AALBORG UNIVERSITET
STUDY BOARD OF PLANNING AND SURVEYING
DEPARMENT OF PLANNING

Integrating Cradle to Cradle and Life Cycle Assessment for product sustainability: Case study insights from International Flavors & Fragrances Inc. and DuPont Nutrition & Biosciences merger process

DANIELA MEJIA ECHEVERRIA

MASTER'S THESIS
ENVIRONMENTAL MANAGEMENT AND SUSTAINABILITY SCIENCE
JUNE 2021

AALBORG UNIVERSITET
STUDENTERRAPPORT

Title:
Integrating Cradle to Cradle and Life Cycle Assessment for Product Sustainability: Case study insights from International Flavors & Fragrances Inc. and DuPont Nutrition & Biosciences merger process

Project period:
February 2021 – June 2021

Document type:
Master's Thesis (30 ECTS)

Author:
Daniela Mejia Echeverria

In collaboration with International Flavors & Fragrances Inc.

Supervisor:
Henrik Riisgaard
Department of Planning,
Aalborg University

Main report length: 65 pages
Appendices: 7 pages
Annexes (submitted separately): 15 pages
Total length: 97 pages

Abstract:

Despite the priority given to sustainability topics on the business agenda today, not much information is available on how to address corporate sustainability in shifting business dynamics such as mergers and acquisitions (M&A). This case study analyses the latest combination between International Flavors & Fragrances Inc. (IFF) and DuPont Nutrition & Biosciences (N&B) from a corporate sustainability standpoint. A focus is given to the two product sustainability approaches that have come across after the merger process: Cradle to Cradle (C2C) and Life Cycle Assessment (LCA). Here, the main objective was to explore C2C and LCA as integrated approaches for promoting product sustainability among the stakeholders of the combined company, which keeps operating under the name of IFF. For this, a comprehensive literature review was carried out, followed by semi-structured interviews conducted to key stakeholders. The data collected was then evaluated and discerned through a qualitative content analysis. Key insights from the case study included the opportunity of broadening sustainability assessments and showcasing further sustainability attributes of IFF products. Challenges related to a diverse product portfolio and dealing with technical contrasts such as metrics incompatibilities were also identified. Overall, the findings showed that C2C and LCA can be used as complementary tools to create a more comprehensive evaluation of product sustainability. Hence, an integrated framework of C2C and LCA is proposed as a first step solution for driving and promoting product sustainability in the recently combined company. Future considerations include projecting the framework to the specific circumstances of each IFF business unit and scaling it down to particular products depending on market demands.

Citations throughout this report are made with APA 6th edition referencing style.

ACKNOWLEDGEMENTS

Throughout this last stage of my graduate studies I have received great support, assistance and mentoring from many nice people worth mentioning:

I would like to thank my supervisor Henrik Riisgaard, who guided me during the second year of my master's degree and whose expertise was essential for developing my research projects, including the successful completion of this master's thesis. Sharing thoughts with you and getting insightful feedback was a fun and enriching process.

I would also like to acknowledge my colleagues from the Sustainability team at legacy N&B and IFF for their incredible collaboration and valuable teachings on the corporate sustainability world. Special thanks to my manager Mikkel Thrane, for all his support and ideas, and for all the opportunities I was given to further my research as part of my professional development.

I would like to thank my family, particularly my parents, who have always encouraged me to achieve my goals and overcome any challenge. You are my greatest source of strength. Additionally, many thanks to my friends and their happy distractions, even though during corona times our social gatherings were affected. Finally, I could not have completed this without the support of my boyfriend, who has been there for me throughout all this journey.

To all and each one of you many thanks, tusind tak, muchas gracias!

SUMMARY

Given the social and environmental challenges that have emerged during the last decades, global sustainability awareness has significantly increased. For instance, the vision of sustainable development has received growing attention in international communities and it is now a high priority in the agendas of both public and private sector, especially after the release of the United Nations (UN) 2030 Agenda for Sustainable Development (Silvestre & Ţîrcă, 2019). Overall, this vision represents an opportunity to redesign human activities and develop strategies for ensuring environmental and social well-being around the globe (UN, 2015; Cavaleri & Shabana, 2018).
When delving into the private sector, it is evident that more and more organisations are now adopting a triple bottom line approach to integrate environmental, social and economic aspects within their business goals and targets. With the vision of sustainable development serving as a guiding path towards a better world, many companies hold an environmental, social and corporate governance (ESG) to drive their commitments to people and planet. Furthermore, it is no secret that sustainability-related strategies are necessary for businesses to stay competitive today and even more so in the upcoming years (Dyllick & Muff, 2016).

Nonetheless, in spite of the high priority given to sustainability topics in the business agenda, not much information is available on how to address corporate sustainability in shifting business dynamics. Different scenarios can take place in the rapidly changing corporate world, and such circumstances can have an influence in the managerial aspects of sustainability. For instance, one particular scenario commonly occurring in companies around the world is the process of mergers and acquisitions (M&A). This process describes the consolidation of entities or assets completed through financial transactions. Here, two or more companies are combined thus, their nature of business and management can be modified. In general, economical and organisational aspects of M&A processes are extensively studied. However, few studies have been developed on M&A structuring from a sustainability and ESG perspective. Nowadays, with sustainable development as high priority framework for actors in the private sector, more efforts should be placed into identifying and understanding the sustainability factors related to before-during-and-after M&A processes (Denčić-Mihajlov, 2020).

This master's thesis is innovative in its goal to explore corporate sustainability aspects under the organisational context of an M&A process. It has been designed as a case study which analyses the latest combination between International Flavors & Fragrances Inc. (IFF) and DuPont Nutrition & Biosciences (N&B) from a sustainability standpoint.
Both companies joined forces in February 2021, since then, operations have continued under the name of IFF (International Flavors & Fragrances, 2021). With this merger completed, IFF is projected to be a leading company in the manufacture and supply of innovative products used across various industry sectors such as food, beverage, health and biosciences. Before the merger, both IFF and N&B had a corporate sustainability profile in place along with similar strategies aimed to generate environmental, social and economic value. Notwithstanding the similarities, bringing together both profiles it's not a straightforward task, but still critical for achieving a well-developed sustainable business model.

One of the challenges that new IFF faces in terms of ESG is on how to address product sustainability, taking into account the different approaches that have converged from IFF and N&B sides. Commonly, in the business markets there is a lack of agreement on what a sustainable product is and how to measure it. Thus, there is no standard procedure, but instead, several approaches for addressing product sustainability (Dyllick & Rost, 2017). Under the particular M&A context discussed in this thesis, two main product sustainability approaches have come across: Cradle to Cradle (C2C) applied in former IFF and Life Cycle Assessment (LCA) applied in former N&B.

This master's thesis was designed as an embedded single-case study for exploring the aspects related to product sustainability within IFF and N&B merger context. The main objective was to conduct an in-depth analysis on C2C and LCA as integrated approaches for promoting product sustainability among the stakeholders of the recently combined company. By means of theoretical and empirical research, it was possible to unfold the opportunities and challenges associated with integrating both approaches, and to establish relevant elements that need to be considered when driving product sustainability in such a diverse business.
In this way, through a literature review, the conceptualisation of both C2C and LCA was outlined. This allowed the construction of a theoretical framework that served as the foundation for understanding these product sustainability approaches and their relevance in the chemical, biotechnology and food industry. Moreover, empirical research was conducted based on qualitative methods which provided clear insights on the application of C2C and LCA in the specific professional context of IFF and N&B. These methods included a stakeholder analysis for identifying relevant actors within the case study, followed by semi-structured interviews conducted to representatives of these key actors. Later, a qualitative content analysis was performed to evaluate the data collected, to discern perceptions on product sustainability and to determine relevant statements regarding C2C and LCA integration.

Overall, by developing this case study it was possible to fathom IFF and N&B merger through the lenses of corporate sustainability, particularly on the efforts to consolidate product sustainability strategies, which is an integral part for driving stakeholder engagement. Key insights from the research of C2C and LCA integration included the opportunity of broadening the company's sustainability performance and enabling competitive advantage by showcasing different sustainability attributes of IFF products. Additionally, some challenges were also identified, mainly in terms of assessing a diverse product portfolio and dealing with technical contrasts such as metrics incompatibilities between C2C and LCA. Though, the overall discussion brought up positive remarks which supported the idea of coupling C2C and LCA to create a more comprehensive evaluation of product sustainability in the combined company. On that account, an integrated framework on C2C and LCA was built based on theoretical and empirical findings. The framework was proposed as a first-step solution for acknowledging key aspects on the applicability of a more nuanced product sustainability approach in IFF. Nonetheless, due to the limitations of the case study research design, this solution is not equipped to provide guidance over which precise conditions is it advantageous to apply an integrated approach. Therefore, future considerations include projecting the framework to the specific circumstances of each IFF business unit and, ideally, scaling it down to particular products depending on market demands.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

The following abbreviations are used throughout the document:

AAU – Aalborg University
AUB – Aalborg University Library
C2C – Cradle to Cradle
C2CPII – Cradle to Cradle Products Innovation Institute
CEO – Chief Executive Officer
EEA – Eco-Efficiency Analysis
EHS&S – Environment, Health, Safety and Sustainability
EPEA – Environmental Protection Encouragement Agency
ESG – Environment, Social and Corporate Governance
EU – European Union
GHG – Greenhouse Gas
GMOs – Genetically Modified Organisms
H&S – Health & Safety
IFF – International Flavors & Fragrances Inc.
ISO – International Organization of Standardization
LCA – Life Cycle Assessment
LCC – Life Cycle Costing
LCI – Life Cycle Inventory
LCIA – Life Cycle Impact Assessment
LCSA – Life Cycle Sustainability Assessment
MBDC – McDonough Braungart Design Chemistry
M&A – Mergers and Acquisitions
N&B – DuPont Nutrition and Biosciences
ppm – Parts per million
P&S –Polak and Schwarz
R&D – Research & Development
SA – Stakeholder Analysis
SDGs – Sustainable Development Goals
sLCA – Social Life Cycle Assessment
SOI – Sustainability-oriented Innovation
UN – United Nations

LIST OF FIGURES AND TABLES

CHAPTER ONE

INTRODUCTION

This chapter outlines the background information of the research field and the purpose of the study. Here, the topic and scope of the research study are briefly described along with the motivation and significance of the thesis statement.

Even though global consumption and production has taken an unsound path over the last decades, people are becoming more aware of the impacts inflicted to the planet and the urgent need for rethinking human activities (Burke *et al.,* 2017). For instance, the vision of sustainable development has received growing attention from researchers, industry and policy-makers (Silvestre & Ţîrcă, 2019). This vision is, nowadays, a high priority in the agendas of public and private sectors and it is internationally recognised as a concerted effort for achieving environmental and societal well-being. The big step that prompted this awareness was the 2015 General Assembly of the United Nations (UN), where the resolution "Transforming our world: The 2030 Agenda for Sustainable Development" was adopted. Along these lines, a majority of business and corporations place sustainability at the centre of their managerial operations. With the vision of sustainable development designating a better path for humanity, more and more organisations have made environmental and social commitments that also act as tangible benefits in terms of reduced risks, value creation and increased brand reputation. Thus, sustainability-related strategies are necessary for businesses to stay competitive today and in upcoming years (Dyllick & Muff, 2016).

Despite the high priority given to sustainability topics in business agenda, few studies have been developed on how to address corporate sustainability in shifting business dynamics, particularly in common processes such as mergers and acquisitions (M&A) occurring between companies. In general, economical and organisational aspects of M&A processes are extensively studied. However, more efforts should be placed into identifying and understanding the sustainability factors related to before-during-and-after M&A processes (Denčić-Mihajlov, 2020).
This master's thesis is innovative in its goal to explore corporate sustainability aspects under the organisational context of an M&A process. The research project has been designed as a case study which analyses the latest combination between International Flavors & Fragrances Inc. (IFF) and DuPont Nutrition & Biosciences (N&B) from a corporate sustainability standpoint. Here, the focus is given to the post-merger period of the new company, which keeps operating under the name of IFF, and to the forthcoming challenges in unifying the sustainability performance, especially in terms of product sustainability.

From a business standpoint, product sustainability explores ways to deliver products that generate economic value while also providing environmental and social benefits. It also serves for increasing competitiveness in times of changing demands, especially in terms of a sustainability performance of the products offered. Under this case study context, two different approaches for assessing product sustainability have come across: Cradle to Cradle (C2C) applied in former IFF and Life Cycle Assessment (LCA) applied in former N&B. The main objective of this study is to conduct an in-depth analysis of C2C and LCA as integrated approaches to promote product sustainability among the stakeholders of the recently merged company. Hence, a thorough description of IFF and N&B background is presented alongside the challenges arising from a sustainability perspective. Furthermore, the study is supported on a broad literature review of product sustainability, LCA and C2C. This is further explored by data collection from key stakeholders involved in IFF and N&B merger process and a qualitative content analysis. Ultimately, the problem formulation is unfolded by means of theoretical and empirical research, while limitations on the research design and further considerations are outlined.

CHAPTER TWO

BACKGROUND AND PROSPECT

This chapter provides an overview of the subject under study. Here, IFF organisation is introduced as well as the merger process with DuPont Nutrition and Biosciences. Key considerations about the new stage of IFF are outlined, especially from a sustainability standpoint. The problem formulation is then defined and contextualised in terms of IFF forthcoming challenges to make way for the research question.

2.1. International Flavors & Fragrances Inc.

International Flavors & Fragrances Inc., mostly known for its trade name IFF, is a global company which manufactures and supplies innovative products used across various industry sectors such as food, beverage, health and biosciences. The company has a strong focus in producing sustainable and innovative solutions based on artistry and scientific expertise in order to deliver high quality experiences to its customers.
IFF runs under the purpose of applying science and creativity for a better world, which has led the company to pioneer in services categories including taste, texture, scent, nutrition, enzymes, cultures and probiotics (IFF, 2021a). Committed to building a better world, IFF claims to be driven by a sustainable approach in the industry, where numerous possibilities are explored to expand customers' opportunities, and at the same time aiming to have a positive impact (IFF, 2021a).

With more than 130 years of history behind, the origins of the company were crucial in the industrial development of sensorial experiences such as flavoring and fragrances. In fact, the first of IFF's parent companies, Polak and Schwarz (P&S), was founded back in 1889 in Zutphen, a small Dutch town. P&S was established as a result of the passion for herbs, spices and flavors, plus the curiosity for the science of senses. During the 20th century, the business of flavoring and fragrances experienced globalisation on a grand scale, and the growing multicultural discovery allowed this industry to flourish. This geographic growth along numerous scientific advances set the stage for the powerful mergers that gave way to the modern IFF (IFF, 2021b).

Nowadays, the company has contributed to the global design and production of a large range of products that meet the needs of customers across the food and beverage, home and personal care, and health and wellness industries. With its current business models, the company expects to continue excelling in these services in the distant future (IFF, 2021c). IFF is headquartered in New York City and has branches, manufacturing facilities and research centres in more than 40 countries around the world. The company has grown over the years by acquiring numerous brands and expanding their portfolio. Most of these brands have been integrated into IFF business, while others have retained their own business models and continued operating alongside the broader IFF brand (IFF, 2021c). As of 2020, with a $5.1 billion market revenue, IFF is a member of the S&P 500 index, which measures the performance of 500 large companies listed on the US stock exchanges (Bloomberg, 2021).

2.1.1. Merger with DuPont Nutrition and Biosciences

As mentioned before, various mergers and acquisitions (M&A) have enabled the business development of IFF throughout the years, conferring the company a wide spectrum of products in its portfolio. The latest and one of the biggest of these M&A was announced in 2019, with the merger of IFF and DuPont Nutrition and Biosciences in a Reverse Morris Trust transaction (DuPont Nutrition & Biosciences, 2019). This type of transaction allowed a tax-efficient manner of combining IFF with the N&B business unit of DuPont de Nemours corporation (DuPont Nutrition & Biosciences, 2019).

Before the merger, N&B has global operations in research and production of specialty ingredients used in food and beverage products as well as in health and pharmaceutical solutions. The product catalogue of N&B included enzymes, antimicrobials, antioxidants, dairy cultures, emulsifiers, fibers, probiotics and proteins among others (DuPont Nutrition & Biosciences, 2020a). Likewise, N&B was driven by science, innovation and a commitment to deliver sustainable solutions to global industries. In this way, both N&B and IFF shared key business values along with a culture guided by development and customer needs. With highly complementary portfolios, both companies were deemed strategic partners as their combination would deliver in-demand innovative solutions for more natural and healthy products on the market (DuPont Nutrition & Biosciences, 2019).

By the beginning of 2021 the merger transaction was completed, valuing the combined company at $45.4 billion on an enterprise value basis, with an annual estimated revenue of $11 billion. Under the terms of the agreement, DuPont shareholders own 55.4% of the shares of the new company, while existing IFF shareholders own 44.6% (DuPont Nutrition & Biosciences, 2019). Continuing under the name of IFF, the combined organisation started operating on February 1st 2021 (International Flavors & Fragrances, 2021).

Upon the completion of the merger, IFF unveiled its new brand identity and began a new era of strategic transformation based on a customer-centric approach, deep research and development and a strong position towards innovation and sustainability. As part of this new identity, IFF launched the new purpose, brand commitments and culture values that will support the success of the new four business divisions that now comprises IFF (International Flavors & Fragrances, 2021).

2.1.2. Reorganisation of IFF

Where science and creativity meet. This is the new IFF tagline that captures the company's long-standing focus on the interrelation between artistry and science to discover, produce and deliver integrated solutions (International Flavors & Fragrances, 2021). As mentioned above in this chapter, the company now runs under the purpose of applying science and creativity for a better and more sustainable future. Moreover, this purpose is supported by three commitments which reflects the vision of the new organisation:

- **Question everything** in order to encourage new discoveries at every opportunity
- **Champion creators** by embracing differences and converting ideas into impact
- **Do more good** and leading the journey to do better for people and the planet

Furthermore, to deliver these three commitments, the cultural principles and values of the new IFF organisation were also updated from the ones established before the N&B merger. The principles are based in progress, passion and integrity extended to empower innovation and collaborate for achieving higher levels of performance (International Flavors & Fragrances, 2021).

Lastly, as part of IFF's reorganisation, its new business divisions were introduced. Previous to the merger with N&B, IFF was formerly operating through two divisions corresponding to Taste and Scent segments. At present, it is now operating through four business units which include Nourish, Scent, Health & Biosciences and Pharma Solutions as shown in ***Table 1*** (International Flavors & Fragrances, 2021).
Altogether, the new brand identity and IFF's reorganisation unleash all the basis for upholding a leader industry in food, beverage, health, biosciences and sensorial experiences that aims to do more good for the people and the planet.

Business division	Foundation
Nourish	The largest of the four divisions, Nourish is composed of IFF's Taste segment and N&B's Food & Beverage segment. This division offers feed innovation products for healthier and more sustainable food choices.
Scent	Scent division pioneers in the creation and production of fragrances, scent solutions and cosmetic actives for key customers and goods industries such as fine perfumery, home and personal care.
Health & Biosciences	Health & Biosciences division is the leading platform in biosciences and microbiome solutions across a broad range of consumers such as the agricultural sector.
Pharma Solutions	Pharma Solutions division researches and develops the ingredients and applications that support global production of pharma and dietary supplements.

Table 1. New IFF's business divisions which were introduced upon the completion of the merger with DuPont Nutrition and Biosciences (International Flavors & Fragrances, 2021).

With sustainability and innovation embedded into the company's vision and culture, IFF challenges *business as usual* operations, aiming to transform the design and manufacture of products in order to have a positive impact and generate greater value. The new IFF era brings with it exciting opportunities from a corporate sustainability standpoint. Furthermore, it also represents challenging times in terms of N&B's merger and the evaluation of different sustainability approaches that come into play in this journey. Leveraging these approaches can be key to success on the integration of sustainability in the new business strategy of IFF.

2.2. The new IFF era: Trends in sustainability

With the launch of its new brand identity, IFF has made clear its mission of creating a better world and doing more good through business based on science and creativity. However, it is also clear that completing a big merger, as the one with N&B, as well as expanding its operations at a large scale imposes great social, economic and environmental responsibilities (Denčić-Mihajlov, 2020; International Flavors & Fragrances, 2021). Therefore, sustainability issues should not be overlooked and must be addressed from early stages and throughout the entire merging process (Denčić-Mihajlov, 2020).
From an environment, social and corporate governance (ESG) perspective, an M&A process requires a thorough plan of activities directed to integrate and improve the sustainability efforts of the combined company (Denčić-Mihajlov, 2020). Numerous factors come into consideration when undergoing this process in order to guarantee a well-developed sustainable business that can add value to its stakeholders and future generations (González-Torres *et al*., 2020).

2.2.1. Environment, social and corporate governance

In the light of N&B and IFF merger, the considerations around environment, social and corporate governance responsibilities have resulted in the re-evaluation of the ESG functions along with the integration of strong approaches brought by the former N&B business. Accordingly, IFF's responsibilities and ESG operations are based on three segments: People, Planet and Product (IFF, 2021d). Through this framework, as shown in ***Figure 1***, the company aims to accelerate the progress to a more sustainable and equitable world while guaranteeing an industry leadership by delivering high standards products.

