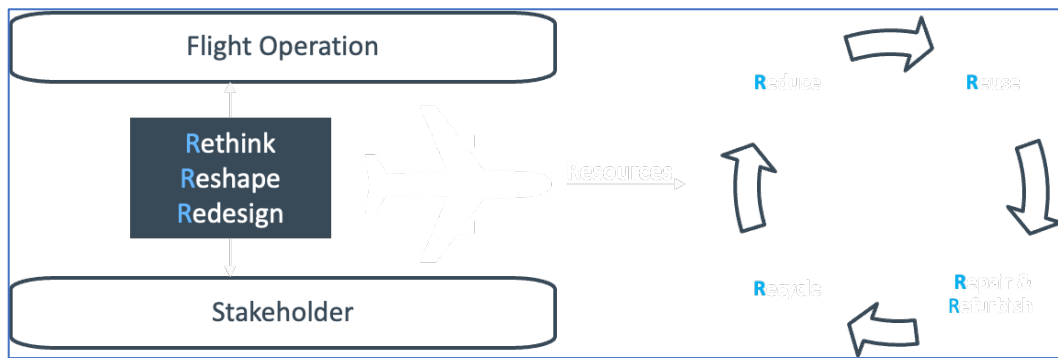


Figure 2: The two perspectives of CE at Airlines.<sup>15</sup>

The second figure emphasizes the importance of integrating circular economy principles into the aviation industry by rethinking, reshaping, and redesigning flight operation. The industry can reduce resource consumption, reuse materials, repair and refurbish equipment, and recycle components, ultimately contributing to a more sustainable future for aviation. Stakeholders at all levels must work together to achieve these goals, ensuring that the circular economy becomes an integral part of the aviation sector.

According to the application, airlines can focus on two perspectives. The Operating flight perspective analysed the adaptation of business models, strategies and value creation process. This perspective looks for in-house opportunities to keep resources in a closed loop to increase the use and influence the value. The stakeholder perspective, on the other hand, includes the external actions, decisions and cooperations of stakeholder. Stakeholders are valuable actors in the value creation process and influence integration. Furthermore, they define the opportunities and challenges of product-lifecycle management from the operation site.

Aircraft and aviation parts producers apply the CE principles by optimizing design and manufacturing processes. This includes using less material, incorporating recycled or more durable materials, and designing for easy disassembly. This increases the aircraft's operational efficiency and makes the recycling and reuse process easier at the end of life.<sup>16</sup>

During the airplane's operational life, airlines can implement CE principles by maintaining and refurbishing aircraft to extend their life and reduce waste. This can include the remanufacturing of parts, equipment upgrades for greater fuel efficiency, and utilization of biofuels.<sup>17</sup>

<sup>15</sup> ICAO Environment Report (2019): Introduction to Circular Economy - By ICAO Secretariat, Chapter 8.

<sup>16</sup> Airbus Aircraft (2022): End-of-life Reusing, recycling, rethinking, Retrieved from: <https://aircraft.airbus.com/en/newsroom/news/2022-11-end-of-life-reusing-recycling-rethinking>.

<sup>17</sup> Rolls Royce (2018): Rolls-Royce welcomes Delta TechOps into expanded service network as Trent 1000 work begins, Retrieved from: <https://www.rolls-royce.com/media/press-releases/2018/04-10-2018-rr-welcomes-delta-techops-into-expanded-service-network-as-trent-1000-work-begins.aspx>.



At the end of an aircraft's life, companies employing the CE principles safely decommission the plane and recycle or repurpose as many components as possible. They can disassemble the aircraft into individual components that can be repaired, refurbished, and resold or recycled. Some companies, like Aircraft End-of-Life Solutions, specialize in this sort of work, making sure aircraft components have a second life in another operation.<sup>18</sup>

Airports also play a role in the adoption of CE. This includes waste management programs, where waste generated at the airport is collected, sorted and recycled; introduction of energy-efficient systems, like LED lighting and solar power, to reduce energy consumption, promoting public transportation, and electric vehicles for airport staff and services to reduce the carbon footprint.<sup>19</sup>

These examples indicate that CE principles are being integrated across the aviation sector with different stakeholders – manufacturers, airlines, and airports – all playing their part in transitioning to a more sustainable industry.

