Escola Tècnica Superior
d'Enginyeria Química

CHANGE IN PACKAGING STAGE– ESSITY PUIGPELAT

FINAL MASTER THESIS
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ABSTRACT

The present project focuses on modifying the packaging stage in a kitchen paper production line, aiming to optimize the current process by changing the type of plastic used. The plant, located in Puigpelat (Tarragona), aims to transition from the current polyolefin to a polyethylene (PE) with recycled content (PCR), in response to customer demand and the company's commitment to sustainability.

The current polyolefin used in the production of packaging rolls has historically exhibited significant variability, leading to operational issues that directly impact the uniformity and quality of the manufactured products.

The project, supported by a Business Case, analyzes the technical, processability, and quality advantages associated with the plastic change. Alternatives will be explored, such as the incorporation of chemical PCR and mechanical PCR into the current plastic, assessing the positive and negative aspects of each. So, the chosen one will be studied in a greater depth, including plant adaptation requirements and a risk analysis.

This project also includes an economic study, encompassing an economic evaluation of the chosen alternative, installation and maintenance costs, as well as the tax advantages associated with the incorporation of recycled plastics into the production process.

Finally, a Life Cycle Analysis (LCA) is conducted to comprehensively assess the environmental impact of migrating to polyethylene with recycled content.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

Nomenclature

SCA	Svenska Cellulosa Aktiebolaget
BRT	Bath Room Tissue
HHT	House Hold Towel
PM	Paper Machine
CV	Converting
SE	Semi-finished
PA	Finished Product
PH	Profesional Hygiene
PC	Personal Care
PCR	Post-Consumer Recycled
HDPE	High-Density Polyethylene
LDPE	Low-Density Polyethylene
PE	Polyethylene
EPR	Ethylene – propylene copolymers
PP	Polypropylene
ISO	International Organization for Standardization
CAPEX	Capital Expenditure
SDG	Sustainable Development Goals
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cyc le Impact Assessment
FU	Functional Unit
con	Consumer Units
ReCiPe	Recipe for the Environmental Footprint
AoP	Areas of Protection

1. INTRODUCTION

1.1. Project Information

Essity, a multinational company with one of its locations in the town of Puigpelat (Tarragona), aims to incorporate a percentage of recycled plastic into its entire product range to respond to the active demand of customers and meet sustainability standards.

Since the incorporation of post-consumer recycled plastic (PCR) into the shrink-wrap polyolefins used in one of the lines at the site is challenging, the possibility of changing the current process to one that allows the implementation of polyethylene (PE), containing at least 33% PCR, will be explored.

Table 1.1: Project Data

Title	Change in Packaging Stage – Essity Puigpelat
Date	2024 January, 15
Student	Ballarín Canales, Mª Paloma
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1.2. Introduction

1.2.1. About Essity. Historical Background

Essity is a leading global company in the field of hygiene and health, headquartered in Stockholm, Sweden. Founded as a spin-off from SCA in 2017, Essity operates independently and has established itself as a leader in the manufacturing and marketing of a wide range of products and solutions related to hygiene and well-being. Its primary focus includes personal care products, professional hygiene products, and consumer paper products.

With a global presence spanning over 150 countries, Essity has built a strong distribution network and operates under recognized brands such as TENA, Libero, Tork, JOHNSON'S, among others.

The company stands out for its commitment to sustainability, corporate responsibility, and innovation, with initiatives aimed at reducing its environmental impact and promoting gender equality.

Essity Iberia, the regional branch responsible for serving the Iberian Peninsula market, has positioned itself at the forefront of the industry, serving not only with its own brands but also under well-known quality brands.

In Spain, the company has approximately 1200 employees, distributed across three production plants: Puigpelat (Tarragona), Telde (Gran Canaria), and Allo (Navarra), in addition to commercial offices in Madrid and Barcelona.

1.2.2. Essity Puigpelat- Background

The Puigpelat site is organized as follows, as shown in Figure 1.1:

Figure 1.1: Aerial view of Puigpelat site

The production at Essity Puigpelat begins with the reception of paper fibres in the paper machine area (PM5 and PM6). There, depending on the needs and characteristics of the final product, paper reels with specific properties are produced.

The paper reels go through the semi-finished warehouses (SE1 and SE2) until they are claimed by a production line distributed across the three converting areas (CV1, CV2, and CV3). This is where the final product is manufactured, ready to go to the market.

There are three types of products: sanitary (BRT), kitchen (HHT), and professional hygiene (PH), all intended for large surfaces such as hotels or airports. Once produced, they are stored in the finished product warehouses (PA1 and PA2) until they are distributed to customer platforms.

The Personal Care warehouse (PC) produces entirely different products from those found in the various converting areas; diapers and sanitary napkins are manufactured there, and its operation is practically independent of the rest of the factory.

1.3. Area of focus

The focus of this thesis work is only the converting lines, particularly in the packaging stage of certain kitchen towel products located in CV2 building.

1.4. Scope

The company has been working for years on implementing recycled plastic in all its products. In the Puigpelat plant, some progress has already been made; most of the lines work with PE 33PCR and a thickness of 30/28 microns. Various projects to reduce microns and increase PCR content are gradually being implemented, with the goal of a complete migration to this recycled plastic in the near future.

With this goal in mind, the modification of a line in CV2 is an option due to the difficulty of working with polyolefins with some recycled plastic content.

The main objective of this project is to assess and explore alternatives for packaging in this line. An analysis of different plastic options will be conducted, considering both those that do not require modifications to the line and those that do.

To carry out this study, the parts to be addressed throughout this project have been defined, including:

- Study of alternatives
- Business case study
- Adaptation to the current installation
- Adaptation of current infrastructures
- Economic comparison study between the new alternative and the current one
- Environmental study

2. GANTT CHART

Once the different parts of this project have been established, it is necessary to set a logical order of completion, marking the start and end dates of these parts. To achieve this, a Gantt chart has been developed, represented graphically in Figure 2.1.

Task	Start Date	End Date
Search for Information of Interest	11/09/2023	25/09/2023
Project Planning	25/09/2023	02/10/2023
Study of Alternatives	02/10/2023	16/10/2023
Business Case	09/10/2023	16/10/2023
Technical Background	16/10/2023	30/10/2023
Adaptation to the current installation	30/10/2023	13/11/2023
PFD Proposal	06/11/2023	20/11/2023
Risk Analysis	20/11/2023	27/11/2023
CAPEX	27/11/2023	11/12/2023
Economic balance	11/12/2023	25/12/2023
LCA - Goal & Scope	25/09/2023	30/10/2023
LCA - Impact Assessment	30/10/2023	27/11/2023
LCA - Interpretation	27/11/2023	25/12/2023
Study on Circular Economy	25/12/2023	01/01/2024
Conclusions	01/01/2024	08/01/2024
Revision & Corrections	08/01/2024	15/01/2024
Delivery	15/01/2024	18/01/2024

Figure 2.1: Gantt Chart

3. THEORY

3.1. Plastic in Modern Society

The first plastic was invented in the early 20th century, and since then, thanks to the unlimited innovative potential of these materials, plastics have shaped the world and continue to offer solutions for our constantly evolving needs.

Plastic has radically transformed how we live, produce, and consume. With unique properties such as malleability, durability, and the ability to be modelled into a variety of shapes, a range of products can be found, from packaging and consumer goods to essential components in manufacturing and technology.

Despite its undeniable benefits, the widespread use of plastic has led to significant environmental consequences. The durability that makes plastic so valuable also contributes to its persistence in the environment, leading to issues such as waste accumulation and ocean pollution.

Although plastic has been a driver of the global economy, it is also a problematic environmental agent.

Even today, the majority of plastics are derived from fossil fuel-based raw materials such as oil or gas. However, in the long term, plastic production should decouple from these types of raw materials. That's why there is a need to examine and rethink how plastic production and use are carried out. [1].

3.2. Plastic Recycling

3.2.1. Plastic Recycling: background

As society and the planet faced the environmental consequences of poor waste management and resource non-conservation, the need for a sustainable response emerged: plastic recycling, a practice considered essential for environmental sustainability today.

Concerns about plastic waste accumulation and its impact on the environment drove the beginnings of the recycling movement in the 1970s, focusing on collecting and processing plastic materials. Although plastic recycling was in its early stages, processes were being developed to reuse and transform these materials.

The enactment of legislation in many countries to address these environmental issues contributed to the growth of environmental awareness. Advances in recycling technologies in the 1990s increased the economic viability of plastic recycling, further expanding its scope. Automated sorting techniques and specialized crushing methods were introduced to separate and process different types of plastic.

In the 21st century, the circular economy became a key concept in plastic recycling. Closing the life cycle of plastic materials through reuse and recycling became crucial to addressing plastic waste issues, making sustainability a global priority.

Plastic recycling transitioned from being merely environmentally responsible to an integral part of the sustainability strategy for businesses and governments. Technology continues to advance, allowing the creation of recyclable and biodegradable plastics with a lower environmental impact.

However, challenges arise on this path to sustainability, complicating plastic recycling, such as accurate classification and the quality of recycled plastic. The diversity of plastic types and the presence of non-plastic materials in waste streams add complexity to effective recycling management. [2].

3.2.2. Plastic Recycling: Current Situation

The worldwide production of plastic has surged from 1.5 million tons in 1950 to 359 million tons in 2018. This growth is closely tied to the increase in plastic waste. The Covid-19 pandemic, which had a global impact in the first half of 2020, notably affected plastic production by reducing the demand for certain products and causing a temporary decrease in production. However, the second half of the year witnessed a swift recovery. [3].

In the European context, the European Union (EU) has acknowledged the need to address the plastic waste crisis and has taken specific measures to reduce the environmental impact of plastic. With the approval of the EU Strategy for Plastics in a Circular Economy, there is now an obligation to incorporate recycled plastic in certain products.

The European Green Deal stipulates that 55% of plastic packaging waste should be recycled by 2030. [4].

This implies better design to make them suitable for recycling, as well as measures to incentivize this process in the market:

- Creation of quality standards for recycled plastics.
- Improvement of certification for products with recycled content to increase confidence both in the industry and among consumers.
- Introduction of mandatory standards on the minimum recycled content of certain products.
- Persuading Member States to consider reducing IVA on recycled products.

3.2.3. Regulations and Standards

The legal framework in Spain regarding plastic waste is regulated by the following Royal Decrees:

- Royal Decree 1055/2022, of December 27, on Packaging and Packaging Waste. Its purpose is to establish the legal framework applicable to packaging and packaging waste with the aim of preventing and reducing their impact on the environment throughout their life cycle.
- Law 7/2022, of April 8, on Waste and Contaminated Soils for a Circular Economy. It aims to regulate the legal framework applicable to the marketing of products in relation to the impact on waste management, as well as the legal framework for the prevention, production, and management of waste, including the establishment of economic instruments applicable in this area, and the legal framework applicable to contaminated soils.

3.3. Plastic PCR

According to ISO 14021:2016, "Recycled Content" is defined as: 'Mass fraction of recycled material in a product or packaging.'

On the other hand, to be considered "Recycled Plastic," the material must have been classified as waste, undergone a recycling operation, not be used as fuel for energy recovery or for landfill operations, and not be classified as a by-product.

The term "PCR Plastic" (Post-Consumer Recycled), considering the previous definitions, refers to plastic material that has undergone a recycling process after being used by the consumer.

3.3.1. Advantages and Disadvantages of Plastic PCR

The fundamental essence of PCR lies in the utilization of plastic already present on the planet, giving new life to previously discarded materials.

Plastic relies on petroleum, a finite resource with diminishing availability each year, leading to an increase in the prices of products containing petroleum, such as virgin resins. Out of the 8.6 billion metric tons of plastic produced, 6.3 billion have become waste, indicating the resources available for this market.

PCR also allows manufacturers to produce high-quality products, similar to virgin resin products, at competitive prices while reducing their environmental impact. The use of these recycled resins does not affect plastic properties such as durability or strength.

On the downside, the required reheating process in creating PCR plastics can alter the colour and clarity of the product depending on the amount of resin that is added.

3.3.2. Conclusion of the Theoretical Framework

It is evident that the adoption of sustainable practices is necessary to mitigate the environmental impacts generated by the industry.

Existing regulations and European guidelines emphasize the importance of transitioning to plastics with PCR content, thus reducing dependence on fossil fuels and closing the life cycle of plastic.

That's why this project evaluates the incorporation of PCR into the current film of one line at the Essity factory in Puigpelat.

4. PRODUCTION PROCESS: ESSITY

This section of the work provides a detailed overview of the transformation process from reels to sellable rolls, focusing on one line, as represented in the attached diagram.

While the overall process description is generic, it is crucial to highlight that the studied line produces a unique product, the big rolls sold in individual packages in the market. The uniqueness comes in the packaging phase, which is the focus of this project.