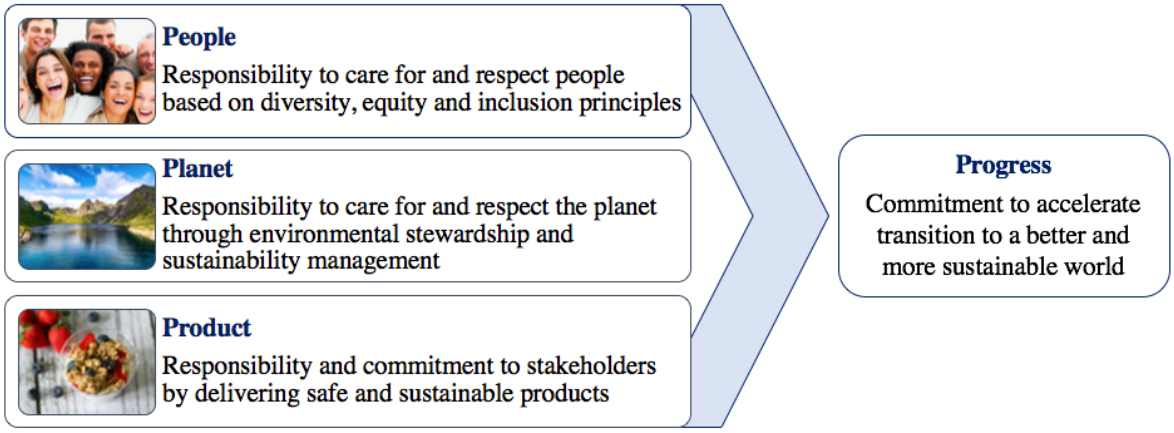

Figure 1. Overall framework of IFF's responsibilities and commitments to environmental, social and corporate governance based on three main segments for ensuring continual progress (based on IFF, 2021d).

The *People* segment includes not only commitment to employees' health and safety, but also outlines social initiatives and supplier partnerships such as the Responsible Sourcing program. Moreover, the *Planet* segment outlines the importance of environmental management and IFF's commitment to reduce its impacts on our planet. Here, sustainability

initiatives and eco-goals on energy, water and waste management are set in order to improve IFF's environmental performance by 2025. Lastly, the *Product* segment highlights the responsibility to customers, consumers, investors and communities by means of operating in a transparent way to deliver sustainable products. This segment includes efforts on product sustainability and innovation as well as ethics and compliance programs (IFF, 2021d).

Historically, IFF has had a forceful position on environmental and social responsibilities (IFF, 2021e). Likewise, DuPont corporation has strengthened its responsibilities approach throughout the years, with a great focus in the health and safety area (DuPont, 2020). Within the new IFF organisation, safety and sustainability have come together as a cornerstone for each one of the business units, aiming to attain ESG operations throughout the different business levels (Cleverly & Thrane, 2020)[1]. Therefore, in the new IFF, the department of Environment, Health, Safety and Sustainability (EHS&S) functions crosswise through all four business divisions as part of the Global Research & Development (R&D) organisation (Yep, 2021)[1], as shown in ***Figure 2***.

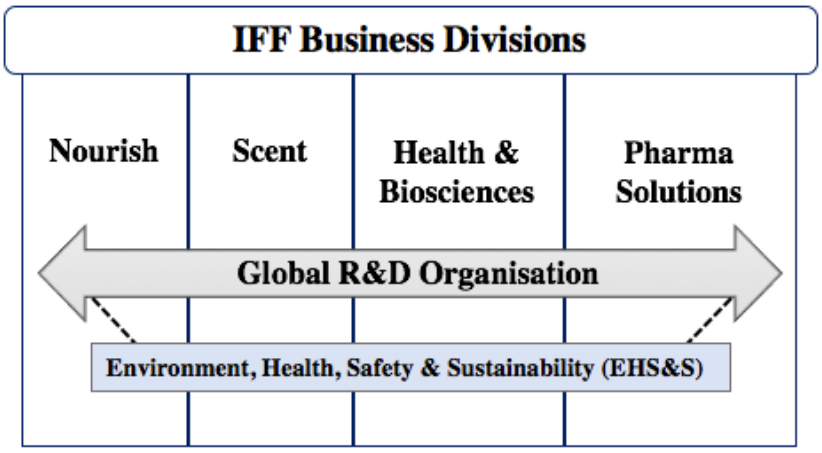

Figure 2. Structural alignment of IFF's EHS&S department. As part of the Global R&D organisation, it functions across all four business divisions to leverage environmental, social and corporate governance efforts in all business operations.

The EHS&S team is responsible for establishing ESG efforts and leveraging the execution of a global sustainability strategy in collaboration with corporate communities, investors, customers and suppliers. While the definite 2030 sustainability strategy is still under review following IFF's reorganisation plan, it will encompass safety and sustainability key points starting off from three pillars: Green Growth, Environmental Reporting & ESG and Responsible Sourcing (Cleverly & Thrane, 2020). Moreover, this supports the United Nations Sustainable Development Goals (SDGs) as a common framework and a call to action for achieving a sustainable and equitable future.

The conceptual model of the 2030 global sustainability strategy is based on reducing IFF's footprint and increasing IFF's handprint, which translate into minimising negative impacts and maximising the positives ones. To accomplish this, a series of goals are being set within

[1] Source derived from International Flavors & Fragrances Inc. (Not publicly available).

each one of the pillars, accommodating to the extent possible the sustainability approaches of IFF and former N&B business (Cleverly & Thrane, 2020).

Before the M&A process, N&B had a 2020 sustainability strategy in place covering all business levels based on three core areas: Sustainable Sourcing, Sustainable Operations and Sustainable Solutions (DuPont N&B, 2020b). Likewise, IFF is still operating under a 2021 sustainability strategy with a similar scope after joining forces with N&B. ***Figure 3*** shows how the core areas of the former N&B 2020 sustainability strategy and the pillars of the IFF 2021 sustainability strategy are being integrated to give way to a newly concerted sustainability vision based on the correlation of both business' approaches (DuPont N&B, 2020b; Cleverly & Thrane, 2020). It is important to note that, as of May 2021, the final version of the global sustainability strategy for the combined company has not been released yet, however, ***Figure 3*** gives an overview of the expected scheme.

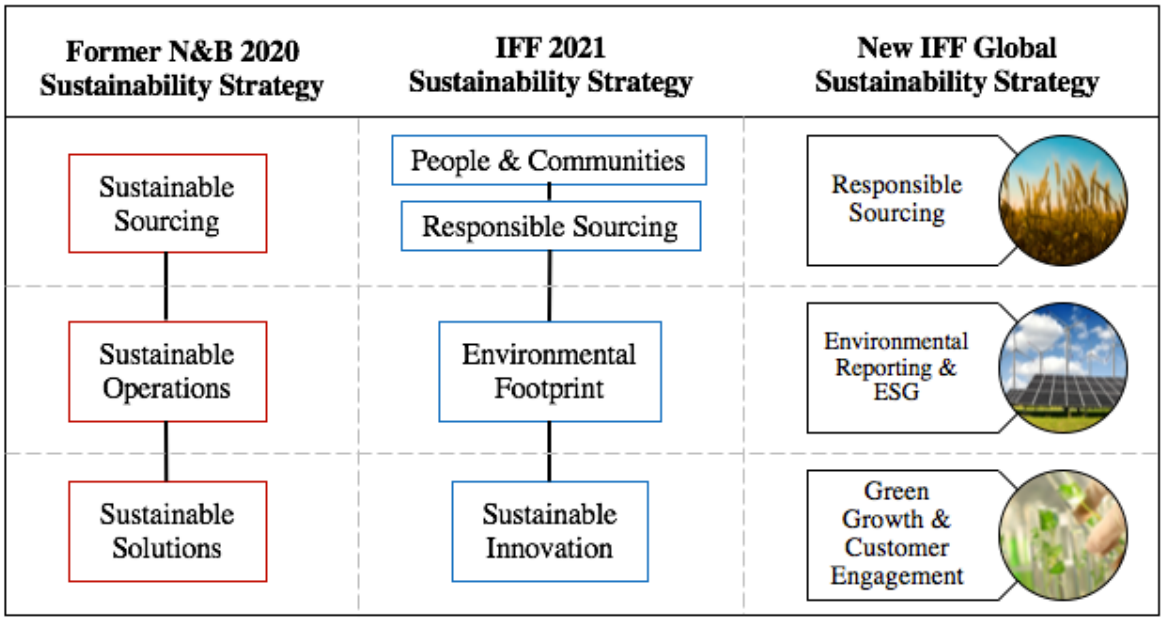

Figure 3. Parallel structure of former N&B 2020 sustainability strategy and IFF 2021 sustainability strategy. Both approaches have led to the proposal of the global sustainability strategy for the new IFF (based on DuPont N&B, 2020b; IFF, 2021d; Cleverly & Thrane, 2020)[2].

Considering this, it is evident that the *People, Planet* and *Product* segments of the overall IFF's responsibilities framework are embedded in what will be IFF's new global sustainability strategy. Due to the high customer engagement of this new organisation, one of the fast-growing areas is product sustainability and innovation (IFF, 2021f). This area is strongly related to the Green Growth pillar of the strategy, although without overlooking its link to the other pillars of Environmental Reporting and Responsible Sourcing (IFF, 2021f). As a key area, a lot of endeavour has been put towards the improvement of product design and production in order to achieve sustainable and innovative outcomes.

[2] IFF Global sustainability strategy not publicly available as of May, 2021.

2.2.2. Product sustainability and innovation

For many years, IFF has worked on designing products that can contribute not only to people's needs but also to society and the environment. With the upcoming sustainability strategy, the company aims to meet the rapidly rising market demand for sustainable products and to strengthen its stakeholder relationships (IFF, 2021f). For this, detailed attention should be given to the efforts designated under the Green Growth pillar of the strategy in order to boost innovation for better and sustainable products. As straightforward as it might sound, there are numerous approaches to product sustainability and innovation, and under the light of IFF and N&B merger context, some of these approaches can be highlighted.

Recently in IFF, a great interest has arisen on circular design as a key principle for sustainable innovation (IFF, 2021f). The principle is based on the circular economy model, one that is restorative and regenerative by maintaining the utility of products and materials while retaining their value along the entire life cycle (Ellen MacArthur Foundation, 2013). Through circular design, IFF has sought to create closed-loop systems where products and materials are continually used and waste is avoided or re-valued to serve as a resource input (IFF, 2021f). For instance, this principle is being applied in early stages of R&D processes where the raw materials are assessed against some requirements such as recyclability and responsible sourcing. Furthermore, these materials are later used to create products that are manufactured in a sustainable way when possible, by using renewable energy in the production process and generating zero waste. Lastly, the products are considered biodegradable when reaching the end of life stage, thus completing a closed-loop system (IFF, 2021f). In order to assess product sustainability based on circular design, IFF advocates for Cradle to Cradle (C2C) certification for some of their products (IFF, 2021f). This certification is widely used for assessing safety and sustainability of production processes aimed at circular economy, thus it represents a globally recognized measure of sustainable products (C2CPII, 2021a).

On the other hand, the recently acquired N&B had another approach to product sustainability and innovation. In N&B 2030 sustainability strategy, the core area of Sustainable Solutions was highly focused on increasing positive impacts in collaboration with customers and stakeholders. Here, providing innovative and sustainable solutions with lower greenhouse gas (GHG) emissions was a key component of the strategy. Some of the projects under this core area included the integration of sustainability in product and process development and the establishment of customer partnerships to facilitate the use of low-impact products (DuPont N&B, 2020a). For this reason, N&B had a strong focus on completing life cycle assessment (LCA) of a large number of products in their portfolio, as a measure of product sustainability and the associated environmental impacts (DuPont N&B, 2020a).

Even though both companies had innovation and product sustainability in the spotlight, their approaches to this field can be considered different and so the way to assess these. With the current fast-changing market and an increasing customer demand for sustainable products, there is a need to generate a common understanding on these two approaches that have come into play following the merger of IFF and N&B business.

2.3. Problem formulation: IFF's forthcoming challenge

For many years, the topic of M&A transactions and the process that this entails has been extensively studied, especially from economical and organisational aspects such as value creation, financial growth, behavioural and cultural elements among others. However, few studies have been developed on M&A structuring from a sustainability and ESG perspective (Denčić-Mihajlov, 2020). Nowadays, being sustainable development a high priority framework for actors in the public and private sector, more efforts should be placed into identifying and understanding the sustainability factors related to before-during-and-after M&A processes (Denčić-Mihajlov, 2020).
This master's thesis is presented as an effort to outline the M&A process occurring between IFF and N&B organisations from a sustainability standpoint. Here, the focus is given to the post-merger period and to IFF's forthcoming challenges in unifying the sustainability performance of the combined entity. As mentioned throughout this chapter, both companies have an equivalent sustainability scope along with comparable strategies. Nonetheless, bringing together ESG and sustainability status from the two parties is critical for achieving a well-developed sustainable business model and maintaining corporate advantage.

One of the challenges that IFF is facing in terms of consolidating sustainability governance is on how to address product sustainability and innovation, taking into account the different approaches that have converged from IFF and N&B sides. Commonly, in the business markets there is a lack of agreement on what a sustainable product is and how to measure it. At the moment, there is no global consensus on sustainable products, but instead, there are many perspectives for understanding product sustainability (Dyllick & Rost, 2017). Under the particular M&A context discussed in this thesis, two different approaches for assessing product sustainability have come across: Cradle to Cradle and Life Cycle Assessment.
Considering IFF's new broad portfolio, assessing product sustainability by integrating both approaches could generate a nuanced understanding and provide a vision of sustainable progress, which is highly relevant for communicating sustainability performance to the stakeholders. In order to do so, it is important to evaluate the concepts and applications of C2C and LCA for fathoming conflict areas and synergies that can exist among both approaches. Moreover, it is crucial to explore the opportunities and challenges of integrating C2C and LCA under the case study context, and to understand how this can lead to a concerted framework for promoting product sustainability among the stakeholders of the recently combined company.

CHAPTER THREE

PURPOSE OF THE STUDY

This chapter presents the research question that has been established based on the problem formulation. Furthermore, the research objectives are outlined along with the delimitations of the research study.

3.1. Research question: Unravelling IFF's challenge

Taking into account the merger background of IFF and N&B presented before, as well as the challenges that the post-merger period represents in terms of corporate sustainability, more specifically in product sustainability of a broader portfolio, the following research question and sub-questions have been defined as the baseline for this master's thesis.

Considering IFF and DuPont N&B merger process, how can Life Cycle Assessment and Cradle to Cradle approaches be integrated for promoting product sustainability among stakeholders of the combined company?

- What are the LCA and C2C approaches used by IFF and former N&B to assess product sustainability?
- How can the stakeholders' perception on product sustainability be discerned and used as a point of departure for integrating C2C and LCA approaches?
- Which opportunities and challenges does the integration of C2C and LCA represent in the given merger context?
- How can these areas be framed as a concerted effort towards a more integrated product sustainability in the new IFF?

3.2. Research objectives

From a business perspective, product sustainability is deemed relevant for generating value while providing social and environmental benefits. It also grants competitive advantage in the market due to the high importance given to sustainable development within the public and private sector. Altogether, promoting product sustainability is a priority in most business agendas nowadays, and in the new era of IFF this is no exception.

The main objective of this study is to conduct an in-depth analysis on Life Cycle Assessment and Cradle to Cradle as integrated approaches to promote product sustainability under the context of the recently merged IFF/N&B company.

This thesis aims to:

- Outline the general scheme on C2C and LCA used by IFF and former N&B when addressing product sustainability.
- Analyse stakeholders' perception on product sustainability and identify relevant statements in relation to C2C and LCA application.
- Identify the opportunities and challenges for integrating C2C and LCA approaches in IFF/N&B context.
- Determine an integrated framework of C2C and LCA based on both, schemes and perception of product sustainability in IFF/N&B context.

3.3. Delimitation of the study

Following the problem formulation and the research objectives, this study is focused on two of the many evolving approaches of product sustainability: C2C and LCA. It is important to highlight that these are not the only product sustainability perspectives, nor the more dominant ones. Some other perspectives within the field include eco-design, eco-efficiency and product-service systems among others (Dyllick & Rost, 2017). However, considering the background of this study as presented in the above chapters, the C2C and LCA approaches were selected given their relevancy to the IFF/N&B merger context. Moreover, the scope under which these approaches are analysed is limited to their application in the chemical, biotechnology and food industry, due to the core business and production lines of the combined company. Likewise, the stakeholders deemed pertinent for the analysis are those primary to the organisation for whom product sustainability is a direct business concern. Furthermore, the selection of these primary stakeholders, explained in next chapters, also supports practicality reasons related to contacts' accessibility and availability for the data collection.

Altogether, this study can be considered as an up-close examination of product sustainability elements from a corporate standpoint. Nonetheless, this examination is done through a solid academic foundation which integrates research principles within a real-life problem as the one described in this study. The conditions around IFF and N&B context delineate the research process, therefore, a case study was designed based on the aforementioned delimitations.

CHAPTER FOUR

RESEARCH DESIGN

This chapter provides a description of the research design established to develop the study. First, the overall research process and its structure is presented, followed by a description of the case study design that was implemented to carry out the project.

4.1. The research pentagon

In order to address the research problem previously presented, a research design was established as the overall strategy for developing the study and tackling the research question. The elements that served as the foundation for the research design were unfolded, as shown in ***Figure 4*** and described in ***Table 2***. These elements indicate the focus of study, the relevance of the problem and the means to advance in the analysis. It is important to highlight that all five elements are related to one another and therefore, represent a dynamic research process rather than a linear one (Rienecker *et al.,* 2013).

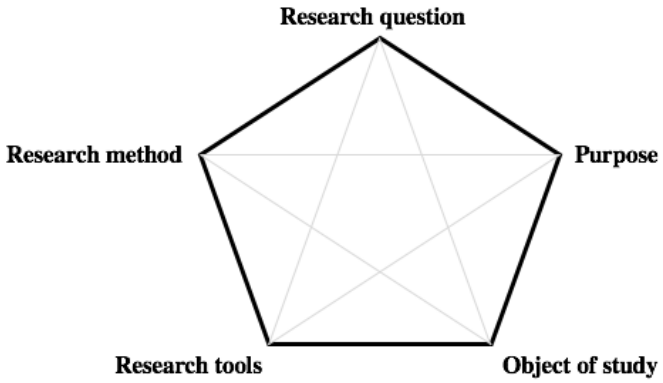

Figure 4. Overall structure showing five essential elements of the research design established for this study. Here, all elements are interconnected, indicating a dynamic research process (based on Rienecker *et al.,* 2013).

Research Question	Purpose	Object of study	Research tools	Research method
Considering IFF and DuPont N&B merger process, how can Life Cycle Assessment and Cradle to Cradle approaches be integrated for promoting product sustainability among stakeholders of the combined company?	To analyse LCA and C2C as integrated approaches for promoting product sustainability within primary stakeholders of the recently combined company.	LCA and C2C schemes used in N&B and IFF respectively. Moreover, product sustainability perceptions from primary stakeholders.	<u>Theoretical framework:</u> Product sustainability, C2C and LCA concepts under the context of study <u>Methodological framework:</u> Literature review, stakeholder analysis, semi-structured interviews, qualitative content analysis	Embedded single-case study design based on an information-oriented selection.

Table 2. Detailed description of the essential elements within the research design. These elements built the foundation for developing the study and are outlined through the thesis report.

4.2. Delineation of the case study

Given the nature of the problem, a case study method was deemed appropriate for carrying out the research project. This choice was driven by the scarcity of information in the particular context of study, thus demanding a more in-depth examination by applying a case study design. This method allows to explore complex issues and provides a comprehensive understanding of specific real world settings across a number of disciplines, especially in social sciences, business and law (Harrison et al., 2017). According to Flyvbjerg (2006), when applying a case study, the method as a whole is subject to misunderstandings related to the generation of knowledge, since it can be seen as a focal context-dependant research. However, he argues that case studies result in valuable knowledge that can be generalised for building up theories and development in the specific field of study (Flyvbjerg, 2006).

Under the circumstances defining this research project, an embedded single-case study design was used to investigate the dynamics present around product sustainability within a single setting, as is the IFF and N&B merger process. Furthermore, both LCA and C2C approaches acted as independent units of analysis, therefore framing the focus of the study, as shown in ***Figure 5***. In this way, identifying the boundaries of the research prior to the development of theoretical and methodological propositions resulted beneficial for guiding the data collection and analysis of the study (Yin, 2009). It is important to highlight that, by narrowing down the case's boundaries, its generalisability could be increased by the strategic selection of samples and data collection. Thus, an information-oriented selection was followed in order to maximise the utility of data collected (Flyvbjerg, 2006). Nonetheless, it should be noted that, being this a case study, it represented a high level of research flexibility depending on its application and given conditions. New and unexpected results were introduced during its course, which led the research process to take new directions as the project developed, yet conserving its integrity under the set boundaries.