Each of these segments is equally important in developing a CE model in aviation, underscoring how interlinked each part is in building an overall robust and sustainable industry. The benefits of adopting a CE approach in aviation are considerable, both environmentally and economically, contributing to direct cost savings, creating new revenue streams, meeting increasing consumer demand for sustainable practices, and positively impacting the environment. The future of the circular economy within aviation largely depends on progress in technology, the development of suitable business models, and political commitment. There will be challenges to overcome, but the potential benefits - both for the environment and the industry's profitability - are significant.

## 2.2 Current Status

The current status of circular economy practices in aircraft manufacturing focuses on minimizing waste and maximizing material reuse throughout an aircraft's lifecycle. Key initiatives include designing aircraft for easy disassembly, using modular components, and incorporating advanced, recyclable materials like composites and lightweight alloys.

Incorporating innovative technology, such as additive manufacturing or 3D printing, is another significant practice. This approach enables the production of complex parts with minimal waste, often using recycled materials, which enhances the sustainability of the manufacturing

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<sup>18</sup> Aircraft End-of-Life Solutions (AELS) (2020): The AELS story.

<sup>19</sup> San Francisco International Airport: (2020): Zero Waste Concessions Program, Retrieved from: <https://www.flysfo.com/community/environment/zero-waste-concessions-program>.

process. Additionally, the development of sustainable aviation fuel (SAF) plays a critical role in reducing the carbon footprint of aircraft during operation, contributing to the industry's goal of carbon neutrality. Efforts are also being made to create more sustainable aircraft cabin interiors by using materials that are easier to recycle and designing interiors that can be updated or refurbished, thereby extending their lifespan and reducing waste. Additionally, sustainable cargo solutions are being developed to further reduce the environmental impact of the aviation industry.

The aviation industry is increasingly collaborating with other sectors, such as material science companies, recycling firms, and regulatory bodies, to enhance circular economy practices across the supply chain. These initiatives are part of a broader effort to reduce the environmental impact of aviation and move towards carbon neutrality, ensuring a more sustainable future for the industry.

## 2.3 Best practice

### 2.3.1 Adaptation and Adoption: Lufthansa's Initiatives in Circular Economy

A vast majority of the global population has at least one flight experience to their name. Nevertheless, the issue of global warming remains a prominent topic in the present era. It is estimated that the aviation industry is responsible for approximately 2% of global greenhouse gas emissions. It is therefore hypothesized that aviation could become a significant source of greenhouse gases by the year 2050. This highlights the necessity for sustainable innovations and policies, including the integration of circular economy principles. By prioritising the reduction of waste, the reuse of materials and the recycling of resources, the circular economy can play a pivotal role in enhancing the sustainability of the aviation industry and in reducing its environmental impact.<sup>20</sup>

This section will examine five principal categories, together with their current and prospective projects. The following categories will be discussed: fuel and future fuel solutions, innovative technology with a focus on ReOil, waste and traceable materials with an emphasis on the future of recycling, cargo plastics including enhancements in the management of cargo plastics, and green fares, examining the future of green fares.

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<sup>20</sup> Bachmann, J., Yi, X., Tserpes, K., Sguazzo, C., Barbu, L.G., Tse, B., Soutis, C., Ramón, E., Linuesa, H., & Bechtel, S. (2021). Towards a Circular Economy in the Aviation Sector Using Eco-Composites for Interior and Secondary Structures. Results and Recommendations from the EU/China Project ECO-COMPASS. *Aerospace*, 8(5), 3-15. <https://doi.org/10.3390/aerospace8050131>