Below is a comprehensive explanation of each stage of the manufacturing process:

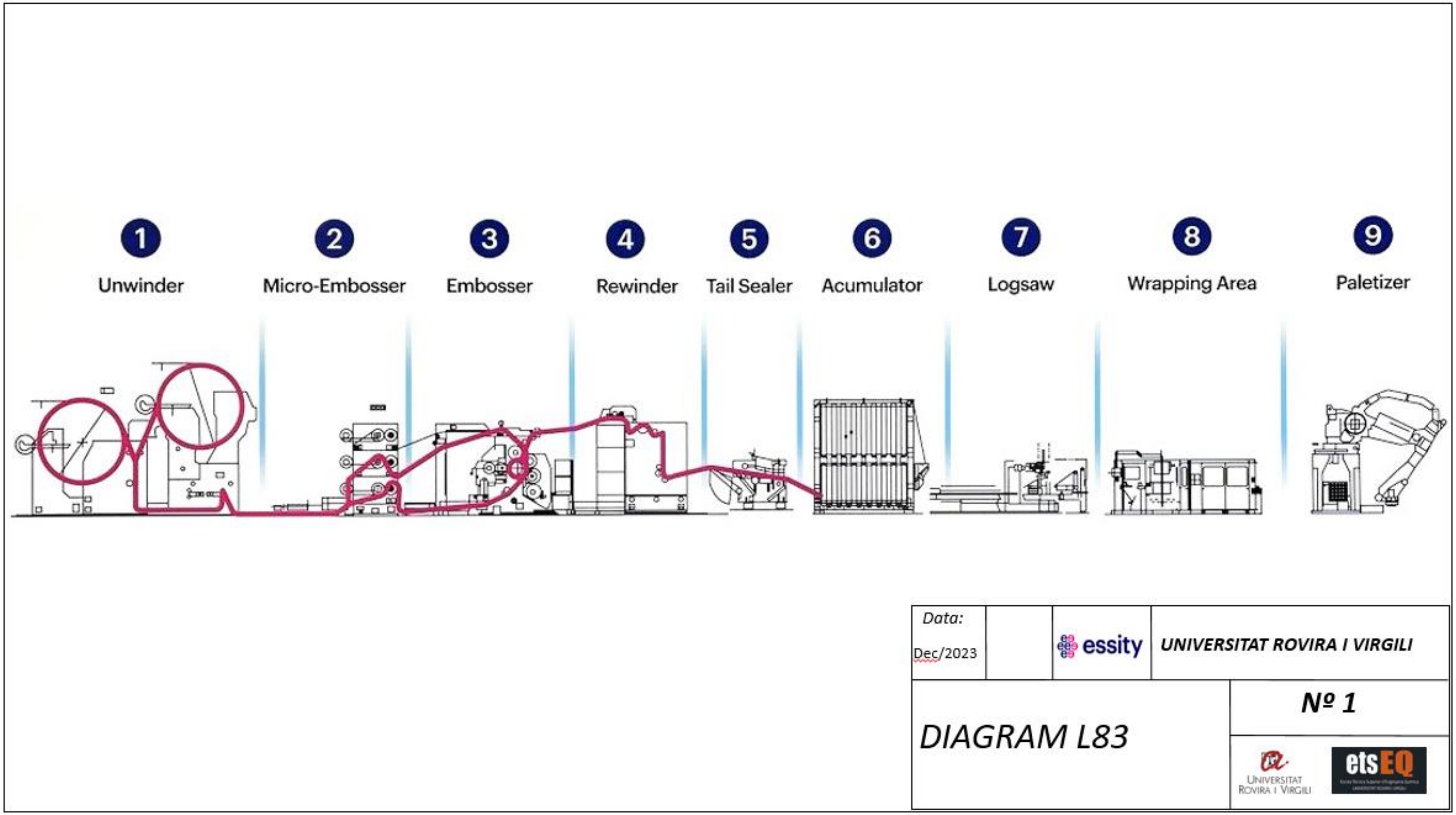

Figure 4.1: Generic diagram of the paper transformation

In the schematic diagram shown in Figure 4.1, the different stages of the production lines can be observed. The scope of this project focuses on the packaging block, leaving the other blocks outsede the boundaries.

Unwinding: The process begins as the mother reels are transported to the converting area. The paper layer is carefully guided through all the rolls within the unwinding section. This crucial step ensures a smooth and controlled supply of paper, setting the foundation for subsequent stages.

Microembossing and Embossing/Gluing: In the microembossing and embossing/gluing phase, the plies destined to form the final product pass through various rolls designed to achieve the desired traction for engraving. This engraving process transfers images onto the paper, a technique known as embossing. Simultaneously, volume is imparted to the paper. Once embossed, a layer of glue is applied to the paper, facilitating the bonding of the different plies. This not only enhances structural cohesion but also adds aesthetic appeal to the final product.

Rewinding: Following embossing and gluing, the tube created in the core winding area is introduced into the machine. The embossed and glued paper is precisely wound around the tube until the desired diameter is reached. The resulting output roll is commonly referred to as a 'log,' exhibiting both precision and consistency in its quality.

Final Gluing: To ensure the integrity and continuity of the product, a strip is affixed to the beginning of the paper bar. This is achieved by applying a band of glue to the exterior of the paper. This final gluing step marks the conclusion of the manufacturing process, preparing the product for subsequent phases.

Accumulating: Before the cutting phase, the logs are carefully left to dry in a warehouse, allowing for the necessary curing of the paper. This drying process is facilitated by an accumulator

Sawing: In the sawing phase, the logs, now adequately dried, undergo precision cutting with a circular saw. This step ensures that the logs are cut to the desired roll width, further refining the dimensions of the paper rolls in preparation for the final product.

Packaging: Upon completion of the manufacturing process, the rolls undergo packaging according to the final product specifications.

Palletizing: In the palletizing phase, robots take charge, building pallets with the packs and/or bags as indicated in the specifications. This automated process streamlines the final stage of production, preparing the paper rolls for storage and transportation in a manner that aligns with product specifications and industry standards.

5. PROJECT DESCRIPTION

5.1. Project Goals

1. Select an optimal alternative for the packaging stage.
- Evaluate different plastic options for the packaging stage, considering their technical suitability and adaptation to the production process.

2. Respond to the Business Case.
- Justify the proposed changes by demonstrating the economic benefits and compliance with customer demands and market trends.

3. Evaluate the Advantages of Plastic Replacement:
- Analyse the technical, processability, and quality advantages associated with the plastic change.

4. Assess Technical Feasibility:
- Conduct a detailed analysis of implementing a standard packer in a specific production line, identifying potential technical challenges, and proposing solutions.

5. Determine Economic Efficiency:
- Quantify the costs associated with adapting the standard packer, comparing it with the current costs of the shrink-wrapping system with polyolefin.
- Evaluate potential savings resulting from the new proposal, considering process efficiency and savings derived from the plastic change.

6. Perform a Comparative Life Cycle Analysis:
- Conduct a comprehensive life cycle analysis of the two types of plastic used in the production process.
- Compare the 'Cradle to Gate' environmental impact, highlighting differences between shrink-wrap plastic and polyethylene plastic with recycled content.

5.2. Project success criteria

The goal is to enhance to produce rolls with a diameter of 196mm and a roll length of 223mm. Manage individually wrapped rolls without creating additional bottlenecks or unplanned machine stoppages.

The required maximum speed of the packer process should be 100 packs/minute.

6. CONSIDERED ALTERNATIVES

Before conducting a detailed analysis of the project, various alternatives are studied to meet market requirements and the company's ideals (PCR content in all products) without making substantial modifications to the studied line or changes to the packaging design. In addition, other options involve migrating to 28-micron polyethylene with 33% PCR, with modifications to the production line.

The first two alternatives explore the possibility of incorporating PCR into the current 19-micron polyolefin. Two alternatives are considered for evaluation: one involving the addition of chemical PCR and another exploring the integration of mechanical PCR.

6.1. Chemically Recycled Polyolefin with a Percentage of PCR

This alternative involves the addition of chemically recycled plastic.

This material is obtained through chemical depolymerization. A process by which a polymer chain present in plastic waste is broken down through the use of chemicals. Once the depolymerization has occurred, the monomers are recovered from the reaction mixture and purified to leave virgin-quality monomer, followed by their integration into virgin plastic at the first link in the production chain.

This process ensures that the properties of chemically recycled plastic homogenize during production, providing consistency and uniformity without traces of contaminants.

The introduction of this chemically recycled plastic into the production chain is characterized by the use of credits.

The credit method is a chain of custody management tool used to allocate the percentage of Chemical Recycled Polymer (PCR) in the final plastic production. It is defined according to ISO 22095. (Chain of custody — General terminology and models). [5].

When a manufacturer serves more than one client, it cannot ensure the specific allocation of the quantity of PCR to each client since this method relies on the total proportion of input and output in the process. In other words, the allocation of recycled plastic is done for the entire production, not on an individualized basis for each client.

This implies that, upon acquiring the resulting plastic, Essity does not have access to detailed information about the exact proportion of incorporated chemically recycled plastic. This could pose problems when justifying the tax deduction for PCR content, and the assurance of the recycled plastic content demanded by customers in their products cannot be guaranteed.

In addition to these considerations, chemically recycled plastic tends to have a higher cost compared to its virgin counterparts. This cost increase is attributed to the complexity of the chemical processes required to ensure the quality of chemically recycled plastic.

6.2. Polyolefin shrink film with a percentage of mechanical PCR

This alternative proposes the addition of mechanical PCR.

It is considered a recycling process in which no chemical changes occur, meaning no chemical bonds are broken. This implies that the polymer itself remains intact.

This material is obtained through mechanical processes that crush and melt recycled plastics while preserving their essential properties.

The obtaining of PCR mechanically begins with the classification of plastics according to their resin type (HDPE, LDPE, PP, among others), colour, and shape.

Once classified, plastics are crushed into separate categories to obtain small fragments that are washed and centrifuged to remove impurities and contaminants.

Once purified, they can be extruded into recycled pellets, which can be controlled blended with virgin polymers to form the final product with the desired PCR content ratio. [6].

Although this option offers transparency advantages, it poses challenges when considering its application in thin polyolefins, as thin as 19 microns, as used in the studied line.

This thinness complicates the guarantee of a significantly high percentage of PCR from suppliers.

Additionally, the polyolefin addressed in this line, being composed of thermoplastics, becomes malleable when heated. If mechanical PCR is added to the plastic, it could generate inconsistencies in the material, which might manifest during the shrinkage process when passing through the oven.

These variations could result in deformities or breakages since the mechanical PCR may contain impurities. This is because the efficiency of classification does not reach 100%, and there are laminated or mixed products that cannot be separated into their original materials.

This alternative may not guarantee the integrity of the process, and there is no possibility, on the part of the suppliers, for a progressive increase in the addition of PCR to the current polyolefin due to its thinness.

6.3. <u>Polyethylene 28 microns 30% mechanical PCR</u>

The consideration of using 28-micron polyethylene with 30% mechanical PCR implies a modification to the existing production line. However, this modification is seen as a viable alternative for several reasons.

Firstly, it is a plastic that Essity suppliers are comfortable working with, as the rest of the site's lines operate with it. This ensures the plastic's quality.

The proposed PE plastic is not designed to have heat-shrink properties, meaning mechanically obtained PCR infusions cannot introduce inconsistencies in the product, such as breakages or deformations.

Moreover, a thickness of 28 microns still allows for the addition of a higher PCR content. In other words, the proposed PCR percentage could be increased in the future.

Although incorporating this plastic involves modifications to the production line and comes with associated costs, transitioning to this plastic would yield long-term savings. The acquisition cost of polyethylene plastic is lower than the current polyolefin, according to Essity suppliers. This is primarily due to the savings from the plastic tax of 0.45 euros/kg of plastic in the PCR percentage. Additionally, the production process is simplified by eliminating the need to sort polymers to achieve heat-shrink properties.

6.4. <u>Justification of the Developed Proposal</u>

After considering the technical, economic, and environmental aspects, one option stands out as the most robust: migrating to Polyethylene (PE) with recycled content (PCR).

From a technical standpoint, PE with PCR offers transparency in its composition, eliminating the uncertainty associated with credits for chemical PCR and overcoming technical challenges present in adding mechanical PCR to 19-micron polyolefins.

From an environmental perspective, migrating to PE with PCR aligns production with increasingly stringent sustainability standards. The 28-micron PE plastic with 33% PCR could be further improved in future projects by experimenting with higher percentages of recycled plastic and reductions in thickness.

In economic terms, PE with PCR emerges as an efficient option, allowing Essity to save costs both in material acquisition (considerably lower prices – see Economic Study) and in taxes associated with the use of recycled plastic. It's worth noting that the modifications to the production line required for the implementation of this option do not compromise its economic viability, making it the most economically viable choice.

In summary, the decision to migrate to PE with PCR appears as the most comprehensive and balanced option, even though it requires modifications to the line. This way, production aligns with sustainability principles without compromising operational efficiency.

7. BUSINESS CASE

7.1. Commercial Background

During the last years, market trends indicate an increase in consumer preference for products and brands that adopt sustainable practices. Environmental awareness has become a crucial factor in purchasing decisions, and Client A seeks to position itself as a pioneer in this movement.

Today, Essity comfortably works with PE plastics of 30/28 microns and 33% PCR, except for the studied line.

This line covers one of Client A key products, big Rolls.

Trends in the Iberian HHT Market have been changing, and large formats of HHT Rolls are gaining market share. These "big Rolls" attract consumers by offering a greater number of services (600 services for the Roll A product and 375 services for the Roll B) and the appeal of their packaging.