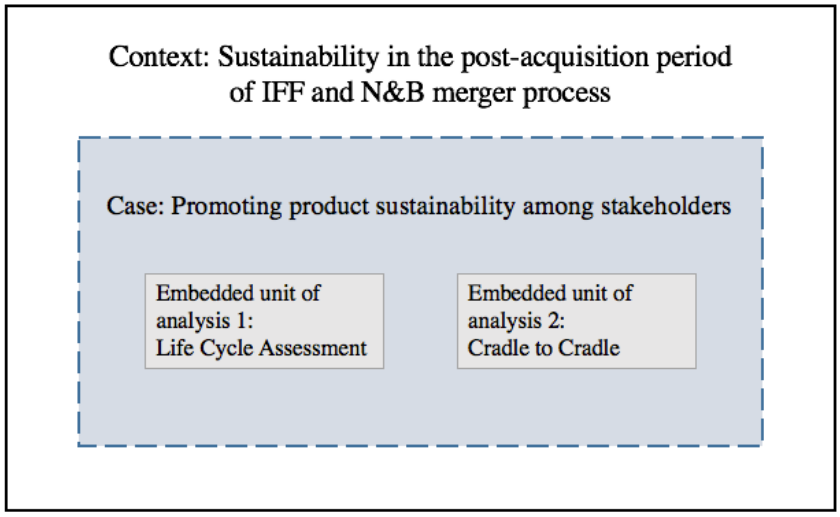

Figure 5. Visualisation of the embedded single-case study design established for developing the project. This design allowed to identify the boundaries of the study at an early stage of the research process in order to preserve the wholeness and integrity of the case (Based on Yin, 2009).

CHAPTER FIVE

THEORETICAL FRAMEWORK

This chapter presents and describes the theories that support the research study. Key concepts such as product sustainability, Cradle to Cradle and Life Cycle Assessment are introduced and defined. Moreover, connections are drawn within these concepts and the specific context of the study.

5.1. Product sustainability

A rapidly growing interest in product sustainability has emerged in global businesses and organisations during the last decades. Due to its undisputed relevance in sustainable development, product sustainability plays a key role in business performance, and thus, it is an important pillar of corporate sustainability (Deng *et al.,* 2020). Now more than ever sustainability-related strategies are crucial for addressing environmental and social issues, as well as for increasing brand reputation, attractiveness and for remaining competitive in the market (Dyllick & Rost, 2017).

Product sustainability is a field focused on products' performance in relation to economic, social and environmental benefits. It aims at balancing the contributions of products from a triple bottom-line, which includes people, planet and profit aspects. From a business perspective, product sustainability can serve organisations to create multiple and shared values for different stakeholders, resulting advantageous in times of changing consumers and public demands (Dyllick & Rost, 2017). Moreover, it can help companies improve competitiveness and enter new market segments (e.g. green consumers market) through cost-effective practices such as efficient use of materials and energy (Li & Li, 2016). From a societal perspective, product sustainability contributes to various aspects of sustainable development, especially by reducing the ecological footprint and/or by improving social conditions. Nonetheless, finding the balance between private and public benefits and values remains challenging when it comes to product sustainability, particularly because of the many considerations and approaches that are available to evaluate it (Dyllick & Rost, 2017).

Even though business success of product sustainability can be measured without difficulty by e.g. economic indicators such as sales and customer satisfaction of sustainable products, its truly sustainability contribution might be dubious depending on the approach taken to achieve it and evaluate it (Dyllick & Rost, 2017). Nowadays, there are numerous approaches towards product sustainability and these seem to increase as time goes by (Deng *et al.,* 2020). Some of the most recognised include eco-design, design for sustainability, cradle-to-cradle, product-service systems and tools such as life cycle assessment. The differences between these approaches range from their triple bottom-line focus, all the way to minimising negative impacts or seeking net-positivity (Dyllick & Rost, 2017). Each one of these concepts opens a path towards developing higher and more ambitious levels of sustainability. These paths include different sustainability dimensions and contributions, however, they should not be seen as parallel courses, but instead as crossing paths leading to a better world.

5.2. Cradle to Cradle as an approach to product sustainability

Ever wonder what it would be like to live in complete harmony with nature and achieve the environmental equilibrium that we humans are expected to have as being part of this planet? Well, this is the type of question that C2C concept intends to answer. As Braungart and McDonough (2008) have stated, "Cradle to Cradle tries to put human beings in the same *species* picture as other living things". By doing it so, C2C proposes a radical and positive vision for the future of planet Earth, where products are designed to be beneficial not only to humans, but to the environment as a whole. The main idea behind this concept is not to reduce

negative impacts from a production process, but to act from an early stage and enhance positive impacts within the entire life cycle of products (Hauschild *et al.,* 2018).

5.2.1. Emergence of Cradle to Cradle concept

C2C is considered a biomimetic approach, which allows to model human industry processes based on natural systems. The term Cradle to Cradle was first used in the 1980s by Walter R. Stahel, in an attempt to challenge the emerging idea of companies being responsible for their products from "cradle to grave". Stahel believed that this perception was only reinforcing the existing linear economic model. Contrarily, he argued that a more sustainable solution would rely on using durable goods in a continuous loop from "cradle back to cradle" (Product Life Institute, 2013). Some years later, in 2002, the German chemist Michael Braungart and the US architect William McDonough developed in a thorough way the C2C concept as is known today. Their published book "Cradle to Cradle: Remaking the way we make things", clarifies the theoretical basis and principles of C2C and serves as a guidance for applying the concept into the design of products and systems (McDonough & Braungart, 2009).

5.2.2. Foundation and principles

As mentioned before, the C2C concept aims to have a positive impact on the environment by imitating nature's way of doing things. By finding inspiration from ecosystems' dynamics, this approach pictures industrial materials as nutrients circulating in a safe and sustainable way. Moreover, it outlines three key principles that must be followed in order to achieve this: Waste equals food, Use current solar income and Celebrate diversity (Hauschild *et al.,* 2018).

Principle # 1: Waste equals food

This principle presents the idea of waste as valuable flows. In nature, materials are continuously cycled within organisms and the ecosystem. What one organism may discard as waste will become a valuable input for another organism, in this way *waste equals food*. This idea is then applied to industrial processes, where from an early stage, products are designed for only having "healthy emissions". Hence, any emissions that may eventually result from the process can be used as a resource input in other industrial processes or systems (Hauschild *et al.,* 2018).

Waste equals food clearly focuses on a design with beneficial effects rather than reducing the amount of emissions. It is important to highlight that the principle encompasses emissions occurring throughout the whole life cycle of the product, including the product itself at the end of life or disposal stage. For this reason, materials should be classified as technical or biological nutrients, this allows to define the continuous cycling that they will undergo within the system. In such a manner, biological nutrients are flows that can be utilised by living organisms to fulfil biological functions such as growth and energy storage, thus they are considered as consumable flows. Contrarily, technical nutrients are flows that can be utilised in technical systems and maintain their value throughout the process by means of e.g. reusing, recycling and refurbishing. For this reason, the value of technical materials is the service they provide and not their components *per se*, thus considered as not consumable flows. The value

of these flows can also be increased as they cycle, which is a process known as "upcycling". Moreover, C2C concepts allow harmful materials such as hazardous substances to be part of the technical nutrients as long as these materials do not enter the environment and as long as living organisms are not exposed to them (McDonough & Braungart, 2002; Hauschild *et al.,* 2018).
Even though, in some cases biological nutrients can be part of the technical nutrient cycle, a key message of the C2C concept is that both nutrient categories should not be mixed beyond easy separability in order to avoid the risk of creating products which will no longer fit either the biological or the technological cycle. This type of product was denominated by Braungart and McDonough (2002) as *the monstrous hybrid*, a product of lower quality and value due to its ravel nature and the high inputs of energy and materials that would be needed for splitting its technical and biological components.

Principle # 2: Use current solar income
The second principle of C2C states that all energy required to fuel the continuous cycling of biological and technical nutrients must originate from current solar income, which includes renewable sources such as photovoltaic, wind, hydro and biomass energy. These types of energy sources are a natural effect of solar radiation on Earth's surface, therefore this principle follows the idea of simulating natural processes that are fuelled by solar income. One important consideration is the fact that only *current* solar income is allowed. Consequently, fossil fuels are not allowed as a source of energy since these are considered *older* solar income. Additionally, from a C2C perspective, there are no restrictions in the amount of energy used throughout the cycles as long as the energy quality aligns with the principle of current solar energy (McDonough & Braungart, 2002; Hauschild *et al.,* 2018).

Principle # 3: Celebrate diversity
The third and last principle of C2C recognises the importance of flexibility in design. Just as natural ecosystems are diverse in terms of structure, processes and functions depending on conditions such as climate and geography, human products and systems should be designed according to their context, e.g. local cultures and economies. This principle seeks to celebrate diversity by ensuring that products and systems' design is flexible enough to meet local energy and material flows and fit into the context. Furthermore, the principle also highlights the role of humans as species interacting among other species. This includes the integration of the environment as part of the system design and the exchange of nutrients with the local landscape (McDonough & Braungart, 2002; Hauschild *et al.,* 2018).

5.2.3. Cradle to Cradle certification scheme

In 2005, three years after the theoretical basis of C2C was presented, a certification program was developed and publicly presented to companies and organisations who wish to apply for a product-level C2C recognition. In North America, the program was initially administered by McDonough Braungart Design Chemistry (MBDC), which is the consulting firm who owns C2C trademark. In Europe, the program used to be administered by the Environmental Protection Encouragement Agency (EPEA), which has the license to use the trademark. However, since 2010, the non-profit Cradle to Cradle Products Innovation Institute (C2CPII)

manages the certification program and trains consultants all over the globe who can assist companies in the certification process (C2CPII, 2021b).

In this sense, Cradle to Cradle Certified™ is a globally recognised measure of sustainable products, widely used by companies advocating for circular economy (C2CPII, 2021a). The standard requirements of this certification are rooted in the C2C principles described before, which traces a pathway for designing and making products with a positive impact on people and planet (C2CPII, 2021b). In the program, products are assessed in terms of environmental and social performance across five sustainability categories: material health, material reutilization, renewable energy and carbon management, water stewardship and social fairness. The reasoning and criteria for each category include:

- Materia health: this category aims to guarantee that products are made using substances and chemicals that are as safe as possible for human health and the environment. Here, the applicant must provide an overview of all homogeneous materials present in the product at a concentration of 100ppm (parts per million) or higher. Hazardous substances must be reported at any level. All materials are then evaluated according to potential human and environmental risks and recyclability.
- Material reutilization: in this category the concept of waste is challenged by ensuring that products are continuously cycled by reutilization. For this, the applicant needs to demonstrate that the product has been designed following the technical or biological distinction so it can be recyclable or compostable. Furthermore, a plan for the end of life stage must be in place.
- Renewable energy and carbon management: this category ensures that the energy used for manufacturing products comes from a renewable source as stated in the *current solar income* principle. The applicant must present quantitative and qualitative information of the energy sources used in the manufacturing stage of the product, as well as on-site emissions reported.
- Water stewardship: this category recognizes the importance of water as a valuable resource and helps guaranteeing that clean water is available in the environment. To evaluate this, a facility water audit is conducted and all water flows associated with the product's manufacturing process are characterised.
- Social fairness: last but not least, the social fairness category seeks to commend business operations that value people and natural systems. This is done through performing a streamlined audit based on fundamental human rights, social conditions and environmental management.

Moreover, the assessed product is assigned an achievement level for each one of the categories: Basic, Bronze, Silver, Gold and Platinum, being the latter the strictest level. Depending on the achievement level, the specific requirements for each category will vary. It is important to note that the lowest achievement level that a product gets in a category will represent its overall certification level, as shown in ***Table 3***. With this scheme, corresponding to the Version 3.1, the certification program encourages the continuous improvement of products over time based on ascending achievement levels. The renewal period of this certification is every 2 years (C2CPII, 2021b).

Certification category	Basic	Bronze	Silver	Gold	Platinum
Material health			X		
Material reutilization				X	
Renewable energy and carbon management		X			
Water stewardship				X	
Social fairness			X		
Overall certification level		X			

Table 3. Example of the scoreboard for C2C certification Version 3.1. Each category is given an achievement level. The overall certification level will be the lowest achievement scored (based on C2CPII, 2021b).

As of March 2021, 626 C2C certifications were in place for many different organisations around the world. Since the certification might cover more than a single product per company (e.g. a series of products only differing in colour), there are currently more than 626 Cradle to Cradle Certified™ products. The types of products certified can include categories such as health and beauty, textiles, home and office supplies, furniture, packaging, building materials and toys among many others (C2CPII, 2021c).
Likewise, the Cradle to Cradle Certified™ Product Standard Version 4.0 was announced in March 2021, as a more ambitious and actionable standard for sustainable product design and development. This latest version is built upon the same principles mentioned before, however, it features new and enhance requirements on each performance category. C2C Version 4.0 will include an improved alignment on Material Health, new frameworks for Product Circularity and Social Fairness and rigorous and expanded requirements in both, Clean Air & Climate Protection and Water & Soil Stewardship. This new scheme will take effect from the third quarter of the year 2021. Thus, all companies interested in certifying their products with the Cradle to Cradle Certified™ Product Standard Version 4.0 can start their application process from July 2021 through the C2CPII (C2CPII, 2021d).

5.2.4. Limitations of Cradle to Cradle concept

Even though the C2C concept is widely recognised in academic, industrial and legislative arenas, it is not free of criticism and various limitations have been pointed out in regard to its principles. First of all, some authors have argued that advocating for biological nutrients cycles as a large scale solution can have repercussions on the ecological balance of the planet, since it will collapse the carrying capacity of ecosystems (Franco, 2017). Moreover, the fact that emissions related to the transportation and use stages of the products are ignored by C2C principles represents a great limitation when evaluating the concept from a life cycle approach (Bakker *et al.,* 2010). It has also been debated that C2C does not address inherently social issues such as growing consumption or the future growth of global economy relative to the baseline ecosystem (Korhonen *et al.,* 2018).
Furthermore, when setting focus on product sustainability, there are many controversies surrounding Cradle to Cradle approach. Some studies have established that C2C requirements do not entirely tackle the environmental aspects of products from a life cycle approach, thus its role as a tool for distinguishing environmentally preferable products can

be questioned (Llorach-Massana *et al.,* 2015). As mentioned before, not taking into account transportation and use stages represents a great gap in C2C scope. This can lead to misconceptions when evaluating environmental improvements for products that e.g. consume large amounts of energy during the use stage (Llorach-Massana *et al.,* 2015). Lastly, some controversies have arisen around the fact that C2C should be considered as a concept available to everyone rather than a trademark, since the idea behind it has been practiced worldwide under a variety of names. In this sense, taking inspiration from natural systems to better develop human activities should not be limited nor labelled (Ehrenfeld, 2009).
Despite its limitations and critiques, C2C serves as one of the many pathways towards sustainable development and it is considered a positive approach for future societies. Nonetheless, it is crucial to identify its extension and use complementary tools as appropriate.

5.3. Life cycle assessment as a tool for evaluating products/services

With a rapidly increasing interest in sustainable development and a race against time for protecting environmental resources, many needs have arisen as to how to quantitatively measure our impact on the planet. Life cycle assessment is a comprehensive tool that has been designed to address these needs and to help facilitate decision-making processes for supporting sustainable development. LCA's basic principle is to follow a product or service through its entire life cycle and focus on energy and material flows within the process in order to quantify negative impacts (van der Werf *et al.,* 2020). Nowadays, LCA is globally acknowledged as a legitimate tool for addressing environmental sustainability issues and its application has been increasing during the last decades. For instance, the European Union (EU) is currently trying to establish a harmonised methodology for calculating the environmental footprint of a wide range of products, and LCA is considered the core method of this initiative (van der Werf *et al.,* 2020).

5.3.1. Beginnings and advancement of life cycle assessment

The idea of developing a tool for quantifying environmental impacts was conceived back in the 1960s when ecosystems' degradation and resource depletion became great concerns. The early development of LCA is rooted to packaging studies and a focus on energy use. The first studies ever conducted were done by companies addressing internal business interests, however, these studies were rarely published or shared with stakeholders. As a matter of fact, one of these projects was done by Coca Cola in the late 1960s in order to assess the environmental impacts of shifting from glass containers to plastic bottles (Koelsch Sand & Boz, 2020). Some years after, in the 1980s, the LCA methodological approach started to gain strength, not only in the industrial arena, but also among the scientific community. This led to a high international collaboration and a common interest in further developing this method. By the end of the 20th century, the methodological basis of LCA was established, reaching its application to a wide range of products and services studies performed by industry, governments and the academic community. Up to this day, the development of the LCA tool has continued along with its educational basis, standardisation and applicability (Hauschild *et al.,* 2018).

5.3.2. Life cycle features and main characteristics

With a growing interest in environmental issues, especially during the boom of fossil fuels in the 2000s, the LCA field experienced rapid development and it was soon considered as a comprehensive method for assessing environmental impacts. Altogether, LCA is defined as a systematic approach applied in environmental management for quantifying negative impacts. On that account, it has four main characteristics that enables it to deeply investigate environmental concerns that other tools within this field cannot address. These characteristics include: having a life cycle perspective, including a broad range of environmental issues, being a quantitative method and being based on science (Hauschild *et al.,* 2018).
First of all, having a life cycle perspective means looking at the whole picture. The *life cycle* analogy comes from the biological sciences field, which looks at all different stages that a living organism undergoes, eventually returning to the starting state. In the same way, life cycle of product systems includes all different phases of a product, from the harvesting and extraction of raw material, followed by the production process, the use stage, all the way to the end of life stage or disposal of the product. Therefore, in an LCA study, all the processes required to deliver the function of a product or service are assessed, as shown in ***Figure 6*** (Hauschild *et al.,* 2018). By applying a life cycle perspective, it is possible to identify and prevent, in terms of environmental impacts, the possible repercussions that any changes in one stage might have in another stage. For example, LCA studies have concluded that using biofuels instead of fossil fuels can considerably reduce impacts on climate change from the use stage, however, it can increase impacts during early stages which include harvest and extraction of resources (Fargione *et al.,* 2010). Even though LCA is a method mostly used for assessing single products or services, it can also be used to study complex man-made systems, ranging from companies to infrastructures and even cities. No matter which product or system is within the scope, an LCA approach always applies a life cycle perspective, taking the function of the object under study as the main focus (Hauschild *et al.,* 2018).

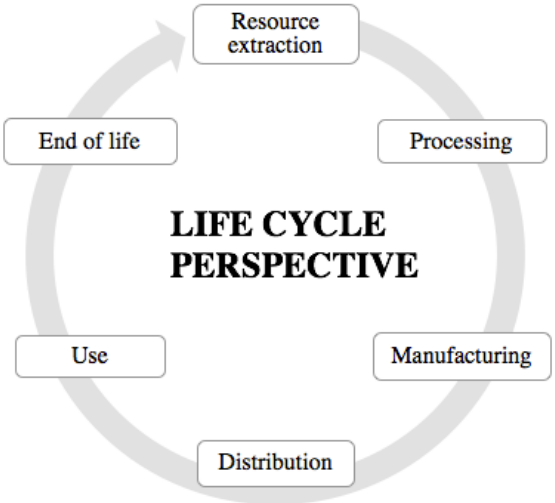

Figure 6. Different stages throughout the life cycle of a product or service. The cycle includes the collection and processing of resources, followed by the manufacturing of the product, the transportation and distribution to the end consumer, the use phase and, eventually, the end of life of the product or service.

Moreover, another characteristic found in the LCA method is the broad coverage of environmental issues within all the life cycle phases. Despite it is mostly used for assessing climate change impact, it does include a comprehensive environmental analysis of issues such as freshwater use, eutrophication, ecotoxicity, human toxicity, ozone depletion, water and air pollution among others (Esnouf *et al.,* 2019). Furthermore, LCA is a quantitative method which allows to quantify all the potential environmental impacts of human activities and to compare these impacts between different products, services and systems. This characteristic is crucial when critically evaluating which products or systems have less impacts on the environment or when identifying which process has the greater impact contribution. Thus, it can be seen as a tool that facilitates decision-making processes (Hauschild *et al.,* 2018).
Lastly, the quantification of potential impacts is rooted in science. All material flows and emissions are based on measurements, and the relationship models between emissions, resource consumption and impacts are based on proven causalities or on empirical observations. LCA also requires consistent and transparent value judgement depending on the study conditions. For instance, the method allows practitioners to make modelling choices based on their own values, considerations and purpose of the study (Hauschild *et al.,* 2018).