It is important to note that the information presented in this section, entitled "Best Practices", is derived from the findings of the Lufthansa Group Climate and Environment Campaign. This campaign represents a comprehensive initiative by the Lufthansa Group, the objective of which is to identify and implement strategies designed to mitigate the environmental impact of aviation. The insights and recommendations presented in this section are the result of extensive research and analysis conducted by the campaign, reflecting the Lufthansa Group's commitment to sustainability and environmental stewardship.<sup>21</sup>

### 2.3.2 The concept of Fuel

In the context of the circular economy, Lufthansa has initiated a campaign titled *#MakeChangeFly* to bolster their sustainability endeavors. A salient example of this initiative is the deployment of the latest-generation aircraft, the A350. This aircraft is designed to be significantly more efficient, utilizing up to 30% less fuel and emitting up to 30% less CO<sub>2</sub> compared to its predecessors. This reduction in fuel consumption and emissions underscores Lufthansa's commitment to integrating circular economy principles into their operations, thereby contributing to a more sustainable aviation industry.

Another notable example of Lufthansa's commitment to sustainability is their investment in Sustainable Aviation Fuels (SAF). As a pioneering airline in this domain, the company has been at the forefront of incorporating SAF into their operations. SAF derived from biogenic source materials has the potential to reduce CO<sub>2</sub> emissions by up to 80%, offering a viable alternative to fossil fuels and conventional kerosene. The production process of SAF involves using waste and cooking oils as raw materials. Initially, water is extracted from these materials. They are then converted into suitable hydrocarbon chains, which are subsequently refined into SAF. This refined SAF is utilized in airplanes, which emit significantly less CO<sub>2</sub> compared to traditional fuels.

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<sup>21</sup> Lufthansa Group: Company, access: <https://www.lufthansagroup.com/en/company>.

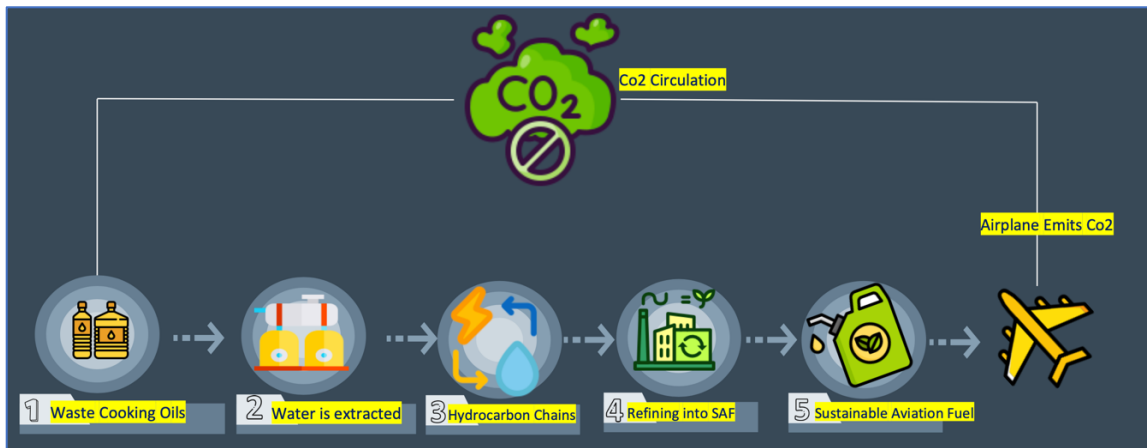


Figure 3: Production Process of SAF (Sustainable Aviation Fuel)

Furthermore, Lufthansa is investing in future technologies such as Power-to-Liquid (PtL) and Sun-to-Liquid (StL) fuels. These advanced fuel technologies promise further reductions in the carbon footprint of aviation, underscoring its proactive approach to environmental sustainability through innovative fuel solutions. These efforts highlight the airline's dedication to integrating sustainable practices within the aviation industry, thereby contributing to the global effort to mitigate climate change.