Modifying the packaging stage of this line would meet Client's A request for the addition of PCR in all its products and introduce a new and refreshed packaging. The idea is to evolve the big Roll product, which currently comes with a 19-micron virgin polyolefin shrink film, to an alternative packaging composed of PE 28 microns and 33% PCR.

In addition to Client A, this investment would support the transition to the same plastic for other brands like Client B, which has recently joined the HHT big rolls customer portfolio. Furthermore, this project could be replicated at other company sites facing similar challenges, such as another line in Telde (Canary Islands).

7.2. Overview affected business

The production affected by this proposed change only involves the studied line, specifically two products: Big rolls A and Big Rolls B for the customer A.

7.3. Production

In Puigpelat, the studied line is one of the key production lines, where Big Rolls A and Big Rolls B are manufactured.

The stage being considered for modification is 'Packaging.' The current process begins once the rolls exit the cutter, and with their final dimensions, they move to the actual Packaging machine, where they are wrapped with polyolefin shrink film and microperforated. In the same machine, the plastic is cut to the roll's size through thermal cutting. Next, the rolls pass through an oven, where the plastic undergoes a shrinkage process when heated. The microperforations in the plastic allow air to escape during this process, ensuring that the plastic fits perfectly around the roll.

Once the shrinkage process is completed, handles are added to the rolls.

8. TECHNICAL AND QUALITY ADVANTAGES IN PLASTIC CHANGE

The exploration of a change in the type of plastic used in this line primarily responds to customer demand for the use of a percentage of PCR supported by the company's ideals of sustainability. However, there are a series of reasons, not only economic, but that also reinforce this idea of change.

The currently used polyolefin has historically shown significant variability, resulting in various operational problems that have directly impacted the uniformity and quality of the manufactured products, leading to operational inconsistencies.

The particularity of the current polyolefin used is its retractable capacity, which requires the film to be microperforated. These perforations are essential to allow the release of air during the retraction process. However, this characteristic carries the potential risk of introducing contamination into the final product through the holes.

Additionally, throughout history, significant complaints related to the fragility of the material have been recorded.

Recurrent problems include plastic breaking in the handle part when manipulated, tears in the adhesive tape section, and consumer complaints about scrapes on the product's packaging when exposed to friction. This compromises the integrity of both the plastic and the kitchen paper roll, which may end up torn, dirty, or with the initial services of the roll rendered unusable.

The proposed plastic change takes all these factors into account to eliminate them. First, the microperforations in the plastic would disappear. They would not be necessary by eliminating the plastic retraction stage. This way, historical issues related to dirty products would no longer be a focal point for the company.

Improvements in plastic strength would also be observed. A higher micron plastic (28 microns vs 19 microns) offers better resistance to breaks or abrasions, supported by mechanical analyses from the Fact Sheets provided by the manufacturers.

9. TECHNICAL AND FUNCTIONAL DESCRIPTION

For a better understand the proposed changes, first it is described the current state of this process stage.

9.1. Packaging stage description

The packaging stage begins once the rolls have exited the cutter and are headed towards the packaging machine.

9.1.1. Wrapping - bag making machine

Wrapping highlights:

- Max. dimensions of the product to be packed:
  I) Wmm: 480
  II) Hmm: 150
- cycles/h: Max. 7200

Wrapping use and application:

The bag sealing machine is designed to package solid products, which can be packaged individually, stacked, or in a continuous bag. In the studied line, it is used to individually package big rolls, with the purpose of protecting and displaying the product in a way that stands out.

The machine operates with microperforated polyolefin plastic sheets.

The rolls enter the actual packager in a horizontal position, with the film wrapping around them, creating a bag. The plastic is thermally cut to the size of the roll, and then it passes through an oven where it undergoes the retraction process.

9.1.2. Contraction tunnel - Oven

Contractional tunnel highlights:

- Max. dimensions:
  I) Wmm: 500
  II) Hmm: 230
- Air temperature max: 230ºC
- Heating Pot. 25kW
- Vel. 5-30 m/min

Contraction tunnel use and application:

The tunnel has been designed for the shrinkage of packaged or bagged products within a shrink film, in this case, polyolefin shrink film.

The transportation through the tunnel is carried out on a rod chain conveyor. These rods are covered with a fabric hose, treating the packaged product carefully.

The air in the tunnel is heated by an upper and lower heating zone, and through circulation systems, it is evenly distributed in the tunnel.

As a result of the film shrinking, a transparent and closely fitted packaging is created, enhancing the appearance of the product.

Right after the oven, a quality control vision camera is located. Its main function is to detect possible breaks and/or holes in the polyolefin packaging at the joint area. The camera performs this task by identifying the presence of an air pocket between the roll and the plastic and rolls that do not meet these specifications are ejected from the process.

For rolls passing the quality control, their progression continues the conveyor belt. During this process, air escapes from inside the packaging through microperforations in the polyolefin. Upon reaching the turner, rotating blades position the rolls vertically.

The final step before entering the palletizing area involves the handle applicator.

9.1.3. Handle applicator machine

Handle applicator machine highlights:

- Dry air supply according to ISO-8573
- Circuit operating pressure: 6 bar

Handle applicator machine use and application:

This machine is designed to automatically apply handles made of adhesive tape and cardboard to packages.

The handle application is done on a single track. The handles are made with transparent polypropylene adhesive tape reinforced with neutral cardboard, printed with the product logo.

The packages that arrive at the feeding conveyor are automatically placed and spaced on the machine's central conveyor, where the handle is applied. The tape is fed by a motorized roller controlled electronically.

During the passage of the adhesive tape, a mechanical eccentric continuously applies the cardboard.

The obtained handle (tape + cardboard) is applied thanks to the movement of a series of arms. The machine automatically centers the handle and applies the free edges symmetrically to the front and back of the package.

After this process, a last quality control check is conducted. Another camera verifies the accuracy of the logo printed on the plastic and the proper positioning of the handle.

9.2. Line Proposal

The machine elements/parts involved are:

- Removal of the actual packaging machine + Oven assembly.
- Elimination of the automatic handle applicator.
- Introduction of the new Wrapping Machine.

Key Points:

- Replacement of the conveyor belt at the cutter's exit with the entrance channel to the new packager. Rolls continue to enter the packager in the same position as in the current process, lying lengthwise.
- The new Wrapping Machine individually wraps the rolls, creating folds in the cross-sectional areas of the package. Simultaneously, as the film enters the packager, the machine performs the automatic placement of handles.
- In the packaging redesign, new handle positions are planned.
- Rigorous quality control is maintained through cameras located at the packager's exit, which discard products that do not meet predefined specifications.
- The conveyor's trajectory remains the same, as any modification to shorten the route would not bring operational advantages.
- In the final stage of the packaging process, the handle applicator is dispensed with, as handles are redesigned. However, the turner is retained, a machine that rotates the rolls with automatic blades and positions them vertically to facilitate the palletization process.

9.2.1. New Wrapping Machine – single and multi-roll wrapper

ENTRA AFH highlights:

- Maximum speed 120 packs/min
- Flexible from 1 to 2 lanes, BRT, HHT
- BRT, HHT, JRT Rolls range:
  - I) Roll diameter: 100÷300 mm
  - II) Roll cut-off: 90÷300 mm
  - III) Maximum diameter/cut-off ratio: 1,3
- Pack range:
  - I) Pack width: 100 ÷ 600 mm
  - II) Pack depth: 100÷600 mm
  - III) Pack height: 100÷300 mm

This automatic machine is manufactured to roll up rolls using a polyethylene film unwound from a coil.

9.3. New roll desing

Due to the change in the packaging stage, especially in the machinery and plastic used, the final product undergoes a new packaging redesign.

The previous appearance of the rolls wrapped without any folds, with a transparent plastic perfectly molded to the final product, would disappear.

The new design simulates packages of more than one roll. would simulate the style of the large bulk of the plant products.

The new design would ensure that any expansions or deformations in the logo of the current plastic disappear completely (due to the elimination of shrinkage).

Another substantial change is the position of the handle on the package. This will be redesigned

10. RISK ANALYSIS

10.1. Acceptance Risk by Client A

There is a possibility that Client A may not accept the proposal for the new packaging, which could lead to a halt in the entire project of changing the packaging machine and replacing the plastic. Customer acceptance is crucial to validate the feasibility and effectiveness of the proposed modifications.

Non-acceptance may occur due to disagreement with the aesthetic changes in the packaging.

Potential Impact:

- Additional costs associated with the need to adjust or revise the proposal.
- Possible loss of confidence from the Client A customer for not meeting environmental requirements.
- Delay in the implementation of the project.

Mitigation Measures:

- Presentation of prototypes and samples to obtain early feedback.
- Establishment of clear and continuous communication throughout the process.

10.2. Technical Risks

Adaptation of the new packaging machine: Compatibility issues or adjustments may arise.

Training of Personnel: Introducing new equipment and processes requires personnel training. The learning curve could result in a temporary decrease in operational efficiency and production.

10.3. Operational Risks

Unplanned Downtime: There is a risk of unplanned downtime during the transition. Technical issues or operational difficulties could result in unplanned stops.

Product Demand Fluctuations: Changing the type of plastic and the aesthetics of the packaging could influence the customer's perception of the product, especially during the transition.

Supply Chain Changes: Incorporating new suppliers for the affected products could disrupt the supply chain. Risks related to logistics should be considered.

10.4. Timeline Risks

Delays in Equipment Acquisition: The delay in the delivery of the new packaging machine and other necessary equipment could directly impact project timelines.

11. SAFETY IMPACT

Safety is integrated as a regulatory requirement inherent in the introduction of new machinery and modernization projects, in line with the guidelines established by the European Community (EC). EC regulations, particularly ISO 12100 – Safety of Machinery, General Principles for Design, Risk Assessment, and Risk Reduction, establish general design principles and provide guidelines for the assessment and reduction of risks associated with industrial machinery.

Risk Analysis methodologies (MSRA/JSA) are also used to ensure the protection of personnel and the operational stability of the project.

12. PROJECT COST

12.1. Initial Investment Costs (CAPEX needs)

Table 12.1: CAPEX needs

Items	Cost
Direct Costs	
WRAPPING MACHINE Includes delivery and installation	88.5%
Subtotal direct costs	*88.5%*
Indirect Costs	
Modification of current facilities	7.1%
Product test, including ship&stack test	1.7%
Contingencies	2.6%
Subtotal indirect costs	*11.5%*
Total cost	100%

12.2. Projected Revenues

The analysis of projected revenues for this project focuses on the benefits derived from the implementation of the new packaging machine and the change in the type of plastic used. Although the main goal is not necessarily to increase sales or production, it is expected that the revenues will reflect improvements in operational efficiency and the reduction of downtime on the production line, in addition to significant savings in materials and energy.

12.2.1. Downtime and Line Problems Reduction:

The implementation of the new standard packaging machine, along with the most suitable plastic for the process, has the potential to significantly reduce downtime and issues on the production line. This translates directly into an increase in operational efficiency and, consequently, a reduction in losses associated with unplanned downtime.

12.2.2. Savings in Maintenance Costs:

With the decrease in line issues, a significant reduction in maintenance costs associated with machinery is anticipated. Fewer stops to address operational problems imply a more efficient investment of resources allocated to maintenance, creating a positive impact on profitability.

12.2.3. Plastic Savings

The replacement of the current film plastic and handles with more efficient alternatives not only reduces acquisition costs but also generates tax savings by incorporating 33% PCR (Post-Consumer Recycled content).

12.2.4. Energy Savings

The implementation of the new packaging system, which eliminates the need for the oven in the process, represents a significant energy saving. The standard packaging machine, requiring fewer energy resources than the current process, will directly contribute to the energy efficiency of the production line, reducing operational costs associated with energy consumption.

13. ECONOMIC BALANCE

13.1. Current Cost Associated with Shrink Wrap Plastic

The Industrial Rolls Line, although only producing two finished goods, has five materials associated with packaging.

Table 13.1 displays the consumption for the past year 2022 of the two polyolefins for this line, the current price per kilo according to the supplier, and the total cost. Additionally, it includes the tax on non-reusable plastic packaging of 0.45 euros/kg of plastic, as mandated by Law 7/2022, dated April 8, on waste and contaminated soils for a circular economy, which came into effect on January 1, 2023.

The economic study is based on the production of the last closed year, that is, 2022. However, it is conducted with the current prices for the year 2023, considering the upward trend that has characterized prices during this period. This decision is intended to offer a practical and current evaluation.

Table 13.1:Current Costs Associated with Polyolefins in the Industrial Rolls Line

Description	Annual'22 kg	Price 2023	Current Spent	Current Plastic Tax
POLYOLEFIN PRODUCT 1	60.5%kg	10.50 €/kg	57.9 % €	2.5 % €
POLYOLEFIN PRODUCT 2	39.5%kg	10.50 €/kg	37.9 % €	1.62 % €
Total Spent		100 % €		

The other three materials consumed by the line for its packaging are the handles. These consist of an adhesive tape (PE) and a paper tape of varying colour depending on the produced product.

In this case, the tax on non-recycled plastic only applies to the adhesive tape.