5.3.3. Life cycle assessment standards and scheme

With LCA studies gaining importance in numerous fields, there was a need for harmonising the different evolving methods and unifying them into a proper methodology in order to ensure consistency between studies. This gave way to a formal standardisation process initiated by the International Organization of Standardization (ISO), which developed a global standard method for LCA based on available sources, research and scientific consensus. This adaptation allowed industries, organisations, governments and researchers to use LCA for addressing product development issues from an environmental standpoint (Hauschild *et al.,* 2018). Ultimately, this process resulted in a series of standards released by the ISO Technical Committee which included: principles and framework (ISO14040), goal and scope definition (ISO14041), life cycle impact assessment (ISO14042) and life cycle interpretation (ISO14043). The last three standards were compiled into the ISO14044 after a revision made in 2006 (Finkbeiner, 2013). In this sense, the ISO14040 series outline the LCA methodology as such. However, some other standards referring to LCA include: the ISO14000 series on Environmental Management, the ISO14062 on LCA applications for e.g. eco-design, the ISO14020 on communication of environmental performance and ecolabels and the ISO14064 on greenhouse gas reporting and reduction (Finkbeiner, 2013; Hauschild *et al.,* 2018).

Even though other methodological approaches are still being discussed and developed, the ISO standards are currently considered the fundamental structure for performing an LCA. ***Figure 7*** shows the LCA framework as explained in the ISO14040 series. The methodology is constituted by four main phases, Goal and scope definition, Inventory analysis, Impact assessment and Interpretation (ISO, 2006).

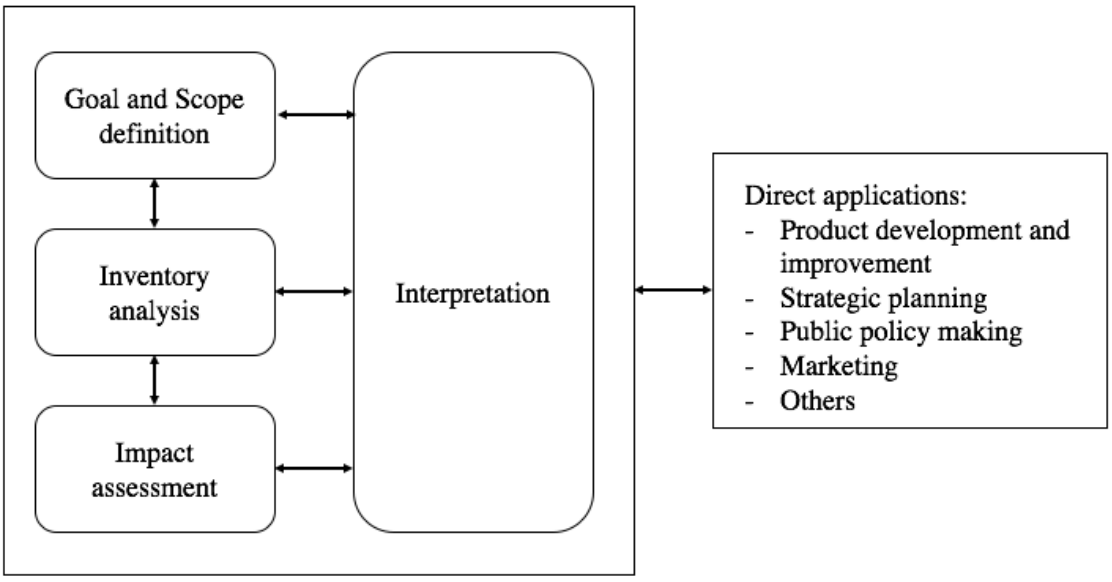

Figure 7. Life cycle assessment framework and its direct applications according to ISO14040 standard. Although the methodology includes four main steps, these should not be seen as independent phases but rather interconnected steps (ISO, 2006; Hauschild *et al.,* 2018).

In this way, an LCA study starts with a thoughtful definition of the goal and scope. Here the context of the study is set, including the reasons and intentions for performing the LCA. One key component of this step is the definition of the functional unit. As mentioned before, LCA is focused on assessing the processes required to deliver a specific function of products or services. Therefore, determining a quantitative description of the function for which the assessment is performed is a crucial point of the process. This sets the baseline for establishing the reference flow of products and the data collection in the following steps. Moreover, in the goal and scope phase, the system boundaries are delineated, including activities and processes, assessment parameters, geographical and temporal boundaries and relevant perspectives to be applied (ISO, 2006; Hauschild *et al.,* 2018).

In the life cycle inventory analysis (LCI), the model is set up by collecting data regarding all physical flows within the product system. Here, the data is collected in terms of both inputs and outputs of the system. Inputs include resources, materials and products flows, while outputs include emissions and waste flows. In the inventory analysis, all the processes and activities that were previously defined in the goal and scope phase are considered, and the flows are scaled in accordance to the functional unit. This inventory is often built on generic data originating from extended characterised processes which are available in databases. The aim of this phase is to generate a list of quantified physical flows associated to the functional unit of the product system (ISO, 2006; Hauschild *et al.,* 2018).

Furthermore, in the life cycle impact assessment (LCIA) phase, the inventory resulting from the LCI phase is analysed in terms of its environmental significance. Here, the physical flows and activities of the product system are translated into impacts to the environment. This is achieved through the following elements:

- *Selection* of relevant impact categories according to the goal and scope
- *Classification* of physical flows in the corresponding impact categories
- *Characterisation* of the flows based on characterisation factors for quantifying their impact and final contribution to the selected impact category
- *Normalisation* of the relative magnitude of the flows for the different impact categories
- *Weighting* of impact categories for establishing an overall environmental impact score of the product system

It is important to highlight that according to the ISO14040, only the first three elements are mandatory. The normalisation and weighting are considered voluntary in an LCA study, but these can be useful when e.g. the LCA results together with economic costs and other aspects are used as part of a decision-making process (ISO, 2006; Hauschild *et al.,* 2018).

Lastly, the interpretation phase considers results from both, the LCI and the LCIA phases, and discusses this in accordance to the goal and scope defined at the beginning of the study. In some cases, sensitivity and uncertainty analysis can be applied as part of the life cycle interpretation for developing accurate conclusions and recommendations. This analysis can help to identify focus points to be addressed in terms of environmental management and for facilitating decision-making processes for sustainable value creation (Hauschild *et al.,* 2018; Manda *et al.,* 2015).

5.3.4. Limitations of life cycle assessment

Throughout this section, LCA has been outlined as an extensive method for analysing the big picture of environmental impacts. However, its comprehensiveness can also represent a downside on the system modelling since it requires simplifications and generalisations of the conditions within the product system. Therefore, when applying LCA to a product or service, an *estimate* of environmental impacts is calculated, rather than the *actual* environmental impacts of the specific system. The mapping of resources, emissions and impacts is full of uncertainties due to the fact that calculations are aggregated over time and space (Hauschild *et al.,* 2018). For example, simplifications within a study can include modelling emissions in 20 years from a specific geographic region as Denmark, meaning that LCA calculates potential impacts instead of current and precise impacts. Along these lines, LCA follows the "best estimate" principle, which might result favourable in the context of comparative assessments. However, this means that LCA models are based on the average performance and might overlook the environmental risks of very problematic but unlikely to happen events, such as marine oil spills and nuclear accidents (Hauschild *et al.,* 2018). Moreover, due to the very nature of the method, there can be a shortage of characterisation factors for some impact categories, thus preventing its inclusion in the LCIA step (Maciel *et al.*, 2019). Finally, it is important to highlight that even though LCA method can be used to establish which product or service is better for the environment, it cannot be used to establish if *better* is, in fact, *good enough*. LCA addresses the environmental performance of products, nonetheless, it should not be considered as an overall indicator of sustainability performance (Ögmundarson *et al.,* 2020; Hauschild *et al.,* 2018).

5.4. Product sustainability in the chemical, biotechnology and food industry

As outlined in previous chapters, IFF's core business is rooted in the production of active ingredients and solutions that are down-streamed to different industries, such as the food and pharmaceutical sector among others. With a broad scope of products applications, IFF has a wide range of production lines, mostly based in chemical research and biotechnology (IFF, 2021e). That being noted, it becomes clear that IFF operates under a very particular but still developing field of product sustainability.

One of today's strategic global challenges is to develop a sustainable bio-based economy along with eco-efficient processes that contribute, not only to economic value creation, but also to social and environmental value (Saling, 2020). In this way, the development of green chemistry and industrial biotechnology is associated with lower environmental impacts and positive socio-economic effects as it gives way to new competitive and sustainable products that support a bio-based economy. Nevertheless, this idea cannot be generalised, since not all products and processes in this field result favourable in terms of sustainability (Fröhling & Hiete, 2020). For this reason, there is a need to identify comprehensive means for achieving product sustainability solutions, as well as to assess the potential risks and environmental impacts associated with biotechnology and chemical production processes (Fröhling & Hiete, 2020; Ögmundarson *et al.,* 2020).

At present, there is an extensive set of approaches and tools for sustainability assessment in the chemical and biotechnology sector. These tools can range from simple metrics to complex assessment frameworks or combined systems, depending on their application, scope and the expected level of detail. Certainly, it has been argued that, for identifying sustainable biotechnological solutions and covering all relevant aspects to be assessed, a life cycle perspective is needed (Saling, 2020). For instance, one of the life-cycle methods that has been commonly used for assessing product sustainability in chemical and biotechnology industries is known as the Eco-Efficiency Analysis (EEA). This method, solidly rooted in LCA, has been used by chemical companies, such as BASF, for analysing the entire life cycle of a product, quantifying and comparing its impacts based on life cycle inventory data. Furthermore, it is also used for contrasting a product's economic value against its impact on the environment, therefore facilitating decision-making processes. However, even if the analysis involves measuring a product's life cycle environmental impacts and life cycle costs, it is purely a comparative analysis and does not determine the sustainability of the product in absolute terms (Saling, 2020).

Some other methods use a more integrated framework to ascertain the environmental, economic and social performance of products, which can also be applied for assessing chemical and biotechnology production (Fröhling & Hiete, 2020). For example, life cycle sustainability assessment (LCSA) is a structural framework integrating different methods and, thereby, enabling a broader evaluation of the product. LCSA integrates environmental impacts through LCA as previously described, but in addition, it also includes social impacts through social life cycle assessment (sLCA) and economic impacts through life cycle costing (LCC) (Fröhling & Hiete, 2020). Just like this approach, numerous other methods are being

used in the industry to assess the sustainability performance of their products, certainly depending on the purpose and target group of the study (Fröhling & Hiete, 2020).

It should be noted that, on a vast existing literature, when reviewing product sustainability assessments of the chemical, biotechnology and food industry, the focus is more inclined to energy use and offset emissions from a life cycle perspective, whereas chemical processes and materials are overlooked (Fröhling & Hiete, 2020). For instance, there is a lack of attention in the type of sourcing of raw materials that are being used in the production phase of this industry sector. Also, social-related aspects such as digestibility and nutritional value do not get much importance or are underestimated (Loveday, 2019).
One could say that the positive conception around green chemistry and biotechnology is grounded in the fact that most of these processes run on renewable feedstock and bio-based materials. Thus, the industry is seen as a feasible road towards a more sustainable economy (Schilling & Weiss 2021). However, the origins of the feedstock used in these production processes should not be overlooked, as these can be accountable for non-sustainable practices (van der Werf *et al.* 2020). At the same time, nutritional attributes should be incorporated when performing product sustainability assessments.
Altogether, the production of feedstock used in biotechnological, chemical and food processes involves a number of resources, emission-intensive steps and environmental impacts such as land use, eco-toxicity and soil degradation (Fröhling & Hiete, 2020; van der Werf *et al.* 2020). Naturally, sustainability and life cycle assessments would account for these impacts, but it has been argued that the study of e.g. agricultural and food systems may lack operational indicators and liability of indirect effects (van der Werf *et al.* 2020). In this way, land competition along its severe social implications, the use of genetically modified organisms (GMOs) and biodiversity loss are additional aspects that should be considered when assessing product sustainability in these industry sector (Saling, 2020). Therefore, it is within these identifiable gaps that the combination of, e.g. LCA and C2C, may result advantageous for building a more holistic approach of sustainability in industrial processes. As presented before, quantitative methods commonly used account for clear-cut impacts, however these can fail when encompassing the complete picture of business dynamics. Companies and organisations who aim to have a positive impact through their business activities also need to position themselves as agents of change and advocate, not only for reducing environmental struggles, but for fighting associated issues such as social justice and inequality (Hauschild *et al.,* 2018).

CHAPTER SIX

METHODOLOGICAL FRAMEWORK

This chapter exposes the set of principles and qualitative methods that supported the development of the research study. The BLOC model and systematic search used for building the literature review is described. Furthermore, the data collection process is outlined based on an information-oriented selection, a stakeholder analysis and semi-structured interviews conducted. Lastly, the structure of the qualitative content analysis performed is presented.

As previously described in Chapter 4, a research design was outlined in order to draw the connections between the different aspects of this work. As a starting point, the research question and the purpose of study traced the pathways towards the type of tools and methods that enabled the development of the research process. Given the nature of the object under study and the specific context within IFF organisation, an embedded single-case study was deemed appropriate for narrowing the scope and identifying key steps along the research process. Furthermore, the elements described below served as the means and tools for unfolding the case study. These elements allowed to fulfil the research objectives and, ultimately, to answer the research question defined at the beginning of this journey.

6.1. Literature Review

Framing the research process and relating it to existing knowledge is the building block of academic activities and research studies, regardless of the field and discipline (Snyder, 2019). In addition, knowledge production in the field of business research has increased considerably in recent years. Thus, it is of great importance to be at the forefront of the state-of-the-art in the particular area that is being studied (Snyder, 2019). For this reason, it was relevant to carry out a literature review as a way of systematically collecting and synthesizing previous research in relation to product sustainability approaches in the chemical and biotechnology industry. This key element held the foundation for advancing knowledge in all different stages of the research process, being a tool that was continuously used throughout the study (Snyder, 2019). Essentially, the literature review consisted of three main phases, which are described in detail in the following subsections.

6.1.1. Designing the literature review based on the problem formulation

The problem formulation described in Chapter 2 along with the purpose of the study described in Chapter 3 were, undoubtedly, the starting point for designing the main scope of the literature review. The aim of the review was to investigate and synthesize trustworthy information of the specific factors related to IFF's product sustainability challenges. Along these lines, the majority of these factors were identified from the established research question as highlighted below:

*Considering **IFF and DuPont N&B merger process**, how can **Life Cycle Assessment** and **Cradle to Cradle** approaches be **integrated** for promoting **product sustainability** among the **stakeholders** of the combined company?*

In this way, *product sustainability*, *LCA*, *C2C* and the particular conditions of IFF company were determined as the key concepts directly related to the research question and, therefore, resulted as the elementary units guiding the literature review. Consequently, these units were selected as the main search terms for identifying and accessing the appropriate books, articles, reports and other sources containing relevant and quality information within the field of study. Naturally, the initial search yielded many articles and an overwhelming amount of information, thus, a search strategy was established in order to path and narrow down the rigor of the review.

6.1.2 Conducting the literature review through a systematic search technique

After defining the scope of the literature review based on the problem formulation, the review process was conducted by using specific search terms along Boolean operators for browsing different databases. As mentioned before, the search terms were built upon key concepts and elementary units related to the research question. ***Table 4*** shows how these units were combined using Boolean operators for improving and narrowing the searching technique.

Elementary units (Key concepts)	Search terms with Boolean operators
Product sustainability	Product sustainability AND (Life cycle assessment OR LCA)
Life cycle assessment	Product sustainability AND (Cradle to Cradle OR C2C)
Cradle to Cradle	Product sustainability AND (Biotech* OR food industr*)
Biotechnology industry	Life cycle assessment AND (Biotech* OR food industr*)
Food industry	Cradle to Cradle AND (Biotech* OR food industr*)
Stakeholders	Product sustainability AND Stakeholders
Sustainable business	Sustainable business AND Stakeholders

Table 4. The elementary units and key concepts extracted from the problem formulation and research question are shown on the left column of the table. Additionally, the combinations of searching terms using Boolean operators are shown on the right column of the table. Truncations using an asterisk (*) were used to include different endings of the same base word.

Moreover, the search was done through two main databases: Google Scholar and PRIMO, which is the search engine from Aalborg University Library (AUB). Additionally, four subject databases were also chosen and used to enhance the searching process: Compendex, Ebsco, ScienceDirect (Elsevier) and SpringerLink. These databases were selected with the support of library professionals from Aalborg University (AAU), based on two criteria: accessibility and subject-orientation. Accordingly, Compendex is a broad engineering literature database that allowed access to various technical articles, mostly within the LCA field. Ebsco is a provider of research databases which allowed browsing within specific research areas, therefore, its business source option was used when searching for business-related articles. Lastly, ScienceDirect and SpringerLink are world leading databases for exploring scientific and technical journals, books and articles. ***Tables 5a*** and ***5b*** summarize the searching technique used to explore relevant material and sources in this study.

Main Databases	Search terms
PRIMO (AUB) Google Scholar	Product sustainability AND (Life cycle assessment OR LCA) Product sustainability AND (Cradle to Cradle OR C2C) Product sustainability AND (Biotech* OR food industr*) Life cycle assessment AND (Biotech* OR food industr*) Cradle to Cradle AND (Biotech* OR food industr*) Product sustainability AND Stakeholders

Table 5a. Search terms used in PRIMO and Google Scholar databases for extracting relevant material.

Subject Databases	Search terms
Compendex	Product sustainability AND (Life cycle assessment OR LCA) Product sustainability AND (Cradle to Cradle OR C2C)
Ebsco – Business source	Product sustainability AND Stakeholders Sustainable business AND Stakeholders
ScienceDirect (Elsevier) SpringerLink	Product sustainability AND (Life cycle assessment OR LCA) Product sustainability AND (Cradle to Cradle OR C2C) Product sustainability AND (Biotech* OR food industr*) Life cycle assessment AND (Biotech* OR food industr*) Cradle to Cradle AND (Biotech* OR food industr*)

Table 5b. Search terms used in subject-oriented databases. Compendex was used to extract engineering-related material. Ebsco was used to extract business-related material. ScienceDirect and SpringerLink were used to extract scientific and technical material.

6.1.3. Evaluating the literature review and selecting relevant sources

After conducting the literature review a final sample of relevant material was selected through three screening steps, as shown in ***Figure 8***. The search terms were inputted in the different search engines and databases, setting the date range from 2010 to 2021. The literature sources, including papers, peer-reviewed articles and books, were then evaluated in three steps. Firstly, the focus was given to the title of the text and its relation to the problem formulation. Secondly, the selection was supported by reading the abstract and getting further insights of the work contained in the sources. Lastly, the screening process was completed by reading the full-text, with a strong focus on introduction, research methods and findings.

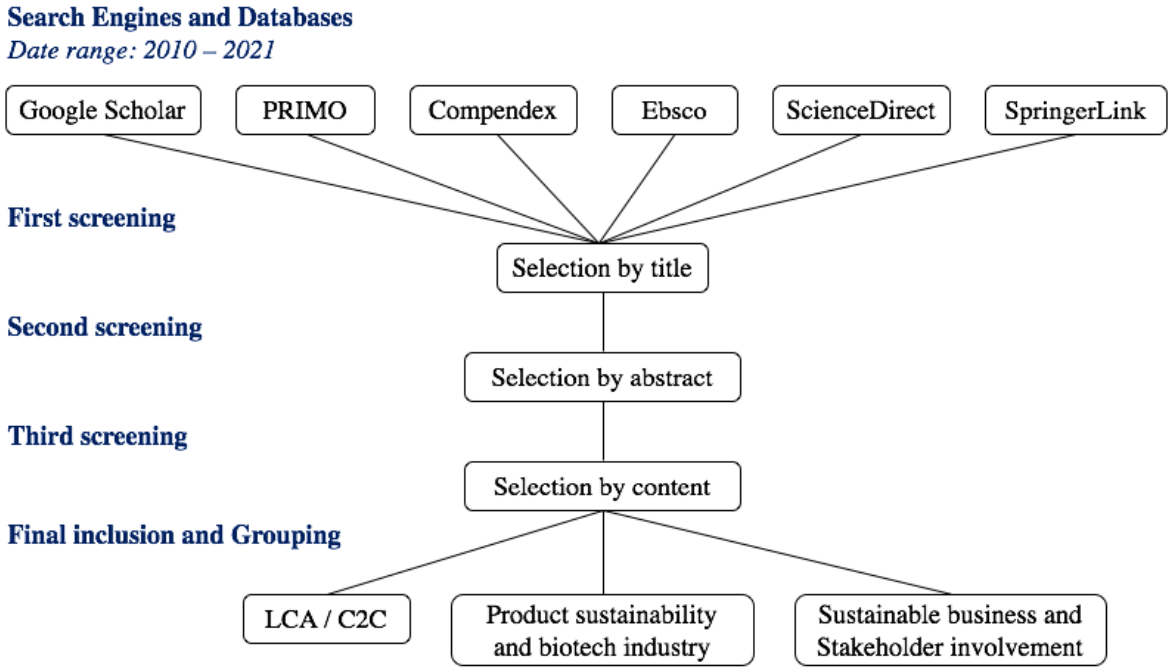

Figure 8. Overall selection process of articles, books and relevant material included within the literature review of the study. Three screening phases were performed to obtain the final inclusion of sources.