### 2.3.3 Innovative Technology

Measures designed to improve fuel efficiency include the application of a sharkskin-like film to aircraft, as exemplified by AeroSHARK technology. This innovation has the effect of reducing drag, which in turn leads to a decrease in fuel consumption and CO<sub>2</sub> emissions of approximately 1%. These developments represent a significant advancement in the field of aviation, demonstrating the potential of advanced technological solutions to enhance environmental sustainability.

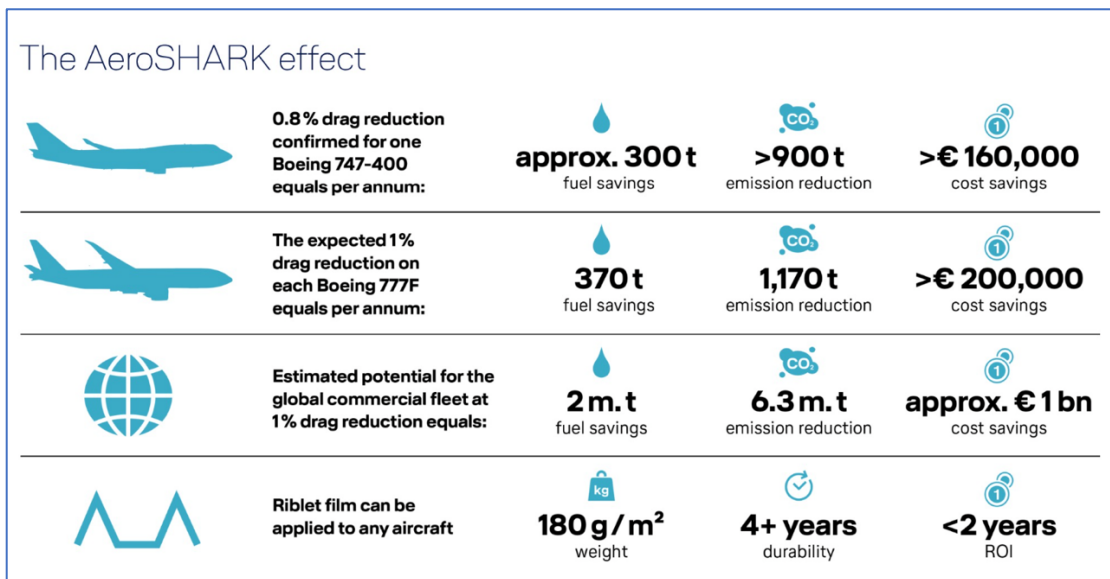


Figure: 4 The AeroShark Effect

Another noteworthy initiative is the ReOil® project, which addresses the issue of plastic waste and promotes the use of alternative fuels. The project results in the production of synthetic oil with 45% fewer greenhouse gas emissions and a 20% reduction in energy consumption compared to conventional oil production methods. These developments illustrate a notable advancement in the sustainability of aviation, characterised by a reduction in environmental impact and an increase in resource efficiency.

The Lufthansa Group adheres to a comprehensive approach to sustainability, which encompasses the principles of "reduce – reuse – recycle – replace" in both product development and service offerings. In particular, the Group places significant emphasis on the reduction of waste and the utilisation of traceless materials. An illustrative example of this commitment can be observed in the "Onboard Delights" initiative, where environmentally conscious packaging is employed. A considerable proportion of their fresh products are packaged in PaperWise, a CO2-neutral material derived from agricultural waste and produced using renewable energy sources.

Moreover, the company's Group has established ambitious targets to eliminate single-use plastics in their entirety by 2025. This initiative reflects the company's proactive stance towards sustainability, with the objective of reducing its environmental impact and promoting responsible consumption practices within the aviation industry. By incorporating these tenets into its operational framework, the Lufthansa Group exemplifies a pioneering approach to fostering a more sustainable and environmentally conscious future.

The key objectives include a 50% reduction in food waste and the minimisation of single-use plastics through the implementation of a 100% circular economy by 2025. Aiming to achieve these goals, the Group is exploring solutions such as the creation of biodegradable packaging from agricultural waste, which decomposes without leaving any residue. By committing to these initiatives, this renamed Group aims to lead the aviation industry in reducing its environmental footprint and promoting a sustainable future.