Table 13.2: Current Costs Associated with Handles

Description	Annual'22 m	Price 2023	Current Spent	Current Handle Tax
ADHESIVE TAPE/HANDLES 25mm*6500m 50	68.9 % m	0.0113 €/m	59.2 % €	2.6 % €
HANDLES PAPER 25mm*990m BLUE	18.7 % m	0.0162 €/m	22.9 % €	-
HANDLES PAPER 25mm*990m	12.4 % m	0.0162 €/m	15.3 % €	-
Total Spent			100% €	

13.2. <u>Cost Associated with the Proposed Plastic</u>

To assess the savings resulting from the plastic change, the following tables display the cost with current supplier prices for PE plastic for the same quantities evaluated previously, based on the consumption of the year 2022.

The plastic tax does not apply to the 33% PCR.

Table 13.3: Assumed Costs for PE Plastic

Description	con/year'22	gr film/con	Tons film	Price 2023	PE Proposal Spent	PE Proposal Plastic Tax
New PE PRODUCT 1 28MY 33PCR	64.5%con	9.228	64.5%T	3.18 €/kg	59.1% €/kg	5.6% €
New PE PRODUCT 2 28MY 33PCR	35.3%con	9.228	35.3%T	3.18 €/kg	32.2% €/kg	3.1% €
Total Spent				100%€		

The following table presents the cost of handles for the proposed PE plastic. In this context, only one model is required, as both products would use the same type of handles. Additionally, these handles are identical to those used in all other lines on the site. This uniformity not only simplifies the logistical process but also provides an additional advantage: both the handles and the proposed plastic are made of polyethylene (PE), facilitating recycling.

Furthermore, at present, all taxes related to PE handles are fully paid. Nevertheless, there is an anticipation of potentially introducing a percentage of PCR in the handles in the near future, which would enable the application of tax discounts.

Table 13.4: Consumed handles year 2022

Description	con/year'22	Con / 1kg handles	Tons handles
New PE PRODUCT 1 28MY 33PCR	64.5%con	1077	64.5%T
New PE PRODUCT 2 28MY 33PCR	35.3%con	1077	35.3%T
Total Tons handle 2022		100% T	

Table 13.5: Assumed Costs for Handles

Description	Annual'22 Tons	Price 2023	PE Proposal Spent	PE Proposal Plastic Tax
PE Blue Handle 30mm	100% T	4.30 €/kg	90.5% k€	9.5% k€
Total Spent		100% k€		

The total cost if the new plastic is implemented, considering the consumption recorded in the year 2022 and the updated plastic prices for the year 2023, is €100% (The sum of plastic + handles).

The total savings per year are shown in Table 13.6.

Table 13.6: Total Savings per year

Total Savings/year	56.4% €

The project to replace the packaging machine, along with the plastic change, demonstrates significant financial efficiency. The savings generated by adopting recycled polyethylene suggest that the investment in machinery will be recovered in less than a year.

The payback period of the project, including all associated expenses, is one year.

13.2.1. Associated Energy Savings

The implementation of the new packaging machine results also in significant energy savings. The following table presents the key data.

Table 13.7: kWh Consumption of Different Equipment.

Equipment	Consumption
Actual Equipment	
Actual Packer	12 kWh
Oven	24 kWh
Automated Handle Applicator	3.2kWh
Suggested Packer	
Standard Packaging Machine	19 kWh

The consumption values represent the nominal power at which the machinery can operate, and it is assumed as consumption when operating at maximum load.

The analysis indicates a significant enhancement in energy efficiency. The new packaging machine, with a consumption of 19 kWh, not only optimizes the packaging process but also represents a significant reduction compared to the current setup, which requires 39.2 kWh (12 kWh from the current packaging machine, 24 kWh from the oven, and 3.2 kWh from the automatic handle placer).

Although this energy saving represents a considerable improvement in operational efficiency, it has been decided not to include it in the project's Capex or Payback rate. Since the benefits extend over time in the form of recurrent reduction in operational costs, including them in the short-term return evaluation could distort the financial representation of the project.

13.3. Direct cost / Running-In. Product test

A budget of 10k € has been set aside for conducting tests on the new packaging in collaboration with the packaging machine manufacturer in Italy. This funding is intended for evaluating the performance and presentation of the new packaging.

This budget covers the costs associated with product testing, which include the need to send samples of paper and plastic to Italy, the location of the manufacturer of the new packaging machine, for conducting tests on this new packaging and subsequent customer approval before the machinery purchase and line modification.

In addition, expenses related to the personnel who will relocate to Italy to oversee and coordinate the testing process are also considered.

13.4. Write-off needs equipment

There is a need to divest from the current wrapping machine plus oven, used in the shrink-wrapping process.

The following table details the current book values of these equipment, providing an overview of their financial status.

Table 13.8:Current Book Value actual Packer.

Asset Description	Current book value (k €)
Actual wrapping machine	97.3 k€
Safety upgrade wrapping machine	0.03 %k€
Total	100% k€

Two options are proposed to address this equipment transition:

13.4.1. Internal Machinery Sale

The first alternative involves internally selling the current machinery, offering it to other production lines within the same company. In this scenario, the machinery, consisting of the packaging machine and the oven, would be acquired by another factory within the multinational. This option could generate immediate revenue and facilitate the reuse of the machinery in other production processes.

13.4.2. Amortization in CAPEX

The second option being considered involves the Valls site absorbing the costs associated with the packaging machine and the oven as part of the CAPEX investment. While this decision can offer increased financial flexibility, it entails directly shouldering the equipment costs.

If the cost of the current machinery is integrated into the initially proposed CAPEX, the economic balance is as follows:

Table 13.9: Amortization in CAPEX

Item	Cost (k €)
Expenses	
Total Direct and Indirect Costs	80.9% k €
Current Book Value wrapping machine	19.1%k €
Total Expenses	100% k €
Savings	
Total Plastic Savings	56.4 %k €

Table 13.10: Payback Period

Payback Period	1’15 years

The payback period of the project, including all associated expenses and the current book value of the actual packer, is achieved in the first quarter of the second year.

13.5. Financial Justification

The investment in this project contributes to the growth and efficiency of the company. The following key points outline the immediate economic benefits and long-term opportunities that this investment can provide.

Cost Reduction: The adoption of the new machinery and the transition to recycled plastic will not only optimize operational efficiency but also generate a significant cost reduction. This saving materializes in acquiring materials at a lower cost, improved operational efficiency that reduces overhead expenses, and the subsequent decrease in maintenance costs.

Tax Savings: The introduction of recycled plastic into the production process opens the door to substantial tax benefits.

Quick Payback: One of the strengths of this investment is the speed at which associated costs are expected to be recovered.

Quality Improvement: The proposed investment not only has a positive impact on economic aspects but also addresses historical issues related to product quality. Fewer problems associated with the current plastic translate into additional maintenance cost reductions and a significant improvement in customer satisfaction.

Alignment with Corporate Objectives: This project aligns directly with corporate objectives related to sustainability.

14. ESSITY - ANNUAL AND SUSTAINABILITY REPORT 2022

In the current context, sustainability and environmental responsibility have become fundamental pillars for business development. In this regard, Essity's annual sustainability assessment not only reflects its commitment to ethical business practices but also serves as a testament to its long-term vision focused on reducing environmental impact. (Annex 2). [9].

14.1. Project Contribution

Essity is committed to the Sustainable Development Goals (SDGs) and works towards reducing its greenhouse gas emissions, as well as addressing air, land, and water pollution. The company also focuses on minimizing water and plastic use and waste.

The proposed plastic change in the studied line at Essity's Puigpelat plant aligns with the ambitious goals of decreasing the total amount of primary (non-recycled) plastic in the company's packaging. The target for 2025 is to have 85% renewable and/or recyclable material in the company's packaging.

It's important to note that the company's annual report and targets specifically reference products under its own brands, such as Tork or Tena. [9]

This means that the implementation of 33% PCR (Post-Consumer Recycled) plastic in the studied line, as it involves an external client (Client A, in this case), might not be reflected in the company's statistics. However, the reduction in the carbon footprint resulting from the increased use of recycled plastic in this project is significant.

14.1.1. Carbon Footprint

Essity participates in the European Union emission allowances and costs for carbon dioxide emissions (EU ETS). [9]. This system, operating within the EU, establishes emission limits for industries and facilitates the buying and selling of emission allowances. Companies in this program adhere to specific limits on greenhouse gas emissions, expressed in terms of CO2 equivalents. Consequently, reducing both direct and indirect CO2 emissions assists the company in complying with regulations and generates surplus emission allowances that can be sold in carbon markets or used to offset future emissions. (Anex 3).

According to ISO 14067:2018 - Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification, the carbon footprint of a product (CFP) is determined by the sum of GHG emissions and GHG removals in a product system, expressed as CO2 equivalents. This calculation is based on a life cycle assessment using the single impact category of climate change. [10]

To accurately assess the contribution of this project to future Annual and Sustainability Reports and to align with the EU ETS, a comprehensive Life Cycle Assessment is conducted. This assessment provides insights into various aspects, including the reduction in CO2 equivalents resulting from the new packaging stage.

15. LIFE CYCLE ASSESSMENT

15.1. Context and Justification of the Life Cycle Assessment

As mentioned throughout this thesis, Essity, in its journey towards adopting more sustainable practices, has reconsidered the use of plastic with retractable properties, whose main components are polyethylene, ethanol, and propylene. The goal is to replace it with a material that contains a percentage of plastic PCR (Post-Consumer Recycled) without this thermoretractile capability.

According to the definition proposed by the International Organization for Standardization (ISO), Life Cycle Assessment (LCA) is a compilation and assessment of inputs, outputs, and potential environmental burdens of a product system throughout its entire life cycle.

The study was developed according to the requirements of the ISO standards 14040:2006 and 14044:2006 dividing it in the following phases: Goal and scope definition, which includes the purpose of the study, the description of the expected product of the study, system boundaries, functional unit (FU) and assumptions; Life Cycle Inventory (LCI): this phase involves the compilation and quantification of both input and output flows and includes data collection and analysis; Life Cyc le Impact Assessment (LCIA): thanks to this phase, based on the inventory analysis results, itis possible to qualify, quantify and weigh the main environmental impacts linked to a product life cycle; and Life Cycle Interpretation, in which the results from the impact assessment and the inventory analysis are analysed and interpreted.

This study is justified by the following items:

- Consumer Demand: Major customers seek products and suppliers that demonstrate a commitment to sustainability. The adoption of recycled plastics can be a competitive advantage and meet market demand.
- Environmental Pressure: In the current context of growing awareness of climate change and environmental degradation, companies face increasing pressure to reduce their ecological footprint and adopt more sustainable practices. Life Cycle Assessment is an essential tool for evaluating environmental impacts at all stages of a product's life.
- Resource Optimization: Life Cycle Assessment can help identify and quantify stages where resources can be optimized, thereby reducing production costs, and improving operational efficiency.

15.2. Goal and Scope Definition

The main objective of this study, utilizing the LCA methodology, is to quantify and compare the environmental impacts of two plastics intended for use as packaging materials. The industrial-use polyolefin will be analysed in detail. Additionally, a plastic composed of polyethylene with a 33% content of recycled plastic will be examined."

Additionally, the goal is to analyse the potential environmental benefits associated with the proposed plastic change.

The results of this study aim to provide valuable insights for the company seeking to compare alternatives and determine which option is the most sustainable from a holistic perspective.

The LCA study has been conducted following the standardized Life Cycle Assessment methodology, adhering to the international standards series UNE-EN-ISO 14040-43.

15.3. Functional Unit

To provide a reference for linking all input and output data and ensuring comparability of results, a functional unit (FU) must be chosen. In this study, it was identified as 1000 consumer units (con) of the final packaged product.

15.4. Product System and System Boundaries

System boundaries determine which unit processes should be included in the LCA and which environmental loads will be studied and at what level of detail.

Geographical boundaries: The conducted LCA is limited to the use of the final product in mainland Spain. For operations within our country, national data have been used to the extent possible, and when available, original data from actual processes.

Temporal limits: The considered time horizon is 2016 (the date of the last update of the EcoInvent database).

Limited Data Source: Due to the limitation of the EcoInvent database in providing specific data for the ethylene-propylene copolymer, it has been decided to use data for the constituent polymers in a common ratio of 65-35%.

Excluded stages from the analysis: For this study, environmental loads related to the production of machinery and infrastructure necessary for the entire production process are excluded. Also, miscellaneous materials and additives such as slip agent, antiblocker, or catalyst, which total less than one percent by weight of the net process inputs, are not included in the assessment.

The production processes of propylene, ethylene, and polyethylene are excluded from the foreground system. In the case of recycled plastic, these is also excluded. The transportation of these materials to the production plant is beyond the defined boundaries. Product flows with secondary data will be utilized to quantify these impacts on the final product.

Detailed identification and assessment will be conducted on the environmental implications and sustainability aspects associated with the initial stages of the life cycle of plastics.

'Cradle-to-gate' encompasses raw materials, the transportation of raw materials, and production processes. The assessment concludes before the finished product reaches its final destination.

In Figures 15.1 and 15.2, a schematic of the activities considered within the study system is presented.