After the third screening step, the final sources selected were grouped into three main categories according to the scope and focus of each article. The categories were as follows: LCA and C2C, Product sustainability and its importance in the biotech industry, and Sustainable business along stakeholder involvement. At the end, a total of 20 sources were selected as part of the literature review, as shown in Appendix A. These sources served as the basis for the theoretical framework presented in Chapter 5, as well as a supporting material for the introduction, analysis and discussion chapters of the study. In this way, the literature review was a continuous backing along the research process and allowed to gain deeper insights and reliable interpretations of the object under study.

For instance, one initial interpretation that was done when performing the literature review was how the concepts from the problem formulation were related to one another. By identifying the common keywords used in the different articles of the literature review, it was possible to get a first impression of the research context and to understand how these concepts can be associated from a theoretical standpoint. As shown in ***Figure 9***, concepts such as LCA and C2C are concurrent with concepts such as sustainability, business innovation and product design for the environment. Furthermore, these are also associated with circular economy, product sustainability, stakeholder management and other terms, which is an indicative of the interconnection found between studies.

Figure 9. Word cloud of common keywords from the 20 sources included in the literature review. The bigger the word, the more common was the concept in the different sources. This shows a strong association between LCA and C2C with concepts such as sustainability, business innovation and product design for environment among others.

Once the research topic was explored through the literature review, a solid base of knowledge was built for collecting qualitative data by means of semi-structured interviews. This process is explained in the following subsection and served as a decisive phase for addressing the research question.

6.2. Qualitative data collection

In order to further support the research process and bridge the gap between the literature review and the specific context being studied, a qualitative data collection was conducted. This was a crucial process consisting mainly of semi-structured interviews which were conducted to representatives of a leading community involved in IFF's product sustainability area. The representatives were determined through a stakeholder analysis and the interviews were designed based on their roles and positions on product sustainability.

6.2.1. Stakeholder analysis

Referring back to the purpose of this study, one important step for exploring how to promote product sustainability was to identify the target audience who considers this as a relevant and meaningful topic. There was a need for determining and establishing the key stakeholders for whom product sustainability is a direct interest or concern, thus, a stakeholder analysis was performed. It is important to note that, under the context of this case study, there are a large number of stakeholders who have come to play a role in IFF company after its merger with DuPont N&B. Therefore, by performing a stakeholder analysis and recognizing those who are unequivocally involved within the product sustainability field it was possible to have an accurate representation of the target audience, which served as point of departure for the qualitative data collection and its further evaluation.

Stakeholder analysis (SA) is a decision-support tool widely used across different fields. In environmental management and sustainability, it is mostly used as a tool for describing and understanding specific stakeholder settings and related obstacles (Bendtsen *et al.,* 2021). In business, it serves as a tool for strategic management of collaborators within an organisation (Bendtsen *et al.,* 2021). Altogether, SA is an effective process for acknowledging the actors involved within a specific issue.

In this study, the SA was done as a three-step process consisting on:

1. Identifying the stakeholders for product sustainability, top-down by its dimensions: Individual, Social, Environmental, Economic and Technical.
2. Prioritising the stakeholders in the given case study context based on their power and interest to influence product sustainability.
3. Understanding key stakeholders, their roles and positions prior to conducting the semi-structured interviews.

Along these lines, the first step in the SA was the identification of general stakeholders' categories. This was done through a top-down approach of the dimensions of sustainability and the roles that are potentially related to each dimension. This approach was based on a study published by Penzenstadler *et al.,* (2013), which resulted appropriate considering the resources available at the time of conducting the SA. It is important to highlight that other approaches such as a bottom-up analysis based on a company's organisational diagram can also be used upon the identification of stakeholders. However, as the definitive structuring

of IFF had not been announced at the time of the analysis and many roles were to be determined after the merger with N&B, there was no reliable organigram that could be used to complete the SA. Therefore, a top-down approach was deemed applicable.

As mentioned before, the identification was based on five dimensions of sustainability as described by Penzenstadler *et al.,* (2013) and adjusted to the case study context:

- **Individual:** Product sustainability aims to maintain human capital and provide personal well-being.
- **Social:** product sustainability aims to preserve societal communities and their services.
- **Economic:** product sustainability aims to maintain capital and added value.
- **Environmental:** Product sustainability aims to protect natural resources and ecosystem services.
- **Technical:** Product sustainability aims to preserve longevity of systems and infrastructure and their adequate evolution upon changing conditions.

By inspecting these dimensions based on the outlined definition, important actors and roles that had a direct connection to each dimension were determined. This allowed the identification of general stakeholders within the company as shown in ***Table 6***. It is important to note that some of the stakeholders were deemed relevant in more than one dimension due to their potential to influence different aspects of product sustainability. In fact, customers and suppliers were considered in a cross-functional dimension, meaning that they can have possible leverage and repercussions in product sustainability from an individual, social, economic, environmental and technical standpoint.

[This space intentionally left blank]

Dimension	Stakeholder	Rationale
Individual	End-consumers	The user is affected by the final product that results from applying IFF solutions
	IFF Employees	From an individual standpoint, each IFF employee plays a role in product delivery and is affected by its performance on the market
Social	Legislation (State authorities)	The state regulates a product system influence on society.
	Community representatives	Local community representatives (governmental and non-governmental) guarantee social rights in the product value chain.
	IFF Customer Engagement team	The customer engagement team is responsible for establishing long-term relationships with the customers and creating a positive perception of IFF.
	IFF Communication and Sustainability reporting team	This team is dedicated to publicly disseminate the sustainability initiatives of IFF through social media posts, articles, annual reports, etc.
Economic	IFF Board of Directors and CEO	The directors and chief executive officer (CEO) are responsible for integrating sustainability goals into IFF's vision.
	IFF Finance team	This team is responsible for making the financial decisions that allow to incorporate and implement sustainability practices in product development.
Environmental	Legislation (State authorities)	The state is responsible for placing environmental laws to protect ecosystem services.
	IFF EHS&S team	This team is responsible for managing safety, health and environmental aspects according to local laws.
	Activists and Lobbyists	Nature conservation activists and environmental groups have an influence on environmental regulations that IFF might need to follow.
Technical	IFF Research & Development team	This team ensures the creation or improvement of product technology for giving IFF competitive business advantage.
	IFF Product Sustainability team	From a technical standpoint, this team develops the strategy to minimise IFF products' environmental impacts throughout all stages of the products' life cycle.
	IFF Manufacturing unit	IFF manufacturing sites comply with the necessary requirements to deliver good quality products for customers.
	Sustainability Consultants	External consultant agencies play a role in assessing IFF product sustainability performance.
Cross-functional dimension	Customers	Direct business customers are considered relevant within all 5 dimensions of IFF product sustainability due to their interests and possibility to influence different aspects.
	Suppliers	Direct suppliers are also relevant within all 5 dimensions since they have an effect in all aspects.

Table 6. Generic list of IFF stakeholders linked to product sustainability based on Penzenstadler *et al.,* (2013). The stakeholders were determined by a top-down approach on five dimensions of product sustainability.

After completing the identification, an analysis was made to map and prioritise the different stakeholders given the case study context. The prioritisation was made based on their interest towards product sustainability, as well as on their power to influence decision-making process in this field. As shown in ***Figure 10***, the assessment was made according to three levels (low, medium and high) of the potential interest and the potential influence of each stakeholder in relation to product sustainability and the purpose of this study. Furthermore, four categories (Partner, Engage, Consult and Inform) were established in order to categorise the priority of each actor. As a result, most of the stakeholders were mapped on medium and high levels, with a similar distribution within the Partner, Engage and Consult categories. This may be the result of unavoidable bias, considering that the stakeholders were initially identified in relation to their importance on product sustainability. Nonetheless, the prioritisation gave a clearer overview of crucial parties to be interviewed as part of the data collection.

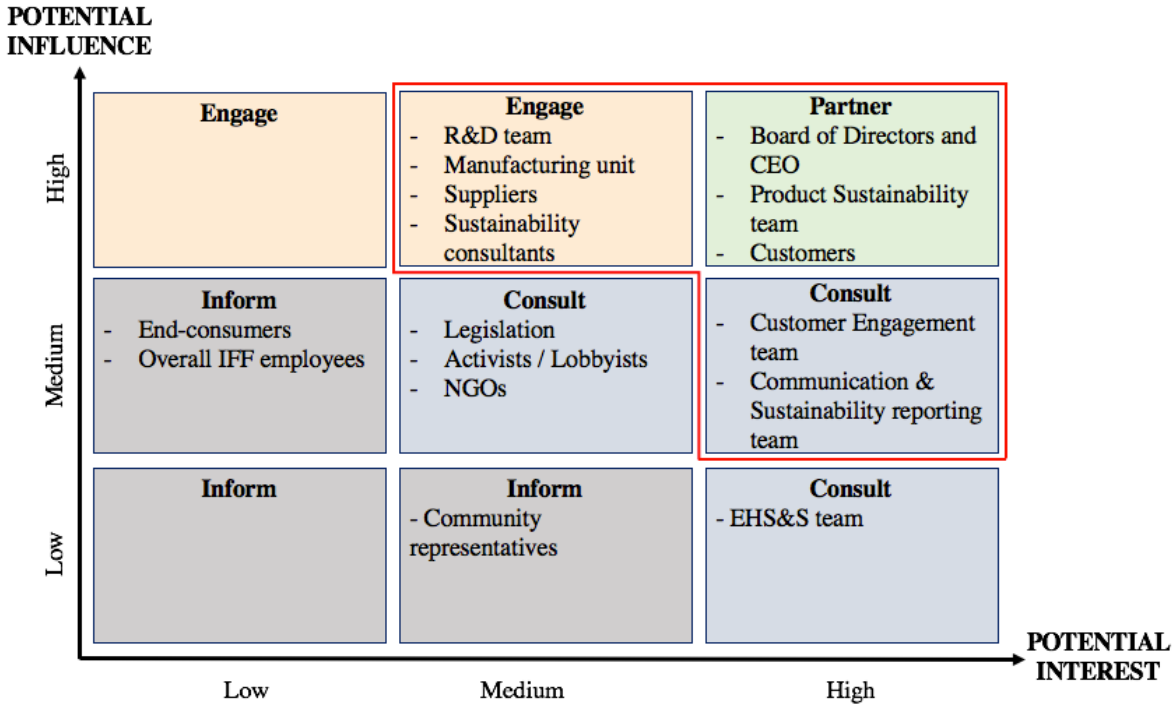

Figure 10. Mapping of IFF stakeholders based on their potential interest and influence towards product sustainability. High priority corresponds to stakeholders included in the *Partner* category. Medium priority corresponds to stakeholders included in the *Engage* and *Consult* categories. Low priority corresponds to the stakeholders pertaining in the *Inform* category. Boxes marked in red indicate the stakeholder groups most relevant to this case study.

The last step of the SA was then to understand the role of the stakeholders prior to conducting the semi-structured interviews. For the sake of the study and for getting more accurate insights, it was deemed relevant to include only high and medium priority stakeholders as possible participants for the data collection. Specifically, looking at ***Figure 10***, those marked in red, which are the stakeholders with the most influence and interest in product sustainability.

Ultimately, for the data collection of this case study, an information-oriented selection was made based on the SA. The first key participant was a representative of IFF Product Sustainability team. For understanding this stakeholder, the previous literature review conducted for the theoretical framework in Chapter 5 was crucial. This team actively works towards assessing IFF products from a sustainability perspective, therefore, approaches such as C2C and LCA are of great focus within their work. Furthermore, a snowball-sampling was applied, as this key participant served to route future interviews by pointing out relevant contacts to stakeholders included in the Engage and Consult categories, as shown in ***Figure 11***. Further research was made on these contacts and their work field prior to the interviews.

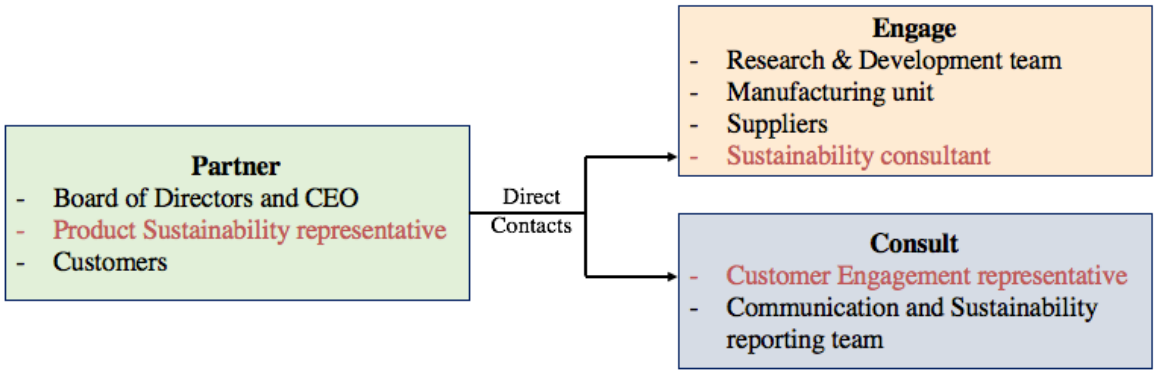

Figure 11. Snowball-sampling representation. The key participant from IFF Product Stewardship team provided direct contacts to the Sustainability consultants and IFF Customer Engagement team that were later included in the data collection.

Due to time availability and ease of contacting stakeholders, a total of four interviews were conducted for this study. The interviews included a representative from each one of the priority categories selected, where two of the contacts were facilitated by a snowball-sampling. The following sub-section outlines further details on the qualitative data collection process.

6.2.2 Semi-structured interviews

With the aim of gathering further information on product sustainability and fathom the stakeholder's perception on this topic, qualitative semi-structured interviews were conducted. Based on the research objectives established on previous chapters, this type of qualitative method was deemed suitable for the case study.
In general, a semi-structured interview enables an acute and dynamic dialogue around a specific topic. It allows to get insights and also build knowledge by redirecting the conversation towards emerging ideas (Kvale & Brinkmann, 2009). Therefore, it was possible to gain a more nuanced perception from each stakeholder by conducting semi-structured interviews rather than by applying other data collection methods, for instance, surveys with fixed questions.
As presented above, the interviewees were identified through an SA and snowball-sampling. ***Table 7*** shows the final list of participants. Before each interview, an interview guide was prepared based on the interviewee's role and field of work, in order to optimize the data collection and get clear-cut insights from each participant in accordance to the purpose of the

study. Appendix B, C, D and E show the interview guide utilised to structure and frame the interview with each stakeholder representative participating in the data collection. The questions were open-ended and concerned the stakeholder's role and responsibilities, the contextualisation of sustainability, their perception of product sustainability and further technicalities. However, the interview guide was a mean for facilitating the discussion, and emerging themes were carefully followed depending on the progression of the interview.

Interviewee	Date	Language	Duration	Rationale
Representative of IFF's Product Sustainability team	April 26th 2021	English	1 hour	Understanding IFF's product sustainability position and initiatives
Former N&B internal consultant – Environmental specialist	April 29th 2021	English	1 hour	Understanding N&B background on product sustainability
Representative of IFF's Customer Engagement team	May 6th 2021	English	30 minutes	Understanding the relation between product sustainability and social engagement
Former N&B external sustainability consultant*	May 4th 2021	English	N/A	Exploring external interpretations on product sustainability assessment

Table 7. Participants interviewed for the data collection of the case study. Each participant was a representative of the relevant stakeholders identified in the SA. The interviews were conducted in English with a duration up to one hour, depending on the availability of the interviewee.
*Due to time conflicts, the N&B external sustainability consultant was not able to join the interview, however, short answers to the interview guide were provided through email correspondence.

For setting-up the interviews, an email correspondence was sent to each of the stakeholders' representatives, inviting them to participate in the study. As shown in ***Table 7***, three out of four participants agreed on joining and were able to attend the interview. After their confirmation, a 1-hour Microsoft Teams meeting was allocated for the interview. It is important to note that the interview guide was sent in advance to allow the interviewees ponder the open-ended questions and give them a better understanding of the meeting expectations. This was convenient for the interviewees since they had the possibility to prepare the answers beforehand. However, the loss of spontaneity during the dialogue could have had repercussions on the data collected and was one aspect considered when completing the analysis (Kvale & Brinkmann, 2009).

Furthermore, the anonymity of the interviewees was guaranteed to encourage open information sharing and to create a comfortable atmosphere (Gioia *et al.,* 2012). With the approval of the participants, the interviews were recorded and notes were also taken throughout the meeting to support audio data. Likewise, a detailed verbatim transcription of each interview was produced to support the study analysis, as shown in Annexes A, B and C. The transcripts were generated using Otter, an automated transcript software, and were edited to remove linguistic tics and get a clean structure of the main body of each interview. Moreover, the data collected was triangulated with supplementary sources on the company's effort towards product sustainability. This included publicly available data such as

sustainability reports and communication articles. The interviewees also provided useful documentation on product sustainability issues specific to IFF and N&B context. For the case of the participant who was not able to join, short answers to the interview questions were provided through email correspondence as seen in Annex D.
Altogether, through the interviews it was possible to record the stakeholders' insights on sustainability, product development and approaches such as LCA and C2C. Moreover, the supplementary data served as a support of the knowledge and experiences exposed by the interviewees, which was very helpful when performing the analysis.

6.3. Qualitative content analysis

Data collected in interview transcripts and supplementary material was analysed by means of a qualitative content analysis. Overall, this method allows to evaluate written, verbal or visual communication messages in a systematic and objective manner (Elo & Kingas, 2008). It also enables to make replicable and valid inferences from data on a specific context, therefore, providing representation of facts and new insights (Elo & Kingas, 2008). For these reasons, the content analysis method was deemed suitable for analysing the compiled data. Here, the aim was to attain a condensed and broad description of the product sustainability phenomenon in IFF and N&B merger context.
The analysis consisted in five different steps, as shown in ***Figure 12***. An inductive approach was applied throughout the process, thus, particular instances were initially observed and then combined into general statements (Elo & Kingas, 2008). The first step towards analysing the information was getting familiar with all data available and making sense of it as a whole. Secondly, a selection of units of meaning was done to help delimit the nature of the information. This was based on the main topics being researched, according to the purpose of the study previously defined in Chapter 3. Later on, first-order codes were established by identifying and collating statements from the interviewees in relation to the units of meaning, which allowed to unfold their perception on product sustainability. Special attention was given to prominent narratives that were common throughout the datasets. This allowed to highlight and set higher importance to those statements that were shared among interviewees. Afterwards, first-order codes were consolidated into higher level categories. This categorisation was crucial to compare and contrast codes emerging from different units of meaning, allowing to identify interrelations and trade-offs between the data collected. Lastly, a conceptual extraction was made through linking and discussing the categories from a more nuanced and integrated system (Brockhaus *et al.,* 2016). Altogether, by performing a content analysis, it was possible to gain insights into the dynamics of product sustainability and its assessment within IFF and N&B context.

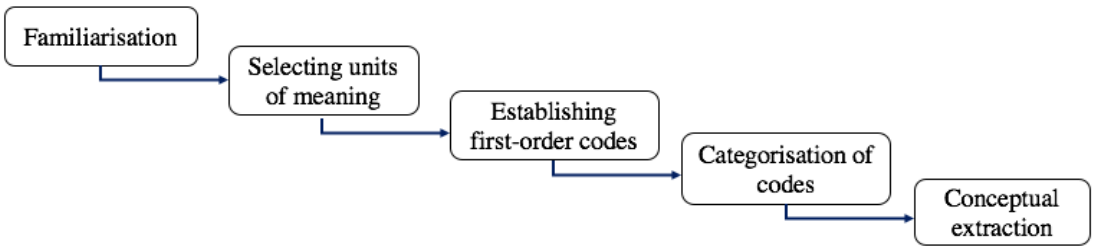

Figure 12. Steps followed in the content analysis process for evaluating and interpreting data collected.

CHAPTER SEVEN

ANALYSIS AND DISCUSSION

In this chapter, the analytical framework of the research problem is presented. By means of a qualitative content analysis, the stakeholders' perception on product sustainability is discerned. Moreover, a synthesis between the theoretical and the empirical research on C2C and LCA is presented. This is then interpreted as an integrated effort for moving product sustainability forward in the newly combined company, while outlining future considerations on this effort.

7.1. Interpretation of qualitative data through content analysis

As presented on the previous chapter, the data collected through interviews served as the foundation for understanding stakeholders' perception in the researched area of product sustainability. In order to unfold this empirical qualitative data, a content analysis was conducted, which allowed to organise facts and opinions into a logical and comprehensive set of information.

7.1.1. Familiarisation with the data

The first step of the analysis involved getting familiar with the data and making sense of the whole information collected. Here, interview tape records, transcripts and supplementary material were essential to become immersed and familiar with its content. By listening to the tape records and reviewing the written material, it was possible to engage with the data and spot prevalent topics in the discussion. Along these lines, an initial acknowledgement of the available information was made.