### **2.3.4 Sustainable Cargo Solutions**

Lufthansa Cargo has made significant advancements in the sustainability of its freight operations through the implementation of circular freight packaging. As the inaugural cargo airline to integrate an environmentally friendly plastic film comprising 10% recycled material, it provides an exemplar of the commitment to reducing the environmental impact. The airline utilises approximately 500 tons of plastic film annually for the purpose of freight protection. Since mid-September 2022, the implementation of a novel film, measuring one micrometre less than its predecessor, has resulted in a reduction of approximately two kilograms of plastic per flight.

Further improvements to the handling of cargo plastics are anticipated, with a particular focus on enhancing the recycled content and biodegradability of the materials in question. The company has set a target of increasing the recycled content of its plastic film to 30% by 2025. Aiming to achieve this objective, the airline plans to utilise biodegradable films produced by Verpa, a manufacturer specialising in sustainable materials. This approach is aligned with Lufthansa Cargo's overarching objective of reducing its environmental impact and promoting sustainable practices within the cargo industry. By pursuing these initiatives, the Group is establishing a standard for sustainability in the field of air freight operations.

### **2.3.5 Achieving Carbon Neutrality**

The concept of Green Fares represents an innovative approach to addressing the environmental impact of air travel. The Lufthansa Group has introduced the concept of Green Fares as part of its strategy to mitigate the environmental impact of air travel. This strategy includes the introduction of CO<sub>2</sub> compensation and emission reduction targets. This initiative allows customers to offset flight-related CO<sub>2</sub> emissions through a combination of sustainable aviation fuel (SAF) and contributions to certified climate protection projects. In particular, 20% of the offset is achieved through the utilisation of sustainable aviation fuel (SAF) derived from

biogenic residues, while the remaining 80% is accomplished through investments in projects that support climate protection and sustainability. This dual approach ensures the comprehensive reduction of the carbon footprint of aviation.