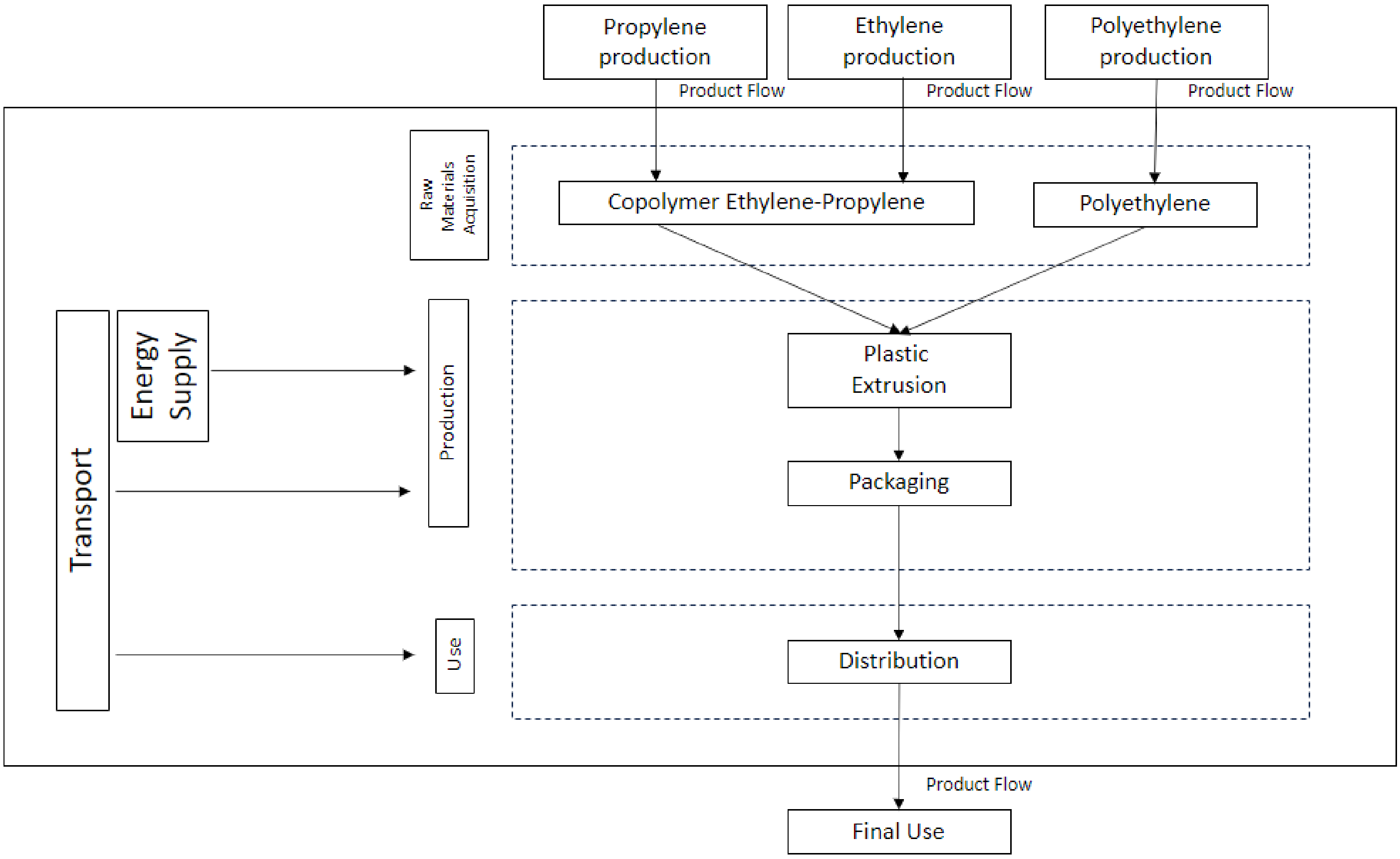

Figure 15.1: System boundaries. Polyolefin film

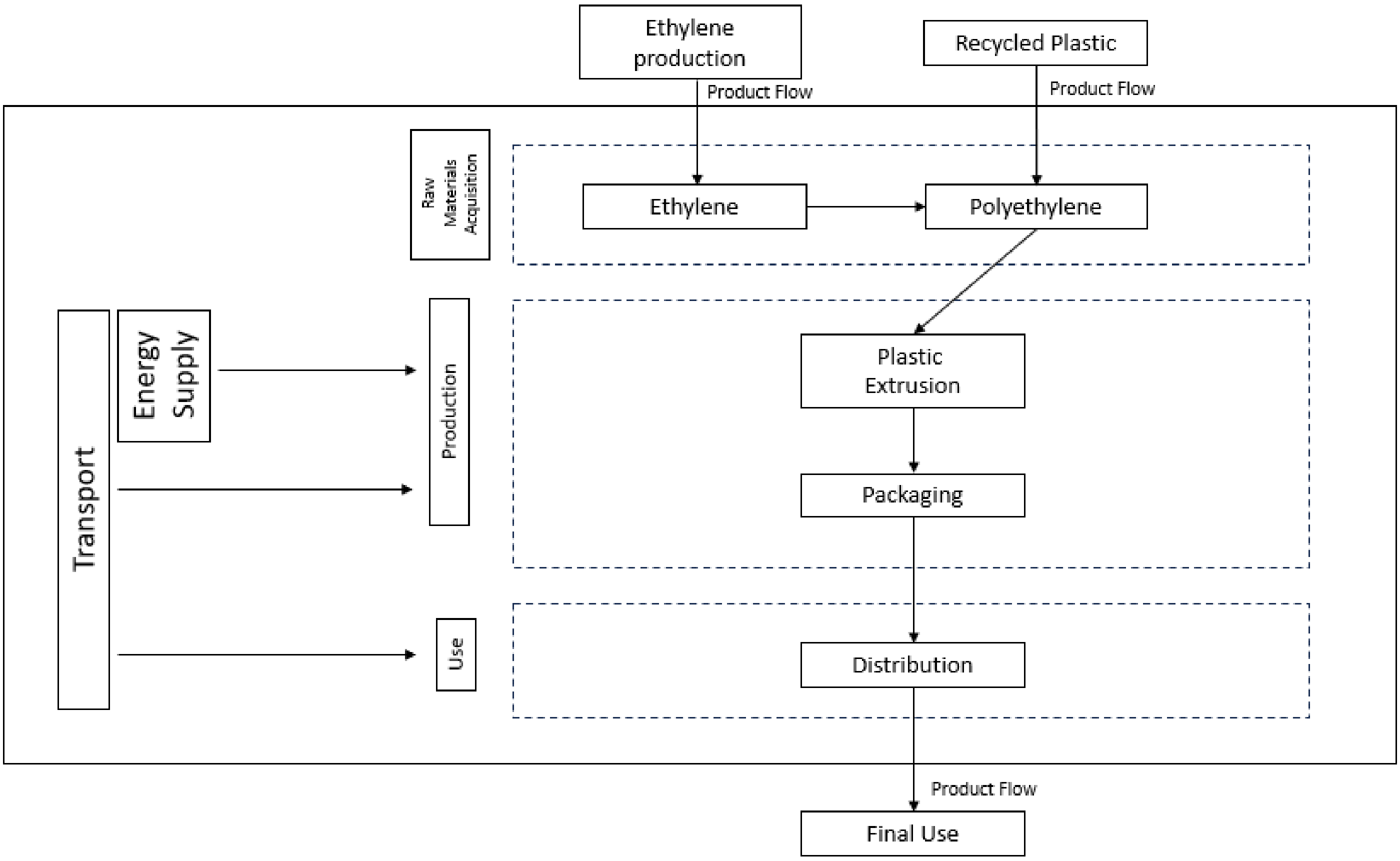

Figure 15.2: System boundaries. Polyethylene film

15.5. <u>Life Cycle Inventory (LCI)</u>

15.5.1. Data Collection and Calculation

This phase of the analysis quantifies the use of resources and materials, as well as the consumption of energy, and the associated transportation throughout the product life cycle.

Below there are Table 15.1 and Table 15.2, where the inputs and outputs of various processes can be observed. The data is already presented based on the functional unit (FU), which is 1000 consumer units.

All input data in the system is considered secondary data, as it has been obtained from the Ecoinvent database. This database provides a robust and extensive collection of inventory data, spanning a wide range of industrial sectors and processes.

Table 15.1: Inputs for each stage of the process based on the production of 1000 con packed for the current thermoretractable plastic

Data			
Input data flow			
Process	Flow	Value	Units
Raw Materials Acquisition	Propylene	0.631	kg
	Ethylene	1.172	kg
	Polyethylene	3.296	kg
Production	Transport	2.396	tkm
	Plastic extrusion	5.150	kg
	Energy wrapping machine	12	kWh
	Energy oven	24	kWh
	Handle Machine	3.2	kWh
Use	Transport	2.83	tkm

Table 15.2: Inputs for each stage of the process based on the production of 1000 con packed for the proposed new plastic.

Data			
Input data flow			
Process	Flow	Value	Units
Raw Materials Acquisition	Polyethylene	3.451	kg
	Polyethylene recycled– 33%	1.699	kg
Production	Transport	0.0515	tkm
	Plastic extrusion	5.15	kg
	Energy	19	kWh
Use	Transport	2.83	tkm

15.6. Results and Discussions

15.6.1. Life Cycle Impact Assessment (LCIA)

For the evaluation of this analysis, the ReCiPe methodology ("Recipe for the Environmental Footprint") has been followed, a tool that addresses various impact categories throughout the different stages of the studied products. This tool distinguishes between intermediate and final impacts, providing a more comprehensive understanding of environmental implications. Additionally, impact characterization through specific factors facilitates the quantification and comparison of results.

MidPoints Classification

Once the system inputs have been quantified based on the functional unit (FU), specific contributions are assigned to each Midpoint category. The analysis considers the 18 impact categories provided by the ReCiPe 2016 v1.1 methodology. Each of these categories represents a specific aspect of environmental impacts throughout the life cycle, ranging from climate change to eutrophication and human toxicity. These categories offer comprehensive coverage for assessing effects on various environmental aspects.

The assignment of specific contributions to each Midpoint category is also done according to the ReCiPe 2016 v1.1 database, establishing a solid foundation for subsequent characterization.

Characterization and Endpoints

Endpoints are numerical representations of the total environmental impacts of the product, providing a comprehensive and quantified view of its environmental performance. These endpoints are expressed in specific units for each category: Human Health, Ecosystem Quality, and Natural Resources.

To achieve these endpoints, it is necessary to apply the characterization factors derived from the ReCiPe methodology to the quantified contributions in each midpoint impact category. This transition from 18 midpoint indicators to 3 endpoints, signifying the Areas of Protection (AoP) refines the assessment, bringing a closer and more realistic depiction of the final environmental damage.

This refinement introduces a certain level of uncertainty into the assessment.

Endpoint Normalization Process

The normalization stage adjusts the obtained values to reflect their relative magnitude compared to predefined global standards and references. Normalization plays a crucial role in providing a contextualized perspective on the significance of the evaluated environmental impacts.

The normalization values are extracted from ReCiPe and incorporate impact values per person and year based on the world population for the year 2000. This approach adheres to a Hierarchist perspective, ensuring a comprehensive and objective normalization process.

In essence, this process involves transitioning from the initial endpoints to normalized endpoints, achieved through the incorporation of normalization values derived from ReCiPe.

Final Indicators

Upon completion of normalization, the subsequent step involves the weighting process, utilizing values from the ReCiPe Average.

The sum of these weighted indicators produces a singular, dimensionless final indicator adapted to the functional unit. This methodology facilitates a rapid comparison between the two alternatives, with the cleanest option identifiable through its lower final indicator value.

15.7. Results

Table 15.3: 18 Midpoint Indicators for the two studied plastics, polyolefin, and polyethylene in 1000 cons of final packaged product.

MIDPOINT INDICATOR	UNITS	TOTAL POLYOLEFIN	TOTAL POLIETHYLENE
Agricultural land occupation: **ALOP**	m2a	8.299	4.964
Climate change: **GWP100**	kg CO2-Eq	12.378	12.085
Fossil depletion: **FDP**	kg oil-Eq	10.48	10.121
Freshwater ecotoxicity: **FETPinf**	kg 1,4-DC.	1.161	0.723
Freshwater eutrophication: **FEP**	kg P-Eq	0.003	0.003
Human toxicity: **HTPinf**	kg 1,4-DC.	3.849	3.284
Ionising radiation: **IRP_HE**	kg U235-Eq	0.471	0.482
Marine ecotoxicity: **METPinf**	kg 1,4-DB.	1.012	0.632
Marine eutrophication: **MEP**	kg N-Eq	0.002	0.002

Metal depletion: **MDP**	kg Fe-Eq	0.984	0.812
Natural land transformation: **NLTP**	m2	-0.001	-3.58E-04
Ozone depletion: **ODPinf**	kg CFC-11.	8.76E-07	1.02E-06
Particulate matter formation: **PMFP**	kg PM10-Eq	0.018	0.017
Photochemical oxidant formation: **POFP**	kg NMVOC-.	0.047	0.045
Terrestrial acidification: **TAP100**	kg SO2-Eq	0.039	0.036
Terrestrial ecotoxicity: **TETPinf**	kg 1,4-DC.	0.002	0.002
Urban land occupation: **ULOP**	m2a	0.234	0.152
Water depletion: **WDP**	m3 water.	0.202	0.206

Table 15.4: Characterized and Normalized Values in Endpoint Format for the Two Studied Plastics.