In general, the participants interviewed recognised sustainability as a core value of N&B/IFF business. Despite the different backgrounds and roles among interviewees, the connections drawn across people, planet, profit and products were evident throughout the discussion. Though, more relevance was given to one aspect or another, thus, it was possible to discern the influence of the interviewees' background on their perception of both sustainability and product sustainability. For instance, participants such as environmental specialists and consultants, which are part of more technical dimensions of sustainability, gave higher priority to environmental aspects related to planet and products. On the other hand, participants engaged in the social dimension displayed more interests and relevance to aspects related to people, including customers, supplier communities and company's employees.
Another important contemplation that emerged in this first step of the analysis was that the merger between N&B and IFF was not seen as a drawback from a sustainability standpoint, instead, it is seen as a pathway of opportunities and combined forces. Even though the merger represents some challenges when it comes to integrating sustainability into broader product development processes, more knowledge is available to propose solutions because two sets of expertise are coming together. Moreover, the participants argued that albeit still an early stage of the post-merger period, this has brought a more integrated vision of product sustainability, which will be beneficial when designing more holistic solutions and showcasing the sustainability attributes of IFF products.

Altogether, the data collected balanced in favour of an integrated product sustainability approach. More specifically for the case study, the stakeholders' representatives shared their experiences, views and perception on product sustainability, life cycle assessment and Cradle to Cradle. By means of these statements, synergies and conflicts between LCA and C2C were determined under N&B/IFF context and utilised as a point of departure for proposing a more concerted effort of product sustainability.

7.1.2. Selecting units of meaning

After getting familiar with the qualitative data collected, the written material was thoroughly evaluated. This step of the content analysis included the selection of *units of meaning* in which the analysis was to be developed. These units were determined based on the purpose of the case study and the particular instances addressed in the interviews. Additionally, the structure of the interview guides (Appendix B – E) also came in handy when selecting the units of meaning, since this allowed a straightforward identification of prevalent topics covered throughout all the interviews.
In this way, the final units that were selected to carry out the following steps of the analysis are presented in ***Figure 13***. This consisted of six main units which were color-coded to allow a better overview of the data gathered and to easily explore emerging patterns that could potentially address the problem formulation of this case study. Hence, sustainability, sustainable products, product development and aspects around C2C and LCA were the building blocks of the analysis within the specific context of the case study.

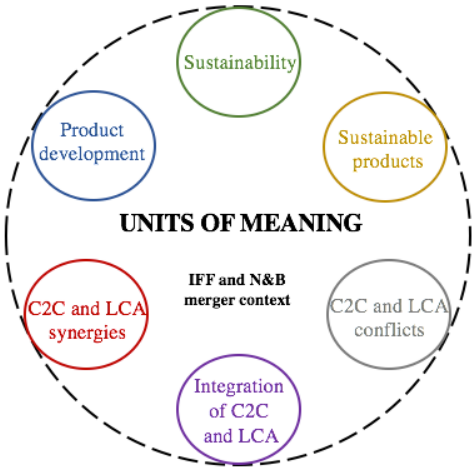

Figure 13. Six units of meaning were determined as the cornerstones of the content analysis. These units represented the main topics covered in the data collection based on the purpose of the case study. (Inspiration for illustration came from Pacak *et al.,* 2020).

7.1.3. Establishing first-order codes

Once the units of meaning were determined, it was possible to carry on with the next step of the analysis by establishing first-order codes. This step consisted in identifying and collating arguments, facts and statements from the interviewees and the supplementary material regarding the perception of product sustainability. More specifically, the codes originated from the units of meaning, which were the main topics to be unfolded. In this sense, the data was analysed through an open-coding process, where common statements related to each unit of meaning were recognised and classified using the color-coding presented above. Afterwards, the statements were abridged into a few words to illustrate the key concepts and elements associated with each unit of meaning, as shown in ***Figure 14***. Statements that were prominent throughout datasets or shared among interviewees are shown slightly highlighted.

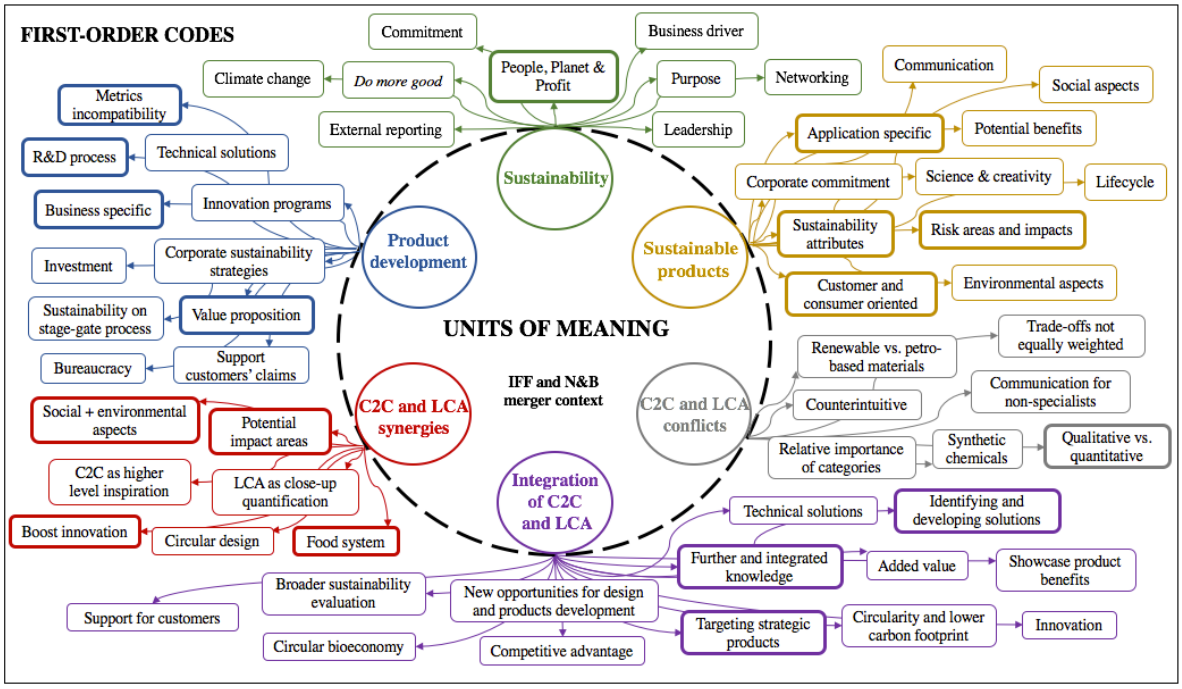

Figure 14. First-order codes associated with each unit of meaning. These codes were the result of statements, facts, ideas, arguments and opinions identified throughout the data (Inspiration from Pacak *et al.,* 2020).

Furthermore, during the open-coding process, it was observed that some of the codes were closely related to one another. Thus, these were simplified into the main elements of each unit of meaning, as shown in ***Figure 15.***

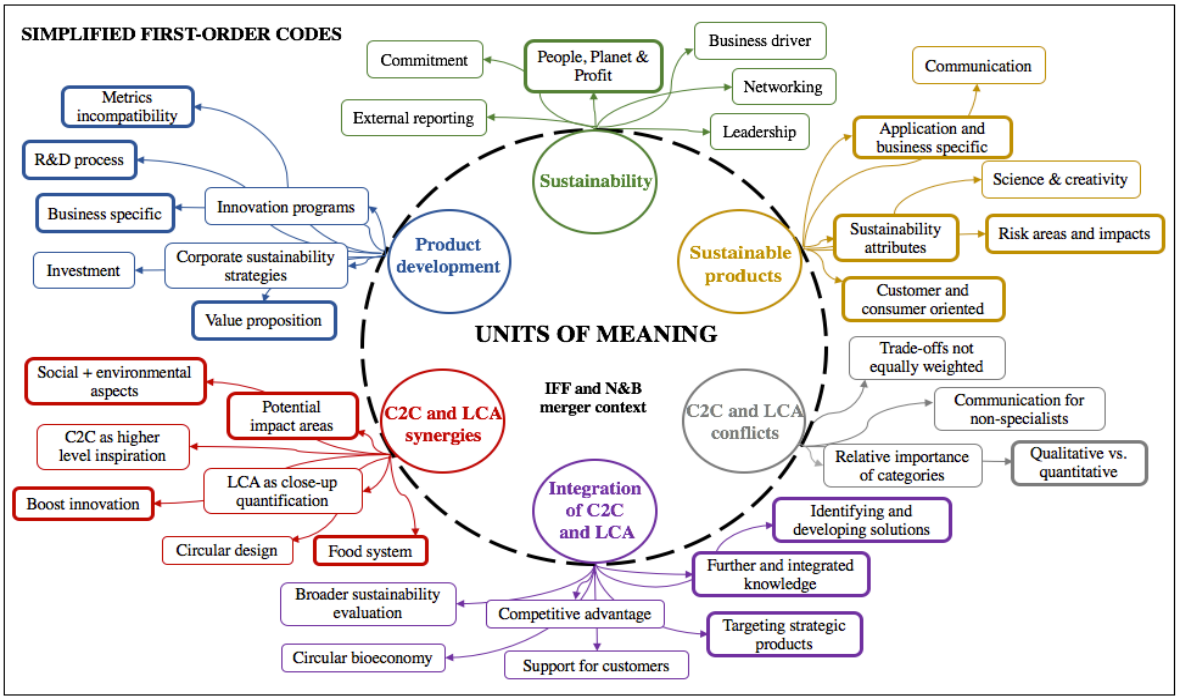

Figure 15. Simplified first-order codes covering the main elements associated with each unit of meaning.

Overall, by identifying first-order codes it was possible to get a representation of the key elements to be considered for addressing the problem formulation of this case study. More importantly, this allowed to identify statements that were prominent throughout the datasets, meaning that those arguments, facts and/or opinions were being told in various occasions by different interviewees, thus showing a significant pattern in the content analysis. As already mentioned, these statements are shown as highlighted codes in ***Figures 14*** and ***15*** as a way to illustrate their importance.
The completion of these open-coding steps led to the creation of 4 categories which supported a better understanding of all the relevant data that was identified. These categories served as a methodic way to encompass concepts and activities for integrating approaches such as C2C and LCA and to embrace product sustainability in the new era of IFF.

7.1.4. Categorisation of codes

The interactions that were evidenced during the open-coding process reiterated the need to elaborate on the importance of the research problem, the reasons for addressing it, the possible drawbacks and its solutions. For this reason, the simplified first-order codes were consolidated into four higher level categories: Purpose, Opportunities, Challenges and Solutions, as shown in ***Figure 16***. This categorisation allowed to have a more nuanced understanding of the key elements that emerged from different units of meaning that, ultimately, were part of a bigger story being told between the lines. As appreciated in the illustration below, the codes belonging to particular units of meaning were distributed throughout all four categories. This showed that, regardless of the segment or the source where these were initially identified, it is possible to discern similar perceptions and build a common language that supports efforts towards product sustainability in the new IFF era.

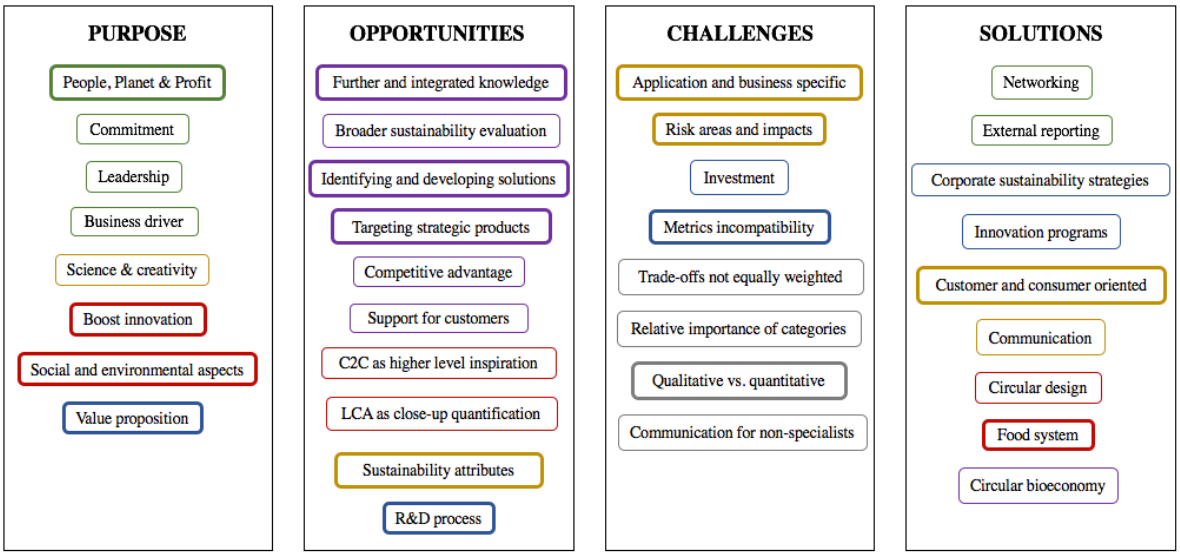

Figure 16. Categorisation of first-order codes. Here, four higher level categories were determined in order to understand the interrelations and trade-offs of the data collected. The color-coding from previous steps was kept to help visualise the distribution of the associated units of meaning. The slight highlight in the prominent codes was also kept to reiterate the importance of these statements in the data collected.

7.1.5. Conceptual extraction

This last step of the content analysis was aimed for comprehending all information extracted in the previous steps and for discussing the data linkage from a more nuanced and integrated perspective. Several conclusions are drawn as an attempt to answer the research question and sub-questions established in Chapter 3.
In first place, **Purpose** was as a high-level category compiling all the statements that demonstrated a meaningful reason towards product sustainability. Noticeably, most of the statements in this category were linked to the *Sustainability* unit (shown in green in ***Figure 16***). Other units represented here were *Sustainable products* (in yellow), *C2C and LCA synergies* (in red) and *Product development* (in blue). What this category showed is that, both N&B and IFF, consider sustainability as a business driver and, in the combined company, the corporate commitment towards people and planet is a key factor for generating value.

Furthermore, the **Opportunities** category displayed all the benefits, positive reviews and advantages that integrating C2C and LCA might bring as for addressing and promoting product sustainability in the new IFF. Here, the predominant statements came from the *Integration of C2C and LCA* unit (shown in purple), while also including *C2C and LCA synergies*, *Sustainable products* and *Product development* units. This category was characterised for possible courses in which combining both, C2C and LCA approaches, can have a positive outcome. Some highlights included integrating expertise for having a broader sustainability evaluation in the company. This will enable competitive advantage by showcasing different sustainability attributes of IFF products and by enhancing inspiration for developing innovative solutions. Also, a strong argument built in this category was that C2C can be used as a high-level vision for encouraging innovative design and supporting R&D process, while LCA being used as a close-up method for assessing those designs.

Regarding the **Challenges** category, this was mainly dominated by technicalities related to the development and assessment of sustainable products in such a broad business. Hence, the units of *Sustainable products*, *Product development* and *C2C and LCA conflicts* (in grey) were evident. Important considerations within this group of codes include the fact that product sustainability is application specific and, therefore, business specific. Considering IFF's broad portfolio, every set of products will have specific sustainability attributes depending on its production, application and risk areas. For this reason, it is very challenging to create tools that are applicable to different products across different business units, such as Nourish, Scent, Health & Biosciences and Pharma Solutions in the case of IFF. Additionally, the creation of such tools and further improvements in product development and sustainability require high investments.
Along these lines, the idea of integrating C2C and LCA is certainly an option, however, technical contrast such as incompatibility between metrics, trade-offs not equally weighted and relative importance on impacts and categories can be demanding concerns. Moreover, the fact that C2C is a qualitative approach and LCA is a quantitative method cannot be ignored. Finally, since both methods require a level of background and expertise, the communication to non-specialists across businesses may represent difficulties when promoting product sustainability among different stakeholders.

The last category, **Solutions**, was intended to expose the silver linings of the challenges discussed above. Evidently, this category contained elements of 5 out of 6 units of meaning, all but *C2C and LCA conflicts* unit. Within the solutions identified in the data analysis, there was the idea of actively expanding business networking in order to develop sustainable products that are both customer and consumer oriented. This solution goes hand in hand with externally reporting the sustainability efforts of the company and improving the communication between specialists and non-specialists in the sustainability arena. Furthermore, the implementation of corporate sustainability strategies and innovation programs that embed product sustainability approaches such as LCA and C2C is highly important when tackling the grey areas of this field among business units. Lastly, one point that was especially discussed with the specialists interviewed was the issue around product sustainability in the food industry. For instance, when applying approaches such as C2C, it tends to oversee, or not address at all, food ingredients and products that are consumed since it is mainly focused on industrial processes. Many of the ingredients that IFF produces are eventually consumed as part of other products launched in the market. For this reason, there is a need to visualise these products as part of a larger food system and address aspects such as biodegradability beyond industrial processes. Ultimately, the type of technology and solution that addresses most of the elements previously described is to use waste streams for generating value. This means, applying circular design to business development and using by-products/co-products as raw materials for new product innovations. This solution is applicable for enhancing product sustainability in the entire IFF bio-based operations, and combines principles of C2C while also being quantifiable through LCA.

7.2. Synthesis of theoretical and empirical research

As previously presented in Chapter 5, the theoretical foundation of product sustainability was explored through an in-depth literature review (see Appendix A), more specifically in terms of Cradle to Cradle and Life Cycle Assessment. Additionally, for supporting and developing further knowledge into the case study, empirical research was done through qualitative data collection and analysis as discussed above. Therefore, in order to bridge both theoretical and empirical research, a critical discussion was built around the results of the case study. By traveling back and forth between the data and the existing theory, it was possible to synthesize what constitutes product sustainability under the problem formulated and to propose a more integrated framework of C2C and LCA as a preliminary solution.

7.2.1. Theoretical nature of C2C and LCA within IFF/N&B merger context

When researching product sustainability, the literature revolves around the contribution of products from a triple bottom line approach. For instance, Dyllick & Rost (2017) defines product sustainability as a products' performance in relation to economic, social and environmental benefits. In a similar way, the notion of product sustainability in this case study is strongly anchored to these three aspects. Since the purpose of the combined company is based on applying science and creativity for a better world, it focuses on the benefits and contributions that IFF products can have on people and the planet while also driving business

and generating profit. Therefore, the theoretical nature of this concept underlies in the profile of the company. In this way, IFF seeks to develop innovative products that generate social and environmental value. According to Deng *et al.,* (2020), this is highly important for business performance, especially in the present times where sustainable development is a priority in international agendas.

One of the main challenges, which also constitutes the problem formulation of this research study, relies on how to evaluate product sustainability. Nowadays there are numerous approaches to achieve this, and Dyllick & Rost (2017) recognise C2C and LCA as two of the most well-known approaches. As presented in the theoretical framework, each of these approaches has its own foundation and means to address a wide range of aspects in product sustainability. Within the case study context, it has been outlined that before the merger process, IFF has implemented the C2C approach to boost product innovation, especially in the Scent segment. On the other hand, former N&B had a strong background on quantifying product sustainability of a wide range of product types through LCA. What is interesting about this specific case is that, even though both companies had similar business activities and production, they had a very distinctive approach towards assessing product sustainability. The biggest difference lies in the production lines that were targeted. In first place, when using the C2C concept the aim is to have a positive impact on the environment by recreating nature's dynamics. This idea is mainly applied to industrial processes, where materials are seen as nutrients circulating safely in the environment (McDonough & Braungart, 2002; Hauschild *et al.,* 2018). In the case of IFF Scent segment, characterised as an industrial chemical production, it was possible to adopt the C2C principles for valuing waste, using renewable energy and ensuring systems' flexibility, which resulted ultimately in the launch of Cradle to Cradle certified fragrances. However, using this approach can have a grey zone when it comes to food ingredients, as explained in the previous section. Since consumed products go beyond the industrial materials tackled in C2C, the approach needs to be rethought in a way that the theoretical foundation and its principles can be applied to a food system. This could be achieved by giving higher priority to what is called "biological cycle" in C2C, but instead of having a materiality perspective, it should include a more basal perspective in order to cover characteristics such as nutritional value and biodegradability among others, which are in a way connected to the social aspects overseen in C2C.

Now, in the case of former N&B, assessing product sustainability of food ingredients was achieved through LCA. Since it is essentially a quantitative method, the outcome is a calculation of a product's negative impacts in terms of different categories. In N&B, this has been done for a wide range of products according to two different modelling methods known as attributional and consequential models. The difference between these two models is that consequential LCA intends to reflect physical and economic causalities, whereas attributional LCA assumes a static system and does not include this level of details (Bamber *et al.,* 2020). Nonetheless, no matter what type of modelling is used, LCA studies are time consuming, expert-oriented and hold a high level of uncertainty (Bamber *et al.,* 2020). The aim of the quantification is defined by the goal and scope of the study and is influenced by several assumptions that the practitioner carrying out the LCA has to make. For these reasons, it is very likely that, just as in C2C, many impacts are being overlooked due to the fact that

these are not prioritised. These LCA limitations have been noted and manifested in this case study research and represent some of the shortcomings that using this approach might have when assessing a large product portfolio.