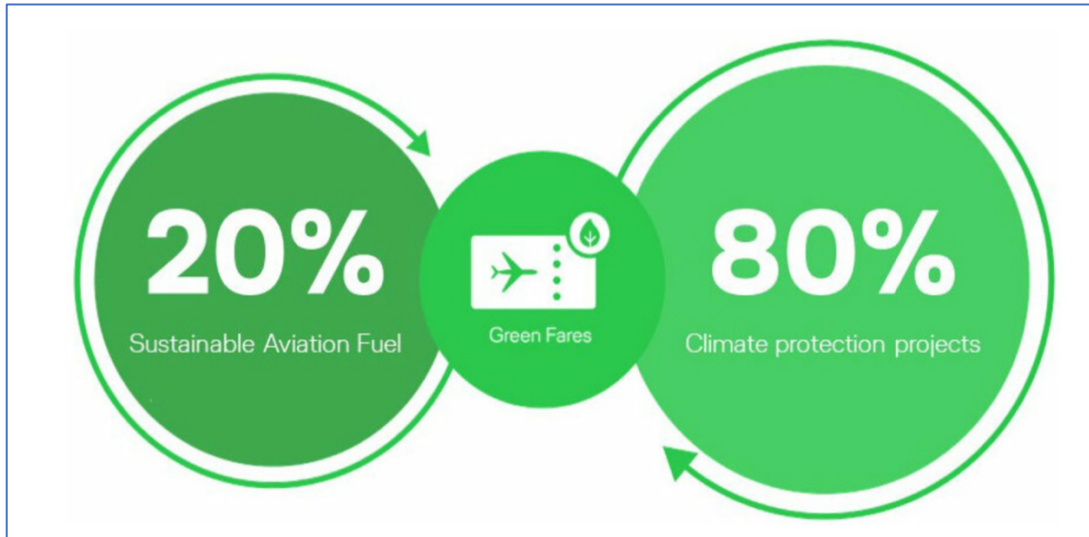


Figure 5: Green Fares

To direct its sustainability initiatives, Lufthansa has set forth explicit carbon emission objectives and is formulating strategies to attain carbon neutrality. The airline has set a goal of reducing its net CO<sub>2</sub> emissions by 50% by 2030, in comparison to emissions levels recorded in 2019. By 2050, the company aspires to achieve carbon neutrality, defined as net zero CO<sub>2</sub> emissions, through a combination of reduction and compensation measures. These targets reflect the airline's commitment to sustainable aviation and its proactive approach to addressing the global challenge of climate change. The incorporation of Green Fares into the Lufthansa Group's portfolio of services serves to illustrate the company's role as a leader in the promotion of environmental responsibility within the aviation industry.

Lufthansa's dedication to sustainability is exemplified by its ongoing initiatives, including the implementation of Green Fares, the adoption of Sustainable Aviation Fuels, and the innovative application of circular economy principles. By setting ambitious carbon emission targets and incorporating cutting-edge technologies, Lufthansa is actively reducing its environmental impact and promoting responsible consumption within the aviation industry.

Through the promotion of these initiatives and best practices, Lufthansa is not only enhancing awareness and participation among customers and stakeholders but is also solidifying its position as a leader in sustainable aviation. By continuing to invest in and develop circular economy projects, the company is paving the way for a more sustainable future in air travel. This demonstrates that environmental responsibility and business success can coexist.



## 2.4 Financial Statements

In the context of financial statement analysis, both quantitative and qualitative considerations are undertaken.

### Quantitative Analysis

The quantitative analysis encompasses an examination of a variety of financial and operational performance indicators derived from the most recent annual financial statements. In particular, the following aspects are considered:

*1. CO<sub>2</sub> emissions (kg/100 pkm):*

It serves as a crucial indicator of the company's environmental friendliness. A lower figure is indicative of a more environmentally beneficial outcome.

*2. Total CO<sub>2</sub> Emissions (in millions of tons):*

This figure represents the total amount of CO<sub>2</sub> emissions produced by the company, measured in millions of tons. This figure represents the total extent of the environmental impact of the company's business activities.

*3. Total Fuel Consumption:*

The consumption of fuel is of particular significance for companies operating in the transportation sector. This indicator provides insight into the quantity of fuel utilized by the company and the efficiency of its fuel consumption.

*4. Planned Use of SAF (Sustainable Aviation Fuel):*

SAF represents sustainable aviation fuel, which is an environmentally friendly alternative to conventional jet fuel. This section examines the extent to which the company plans to utilize this fuel in the future, providing insight into its future environmental strategies and willingness to invest in sustainable solutions.

In the context of a qualitative analysis, it is not always immediately evident which aspects of a given subject require closer examination. In this case, the reporting of Lufthansa regarding sustainability is subjected to such an analysis. In this context, both voluntary and obligatory disclosures are considered. Furthermore, the scope of the sustainability reports is examined,



with a particular focus on the evolution of the reports over time in terms of their relevance and extent.

A direct examination of the CO<sub>2</sub> emissions per passenger kilometre reveals a fluctuating trend over the past five years. If we consider the period between 2020 and 2021, during which the global impact of the Corona pandemic led to a significant reduction in air travel, it may be erroneous to conclude that there has been an overall increase in emissions. A closer examination of the underlying significance of the index definition reveals that, although there were few flights, these were not fully utilised and therefore not operating efficiently. The lack of passenger occupancy on flights results in a disproportionate distribution of CO<sub>2</sub> emissions, which in turn leads to a significant reduction in efficiency. Consequently, the value increased during the two years of the pandemic, but subsequently declined significantly in the subsequent period, reaching a new minimum in the most recently published financial year.