	Human Health	Ecosystem Quality	Natural Resource
EndPoint	Daly/1000cons	species.yr/ 1000cons	USD/1000cons
Polyolefine	3.72E-05	5.67E-08	4.94E+00
Poliethylene	3.42E-05	5.38E-08	4.91E-01
Normalizated EndPoint	pr.yr/1000cons	pr.yr/1000cons	pr.yr/1000cons
Polyolefin	2.73E-03	6.18E-05	2.02E-02
Poliethylene	2.51E-03	5.87E-05	2.00E-03
Weighted Indicators	0.4	0.4	0.2
Final Indicators	-/1000cons	-/1000cons	-/1000cons
Polyolefin	1.09E-03	2.47E-05	4.03E-03
Polyethylene	1.00E-03	2.35E-05	4.01E-04
Unique indicator		-/1000cons	
Polyolefin		5.15E-03	
Polyethylene		1.43E-03	

15.8. Life Cycle Interpretation

For a better interpretation of the results, the midpoint and endpoint results for the two studied plastics are presented in graphical format.

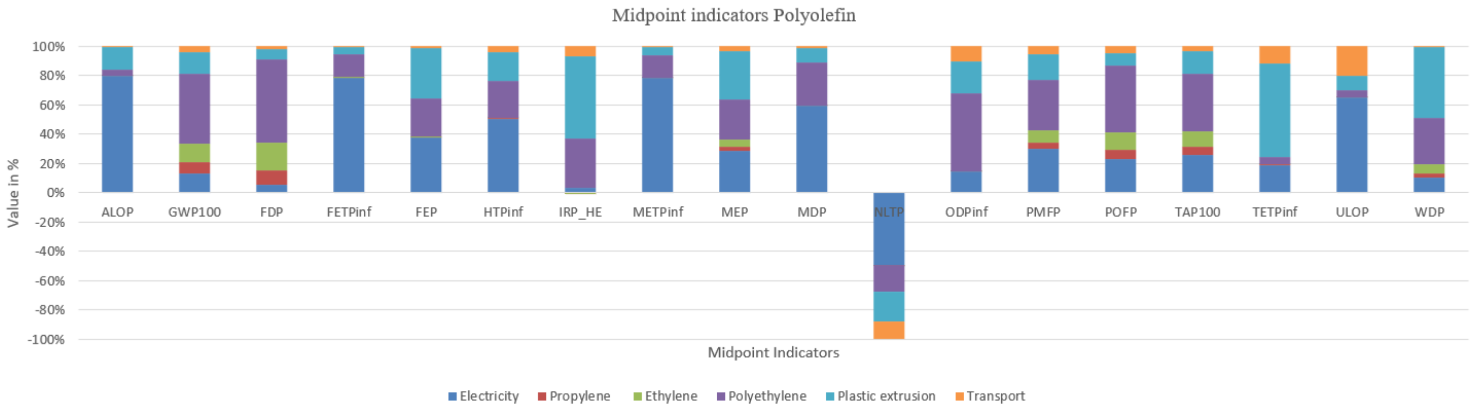

Figure 15.3: Midpoint Indicators Evaluated in %. Results for each process unit for polyolefin plastic.

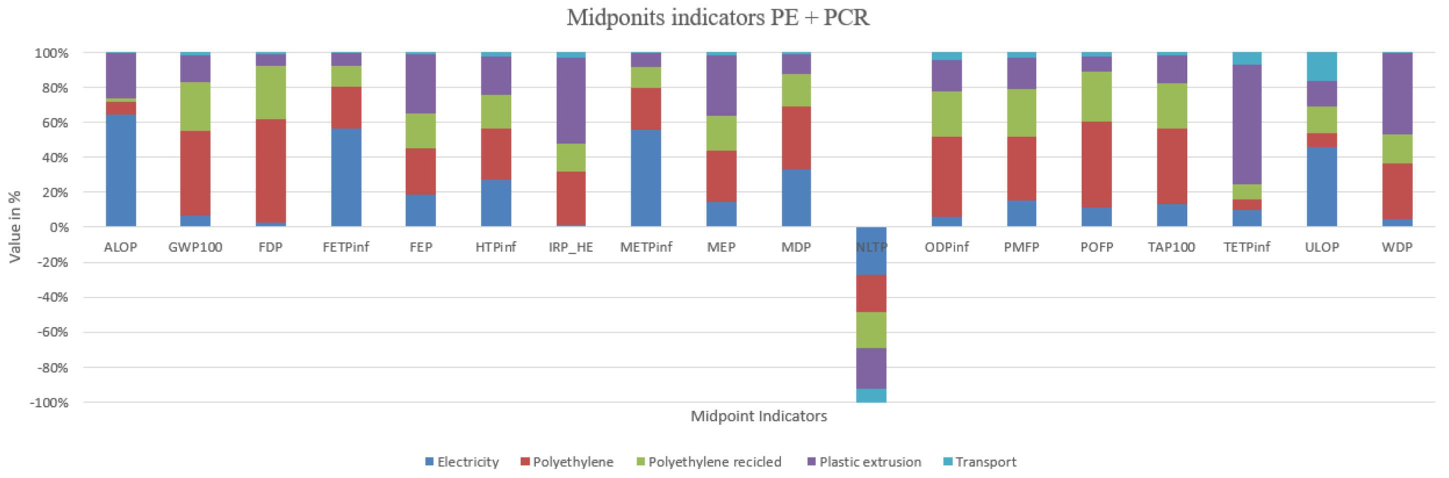

Figure 15.4: Midpoint Indicators Evaluated in %. Results for Each Process Unit for Poliethylene Plastic

Highlighting Variations in the Following Categories when Comparing the Two Analysed Plastics.

The graphs illustrate that the use of polyolefin has a greater impact in the category of Agricultural Land Occupation (ALOP), with its contributions significantly higher compared to the polyethylene process. Particularly in electricity generation, polyethylene production, and plastic extrusion. These results emphasize the need to consider mitigation strategies to reduce the footprint of agricultural land occupation.

In another category where the impact of polyolefin usage is greater, Freshwater Ecotoxicity Potential (FETPinf) stands out. Electricity generation and polyethylene production are the main contributors to water ecotoxicity when using polyolefin. These results underscore the importance of identifying strategies to minimize the release of toxic substances in the mentioned processes, aiming to reduce the impact on aquatic ecosystems.

Both processes have insignificant impacts in terms of ozone depletion (ODPinf), although the differences are minimal, with polyethylene plastic having a slightly higher impact. It is crucial to ensure that these impacts remain at negligible levels.

It's worth highlighting the Natural Land Transformation (NLTP) category since it has a negative value for both processes.

This negative value is assumed as a result of the datasets used to cover the background. This data takes into account impacts avoided by the generation of by-products, or in the case of PE with PCR, by the use of recycled materials. That is why the assessed activities appear as beneficial contributors to this category.

Their impact helps preserve or regenerate land areas instead of transforming them in a harmful way to the environment. This can be beneficial from a sustainability and environmental conservation perspective.

To gain a holistic view of the final impacts and to compare them more visually, Figure 15.5 shows the net impact for each plastic by comparing, through normalized Endpoints, the aspects of human health, ecosystem quality, and resource depletion.

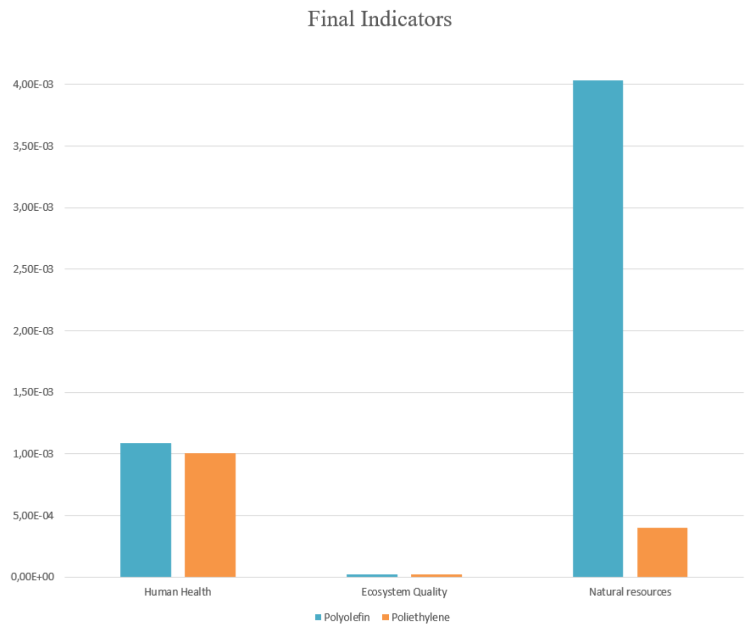

Figure 15.5: Representation of Normalized Endpoints for the Two Studied Plastics.

Normalized data represents the relative contributions of the two plastics studied in this project in the three categories of environmental impact.

The most significant difference can be observed in the Natural Resources category, where the polyolefin process exerts a stronger pressure on natural resources.

The following Figure 15.6 shows the values of the unique indicator for both alternatives assessed. It is important to highlight that a lower value of the unique indicator signifies a lesser environmental burden, and thus, is considered the more environmentally favourable option.

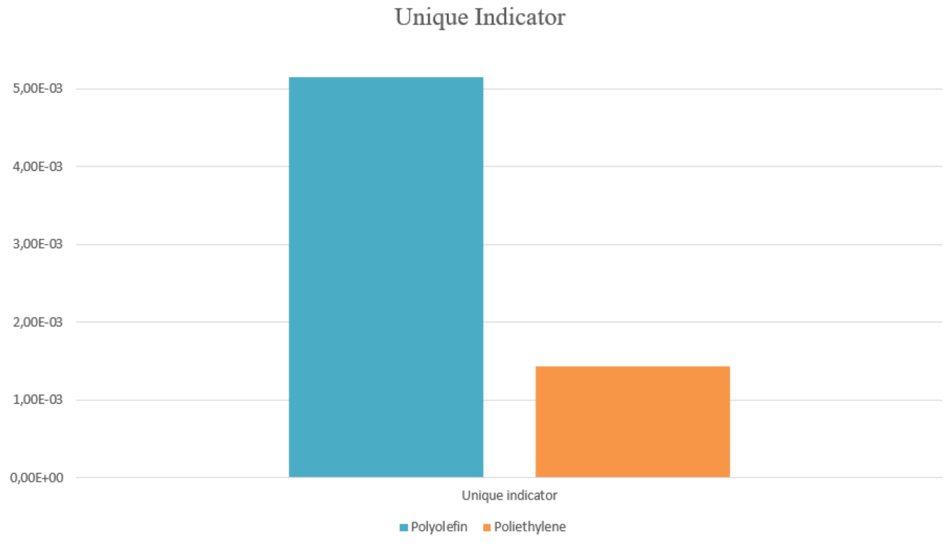

Figure 15.6: Representation of Unique indicator for the Two Studied Plastics.

15.9. LCA Conclusion

The detailed assessment of impact categories has provided valuable insights into the environmental implications of both options. The key conclusions are as follows:

The results indicate significant differences in environmental impacts between the processes using polyolefin and polyethylene. The "Natural Resources" category stands out as an area where thermoretractable polyolefin exerts a stronger pressure, both in midpoints and endpoints.

Key factors in reducing impacts in the use of polyethylene compared to polyolefin include the elimination of the furnace, leading to a reduction in the electricity stage. Additionally, the addition of recycled plastic results in a decrease in natural resource use.

The benefits associated with implementing the use of polyethylene with a 33% PCR content are summarized in a significant reduction in pressure on natural resources and other environmental aspects. This would contribute to a more environmentally sustainable operation. Furthermore, its implementation could translate into significant material and energy savings, providing economic benefits and contributing to resource sustainability.

In conclusion, the option with polyethylene packaging is the most favourable, as evidenced when comparing the unique indicator.

Embracing more sustainable and responsible practices can have benefits in public perception. Consumers and stakeholders increasingly value sustainable practices, which could translate into an improved company image and customer loyalty.

15.10. Carbon Footprint

The carbon footprint identifies the amount of greenhouse gas emissions released into the atmosphere as a result of any activity's development.

Once the Life Cycle Assessment (LCA) is completed, the total greenhouse gas emissions can be compared in terms of the amount of CO2 equivalent when producing 1000 units with the two studied plastics.

The MidPoint GWP100 (Global Warming Potential at 100 years) is a numerical indicator that quantifies the global warming potential of a specific greenhouse gas compared to CO2 over a 100-year period, as defined by the IPCC. It represents the amount of heat trapped by the gas in the atmosphere during that time, expressed as multiples of the impact of CO2, which is defined as 1.

The following table shows the results obtained for this indicator, corresponding to the amount of greenhouse gases multiplied by their Global Warming Potential (GWP).