Overall, the solely theoretical extent of C2C and LCA can represent challenges when assessing product sustainability for a diverse industrial business such as the new IFF. These drawbacks are more notorious when both approaches are viewed separately. However, the results of the case study have also shown that there are occasions where both approaches can be coupled to reduce ambiguity and create a more comprehensive framework for product sustainability.

7.2.2. Empirical aspects of C2C and LCA within IFF/N&B merger context

As it has been noted, many interesting aspects of product sustainability were brought to light in the qualitative data collection of this research study. Some of them were previously discussed from a theoretical standpoint as deemed relevant. Nevertheless, some statements identified through the content analysis had a strong empirical origin, in the way that these are specific examples and experiences of IFF and N&B integration in the field of product sustainability.

One prominent empirical aspect that was exposed by the interviewees is the delineation and interpretation of C2C and LCA metrics, which can lead to incompatibility in some occasions. Even though C2C and LCA advocate for sustainable solutions, there can be times where one of the metrics points to one solution and the other metric points to the opposite way. In general, when following C2C principles, the overall product circularity is a centralised priority and this can be achieved, for instance, by utilising renewable materials and avoiding fossil-based products. Now, when applying the LCA approach the aim is to minimise environmental impacts and to reduce the carbon footprint throughout the lifecycle. However, trying to follow these two metrics might not be as straightforward and intuitive as expected, besides its interpretation can be affected. IFF's director of Product Sustainability gave two specific examples where this can happen based on the experience among business segments. On the one hand, the Scent segment could aim for reducing its reliance on fossil fuels and avoid making e.g. synthetic rose fragrances by choosing to grow extensive flower fields and relying on renewable materials. Here, part of the principles of C2C are followed, however, the overall lifecycle carbon footprint of this natural fragrance is most likely to be higher than the one of a synthetic fragrance. As said, making the natural fragrance will imply large agricultural inputs (e.g. land use and fertilizers) in order to extract the necessary amount of essential oils from the rose petals. Contrarily, making a fragrance from synthetic molecules is a highly optimized process that would need a significantly smaller amount of fossil-based materials, thus possibly resulting in a lower carbon footprint.

On the other hand, in a business segment such as Nourish, a lot of questions are related to the nutritional value of the products, as already discussed in the previous section. In this case, the example presented by IFF's director of Product Sustainability illustrates how metrics and subjective interpretation can play a role when developing sustainable products, especially when it comes to meeting customers' demands. The situation is exemplified by the production of orange juice. Most people would assume that the best way to have orange juice

would be by squeezing the oranges and directly drinking the juice. This is indeed a healthy and nutritious way for an individual. However, scaling up this situation from one person to 9 billion people on planet Earth would no longer be a sustainable process. This happens because tons of oranges would need to be shipped whole and refrigerated around the world in order to meet the demand of freshly squeezed orange juice. This will have a much higher carbon footprint as compared to growing all of the oranges in one part, squeezing them out concentrated and then shipping this solution at a room temperature to the rest of the world, so it can eventually be turned into orange juice at the facilities (IFF's director of Product Sustainability, 2021; Annex 1). Moreover, shipping whole oranges could potentially translate into to more food waste since fruits might be prone to spoilage during this process. There may also be a lower use of resources by choosing this option because it is less likely that people in their households will take advantage of the whole fruit. Contrarily, if the juice is initially extracted in an industrial facility for shipping the concentrated, then the remaining orange peels can be upcycled and used as valuable resource inputs for other processes.
These cases show some of the controversies that the application of C2C and LCA can have in this industry. The assessment of trade-offs and the transparent definition of risks areas and targets is key for solving these challenges and finding the technical solutions that are best for people, planet and profit. Doing so represents a thorough study of market demands, customers' requests, business goals, international policies and many other considerations that can eventually influence the investment allocated towards the development of a sustainable product. Nonetheless, many positive outcomes have come from implementing C2C and LCA and both N&B and IFF have had benefits for establishing these approaches. Overall, product sustainability initiatives have led to unleash great innovation potentials and to embed sustainability from early stages of product design and development. It has also resulted in a competitive advantage due to the disclosed information given to the stakeholders on sustainability attributes of the solutions being offered. Lastly, among other benefits, it has helped endorse the ESG commitments of the businesses for contributing to a better world. With that being said, there is an increased interest for integrating product sustainability approaches for the new combined company with the purpose of leveraging sustainable business and stakeholder engagement.

7.2.3. Proposed integrated framework of C2C and LCA

Up to this point, the research problem formulated in this case study has been analysed both from a theoretical and an empirical perspective. In this way, theories on C2C and LCA allowed to understand the foundations of these two approaches when it comes to product sustainability in the chemical, biotech and food sector. Additionally, the empirical research based on qualitative methodologies, supported the analysis by giving a clear view of the application of C2C and LCA in a professional context. Altogether, these research tools provided the necessary elements to build a critical assessment of the problem and to achieve the following objectives set during the initial phase of the case study:

- Outline the general scheme on C2C and LCA used by IFF and former N&B when addressing product sustainability.

- Analyse stakeholders' perception on product sustainability and identify relevant statements in relation to C2C and LCA application.
- Identify the opportunities and challenges for integrating C2C and LCA approaches in IFF/N&B context.
- Determine an integrated framework of C2C and LCA based on both, schemes and perception of product sustainability in IFF/N&B context.

Precisely, in accordance with the last objective just mentioned, a framework of C2C and LCA was developed to consolidate the theoretical and empirical findings of this case study. The framework is laid out on ***Table 8***, where ten main elements were identified based on the information gathered throughout the research process, including literature review and semi-structured interviews. More specifically, these elements were established by building up on a C2C and LCA discussion propose by Hauschild *et al.,* (2018) and bringing together key aspects that arose from the qualitative content analysis performed. Hence, both C2C and LCA were described in respect to these elements, and an integrated outcome was proposed as a first-step solution for driving and promoting product sustainability in the new IFF.

Table 8. Framework of C2C and LCA built upon both theoretical schemes and empirical statements of the case study. The framework is based on ten key elements (in grey) which covers the main foundations and applications of these approaches. C2C (in yellow) and LCA (in blue) are then described in respect to these ten elements. Furthermore, a proposed scenario on the integration of C2C and LCA (in green) is described.
The colors on this chart are not related to the ones previously used in the analysis. Here, colors are used for aesthetic purposes and to illustrate the combination of C2C (yellow) and LCA (blue) resulting in an integrated approach (green).

Elements	C2C	LCA	C2C and LCA integration in IFF
Purpose	Inspired by nature's dynamics, the purpose is to design products and processes that are beneficial to people and the planet.	To quantify negative environmental impacts from the life cycle of a product or service.	To thoroughly apply science and creativity for developing solutions that minimise negative impacts and enhance benefits on people, planet and profit.
Target	To be applied mainly in R&D and manufacturing processes.	Depending on the goal and scope of the study, but to be applied mainly on strategic products upon customers' demands.	To be implemented in early stages of R&D, innovation programs and manufacturing processes. Moreover, marketing and sales operations to be involved for generating stakeholders' value.
Sustainability definition and vision	To have a positive impact on people and planet by following the three principles for imitating nature's way of doing things.	No explicit sustainability vision. Although, based on the goal and scope, the idea is to minimise negative impacts resulting from	Following a triple bottom line approach, commit to generate social, environmental and economic benefits. Become an industry

		the delivery of a products' functional unit.	leader for embedding sustainability in all activities.
Role within product development	Serves as a guidance for product development. It can provide a qualitative perspective for designing and developing innovative and sustainable solutions.	It does not necessarily play a role in product development. However, it can help determine those areas where a product is having bigger negative impacts. Thus, provides considerations for future developments.	Stepwise coupling where C2C can provide a high-level qualitative assessment to identify risk areas. Then LCA can be used as a close-up tool to quantify details on those areas and improve the product development process.
Life cycle approach	Adopts a life cycle approach were industrial materials are seen as nutrients constantly circulating through the system in a safe and sustainable way. The application of the three principles and the carefully selection of material composition are key to guarantee the fate of products in multiple cycles.	Takes into consideration the entire life cycle of a product or service. The impacts throughout the different life cycle stages are evaluated in a systematic way. It should also be objective to the extent possible.	Broader sustainability evaluation. Assessment of the entire life cycle of products from a qualitative and quantitative standpoint. The integrated framework also represents and opportunity to identify more areas of improvement for strategic products.
Addressing social and environmental impacts and risks	The concept assumes that if the three principles are being followed, no social nor environmental risks should result during the different stages of a product life cycle.	Depending on the goal and scope, following steps such as the LCIA can cover different impact categories, mainly on environmental issues.	Possibility of a more comprehensive approach towards risks areas and possible impacts. This can support better decision making processes.
Assessment method	Qualitative aspects outweigh quantitative aspects. E.g. quantities of energy use and emissions are irrelevant as long as there is compliance with the principles.	It is essentially a quantitative method. LCA systematically quantifies the impacts related to a functional unit of a product or service based on an objective modelling.	Combination of both, qualitative and quantitative assessments. Quantifiable parameters provide robustness to the method. Qualitative guidelines decrease subjective bias.
Business innovation drivers	Aims to stimulate radical innovation by rethinking *business as*	Can provide a comparison between a product and its	Grants competitive advantage by boosting innovation during early

	usual processes and getting exposed to new considerations for building sustainable societies.	alternative option on the market. However, it is difficult to predict impacts of a product that has not yet been developed.	development stages and re-evaluating products already in the market as compared to their alternatives.
Value proposition	A design framework inspired by nature. It seeks to not only minimise negative impacts, but to enhance the positives ones. As a result, societies that are safe for people, healthy for the planet and successful for business will emerge. Moreover, C2C certification supports the symbolic value provided by sustainability.	A methodological tool used to identify impacts and assess trade-offs related to certain processes. By doing so, LCA provides and understanding of materials and processes. Thus, it facilitates strategic decision making along the entire value chain.	Integrating life cycle approaches can develop sustainable value propositions for industrial offerings. Jointly, C2C and LCA can be used to leverage sustainability attributes and to demonstrate the life cycle value of a product in the long term. This paradigm will ultimately create value for stakeholders.
Communication and engagement	Supports the idea of showcasing efforts that are placed to create a safe and sustainable world. This qualitative plan values intentions and operates with positive impacts to people and planet. Its communication is straightforward, making it possible that non-specialists get involved.	Supports decisions on how to reduce negative environmental impacts. Since it is a field of expertise, it does not necessarily advocate for engagement and communication to non-specialists is not straightforward.	Allows to adopt a positive framing of the challenges towards sustainable development. An integrated framework could help emphasize improvement areas, opportunities and communicate positive impacts. It can allow the business to position as an agent of change for a better world.

For a company like IFF, working towards product sustainability with two different approaches such as C2C and LCA can represent areas for opportunities and challenges. In such a manner, these areas have been enunciated, analysed and discussed to provide a clear view of where the new IFF stands in terms of product sustainability after completing the merger with N&B. Evaluating these areas has not only provided further understanding of the research problem, but it has also led to suggest various key points to be considered in this transition. As presented in ***Table 8***, opportunities and challenges both from a theoretical and empirical standpoint, have been framed as a concerted effort towards a more integrated product sustainability approach that could potentially be adopted and improved in the new IFF. Going forward, further discussion with IFF sustainability team could provide new insights on the feasibility and possible action plans for implementing this framework.

7.3. Limitations and future considerations

Certainly, this case study comes with limitations that can lead to future considerations and further research. In general, the limitations are associated with the research design, thus some reflections have emerged in respect to the theories and methods used throughout this study.
In the first place, the theoretical framework was primarily focused on C2C and LCA as separate units, while the research process opened the way to bring these two units together. However, this process could have been strengthened by exploring more in-depth the business theories related to the case study, for instance, by delving into the theoretical foundation of M&A strategies and how these are translated into operations. Doing so could have provided new insights on how to merge product sustainability strategies coming from IFF and N&B.
Furthermore, as previously presented both C2C and LCA have limitations from a theoretical and empirical basis. For this reason, it could be plausible to explore how this research relates to other life cycle approaches or areas applicable to the chemistry, biotech and food industry, e.g. green chemistry and eco-efficiency among others. Additionally, elaborating further on possible theoretical concepts that can enhance product sustainability in IFF, such as the concept of circular bioeconomy, could give a better overview of the areas of improvement proper to this case study.

Second, a methodology with limited sample size was employed for the data collection. Even though a larger number of relevant stakeholders was identified by means of a stakeholder analysis, it was only possible to gather data from four participants representing different stakeholder groups. Three out of four participants were internal stakeholders related to IFF or former N&B. Although good insights which served as a fundamental understanding of the case study were provided, it could have been enriching to obtain further inputs from external stakeholders relevant to this research. In fact, one of the participants was an external stakeholder, unfortunately, the interview could not be accommodated and thus, very superficial answers were provided by email correspondence instead. This information was clearly not as insightful as the information obtained in the semi-structured interviews. Overall, increasing the number and variety of participants could have provided more constructive outcomes. Moreover, the qualitative content analysis was designed to be an impartial evaluation. However, qualitative methodologies like this are prone to have subjective elements, thus, representing possible biases rooted to the individual interpretation.

Despite the limitations of the research design, this case study exposes relevant factors on how to integrate C2C and LCA for enhancing and promoting product sustainability among stakeholders of the new IFF. In this sense, the findings serve as a guidance of the elements that should be taken into account moving forward with a jointly C2C and LCA strategy. Nonetheless, this guidance is not equipped to provide reliable conclusions on which specific conditions it is best to integrate both approaches. Therefore, future considerations include projecting the integrated framework in the specific context of each business unit and, ideally, scaling it down to specific products depending on market demands. In addition, assessing the effectiveness of the C2C and LCA integrated framework in operations such as marketing and sales can provide further arguments for its implementation. Ultimately, this can bring advantages by setting an effective way to address product sustainability by product category.

CHAPTER EIGHT

CONCLUSION

In this chapter, general statements that sum up the insights of the case study are presented in relation to the main research question. Altogether, the research process is summarised and reflected upon.

From a business standpoint, product sustainability explores ways to deliver products that generate economic value while also providing environmental and social benefits. However, in the industry sector, there is no consensus that dictates what a sustainable product is. Instead, various approaches for assessing products in terms of sustainability performance have emerged during the last decades. In most cases, these approaches are applied independently from one another, based on the business context, purpose and desired outcome. Nonetheless, business dynamics can rapidly shift and new aspects need to be considered when addressing product sustainability.

Under the context of International Flavors & Fragrances Inc. (IFF) and DuPont Nutrition & Biosciences (N&B) merger process, two different approaches for assessing product sustainability have come across: Cradle to Cradle (C2C) and life cycle assessment (LCA), respectively. This case study was presented as an attempt to outline the merger process between these two organisations from a sustainability standpoint, more specifically to explore the possibilities for integrating C2C and LCA as a concerted framework for driving product sustainability in the newly combined IFF. Along these lines, a research process was properly developed to provide an answer to the following research question:

Considering IFF and DuPont N&B merger process, how can Life Cycle Assessment and Cradle to Cradle approaches be integrated for promoting product sustainability among stakeholders of the combined company?

By means of theoretical and empirical research, it was possible to conduct an in-depth analysis of C2C and LCA under the case study context. In first place, the conceptualisation of both approaches and their suitability in the industry was outlined based on a literature review. This allowed to understand its foundations when addressing product sustainability in the chemical, biotech and food sector. Secondly, an empirical research based on qualitative methods supported the analysis by providing clear insights on the application of C2C and LCA in a professional context. Through a stakeholder analysis, it was possible to identify key stakeholders for whom product sustainability is a direct interest or concern in the combined company. Later on, statements and experiences from key stakeholders were collected and analysed in order to unfold different perceptions on product sustainability, especially on the feasibility of integrating C2C and LCA. Key aspects included the opportunity of broadening the company's sustainability performance and enabling competitive advantage by showcasing different sustainability attributes of IFF products. Additionally, some challenges were also identified, mainly in terms of assessing a diverse product portfolio and dealing with technical contrasts such as metrics incompatibilities between C2C and LCA. Though, the overall discussion brought up positive insights which supported the idea of coupling C2C and LCA to create a more comprehensive evaluation of product sustainability in the combined company.

Hence, theoretical and empirical findings were framed as a concerted effort towards a more nuanced product sustainability approach. This was presented in the form of an integrated C2C and LCA framework that could potentially be adopted in the new IFF. The framework is a proposed solution for acknowledging key aspects of both approaches and their joint applicability in the context of the case study. Nonetheless, this framework is not equipped to provide guidance over which specific conditions it is best to integrate both approaches.

Therefore, future considerations include projecting the integrated framework to the specific circumstances of each business unit and, ideally, scaling it down to particular products depending on market demands.

Altogether, this master's thesis has contributed to the understanding of organisational dynamics from a sustainability standpoint. By developing a case study focused on the managerial aspects of sustainability within a corporate merger, it was possible to identify relevant matters that are not commonly addressed in the research community but that are still decisive in the business sector. In this way, exploring the combination of IFF and N&B through the lenses of corporate sustainability raised many inquiries, especially on the process for merging two sustainability profiles. Under the specific topic studied, it was possible to unfold the applicability of two product sustainability approaches and determine a way for bringing them together in order to promote the sustainability efforts among stakeholders of the recently combined company.

This research has brought to light the advantages of fitting together different theories and methods to achieve the same goal, working towards a sustainable future. It has also reassured the importance of thinking outside the box and not assuming that there is only one true way of doing things. Challenging fields such as product sustainability calls for interdisciplinary collaboration and for coalition-building methods, especially in large industries. By integrating knowledge, a greater coverage of issues can be ensured, thus leading to more comprehensive and innovative solutions. Overall, this has been the case of IFF in the post-merger period. Many issues have arisen, not only in sustainability as described in this case study, but across multiple fields. One thing is for certain, in order to solve diverse issues, a wide spectrum of tools needs to be contemplated.

REFERENCES

Bamber, N., Turner, I., Arulnathan, V., Li, Y., Zargar Ershadi, S., Smart, A., & Pelletier, N. (2020). Comparing sources and analysis of uncertainty in consequential and attributional life cycle assessment: Review of current practice and recommendations. *The International Journal of Life Cycle Assessment, 25*(1), 168-180. doi:10.1007/s11367-019-01663-1

Bakker, C., Wever, R., Teoh, C., & De Clercq, S. (2010). Designing cradle-to-cradle products: A reality check. *International Journal of Sustainable Engineering, 3*(1), 2-8. doi:10.1080/19397030903395166

Bendtsen, E. B., Clausen, L. P., & Hansen, S. F. (2021). A review of the state-of-the-art for stakeholder analysis with regard to environmental management and regulation. *Journal of Environmental Management, 279*, 111773. doi:10.1016/j.jenvman.2020.111773

Berkes, F. (2017). Environmental governance for the Anthropocene? Social-Ecological Systems, resilience, and collaborative learning. *Sustainability, 9*(7), 1232. doi:10.3390/su9071232

Bloomberg – International Flavors & Fragrances Inc. statement (2021). Retrieved February 16, 2021, from https://www.bloomberg.com/quote/IFF:US

Brockhaus, S., Fawcett, S., Kersten, W., & Knemeyer, M. (2016). A framework for benchmarking product sustainability efforts. *Benchmarking: An International Journal, 23*(1), 127-164. doi:10.1108/bij-09-2014-0093

Burke, T. A., Cascio, W. E., Costa, D. L., Deener, K., Fontaine, T. D., Fulk, F. A., Zartarian, V. G. (2017). Rethinking environmental protection: Meeting the challenges of a changing world. *Environmental Health Perspectives, 125*(3). doi:10.1289/ehp1465

Cavaleri, S., & Shabana, K. (2018). Rethinking sustainability strategies. *Journal of Strategy and Management, 11*(1), 2-17. doi:10.1108/jsma-08-2016-0050

Cleverly, K. & Thrane, M. (2020, October) Directional EHS & Sustainability Strategy [Slides]. Project Neptune, International Flavors & Fragrances Inc.