A review of total CO<sub>2</sub> emissions reveals a decline in emissions due to a reduction in flights during the period of the global pandemic. It is evident that total emissions are on the rise once more, reverting to a trajectory that aligns with the pre-corona levels. Considering the imperative for sustainability, it is of paramount importance to pursue a reduction in overall emissions in tandem with the growth in air travel. In the context of globalisation, this transition will prove pivotal and necessitates a concerted effort to make aviation as sustainable as possible.

Another noteworthy performance indicator is the total fuel consumption, which has exhibited a nearly identical trajectory as the total CO<sub>2</sub> emissions. In this regard, the primary objective should be the minimisation of the total fuel consumption and, concurrently, the promotion of sustainability through the utilisation of SAF, for instance.

A review of the planned utilisation of SAF reveals that its projected usage in the coming years will remain relatively low. It is therefore recommended that greater emphasis be placed on integrating the planning of SAF more effectively and expeditiously to achieve the desired temporal framework for the objectives.

A review of the reporting standards reveals that Lufthansa has published numerous sustainability reports, including the fact sheet, the SASB<sup>22</sup> report, the TCFD<sup>23</sup> report and the CDP<sup>24</sup> report. It is crucial to recognise that the new ESRS standards require Lufthansa to delve

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<sup>22</sup> Sustainability Accounting Standards Board (SASB).

<sup>23</sup> Task Force on Climate-related Financial Disclosures (TCFD).

<sup>24</sup> Carbon Disclosure Project (CDP).

even deeper into the subject of climate and environmental friendliness, as well as emissions. Furthermore, relevant topics include energy efficiency and utilisation, working conditions in accordance with the Supply Chain Transparency Act, and the establishment of sustainable supply chains and cycles throughout the entire value chain.

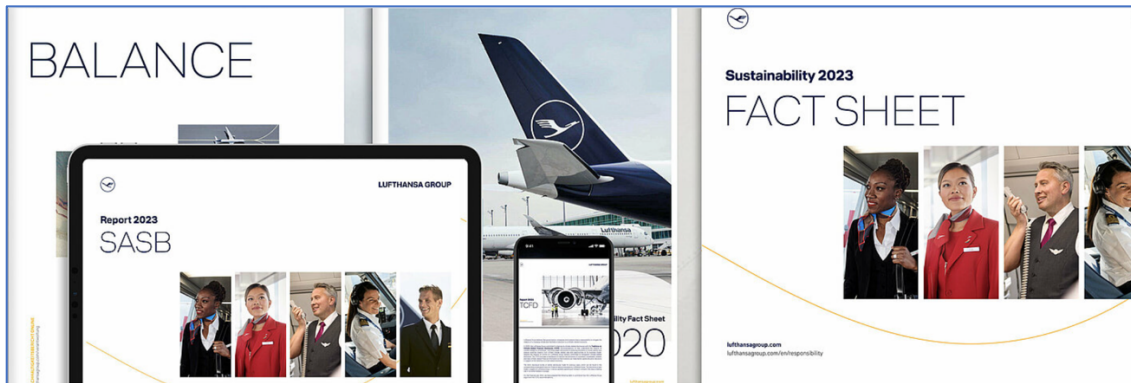


Figure 6: Overview - Lufthansa Sustainability Reports

## 2.5 Barriers regarding the implementation Circular Economy

Regarding the implementation of the Circular Economy in the aviation sector, there are various challenges and barriers. In this context, three perspectives are particularly considered: the aviation industry, the airline perspective (especially Lufthansa) and the regulatory perspective. Starting with the aviation industry, it faces primary cost related and technological challenges in implementing the circular economy. One of the primary barriers is the high cost associated with the development and production of circular economy products within the aviation sector. Environmentally friendly materials that have undergone circular economy processes often incur substantially higher costs compared to traditional materials that are currently used. Technologically, the aviation sector requires materials and products that adhere to rigorous safety standards and certifications. These materials must withstand extreme conditions, including high pressure and low temperatures. Consequently, aviation products are typically more complex and have a longer life cycle. This complexity and the extended lifespan of aviation products pose substantial challenges in developing technologies for producing and utilizing circular economy materials. The need for products to endure harsh conditions and meet safety criteria makes it difficult to adopt new materials and technologies that align with circular economy principles.<sup>25</sup>

<sup>25</sup> Bachmann et al.: Towards a Circular Economy in the Aviation Sector Using Eco-Composites for Interior and Secondary Structures – Results and Recommendations from the EU/China Project ECO-COMPASS, in: Aeospace, Vol. 8, Issue 5, 2021.