Table 15.5: GWP results

Polyolefin							
	Electricity	Propylene	Ethylene	Polyethylene	Plastic extrusion	Transport	Total
GWP100 (Co2 eq)	1.65	0.90	1.63	5.85	1.86	0.48	12.38
Poliethylene							
	Electricity	Polyethylene	Polyethylene recicled		Plastic extrusion	Transport	Total
GWP100 (Co2 eq)	0.80	6.12	3.04		1.86	0.26	12.08

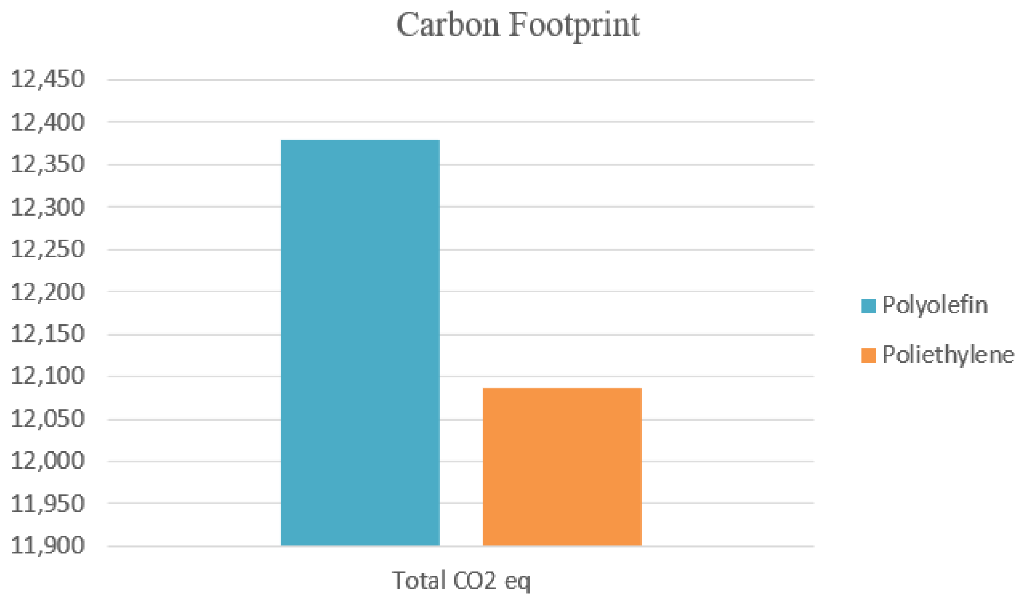

Figure 15.7: Carbon Footprint for Polyolefin and PE + PCR

With the plastic change, a 2.36% reduction in CO2 equivalent emissions is anticipated for the overall production process per functional unit, in this case, 1000 units.

Notably, owing to decreased electricity consumption (the only input accounted for the Essity – Puigpelat site), the reduction in CO2 equivalent emissions amounts to 51.5% in this specific process.

16. PROMOTION OF THE CIRCULAR ECONOMY

16.1. Post-Consumer Recycling Facilitation

The proposal for the new packaging facilitates more effective waste management, resulting in a more positive environmental impact. Adopting polyethylene (PE) as the main material for both packaging and handles increases the homogeneity of the product. This simplifies the recycling process as both elements can be recycled without the need for separation.

This change promotes a higher rate of post-consumer recycled material recovery. The efficiency in post-consumer recycling is enhanced by using exclusively PE, as modern recycling systems are designed to efficiently handle this material. Additionally, PE has a standardized resin identification code (recycling code 2), simplifying material identification and classification for recyclers and consumers.

Contrasting this initiative with the current system, which is based on polyolefin (PE + ethylene-propylene copolymer) along with handles made of polypropylene reinforced with cardboard, where recycling is more cumbersome due to the consumer's need to separate the handle from the packaging for proper recycling.

17. CONCLUSIONS

Based on the various studies conducted in this project, the main conclusion is that, to respond optimally to the Business Case, the best option is to replace the current polyolefin plastic with polyethylene, making a modification in the packaging stage of studied line.

Comparing the technical, processability, and quality characteristics associated with different plastics, the results demonstrate that the alternative involving the new packaging machine is the best option, especially in terms of economics, with savings of over 56.4% k€ per year, once the short payback of less than one and a half years for the proposal studied has elapsed.

While the proposal is not aimed at increasing productivity, an improvement is anticipated by reducing elements involved in the packaging process and eliminating a bottleneck, such as the current packaging machine. Moreover, with the current layout of the line, there is no need to modify stages before or after the packaging stage due to the available space for the new machinery.

The new packaging features a redesigned layout. There is a residual risk that the customer may not accept this proposal.

A comparative life cycle analysis study has also been conducted, supporting the environmental advantages of polyethylene over polyolefin, summarized in a significant reduction in pressure on natural resources and other environmental aspects. Also highlight the 2.36% reduction in CO_2 equivalent emissions throughout the production cycle proposed for the new packaging.

Finally, the packaging change also facilitates post-consumer recycling, eliminating the need to separate the handle from the packaging plastic for proper disposal in containers.

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ANNEXES

1. <u>SUPPLIER OFFER</u>

Essity Spain S.L.

1x ENTRA AFH - 1x XWRAP

Q23-005524

A. PRICE SUMMARY

Pos	Description	Unit Price €	Qty	OPT ALT FOC	Alt-to	Opt/Alt Price €	Final Price €
1	**WRAPPING MACHINE ENTRA AFH**		**1**				
1-1	ENTRA AFH single and multi-roll wrapper	439.560,00	1				439.560,00
1-2	3D spare-parts catalogue and manuals		1	FOC			
1-3	**FORMATS PARTS**		**1**				**1.152,00**
1-3-1	Horizontal pack format	1.152,00	1				1.152,00
1-4	**OPTIONS**		**1**	**OPT**		**71.604,00**	
1-4-1	Integrated handle applicator	17.640,00	1			17.640,00	
1-4-2	Outfeed pack turner	15.600,00	1			15.600,00	
1-4-3	Click&Cut knife	4.404,00	1			4.404,00	
1-4-4	Pack transversal Easy-open	33.960,00	1			33.960,00	
1-5	**ELECTRICAL AND CONTROL**		**1**				**648,00**
1-5-1	SECOMEA Modem for Remote Access	648,00	1				648,00
1-5-2	A4GATE hardware platform	5.556,00	1	OPT		5.556,00	
1-5-3	IMA Sentinel annual service pack (single machine)	2.568,00	1	OPT		2.568,00	
1-6	Paper Wrapping Kit		1	FOC			
1-7	**Essity Specifications ENTRA AFH**		**1**				**69.079,20**
1-7-1	SEW Motors	13.296,00	1				13.296,00
1-7-2	Padlock Presisposition	3.360,00	1				3.360,00
1-7-3	Ethernet data Exchange	6.240,00	1				6.240,00
1-7-4	Manual air dump	993,60	3	OPT		2.980,80	
1-7-5	ink-jet integration	1.797,60	1	OPT		1.797,60	
1-7-6	Mandrel to allow the replacement of wear parts	960,00	1				960,00
1-7-7	Industrial service laptop	7.680,00	1				7.680,00
1-7-8	Rubber protection sharp edges	1.176,00	1				1.176,00
1-7-9	Fireproof pneumatic piping	1.200,00	1				1.200,00
1-7-10	Add. Sensors for hand crack (Single and Double bar adjustment)	720,00	1				720,00
1-7-11	Light on elevator area Removal		1	FOC			
1-7-12	Etipack predisposition	14.400,00	1	OPT		14.400,00	
1-7-13	Vortex improvements UNIVERSA	5.136,00	1				5.136,00
1-7-14	Additional platform as per last Essity project	3.062,40	1				3.062,40
1-7-15	Spare part Manual - Exploded View	2.400,00	1	OPT		2.400,00	
1-7-16	Reject packs automatic with push bottom (interfaced with plc)	8.160,00	1	OPT		8.160,00	
1-7-17	Antistatic Kit	9.840,00	1				9.840,00
1-7-19	**Electrical Safety specifications**		**1**				**16.408,80**
1-7-19-1	Safety guard switches: Schmershal AZM300Z, interlocked, coded	5.160,00	1				5.160,00
1-7-19-2	Grace Indicator Electrical Cabinet	2.032,80	1				2.032,80
1-7-19-3	Modification Lamp allarm color sequence	312,00	1				312,00
1-7-19-4	Wires colors as per Essity Standard		1	FOC			
1-7-19-5	Elect. Labels with PLC & Component reference	2.304,00	1				2.304,00
1-7-19-6	Modification Start up warning signals	3.000,00	1				3.000,00
1-7-19-	Main electrical cabinet switch	720,00	1				720,00

7	repositioned						
1-7-19-8	Lubrification tank to be filled from outside the machine	2.640,00	1				2.640,00
1-7-19-9	Lamp inside electrical cabinet turn on when door is open	240,00	1				240,00
	WRAPPING MACHINE ENTRA AFH					**109.466,40**	**510.439,20**

2. ESSITY - ANNUAL AND SUSTAINABILITY REPORT 2022

In the current context, sustainability and environmental responsibility have become fundamental pillars for business development. In this regard, Essity's annual sustainability assessment not only reflects its commitment to ethical business practices but also serves as a testament to its long-term vision focused on reducing environmental impact. [9]

2.1. Essity's commitment to sustainability

Sustainability is and has been high on Essity agenda for many years. Essity improves the well-being of people through its leading hygiene and health solutions.

The company is committed to reduce their environmental impact, reduce waste and provide circular solutions, and protect and restore biodiversity.

As a leading global hygiene and health company, Essity plays an important role in contributing to the achievement of the UN Sustainable Development Goals. Focus on goals 3, 5, 6, 12, 13 and 15, as this is where company has expertise and can make the greatest contribution. Essity supports the UN Global Compact and works to overcome global challenges through cooperation and partnerships.

2.2. Essity Sustainable Development Goals

Goal 3: good Health and Well-being.

Developing sustainable products and services for hygiene and health, educating children, consumers, patients and care professionals, and preventing the spread of diseases and other health risks.

Goal 5: Gender Equality.

Essity works to break the silence around issues such as menstruation and incontinence. Essity wants a society where everyone can fully participate. Essity's contribution toward Goal 5 includes pursuing a global dialogue, making our knowledge about hygiene and health available to boys and girls and to customers and consumers, and ensuring access to affordable, sustainable hygiene and health solutions to contribute to a dignified life on equal terms.

Goal 6: Clean Water and Sanitation.

Essity improves access to sustainable sanitation and hygiene solutions. Essity's contribution toward Goal 6 includes the work to achieve efficient water usage throughout the entire lifecycle of our products and improve access to sustainable sanitation and hygiene solutions, with special focus on girls and women.

Goal 12: Responsible Consumption and Production

Essity contributes to a sustainable and circular society, mainly by offering solutions that meet consumer and customer needs and that enable sustainable consumption. Designing sustainable products and services is about resource efficiency across the entire lifecycle and improving circularity with a focus on re-use, recycling or composting as well as renewable materials.

Goal 13: Climate Action

Essity aims to reduce the carbon footprint of our products. This means focusing on forest management, energy efficiency at our production facilities and among our suppliers, as well as smarter product designs.

Goal 15: Life on Land

Essity enables more people every day to enjoy a fuller life by offering access to sustainable hygiene and health solutions and providing hygiene and health education. The company works to promote responsible forest operations throughout it supply chain and require Essity suppliers to fulfill strict criteria stipulated in the Global Supplier Standard and the fiber policy.

2.3. Essity environmental impact

2.3.1. Forest and Fiber

Nature consideration and protection of biodiversity through responsible forestry is a priority for Essity.

As a global purchaser of both fresh and recycled wood-based fiber materials, Essity is dependent on healthy and resilient forests. The impact on forest biodiversity is primarily through use of wood-based fresh fiber. Responsible procurement and responsible forest management is an integral part of the fresh fiber procurement and is therefore central to Essity's sustainability strategy.

Responsible fiber procurement

The long-standing work with responsible fiber procurement is an important part of the sustainability strategy. Essity ensure responsible fiber procurement through certifications such as the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC) and can thereby prevent deforestation and promote biodiversity. Every FSC-certified forest must be annually assessed by the accredited body.

Targets and transparency

In 2022, Essity was again recognized for the company's leadership in sustainability by the non-profit environmental organization CDP.

Each year, Essity reports according to the agreed targets in the Forest Positive Coalition of Action.

Fresh fiber

Table 2.1: Share of FSC or PEFC-certified fresh fiber.

Target	100%
Outcome:	
2020	95%
2021	98%
2022	97%

2.3.2. Reduction in greenhouse gas emissions

Reduce greenhouse gas emissions and the carbon footprint of the operations has been a major focus for Essity for many years. The company has committed to achieve net zero emissions of greenhouse gases by 2050.

Essity, also, has joined the UN Global Compact's "Business Ambition for 1.5°C". The climate targets are aligned with the ambitions of the Paris Agreement to reduce global warming. The initiative is supported by the CDP, World Resources Institute (WRI), WWF and UN Global Compact.

Essity focuses on the following areas to achieve our ambition of net zero emissions:

Sustainable innovations:

Essity have worked with life cycle assessments (LCAs) to reduce material use in products and to develop thinner products without affecting functionality or quality.

Through sustainable innovation and daily improvements, Essity has reduced the carbon footprint in the company's different product offerings by up to 43% over a ten-year period in Europe. Essity's Group target is that at least 50% of the company's innovations are to yield social and/or environmental improvements. In 2022, the outcome was 68%.