Cradle to Cradle Products Innovation Institute (C2CPII). (2021a). What is Cradle to Cradle Certified™? Retrieved February 27, 2021, from https://www.c2ccertified.org/get-certified/product-certification

Cradle to Cradle Products Innovation Institute (C2CPII). (2021b). About the Institute. Retrieved March 15, 2021, from https://www.c2ccertified.org/about/about

Cradle to Cradle Products Innovation Institute (C2CPII). (2021c). Cradle to Cradle Certified Product Registry. Retrieved March 15, 2021, from https://www.c2ccertified.org/products/registry

Cradle to Cradle Products Innovation Institute (C2CPII). (2021d). The Cradle to Cradle Certified Product Standard Version 4.0 is here. Retrieved March 15, 2021, from https://www.c2ccertified.org/news/article/c2ccertified-v4.0-is-here

Denčić-Mihajlov, K. (2020). Does sustainability matter in mergers and acquisitions?: The case of the Serbian food industry. *Economics of Agriculture (Ekonomika Poljoprivrede), 67*(1), 25-36. doi:10.5937/ekopolj2001025d

Deng, W., Feng, L., Zhao, X., & Lou, Y. (2020). Effects of supply chain competition on firms' product sustainability strategy. *Journal of Cleaner Production, 275*(124061). doi:10.1016/j.jclepro.2020.124061

DuPont Corporation. (2020). Retrieved February 18, 2021, from https://www.dupont.com/news/safety-at-our-core.html

DuPont Nutrition & Biosciences. (2019, December 15). *IFF to merge with DuPont's Nutrition & Biosciences business* [Press release]. https://www.dupont.com/news/iff-to-merge-with-dupont-nutrition-biosciences-business.html

DuPont Nutrition & Biosciences. (2020a). Retrieved February 15, 2021, from https://www.dupontnutritionandbiosciences.com/sustainability.html

DuPont Nutrition & Biosciences. (2020b). *Sustainability Strategy* [Brochure]. Retrieved February 19, 2021, from https://www.dupontnutritionandbiosciences.com/content/dam/dupont/amer/us/en/nutrition-health/general/documents/HO%2048-2_Sustainability_A4%20NL%20FINAL%20HR.pdf

Dyllick, T. L., & Muff, K. (2016). Clarifying the meaning of sustainable business: Introducing a typology from business-as-usual to true business sustainability. *Organ. Environ., 29*(2), 156-174. doi:10.2139/ssrn.2368735

Dyllick, T., & Rost, Z. (2017). Towards true product sustainability. *Journal of Cleaner Production, 162*, 346-360. doi:10.1016/j.jclepro.2017.05.189

Ehrenfeld, J. R. (2009, March 27). Cradle to Cradle is an idea, not a trademark [Web log post]. Retrieved March 27, 2021, from https://www.johnehrenfeld.com/cradle-to-cradle_is_an_idea_no/

Ellen MacArthur Foundation. (2013). *Towards the circular economy: Economic and business rationale for an accelerated transition*. Isle of Wight.

Elo, S., & Kingas, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing, 62*(1), 107-115. doi: 10.1111/j.1365-2648.2007.04569.x

Esnouf, A., Heijungs, R., Coste, G., Latrille, É, Steyer, J., & Hélias, A. (2019). A tool to guide the selection of Impact categories for LCA studies by using the Representativeness index. *Science of The Total Environment, 658*, 768-776. doi:10.1016/j.scitotenv.2018.12.194

Fargione, J. E., Plevin, R. J., & Hill, J. D. (2010). The Ecological Impact of Biofuels. *Annual Review of Ecology, Evolution, and Systematics, 41*, 351-377. doi:10.1146/annurev-ecolsys-102209-144720

Finkbeiner, M. (2013). From the 40s to the 70s—the future of LCA in the ISO 14000 family. *The International Journal of Life Cycle Assessment, 18*(1), 1-4. doi:10.1007/s11367-012-0492-x

Flyvbjerg, B. (2006). Five misunderstandings About Case-Study Research. *Qualitative Inquiry, 12*(2), 219-245. doi:10.1177/1077800405284363

Franco, M. A. (2017). Circular economy at the micro level: A dynamic view of incumbents' struggles and challenges in the textile industry. *Journal of Cleaner Production, 168*, 833-845. doi:10.1016/j.jclepro.2017.09.056

Fröhling, M., & Hiete, M. (2020). Sustainability and life cycle assessment in Industrial biotechnology: A review of current approaches and future needs. *Sustainability and Life Cycle Assessment in Industrial Biotechnology,* 143-203. doi:10.1007/10_2020_122

Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2012). Seeking Qualitative Rigor in Inductive Research. *Organizational Research Methods, 16*(1), 15-31. doi:10.1177/1094428112452151

González-Torres, T., Rodríguez-Sánchez, J., Pelechano-Barahona, E., & García-Muiña, F. E. (2020). A systematic review of research on sustainability in mergers and acquisitions. *Sustainability, 12*(2), 513. doi:10.3390/su12020513

Harrison, H., Birks, M., Franklin, R., & Mills, J. (2017). Case Study Research: Foundations and Methodological Orientations. *Forum Qualitative Social Research (FQS), 18*(1), Art 19.

Hauschild, M. Z., Rosenbaum, R. K., & Olsen, S. I. (2018). Cradle to Cradle and LCA. In *Life Cycle Assessment: Theory and Practice* (pp. 605-631). Cham: Springer International Publishing. doi:10.1007/978-3-319-56475-3_25

Hauschild, M. Z., Rosenbaum, R. K., & Olsen, S. I. (2018). Main characteristics of LCA. In *Life Cycle Assessment: Theory and Practice* (pp. 605-631). Cham: Springer International Publishing. doi:10.1007/978-3-319-56475-3_25

International Flavors & Fragrances. (2021, February 1). *IFF unveils new brand identity to accelerate strategic transformation* [Press release]. https://ir.iff.com/news-releases/news-release-details/iff-unveils-new-brand-identity-accelerate-strategic

International Flavors & Fragrances (IFF). (2021a). Retrieved February 15, 2021, from https://www.iff.com/about/purpose

International Flavors & Fragrances (IFF). (2021b). Retrieved February 15, 2021, from https://www.iff.com/about/history

International Flavors & Fragrances (IFF). (2021c). Retrieved February 15, 2021, from https://www.iff.com/about

International Flavors & Fragrances (IFF). (2021d). Retrieved February 19, 2021, from https://www.iff.com/responsibilities

International Flavors & Fragrances (IFF). (2021e). Retrieved February 19, 2021, from https://www.iff.com/about/what-we-do

International Flavors & Fragrances (IFF). (2021f). Retrieved February 19, 2021, from https://www.iff.com/responsibilities/sustainable-innovation

International Organization of Standardization (ISO). (2006). Environmental Management, Life Cycle Assessment Principles and Framework (ISO14040:2006). Retrieved March 23, 2021, from https://www.iso.org/obp/ui/#iso:std:iso:14040:ed-2:v1:en

Koelsch Sand, C., & Boz, Z. (2020). Life Cycle Assessments Guide Sustainability. *Food Technology*. Retrieved March 16, 2021, from https://www.researchgate.net/profile/Claire-Sand/publication/341435221_May_2020-_Life_Cycle_Assessments_Guide_Sustainability/links/5ec05611a6fdcc90d67a66ae/May-2020-Life-Cycle-Assessments-Guide-Sustainability.pdf

Korhonen, J., Honkasalo, A., & Seppälä, J. (2018). Circular economy: The concept and its limitations. *Ecological Economics, 143*, 37-46. doi:10.1016/j.ecolecon.2017.06.041

Kvale, S., Brinkmann, S. (2009). Interview: Learning the craft of qualitative research interviewing. Thousand Oaks, USA: Sage Publications.

Le, T. T., Engel, J., & Macht, G. A. (2016). Measuring Product Sustainability: A Literature Review. *Proceedings of the 2016 Industrial and Systems Engineering Research Conference*. Retrieved March 30, 2021, from https://www.researchgate.net/profile/Gretchen-Macht-2/publication/316858274_Measuring_Product_Sustainability_A_Literature_Review/links/59147039aca27200fe4e7aae/Measuring-Product-Sustainability-A-Literature-Review.pdf

Li, X., & Li, Y. (2016). Chain-to-chain competition on product sustainability. *Journal of Cleaner Production, 112*(3), 2058-2065. doi:10.1016/j.jclepro.2014.09.027

Llorach-Massana, P., Farreny, R., & Oliver-Solà, J. (2015). Are Cradle to Cradle certified products environmentally preferable? Analysis from an LCA approach. *Journal of Cleaner Production, 93*, 243-250. doi:10.1016/j.jclepro.2015.01.032

Loveday, S. M. (2019). Food Proteins: Technological, Nutritional, and Sustainability Attributes of Traditional and Emerging Proteins. *Annual Review of Food Science and Technology, 10*(1), 311-339. doi:10.1146/annurev-food-032818-121128

Maciel, V. G., Wales, D. J., Seferin, M., Ugaya, C. M., & Sans, V. (2019). State-of-the-art and limitations in the life cycle assessment of ionic liquids. *Journal of Cleaner Production, 217*, 844-858. doi:10.1016/j.jclepro.2019.01.133

Manda, B. M., Bosch, H., & Worrell, E. (2015). Sustainable value creation with life cycle management. *LCA Compendium – The Complete World of Life Cycle Assessment,* 129-146. doi:10.1007/978-94-017-7221-1_11

McDonough, W., & Braungart, M. (2002). *Cradle to Cradle: Remaking the way we make things*. New York: North Point Press.

McDonough, W., & Braungart, M. (2009). *Cradle to Cradle: Remaking the way we make things*. London: Vintage.

Pacak, D., Vassova, M., & Jerabek, S. (2020). *Tightening the Circular Economy model by utilization of BIM at Early Stages of Building Projects* (Master's thesis, Aalborg University, 2020). Aalborg: AAU Library.

Penzenstadler, B., Femmer, H., & Richardson, D. (2013). Who is the advocate? Stakeholders for sustainability. *2013 2nd International Workshop on Green and Sustainable Software (GREENS)*. doi:10.1109/greens.2013.6606424

Product Life Institute. (2013). Cradle to Cradle. Retrieved March 13, 2021, from http://www.product-life.org/en/cradle-to-cradle

Rienecker, L., & Jørgensen, P. S. (2013). *The good paper: A handbook for writing papers in higher education*. Frederiksberg: Samfundslitteratur.

Saling, P. (2020). Assessing industrial Biotechnology products with LCA AND Eco-efficiency. *Adv Biochem Eng Biotechnol, 173*, 325-357. doi:10.1007/10_2019_102

Schilling, C., & Weiss, S. (2021). A roadmap for industry to harness biotechnology for a more circular economy. *New Biotechnology, 60*, 9-11. doi:10.1016/j.nbt.2020.08.005

Schneider, F., Kläy, A., Zimmermann, A. B., Buser, T., Ingalls, M., & Messerli, P. (2019). How can science support the 2030 agenda for sustainable Development? Four tasks to tackle the normative dimension of sustainability. *Sustainability Science, 14*(6), 1593-1604. doi:10.1007/s11625-019-00675-y

Silvestre, B. S., & Ţîrcă, D. M. (2019). Innovations for sustainable development: Moving toward a sustainable future. *Journal of Cleaner Production, 208*, 325-332. doi:10.1016/j.jclepro.2018.09.244

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research, 104*, 333-339. doi:10.1016/j.jbusres.2019.07.039

United Nations (2015). Transforming our world: The 2030 agenda for Sustainable Development. Retrieved April 24, 2021, from https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf

van der Werf, H. M., Knudsen, M. T., & Cederberg, C. (2020). Towards better representation of organic agriculture in life cycle assessment. *Nature Sustainability, 3*(6), 419-425. doi:10.1038/s41893-020-0489-6

WWF. (2016, October). Living Planet Report 2016. Risk and Resilience in a New Era. Retrieved April 24, 2021, from http://awsassets.panda.org/downloads/lpr_living_planet_report_2016.pdf

Yep, G. (2021, February 3). Introducing the new IFF R&D [Slides]. Global Town Hall R&D and Integrated operations. Project Neptune, International Flavors & Fragrances Inc.

Yin, R. K. (2009). Case Study Research Design and Methods (4). Thousand Oaks, USA: Sage Publications.

Ögmundarson, Ó, Herrgård, M. J., Forster, J., Hauschild, M. Z., & Fantke, P. (2020). Addressing environmental sustainability of biochemicals. *Nature Sustainability, 3*(3), 167-174. doi:10.1038/s41893-019-0442-8

APPENDIX A – LITERATURE REVIEW SUMMARY

Source	Key words	Topic	Major findings
Bakker *et al.*, (2010)	Cradle to Cradle, Life cycle assessment, Sustainable innovation, Design for environment	Applicability of Cradle to Cradle concept in product development in a business setting	Cradle to Cradle and life cycle assessment (LCA) can be used as complementary tools for designing and developing products with better environmental performance.
Bendsten *et al.*, (2021)	Stakeholder analysis, Environmental management, Environmental regulation	Review of the state-of-the-art of Stakeholder Analysis within environmental management and regulation	Stakeholder Analysis studies cover a wide range of environmental issues. The most used data collection methods are snowball-sampling, interviews and literature review.
Brockhaus *et al.*, (2016)	Sustainability, Stakeholders theory, Qualitative research, Sustainable products	Explore business dynamics as they relate to sustainable product programs for developing a framework to align business efforts	Six dimensions of product sustainability were identified. Using relational dynamics, a common framework on product sustainability was presented for facilitating analysis and reducing ambiguity.
Deng *et al.*, (2020)	Supply chain management, Sustainability, Competition	Supply chain competition on a product sustainability level	Horizontal and vertical competition between sustainable products play an important role in determining a firm's strategy.
Dyllick & Muff, (2016)	Corporate sustainability, Sustainable development, Triple bottom line	Clarifying the meaning of true business sustainability	Development of a typology of three levels of business sustainability with a focus on effective contributions to sustainable development.
Dyllick & Rost, (2017)	Product sustainability, Business innovation, Sustainable Development, Net positive	Contributing to sustainable development through product sustainability	Systematic framework of the evolving perspectives of product sustainability by levels of development.
Franco, (2017)	Circular economy, Sustainable production, Supply chain collaboration	Influence of the different production systems aspects towards the transition to circularity	Understanding of the dynamics of supplier-buyer innovation factors and product design aspects in determining the output of circular products in the textile industry.
Fröhling & Hiete, (2020)	Life cycle assessment, Bioeconomy,	Role of sustainability and life cycle assessment in	This review characterises industrial biotechnology from a sustainability assessment perspective, exploring

	Renewable raw material	industrial biotechnology	current approaches and future needs.
Korhonen *et al.*, (2018)	Circular economy, Business strategy, System boundaries, Sustainability	Analysis of circular economy from the perspective of environmental sustainability	Challenges such as thermodynamics and system boundaries were identified.
Li & Li, (2016)	Sustainability, Supply chain management, Chain-to-chain competition	Sustainable supply chains systems and product sustainability	Variations in the dynamics of sustainable supply chains under competition in product sustainability
Le et al., (2016)	Cradle to Cradle, Life cycle assessment, Product design for environment, Sustainability	Unfolding available methods for measuring product sustainability	Characterises methods for measuring product sustainability, such as C2C and Environmental LCA. It also suggests that product design should include Social LCA for measuring sustainability.
Llorach-Masana *et al.*, (2015)	Product sustainability, Cradle to Cradle, Life cycle assessment, Ecolabelling	Analysis of environmental performance of C2C certified products from a life cycle perspective	Cradle to Cradle requirements do not entirely tackle the environmental aspects of products from a life cycle approach.
Loveday, (2019)	Sustainability, Food system, Protein, Plant protein, Digestability	Nutritional and sustainability attributes of food proteins	The review highlights underappreciated sustainability attributes of traditional and emerging proteins.
Maciel *et al.*, (2019)	Life cycle assessment, Chemical inventory, Ionic liquids	Limitations in the life cycle assessment of chemicals	The review identifies existing shortcomings in LCA of chemicals, such as insufficient life cycle inventory data and missing characterization factors.
Manda *et al.*, (2015)	Corporate sustainability, Life cycle management, Product sustainability, Value creation	Importance of life cycle management for linking sustainability and value creation in businesses	Contributions for bridging the gap between sustainability science and business management by applying LCA-based insights in corporate sustainability and decision-making processes.
Penzenstadler *et al.*, (2013)	Stakeholder analysis, Sustainability, Case study	Identifying crucial stakeholders for implementing sustainability support in a given context	Four approaches for identifying stakeholders for sustainability: a top-down by sustainability dimensions, application of generic lists, a bottom-up by organigrams and the iterative use of activity models.
Saling, (2020)	Sustainability management Eco-efficiency, Life cycle assessment	Assessing industrial biotechnology products with LCA and Eco-efficiency	This work outlines different types of sustainability assessment for evaluating numerous aspects in the industrial biotechnology field, in

			order to identify and promote more sustainable solutions.
Schilling & Weiss (2021)	Circular economy, Biotechnology, Product lifecycle design	Applications of biotechnology for accelerating the transition to a more circular economy	Identification of five key points within a product lifecycle where biotechnology can be impactful for promoting circular economy and sustainable products.
van der Werf *et al.* (2020)	Life cycle assessment, Food systems, Organic agriculture	Limitations of life cycle assessment in organic agriculture systems	LCA assess agroecological systems inadequately due to a lack of operational indicators, a narrow perspective on agricultural systems' functions and an inconsistent modelling of indirect effects.
Ögmundarson *et al.*, (2020)	Sustainable biotechnology, Life cycle assessment, Environmental sustainability	Addressing environmental sustainability in biochemicals	To boost sustainable biochemicals, LCA practitioners should include a broader range of impact indicators and address missing data. In the biotech industry, LCA could be used to direct research and identify impact hotspots.

APPENDIX B – INTERVIEW GUIDE # 1

Interview guide for IFF's Product Sustainability representative

Introduction

1. What is your role in IFF and how does it relate to product sustainability?

Contextualising *Sustainability*

2. How do you define sustainability within IFF? Has this perception been influenced somehow after the merger with DuPont N&B?
3. What can be seen as a major driving force for sustainability initiatives in IFF?

Developing sustainable products

4. How do you define "sustainable products"? What makes a product sustainable?
5. How does IFF integrate sustainability into the product development process? Has this process changed after the merger with N&B?
6. What challenges and barriers does IFF face in the collaborative development of sustainable products considering the broad portfolio?

Addressing product sustainability

7. What does IFF consider to be the most relevant aspects of product sustainability?
8. What does IFF consider to be the least relevant aspects of product sustainability?
9. Taking into account C2C and LCA approaches, what synergies and conflicts could such approaches have when assessing IFF products?
10. Do you believe that integrating LCA and C2C would give IFF products an added value in the market? Could this be advantageous for some specific products?

APPENDIX C – INTERVIEW GUIDE # 2

Interview guide for IFF environmental specialist (former N&B internal consultant)

Introduction

1. What is your role in IFF and how does it relate to product sustainability?

Contextualising *Sustainability*

2. How do you define sustainability within IFF? Does it align with legacy N&B definition of sustainability?
3. What can be seen as a major driving force for sustainability initiatives in IFF?

Developing sustainable products

4. How do you define "sustainable products"? What makes a product sustainable?
5. How does IFF integrate sustainability into the product development process? Has N&B merger influenced this process somehow?
6. What challenges does IFF face in the collaborative development of sustainable products, especially after broadening the portfolio with N&B merger?

Addressing product sustainability

7. What does IFF consider to be the most relevant aspects of product sustainability?
8. What does IFF consider to be the least relevant aspects of product sustainability?
9. Considering Cradle to Cradle (C2C) and Life Cycle Assessment (LCA), what synergies and conflicts could such approaches have when assessing IFF products?
10. Do you believe that integrating LCA and C2C would give IFF products an added value in the market? Could this be advantageous for some particular products compared to others?

APPENDIX D – INTERVIEW GUIDE # 3

Interview guide for IFF's Customer Engagement representative

Introduction

1. Please provide a brief overview of your role and responsibilities within IFF.

Contextualising *Sustainability*

2. How do you define sustainability within IFF? Does this align with stakeholders' perception of sustainability?
3. What is the major driving force for sustainability initiatives within IFF?

Developing sustainable products

4. How does IFF integrate sustainability claims coming from external stakeholders into the product development process? Has this process changed after the merger with N&B?
5. What challenges and barriers does IFF face when meeting customers' expectations of product sustainability for such a broad portfolio?

Addressing product sustainability

6. What do external stakeholders consider as relevant aspects of product sustainability?
7. Has the merger process between N&B and IFF influenced somehow the sustainability demands coming from external stakeholders?
8. Do you believe that integrating different product sustainability approaches would give IFF products an added value in the market? Could this be advantageous for some specific products?

APPENDIX E – INTERVIEW GUIDE # 4

Interview guide for N&B external sustainability consultant

Introduction

1. Please provide a brief overview of your previous responsibilities with DuPont Nutrition & Biosciences.

Contextualising *Sustainability*

2. As an external consultant, how do you define sustainability when working with such a variable group of businesses and organisations?

Developing sustainable products

3. How do you define "sustainable products"? What makes a product sustainable in the food and biotechnology sector?
4. When supporting clients such as N&B in better decision-making for sustainable development, how do you prioritise aspects of product development processes?
5. What challenges do LCA consultants face in the collaborative development of sustainable products, especially when working with multinationals with a broad portfolio and numerous stakeholders involved?

Addressing product sustainability

6. Considering Cradle to Cradle (C2C) and Life Cycle Assessment (LCA), what synergies and conflicts could such approaches have when assessing food and biotech products?
7. Do you believe that LCA and C2C can potentially be used as complementary approaches to enhance product sustainability efforts in the food and biotech sector?