When examining the implementation of the Circular Economy from Lufthansa's perspective, two primary challenges emerge: supply chain issues and higher costs. Lufthansa, like other airlines, has limited influence on the selection of materials and the design of aircraft. While they can specify their preferences and requirements to manufacturers, the final decisions on production processes and materials largely rest with companies like Airbus and Boeing. The use of Circular Economy products is often associated with higher costs for the company. For example, Lufthansa's use of Sustainable Aviation Fuels is currently minimal, at only 0,2% of their total fuel needs. This is due to the high production costs of SAF, which results in market prices that are three to five times higher than fossil kerosene. The next generation of SAF is expected to be up to ten times more expensive than traditional fossil fuels, further emphasizing the cost challenges associated with implementing Circular Economy practices in aviation.<sup>26</sup>

Regarding regulatory aspects there are significant challenges with the implementation of circular economy for airlines that lead to higher costs and increased competitive distortion. The revision of the emissions trading system involves lowering the emission cap and abolishing the free allocation of emissions allowances. This change will result in higher costs for Lufthansa and increase competitive distortion. Additionally, the implementation of blending quotas for Sustainable Aviation Fuels will raise fuel costs. This situation is further exacerbated because non-European airlines are not subject to these quotas, leading to further competitive disparities.<sup>27</sup>

### 3. Conclusion and outlook

The aviation industry is at a critical juncture where the integration of Circular Economy Principles is not just an option but a necessity to address environmental concerns and achieve sustainable growth. The adoption of Circular Economy within aviation can significantly reduce waste, optimize resource use and lower greenhouse gas emissions, contributing to the global fight against climate change.

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<sup>26</sup> Lufthansa: Häufig gestellte Fragen zu Sustainable Aviation Fuel (SAF), access: <https://www.lufthansa.com/de/de/discover-lufthansa/carbon-offsetting/faq-saf>, 01.06.2024.

Bauen, Ausilio (2020): Sustainable Aviation Fuels – Status, challenges and prospects of drop-in liquid fuels, hydrogen and electrification in aviation, in: Johnson Matthey Technology Review, Vol. 64, Issue 3, London 2020.

<sup>27</sup> Lufthansa: Risiken in der Einzelbetrachtung, access: <https://report.lufthansagroup.com/2023/annual-report/de/zusammengefasster-lagebericht/chancen-und-risikobericht/risiken-in-der-einzelbetrachtung/>, 01.06.2024.

The implementation of Circular Economy in aviation, as demonstrated by Lufthansa and other industry stakeholders, reveals a promising yet challenging path. Circular Economy principles, such as reducing, reusing and recycling, have been integrated into various aspects of aviation operations. Lufthansa's initiatives in sustainable aviation fuels, innovative technologies like AeroSHARK and comprehensive waste management strategies exemplify the practical application of CE concepts. These efforts not only enhance sustainability but also contribute to cost savings and operational efficiency.

However, the industry faces significant hurdles. High costs associated with the development and production of CE products, stringent safety standards, and the need for materials that can withstand extreme conditions pose substantial challenges. Additionally, regulatory changes, such as revisions to the emissions trading system and the implementation of blending quotas for sustainable aviation fuels, increase operational costs and create competitive disparities.

Despite these challenges, the commitment of industry leaders like Lufthansa to sustainability initiatives underscores the potential for significant progress. The successful implementation of CE principles in aviation will require coordinated efforts from manufacturers, airlines, airports and regulatory bodies. These efforts must focus on developing cost-effective, safe and durable materials, advancing technological innovations and establishing supportive policies and regulations.

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