Climate-smart materials:

Essity strives to use more materials with lower greenhouse gas emissions. The largest share of greenhouse gas emissions from purchased raw materials is from fresh fiber and fossil-based plastic used in the products and packaging. Essity collaborate with the suppliers to develop sustainable products with a focus on alternative, renewable and recycled materials.

Fossil-fuel-free tissue production:

Tissue manufacturing is an energy intensive process and one of the most important tasks to achieve net zero emissions by 2050 is therefore to become free from fossil fuels. To achieve this, measures include the increased use of low-carbon hydrogen, biomass, biogas, geothermal steam, and electrification of the tissue processes.

The reduction in CO2 emissions per ton produced between 2005 and 2022 was 23%.

Zero production waste:

Essity acts to make production waste a valuable resource and reduce our greenhouse gas emissions at the same time. The target for 2030 is that all production waste will be subject to material and energy recovery. In 2022, the total amount of production waste decreased, and 62% was recycled.

2.3.3. Plastic

The production of fossil plastic has a negative impact on our planet as it releases carbon emissions into the atmosphere and thereby accelerates the existing climate crisis.

Plastic waste and pollutants threaten human welfare as well as wildlife and biodiversity. Nations worldwide, with the European Union (EU) at the frontline, are placing bans on single-use plastics and transitioning toward a more circular economy.

In parallel, plastic is required to ensure necessary levels of sanitation, safety and functionality for hygiene and health products. Paper industry must change how designs, use, and reuse plastic by shifting from linear to circular business models.

Packaging:

Essity has ambitious targets to reduce the total amount of primary plastic in the company's packaging, to increase the use of renewable or recycled plastic and to make all plastic packaging recyclable.

The packaging strategy includes innovating for increased circularity while simultaneously reducing existing greenhouse gas emissions.

Essity is striving for 85% renewable and/or recycled material in the company's packaging. This target applies to both paper and plastic packaging for Essity's brands.

Essity reduce the carbon footprint primarily by using recycled plastic packaging materials. To achieve more rapid results in the development of better packaging material, Essity is part of the Ellen MacArthur Foundation and Circular Plastic Alliance, among other organizations.

Table 2.2: Share of packaging manufactured from renew able and/or recycled materia

Target 2025	85%
Outcome	
2020	77%
2021	78%
2022	80%

2.3.4. Circularity

Essity has integrated circularity in the company's business model, from responsible raw material procurement, more resource-efficient production with a smaller climate footprint, to circular solutions that enable customers and consumers to minimize waste. We carry out circularity assessments as part of the innovation process to obtain a better understanding of how waste can be avoided during and after use.

3. EUROPEAN UNION EMISSION ALLOWANCES

The following describes how Essity participates in the European Union Emissions Trading System (EU ETS).

The EU ETS is an emissions trading system operating in the European Union. It establishes emission limits for various industries and allows the buying and selling of emission rights.

When Essity receives emission allowances related to CO2 from an EU member state, these allowances are recognized as an intangible asset and deferred income (recorded as a liability).

In other words, these allowances, considered intangible assets, represent Essity's right to emit a certain amount of CO2 according to the EU ETS. These allowances have an economic value for the company as they impact its ability to operate within the limits set by environmental regulations.

The emission allowances that Essity receives are also considered deferred income because, although the company has received the allowances, it has not yet earned that income. This is because it is expected to correspond to the CO2 emissions it will generate in the future. As Essity emits CO2, the deferred income is proportionally reversed to reflect the realization of emissions and recognize the income as earned.

If the received emission allowances do not cover the actual emissions made by Essity, the company makes a provision for the deficit. This provision is valued at the market value on the balance sheet date.

On the other hand, if Essity has surplus emission allowances, meaning more allowances than needed to cover its actual emissions, the sales of these allowances are recognized as income on the delivery date.

4. LIFE CYCLE ASSESMENT

4.1. Midpoint Indicators Categories

The following table provides an overview of the 18 environmental impact categories used in the ReCiPe 2016 v1.1 methodology, their units of measurement, and a brief description.

Table 4.1: MidPoint indicators description

MIDPOINT INDICATOR		UNITS	DEFINITION
Agricultural land occupation	ALOP	m2a	Incicator of the environmental impact related to agricultural land occupation
Climate change	GWP100	kg CO2-Eq	Indicator of the impact of greenhouse gas emissions on global warming over 100 years.
Fossil depletion	FDP	kg oil-Eq	Indicator of natural resource depletion.
Freshwater ecotoxicity	FETPinf	kg 1,4-DC	Indicator of the impact on the ecotoxicity of freshwater bodies.
Freshwater eutrophication	FEP	kg P-Eq	Indicator of the risk of freshwater eutrophication due to human activities
Human toxicity	HTPinf	kg 1,4-DC	Indicator of the impact on human toxicity

Ionising radiation	IRP_HE	kg U235-Eq	Indicator of ionizing radiation on human health in terms of equivalent radiological toxicity units
Marine ecotoxicity	METPinf	kg 1,4-DB	Indicator of the impact on the ecotoxicity of marine ecosystems
Marine eutrophication	MEP	kg N-Eq	Indicator of the risk of marine ecosystem eutrophication due to human activities.
Metal depletion	MDP	kg Fe-Eq	Indicator of the impact on metal depletion
Natural land transformation	NLTP	m2	Indicator of the impact on natural ecosystem transformation
Ozone depletion	ODPinf	kg CFC-11	Indicator of the impact on stratospheric ozone depletion.
Particulate matter formation	PMFP	kg PM10-Eq	Indicator of the impact on airborne particulate matter formation.
Photochemical oxidant formation	POFP	kg NMVOC	Indicator of the impact on photochemical oxidant formation in the atmosphere.
Terrestrial acidification	TAP100	kg SO2-Eq	Indicator of the impact on terrestrial ecosystem acidification over 100 years.
Terrestrial ecotoxicity	TETPinf	kg 1,4-DC	Indicator of the impact on the ecotoxicity of terrestrial ecosystems over time
Urban land occupation	ULOP	m2a	Indicator of the impact on land occupation in urban environments.
Water depletion	WDP	m3 water	Indicator of the impact on water resource depletion

4.2. Midpoint Values

The 18 impact categories provided by the ReCiPe 2016 v1.1 methodology have been considered. Each of these categories represents a specific aspect of environmental impacts throughout the life cycle. From climate change to eutrophication and human toxicity, these categories offer broad coverage to assess effects on various environmental aspects.

The following tables display the complete data for different Midpoint categories for the two plastics studied.

Table 4.2:Midpoint Indicators for Thermometrical Polyolefin

MIDPOINT INDICATOR	Electricity	Propylene	Ethylene	Polyethylene	Plastic Extrusion	Transport
	39.2 kW	0.631 kg	1.171 kg	3.296 kg	5.15 kg	5.201 tkm
ALOP	6.62E+00	1.48E-03	2.68E-03	3.44E-01	1.32E+00	1.21E-02
GWP100	1.65E+00	9.04E-01	1.63E+00	5.85E+00	1.86E+00	4.75E-01
FDP	5.39E-01	1.04E+00	1.90E+00	5.86E+00	7.34E-01	1.80E-01

FETPinf	9.13E-01	6.58E-04	1.21E-03	1.81E-01	6.09E-02	4.22E-03
FEP	1.11E-03	7.09E-06	1.23E-05	7.53E-04	1.01E-03	4.52E-05
HTPinf	1.95E+00	5.73E-03	9.99E-03	9.68E-01	7.55E-01	1.58E-01
IRP_HE	1.51E-02	-2.21E-05	-4.12E-05	1.58E-01	2.66E-01	3.12E-02
METPinf	7.91E-01	5.47E-04	1.01E-03	1.59E-01	5.45E-02	5.58E-03
MEP	6.45E-04	5,.80E-05	1.12E-04	6.11E-04	7.48E-04	7.19E-05
MDP	5.85E-01	3.26E-04	5.68E-04	2.90E-01	9.56E-02	1.33E-02
NLTP	-2.48E-04	-9.46E-08	-1.68E-07	-9.02E-05	-1.02E-04	-6.31E-05
ODPinf	1.28E-07	7.15E-11	1.28E-10	4.70E-07	1.90E-07	8.81E-08
PMFP	5.55E-03	7.91E-04	1.45E-03	6.36E-03	3.28E-03	9.75E-04
POFP	1.08E-02	2.96E-03	5.63E-03	2.14E-02	3.95E-03	2.13E-03
TAP100	1.01E-02	2.27E-03	4.13E-03	1.53E-02	5.83E-03	1.42E-03
TETPinf	4.66E-04	1.96E-06	3.44E-06	1.28E-04	1.54E-03	2.88E-04
ULOP	1.52E-01	4.44E-05	7.83E-05	1.14E-02	2.42E-02	4.66E-02
WDP	2.07E-02	6.61E-03	1.23E-02	6.38E-02	9.78E-02	7.06E-04

Table 4.3: Midpoint indicators for the polyethylene

MIDPOINT INDICATOR	Electricity	Polyethylene	Polyethylene Recycled	Plastic Extrusion	Transport
	19 kWh	3.45 kg	1.69kg	5.15 kg	2.88tkm
ALOP	3,21E+00	3,60E-01	6.88E-02	1,32E+00	6,69E-03
GWP100	8,02E-01	6,12E+00	3.04E+00	1,86E+00	2,63E-01
FDP	2,61E-01	6,13E+00	2.90E+00	7,34E-01	1,00E-01
FETPinf	4,43E-01	1,89E-01	2.80E-02	6,09E-02	2,34E-03
FEP	5,38E-04	7,88E-04	4.46E-04	1,01E-03	2,50E-05
HTPinf	9,46E-01	1,01E+00	4.81E-01	7,55E-01	8,78E-02
IRP_HE	7,32E-03	1,66E-01	2.58E-02	2,66E-01	1,73E-02
METPinf	3,84E-01	1,66E-01	2.40E-02	5,45E-02	3,09E-03
MEP	3,13E-04	6,39E-04	1.98E-04	7,48E-04	3,98E-05
MDP	2,84E-01	3,03E-01	1.22E-01	9,56E-02	7,36E-03
NLTP	-1,20E-04	-9,44E-05	-5.53E-06	-1,02E-04	-3,50E-05
ODPinf	6,21E-08	4,92E-07	2.26E-07	1,90E-07	4,88E-08
PMFP	2,69E-03	6,65E-03	4.11E-03	3,28E-03	5,41E-04
POFP	5,24E-03	2,24E-02	1.19E-02	3,95E-03	1,18E-03
TAP100	4,91E-03	1,60E-02	8.57E-03	5,83E-03	7,88E-04
TETPinf	2,26E-04	1,34E-04	1.21E-04	1,54E-03	1,60E-04
ULOP	7,37E-02	1,20E-02	1.60E-02	2,42E-02	2,58E-02
WDP	1,01E-02	6,68E-02	3.05E-02	9,78E-02	3,91E-04

4.3. Characterization and Endpoints

According to the ReCiPe methodology, once the values of the Midpoint Indicators are known, their contributions need to be weighted based on their relevance to final impacts in key areas such as Human Health, Ecosystem Quality, and Resource Depletion (the Endpoints).

Thus, the resulting values represent the total environmental impacts quantified in a coherent and comparative manner. The table below presents the conversion factors from Midpoint to Endpoint.

Table 4.4: Conversion factors from Midpoint to Endpoint

MidPoint to EndPoint conversion factor	Unit	Hierarchic Value
HUMAN HEALTH		
Global Warming GWP100	DALY/kg CO2 eq.	9.28E-07
Stratospheric ozone depletion ODPinf	DALY/kg CFC11 eq.	5.31E-04
Ionizing Radiation IRP_HE	DALY/kBq Co-60 emitted to air eq.	8.50E-09
Fine particulate matter formation PMFP	DALY/kg PM2.5 eq.	6.29E-04
Photochemical ozone formation POFP	DALY/kg NOx eq.	9.10E-07
Toxicity (cancer) HTPinf	DALY/kg 1,4-DCB emitted to urban air eq.	3.32E-06
Toxicity (non-Cancer) HTPinf	DALY/kg 1,4-DCB emitted to urban air eq.	2.28E-07
Water consumption WDP	Daly/m3 consumed	2.22E-06
ECOSYSTEM QUALITY		
Terrestrial ecosystems		
Global Warming GWP100	Species.year/kg CO2 eq.	2.80E-09
Photochemical ozone formation POFP	Species.year/kg NOx eq.	1.29E-07
Acidification TAP100	Species.year/kg SO2 eq.	2.12E-07
Toxicity TETPinf	species*yr/kg 1,4-DBC emitted to industrial soil eq.	1.14E-11
Water consumption WDP	species.yr/m3 consumed	1.35E-08
Land use ULOP	Species/(m2·annual crop eq)	8.88E-08
Freshwater ecosystems		
Global Warming	Species. Year/kg CO2 eq.	7.65E-14
Eutrophication	Species. Year/kg P to freshwater eq.	6.71E-07
Toxicity	Species.yr/kg 1,4-DBC emitted to freshwater eq.	6.98E-10
Water consumption	species.yr/m3 consumed	6.04E-13
NATURAL RESOURCES		
Mineral resource scarcity MDP	USD2013/kg Cu	2.31E-01
Fossil resource scarcity FDP	USD2013/kg	0.46